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The Bus Stops Here: Best Practices in Bus Stop Consolidation and Optimization



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THE BUS STOPS HERE

Best Practices in
Bus Stop Consolidation and Optimization

A comprehensive project submitted in partial
satisfaction of the requirements for the degree
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by

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# Executive Summary

Public transportation in Greater Houston is currently undergoing a dramatic evolution. Since 2013, the Metropolitan Transit Authority of Harris County (Houston Metro) has opened three new light rail extensions. In February 2015, the Houston Metro board passed the *System Reimagining Plan*, which aims to quickly transform Houston's bus system from a patchwork of lines oriented towards downtown to a grid-oriented network of high frequency transit corridors. The core of this new bus system is the Frequent Network, a category of bus lines that run at least every 15 minutes and have extended hours. Despite this dramatic overhaul of bus routes, the vast majority of existing bus stops, many of which are spaced less than 500 feet apart, will continue to receive service. Having bus stops spaced so closely together can reduce operating speeds and decrease service reliability (Levinson, 1983). Consolidating stops to increase spacing is widely viewed by transit planners as an effective strategy to improve transit service with minimal capital investment (Boyle, 2013).

To assist Houston Metro in its ongoing effort to improve their transit network, this applied planning research project evaluates best practices in bus stop consolidation and optimization among transit agencies in the United States. I conducted interviews with planners and outreach coordinators at over a dozen transit operators. The interviews were by telephone and lasted from about 15 to 45 minutes. Each focused on why each agency initiated a stop consolidation program, the tools and criteria used to identify consolidation targets, and political and community engagement strategies. Based on the findings from these interviews, I detail recommendations for a bus stop consolidation program in Houston.

## Findings and Recommendations

Most stop consolidation programs follow a similar pattern. Agencies first set goals for their programs and develop phasing and implementation strategies. Next, they establish a set of criteria used to evaluate stops considered for consolidation. Once formalized consolidation lists are developed, planners present their proposals to political and community constituents. With consideration given to these outreach processes, consolidation proposals are implemented.

### Program Goals

**Findings:** Most planners interviewed for this study targeted bus stops whose spacing did not conform to standards, as well as stops with low ridership, for consolidation. Their primary goals for removing or relocating these stops can be defined in two broad categories, operational efficiency goals and stop quality goals. Most planners pursued goals in both categories. Operational efficiency goals included increasing average bus speed and increasing on-time performance. Stop quality goals primarily focused on removing unsafe or inefficient stops. Several interviewees also noted that removing underutilized bus stops would allow agencies to more effectively utilize capital resources to fund upgrades.

***Recommendation:*** *The stop consolidation program should be framed as both a stop quality and service quality improvement program. Ideally, Houston Metro should also initiate a parallel stop infrastructure investment program to best leverage consolidation benefits. Specific stop quality goals could be provided to the public. The agency should refrain, however, from publicizing specific service operational improvement goals (such as average bus speeds or service reliability), as previous analyses of consolidation projects have found some positive, but inconsistent operational benefits. Instead, the agency should monitor such broad-based operational metrics internally. If consistent operational improvements are identified, Houston Metro could establish more specific operational goals for the program.*

## Program Strategy and Phasing

**Findings:** Most of the agencies I examined either implemented stop consolidation on groups of routes or focused on efforts on a single route at a time. Stops were typically removed during normally scheduled service updates. Initial routes were targeted for stop consolidation based on need, with higher ridership routes more likely to undergo consolidation earlier in the program. Many transit agencies implemented stop consolidation alongside other service improvements, most commonly bus stop amenity upgrades.

***Recommendation:*** *Houston Metro should implement consolidation in groups of routes during regularly scheduled service changes. The initial groupings should include bus lines that are part of the Frequent Network described above. As these routes have the greatest service frequency and highest ridership, they stand to gain the most from potential operational benefits and will provide the best opportunities for stop infrastructure investment.*

## Stop Evaluation

**Findings:** When evaluating stops, most of the agencies I examined focused on stop spacing and boardings and alightings as the primary determinants for stop removal or relocation. Typically, data relating to these determinants were collected using Automatic Passenger Counter (APC), Automatic Vehicle Location (AVL), and Geographic Information Systems (GIS) technology. Poorly designed stops, such as those lacking nearby crosswalk access, were more likely to be removed. Stops with existing infrastructure improvements, such as shelters, were less likely to be removed. While many agencies utilized manual fieldwork methods to evaluate stops, several planners noted that improved technology and data analysis methods, including bus stop ranking, have reduced the need for this practice.

**Recommendation:** *Houston Metro should conduct a bus stop ranking analysis that considers both stop spacing and factors commonly highlighted during previous community outreach processes, including*: *total ridership, senior boardings, total wheelchair ramp deployments, existence of street furniture and shelters, and the availability of transfer opportunities.*

## Engagement

**Findings:** Most planners I interviewed anticipated that they would encounter both community and political resistance to their consolidation proposals. To counter these potential challenges, they utilized a variety of engagement techniques to communicate with political officials, the community, and staff. Most planners engaged with political officials during the consolidation process, typically sending written notifications. The most common community engagement technique was posted notifications on affected stops with a phone/online comment system. Some agencies held public meetings with community members and political officials. Community and political engagement typically took place after the development of a list of stops to be consolidated. Nearly all agencies altered their consolidation list during the engagement process, though only two agencies significantly changed or eliminated their programs due to public response. It appears that increased levels of community engagement may lead to more significant changes to the initial proposal. Only one agency formally engaged with staff members, though several planners communicated with operators through established formal or informal channels.

**Recommendation:** *Houston Metro should provide written notices that inform political officials about the intent, goals, and methods of the stop consolidation program. Planners should attempt to meet with officials that have been politically active on transit issues, and all officials should be given the opportunity to meet with Houston Metro if they request.*

**Recommendation:** *Houston Metro should solicit public comments by phone and the internet, and also post notices on stops that will be affected by the consolidation program. Adjustments should be made in circumstances where comments identify issues that are consistent with the goals of the program, such as concerns about accessibility for senior riders.*

**Recommendation:** *If Houston Metro does not already have a forum for operators to express concerns about stop safety, one should be established. The agency probably does not, however, need to create a specific outreach program related to the stop consolidation effort.*

## Post-Implementation Analysis

**Findings:** Only one agency in my study completed a formal post-implementation analysis of their bus stop consolidation program. Two of the planners I interviewed specifically noted that it would be difficult to isolate the effects of consolidation, because it is often implemented in conjunction with other service improvements. Planners typically only formally documented the number of stops removed or relocated during the program. Many planners interviewed, however, noted that they had also monitored several operational efficiency metrics pre- and post-consolidation. Based on this informal analysis, several of those interviewed suggested that stop consolidation has had a positive effect on bus operations.

**Recommendation:** *Houston Metro should track the number of stops removed during the program, as well as the percentage of stops with improved amenities. Additionally, the agency should monitor before and after ridership, on-time performance, and running time data for routes that undergo consolidation and optimization. Due to the significant changes related to the System Reimagining Plan, it will likely not be possible to directly attribute any variation in these metrics directly to the stop consolidation program.*

# Introduction

The Greater Houston metropolitan area is one of the largest and fastest growing regions in the United States. As of the 2010 Census, Houston was the seventh largest urbanized area[1] (UZA) in the country, with a population approaching five million (US Census Bureau, 2010). Most of the metropolitan region consists of low-density residential neighborhoods, interspersed with low-rise commercial and industrial developments. Like many other Sunbelt cities, Houston features several clusters of urban density, rather than a single downtown core. Population density therefore remains relatively constant throughout the region, rather than dropping off significantly outside of downtown. The region, however, remains less dense than many urban areas of similar population and is just the 66th densest UZA in the country (US Census Bureau, 2010).

Public transportation in the Greater Houston region is primarily provided by the Metropolitan Transit Authority of Harris County (Houston Metro). In FY2013, Houston Metro served just under 82.5 million passenger boardings, the 20th most of any transit network in the United States. Just over 83 percent of boardings occurred on local bus services, while just under 17 percent of boardings were on the emerging light rail network (American Public Transportation Association, 2014). Of the ten largest UZAs by population, only Dallas has lower transit ridership than Houston. In fact, the Minneapolis-St. Paul UZA has similar annual passenger boardings as Houston, despite having just over half of the regional population. While some of this disparity in ridership is attributable to Houston's urban form, it also suggests an opportunity to increase public transit usage in the region.

Houston Metro, as well as the political and community organizations that support it, are currently leading a dramatic evolution of Houston's public transit network. Since 2013, the agency has opened three new light rail extensions. These capital projects grew the existing rail system from 7.5 miles and 16 stations to 22.7 miles and 43 stations. Further light rail, bus rapid transit (BRT), and commuter rail extensions are in the planning stages. Alongside this rail capital program, Houston Metro is currently implementing a radical transformation of its local bus network. This program, known as the *System Reimagining Plan*, was passed by the Houston Metro board in February 2015 and will be implemented over the following six months.

The *System Reimagining Plan* will transform Houston's bus system from a patchwork of lines oriented towards downtown to a grid-oriented network of high frequency transit corridors. The plan consolidates circuitous bus lines with low levels of service, combines lower ridership routes that were operated on adjacent parallel streets, and facilitates better connections between services. Without increasing system operating costs, the number of bus lines with headways of 15 minutes or less will be nearly doubled. These new high frequency lines, branded

[1] The US Census Bureau defines an Urbanized Area (UZA) as an urban center and its densely populated surroundings. Metropolitan Statistical Areas (MSAs) contain at least one UZA and include the entirety of any county that includes an area that is associated with the urban center. MSAs often contain significant areas of rural or uninhabited land, which can distort urban/suburban density calculations. UZAs are therefore more representative of the land area, population, and density of an urban region (Federal Highway Administration, 2012). For example, as of the 2010 Census, the Houston, TX UZA is 1660 square miles and has a population of 4,944,332. The Houston-Sugar Land-Baytown, TX MSA is 8,827.5 square miles and has a population of 5,496,800. The Houston MSA is therefore 432 percent larger than the Houston UZA, while having only 11 percent greater population, making the UZA 342 percent denser than the MSA (US Census Bureau, 2010).

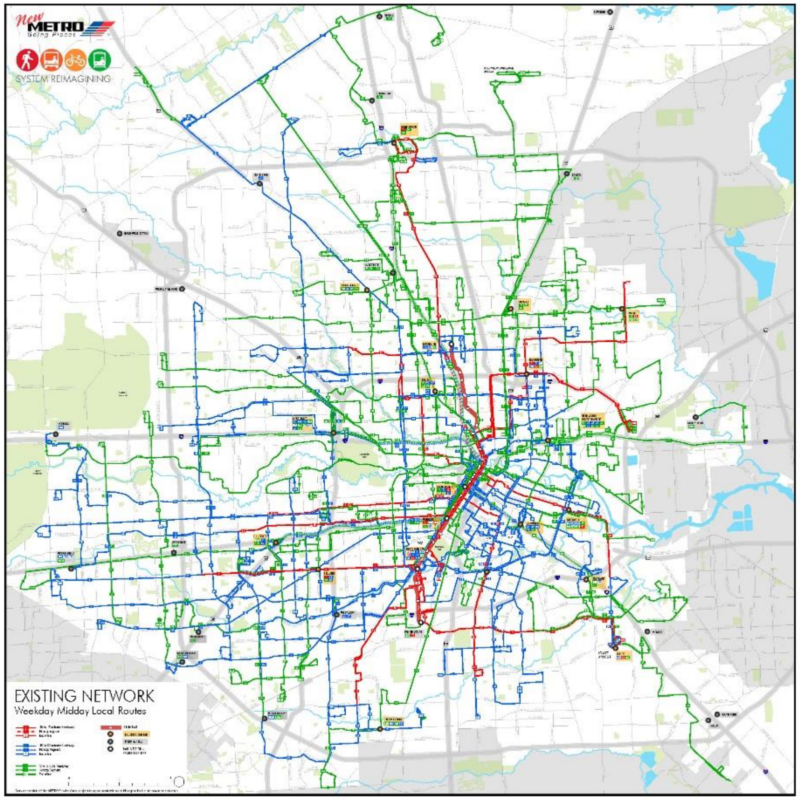
as the Frequent Network, will better serve business districts and social services that have emerged outside the downtown core. Houston Metro also plans on dramatically increasing weekend service (Metropolitan Transit Authority of Harris County, 2014).

While the *System Reimagining Plan* significantly alters the bus network, most bus stops on the remaining routes will not be changed. Houston Metro estimates that 94 percent of current transit users will be able to utilize the same bus stop after the system is reconfigured (Metropolitan Transit Authority of Harris County, 2014). Houston's local bus system currently has over 9,500 bus stops with an average stop spacing of around 1,300 feet. Many local bus services, however, include long segments on freeways without stops, as well as wide stop spacing in neighborhoods with disconnected street grids. Not including these segments, average stop spacing on local routes is generally 850 to 950 feet. On many of the route segments that will comprise the future Frequent Network, especially in Downtown Houston and immediate surrounding neighborhoods, average stop spacing is around 500 feet. As Frequent Network routes have the highest ridership, many customers will utilize services with this narrower stop spacing, rather than the 1,300 foot average.

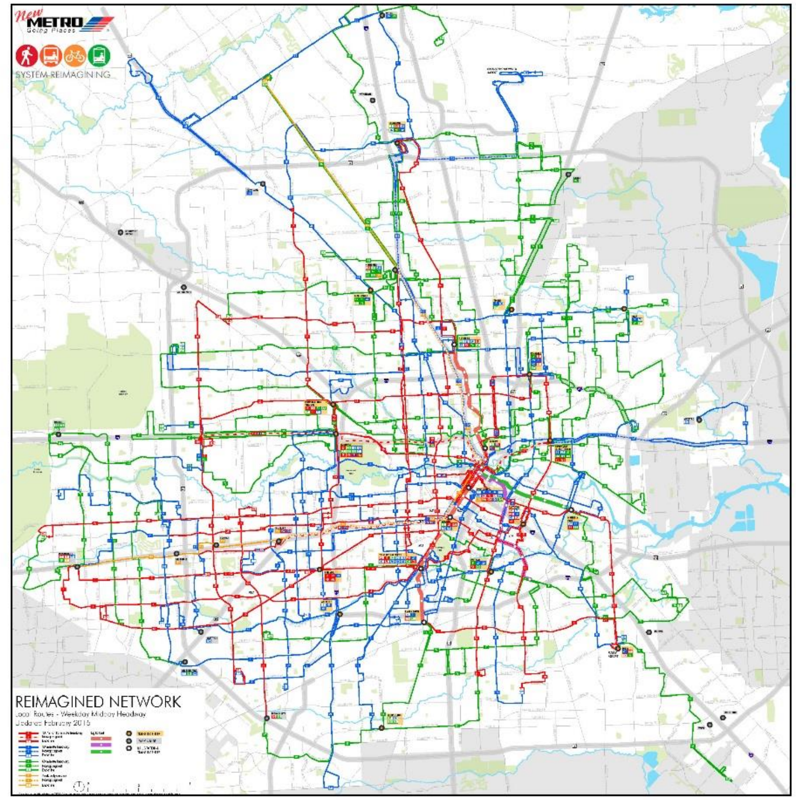
While Houston's narrow stop spacing is not unusual among U.S. transit systems, research shows that having bus stops spaced so closely together can reduce operating speeds and decrease service reliability (Levinson, 1983). Increasing stop spacing through consolidation is widely viewed by transit planners as an effective strategy to improve transit service with minimal capital investment. The tradeoff of such efforts is an increase in average walk distances between trip origin, bus stop, and trip destination on the one hand, and faster bus speeds, more frequent service, and shorter average wait times on the other (Walker, 2012). Transit riders are often resistant to increases in average walk distance, despite highly valuing the resulting operational benefits (Boyle, 2013; Yoh, Iseki, Smart, & Taylor, 2011). Bus stop consolidation programs are thus frequently initially challenged by transit riders, as well as by the politicians that represent them. After implementation, however, this opposition fades as riders begin to respond positively to reconfigured services (Boyle, 2013).

The purpose of this applied planning research project is to evaluate best practices in bus stop consolidation and optimization among transit agencies in the United States. Initially, I examine the relevant literature pertaining to bus stop consolidation. Topics include factors affecting bus service reliability, bus stop location optimization models, post-implementation evaluations of actual bus stop consolidation programs, and the role of public participation in planning. This also includes a review of bus stop ranking, a newly proposed methodology for identifying bus stop consolidation candidates. The core of this report includes detailed findings from interviews conducted with practicing transportation planners and public outreach coordinators at over a dozen major transit agencies nationwide. These discussions encompassed consolidation program initiation, strategy and planning, stop spacing standards, pre and post-evaluation processes, as well as political, community, and staff engagement. Based on these findings, I conclude with recommendations specific to the implementation of a bus stop consolidation program in Houston.

*Figure 1: System Reimagining Plan Service Changes*




METRO's Existing System




METRO's New Bus Network

# What does past research tell us about bus stop siting and spacing?

Bus stop consolidation is inherently a technical and political process. Any complete evaluation must, therefore, fully consider the tools used by transit planners to develop their respective consolidation programs and address how outreaching to politicians and the public helps to facilitate program implementation. This literature review is divided into five parts. Initially, an overview of the research pertaining to bus service reliability, a key transit characteristic that may be affected by bus stop spacing and placement, is provided. I then examine theoretical models of ideal bus stop spacing as well as post-implementation studies of actual bus stop consolidation programs. Arguments for and against public participation in planning are then detailed, followed by a review of bus stop ranking, a new methodology that could bridge the gap between theoretical stop spacing modeling and current planning practice. Finally, I consider how the existing body of literature will guide my examination of common practices in bus stop consolidation.

## Bus Service Reliability

Many transit services in the United States, especially local bus lines, suffer from poor service reliability. Running time[2] variations decrease the utility of public transit services by creating uncertainty regarding wait times at stops and reducing the probability for timely transfer opportunities (Turnquist, 1981). Studies have routinely shown that riders highly value service reliability, and that undependability reduces their satisfaction with transit (Eboli & Mazzulla, 2007; Nam, Park, & Khamkongkhun, 2005; Yoh et al., 2011). Ensuring reliable service is also beneficial to transit operators, as operating costs increase when agencies pad schedules to account for potential delays (Turnquist, 1981).

Despite its relevance to both customer satisfaction and operating costs, there is only a limited body of research regarding transit service reliability. Studies focusing on this topic were long hindered by the high cost of collecting vehicle travel time, vehicle location, and passenger boarding/alighting data (Abkowitz & Engelstein, 1983; Strathman & Hopper, 1993). This impediment has been alleviated in more recent years with the development of Automatic Passenger Counter (APC) and Automatic Vehicle Locator (AVL) technology. These technologies have provided service planners with the opportunity to better understand how transit systems function (Boyle, 2008; Moreira-Matias, Mendes-Moreira, de Sousa, & Gama, 2015). The reliance on APC and AVL does have some drawbacks, as many manual surveys include finer grain details, such as notation on the causes of unusual delays, which cannot be easily determined using computer-generated datasets (Milkovits, 2008).

The factors affecting service reliability can be separated into two categories, external and internal. External factors increase variability due to interactions with impediments, mainly congestion, that are generally beyond a transit agency's control. Levinson (1983) found that 12 to 26 percent of total peak period bus running time is attributable to congestion. McKnight, Levinson, Ozbay, Kamga, and Paaswell (2003) found that running time variability due to congestion increased New Jersey Transit's operating costs by about six percent. The effects of

[2] *Running time* refers to the duration of a one-way bus trip. For example, the 8:00 AM trip of Houston Metro's 2-Bellaire route takes one hour and one minute to travel from its origin at TMC Transit Center to its destination at Meadowglen & Wilcrest. Therefore, running time for that trip is one hour and one minute.

congestion, and its associated costs, may be mitigated through the reallocation of road space to bus only lanes (Surprenant-Legault & El-Geneidy, 2011; Turnquist, 1981) or through the dedication of signal time using transit signal priority systems (Dion, Rakha, & Zhang, 2004; Skabardonis, 2000; Turnquist, 1981).

Internal factors affecting service reliability include variables directly related to the operation of a transit line. Much of the variation due to internal factors occurs at bus stops. There is a fixed cost associated with pulling into a stop, opening and closing the doors, and exiting the stop. Additionally, there is a variable time cost, known as dwell time, associated with the boarding and alighting of passengers. Levinson (1983) found that passenger stops account for 9 to 26 percent of total bus running time during peak periods, a similar effect to that of roadway congestion. Dueker, Kimpel, and Strathman (2004) found that median fixed dwell time was 5.12 seconds, while each additional boarding added 3.48 seconds and each alighting added 1.70 seconds. Transit agencies can affect dwell times through capital interventions. For example, Milkovits (2008) found that utilizing contactless smart cards for fare payment reduced boarding times by 1.5 seconds on buses operating below max seated capacity.

In addition to dwell time variability at each stop, buses typically do not pick up or drop off passengers at every single stop during a given trip. Dueker et al. (2004), for example, found that on a typical Tri-County Metropolitan Transportation District of Oregon (TriMet; Portland, Oregon) bus trip, vehicles stop at only 60 percent of stops. Furthermore, they found an average of 1.22 boardings and 1.28 alightings occurred at each stop. This essentially means that each time a bus stops, it is typically picking up only one or two passengers. Reducing the number of stops could result in more passengers utilizing each remaining stop, thereby increasing the likelihood of stopping at the majority of stops during most trips. Levinson (1983), for example, found that bus running times could be reduced by over 25 percent by reducing the number of stops per mile from eight to six, and modestly decreasing dwell times. Service planners thus widely consider bus stop consolidation an effective tool to increase service speeds and reduce running time variability (Boyle, 2013).

## Bus Stop Optimization and Consolidation

Most research analyzing the effects of bus stop spacing has been theoretical in nature, rather than evaluations of actual consolidation efforts. Much of this research has been based on a commuter rail stop spacing model first proposed by Vuchic and Newell (1968). Many improvements to and adaptations of this model rely on simulations of a theoretical transit line (Chien & Qin, 2004; Kuah & Perl, 1988; Saka, 2001; Wirasinghe & Ghoneim, 1981) or have been utilized to calculate ideal stop locations on actual transit lines (Furth & Rahbee, 2000; Murray & Wu, 2003). Ibeas, dell'Olio, Alonso, and Sainz (2010) uniquely utilize an optimization model to determine ideal stop locations across an urban area.

Existing academic research on efficient bus stop spacing generally agrees that wider stop spacing leads to increased bus service speeds. However, estimates of ideal spacing, as well as the effects of demand on spacing, vary widely between models. As noted by Tirachini (2014), a primary, and unresolved, disagreement is whether stop spacing should increase or decrease with demand. This variation occurs in part due to which costs and benefits to transit operators and riders, as well as fleet characteristics, are included in the model (El-Geneidy, Grimsrud, Wasfi, Tétreault, & Surprenant-Legault, 2014; Ibeas et al., 2010; Tirachini, 2014). Furthermore, many of the models allow the weighting of these factors to be changed, and the authors demonstrate that these adjustments lead to varying optimal spacing outcomes.

There are only three published post-implementation evaluations of implemented bus stop consolidation programs. Two of these focus on the Streamline program, an effort by TriMet to improve service speeds and reliability on 12 major bus routes. Koonce, Ryus, Zagel, Park, and Parks (2006) evaluated the overall Streamline program, without specifically isolating the effect of bus stop consolidation. They found that the program resulted in an average running time savings of 2.1 minutes compared to non-program routes. Much of this savings was due to an increase in running times on non-program routes, presumably due to increased congestion. Furthermore, they found that on-time performance decreased more slowly on program routes. These benefits, however, did not translate into short-term cost savings.

El-Geneidy, Strathman, Kimpel, and Crout (2006) conducted a field study analyzing the effects of the bus stop consolidation program on an individual Streamline route. They found that consolidation led to a 5.7 percent reduction in running time, with the potential for increased time savings with additional timetable adjustments. These savings were achieved without a noticeable effect on corridor ridership. They did not, however, find that the stop consolidation program had led to increased service reliability.

Flint, Ben-Amos, Ellis, and Krykewycz (2014) analyzed the process of implementing a pilot bus stop consolidation program on a 2.5 mile corridor segment of Route 47 in Philadelphia. In addition to removing half of the stops, the Southeastern Pennsylvania Transit Authority (SEPTA) implemented rear door boarding at two heavily used stations, optimized the placement of several stops, and coordinated trash pickup along the route. After implementation, morning peak running times decreased by 7.1 percent, but evening peak running times actually slightly increased. Additionally, reliability on the route declined. Flint et al. (2014) attribute the variation in running times to increase signal delays at key intersections, and attribute the decline in reliability to a switch to headway-based scheduling.

Flint et al. (2014) provide key insights into the process that transit agencies use to implement bus stop consolidation and optimization programs. SEPTA planners on the Route 47 project opted to simply remove every other stop, rather than conduct an in-depth analysis of ideal bus stop location. This consolidation approach increased average spacing from 500 to 1000 feet, a distance that better reflected SEPTA's ideal minimum stop spacing standard. Additionally, the planners conducted a public outreach process, which led to changes in aspects of the program. This outreach process included the framing of the program as a pilot, rather than a permanent change. Ultimately, the service changes did not result in consistent time savings or increased reliability. Over 100 riders also submitted complaints related to the removal or relocation of bus stops. As a result, SEPTA decided to roll back most of the service changes at the end of the pilot period, and reinstated nearly all of the consolidated stops.

The experiences in Philadelphia reflect an underlying problem with the traditional theoretical approaches to bus stop spacing. Most theoretical bus stop spacing models rely on data analysis that is significantly more complex than the process typically followed in actual bus stop consolidation programs. Rather than determine optimal stop spacing for each corridor, transit agencies instead attempt to match actual stop spacing to defined bus stop spacing standards. Stop consolidation programs are also affected by concerns and suggestions from community members and political officials. Many transit agencies incorporate public preferences, such as maintaining stops in close proximity to senior centers, when determining stops targeted for consolidation. The inability to easily adapt to both public concerns and the reality of the built environment significantly lessens the practicality of bus stop spacing optimization models.

## Public Participation

While bus stop consolidation generally increases walking distances to bus stops by a few hundred feet, and only for some riders, programs are frequently met with significant community opposition. This resistance may occur due to the uncertainties surrounding changes in bus stop location, rather than the outcome of a consolidation program itself (Abbott, 2005; Marris, 2015). Riders may become more supportive once they experience the positive effects associated with greater bus spacing. In an analysis of bus service enhancement strategies conducted by Boyle (2013), one interviewee noted that "Bus operators who initially oppose stop consolidation may become your biggest champions. Riders, too, will begin to push for stop consolidation as they see the benefits to their own commutes."

Initial opposition, however, can derail the stop consolidation process entirely. This may be mitigated through public participation and community outreach programs. Flint et al. (2014), for example, note that previous attempts at bus stop consolidation in Philadelphia "were met with little political support and a lot of pushback from the public." The development of a public outreach program "helped to minimize community opposition to consolidation and resulted in minimal push back." Formalized public participation programs have long been a cornerstone of urban planning in the United States, beginning with the 1954 Urban Renewal Act. The goals of these processes have shifted over time, fluctuating between often conflicting goals of generating public support for previously established planning decisions and involving the public throughout the planning process (Day, 1997). Today, many federal programs include strict participation requirements; however mandates at the state level are often lax and poorly enforced (Brody, Godschalk, & Burby, 2003).

Proponents of public participation in planning argue that effective outreach processes lead to better planning decisions. Such outreach allows planners to become informed about community concerns, while educating the public about effective planning practices (Irvin & Stansbury, 2004). As a result, planners are able to better understand and predict potential reaction to proposals. Community members are also able to make more significant contributions, which can lead to reduced conflict during the later stages of a project or planning effort (Brody et al., 2003). Productive outreach can foster ongoing dialogue across a wide range of community actors, leading to more inclusive planning over time (Innes & Booher, 2004).

Critics of existing public participation practices argue most planning decisions are not significantly affected by outreach processes. They believe these efforts are both expensive and time consuming for planning agencies, and potentially distract from other functions (Kweit & Kweit, 1984). It is also costly for community groups, both in money and time, to prepare effective critiques of planning proposals. Therefore, the most active participants in outreach processes tend to be actors with existing political or economic influence, like developers or business groups, rather than those most affected by the planning intervention (Kweit & Kweit, 1984). In fact, planners may actually target these groups specifically during the outreach process, rather than seek to consult a broad range of constituents (Brody et al., 2003). Finally, the public often reacts negatively when their concerns do not lead to constructive changes in a planning proposal. This reaction can manifest into lawsuits or influential political opposition (Innes & Booher, 2004).

## Bus Stop Ranking Systems

As discussed previously, there appears to be a disconnect between idealized bus stop optimization models and actual industry practices. The former do not adequately consider community preferences, while industry practice relies heavily on fieldwork observations and generalized standards, but little in the way of formal analysis. Bus stop ranking systems, first proposed independently by Ma, Hsiao, and MacKechnie (2014) and Stewart (2014), represent the most significant efforts to rationalize the bus stop spacing optimization problem with the realities of constituent-influenced transportation planning.

Ma et al. (2014) proposes a relativity simple method to rank bus stops across a transit network. Bus stops are assigned a point value based on an adaptable set of variables, and then grouped into six tiers. In one example, they use ridership and being a transfer station as the variables to rank bus stops for a potential consolidation and elimination program. They then calculate the distance between each stop, determine which stop pairs fall below a defined stop spacing standard, and target lower tiered stops for elimination.

Stewart (2014) utilizes a more complex python script model [3], in addition to basic GIS analysis, to determine candidate bus stops for removal in Montreal, Canada. Like Ma et al. (2014), Stewart (2014) utilizes a tiered stop ranking system based on adaptable variables, though his model specifically factors ridership, being a transfer station, and being located near a social service. He additionally utilizes a python script model in GIS to calculate a catchment area for each bus stop. Bus stop rankings are then used to determine which stops within an overlapping catchment area should be subject to removal. Finally, Stewart (2014) demonstrates that this script can be run successively for multiple lines, allowing agencies to determine the optimal stops for removal across an entire transit network. Using this method to analyze the bus network operated by La Société de transport de Montréal (STM) in Montreal, Quebec, Canada, Stewart (2014) found that the agency could remove a quarter of their stops while maintaining existing service coverage. He projected that this consolidation program would increase average walk time to a bus stop by just 27 seconds, while allowing STM to maintain existing peak morning frequencies using 42 fewer vehicles.

Both stop ranking system proposals include methodologies for incorporating community preferences. Stewart (2014) details a process for identifying which stops serve large social service facilities, like hospitals, and excluding those stops from elimination. Ma et al. (2014) note that census tract-based data, such as poverty rates or median income, can be tied to a stop and included in the ranking system. Despite the inclusion of these methodologies, neither Ma et al. (2014) nor Stewart (2014) fully explore the potential for bus stop ranking systems to consider community or agency preferences. For example, neither proposed ranking system incorporates data regarding stop infrastructure, such as bus shelters, or Americans with Disabilities Act of 1990 (ADA) compliance. However, both proposals demonstrate the potential for additional variables to be added to the model, suggesting that these oversights can easily be remedied. Ultimately, while the methodology is in its infancy, bus stop ranking systems present a valuable and applicable tool for planners implementing bus stop consolidation programs.

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[3] Python is a programing language that can be used to automate or enhance data processing and analysis functions within GIS.

## Lessons for this study

The existing literature provides important insights into the potential benefits of bus stop consolidation, as well as some of the challenges transit agencies have faced when implementing such programs. Stop optimization modeling provides support for the theory that increasing stop spacing can increase bus service speeds without significantly reducing access for transit riders. These models, however, fail to take into account the political dimensions of stop placement, and also rely on data and calculations that far exceed those typically used in actual planning practice. The three post-evaluation studies reviewed here demonstrate that stop consolidation can lead to operational benefits, but that the nature of these benefits is inconsistent and not yet fully understood. One of these studies, Flint et al. (2014), provides a more detailed analysis of the decision-making processes of a single agency that pursued stop consolidation. While this study provides valuable insights, the actions of a single agency cannot be used to develop an understanding of the range of potential approaches to stop consolidation.

A nuanced examination of planning practice is needed to more fully understand the potential benefits of stop consolidation. Why do planners decide to pursue stop consolidation and what goals do they have for their programs? Which criteria are used to determine which stops to consolidate? How do communities and political leaders react to consolidation proposals and what actions do planners take to assuage their concerns? What are the operational benefits of stop consolidation, if any, and have planners determined practices that best maximize these benefits? Are there ways to improve or streamline consolidation efforts? Many of these questions can only be answered through dialogue with planners that have pursued stop consolidation, as well as an examination of a wider range of consolidation programs. This study seeks to add to the existing body of knowledge by interviewing these planners and examining how they approach both the technical and political aspects of bus stop consolidation.

# The questions guiding this research, and the methods employed to answer them

This applied planning research project examines how transportation planners approach bus stop consolidation and optimization. I specifically focused on how planners balance the ideals of improved transit service resulting from stop consolidation against the often visceral opposition to stop removal or relocation among riders, property owners, and elected officials. In addition to the literature review summarized in the previous section, this research entailed detailed interviews with transportation professionals across the United States, as well as a review of available planning documents and post-implementation data. All acquired information was then analyzed to identify common practices in order to develop recommendations for a potential consolidation effort at Houston Metro, as well as other agencies that plan to study and implement bus stop consolidation and optimization projects in the future.

## Selection Process

In order to develop a list of potential interviewees, I first created an inventory of major public transit agencies[4] in the United States. Utilizing the public records search functions available on each agency's website, as well as a general internet search engine, I identified completed, active, or proposed bus stop consolidation and optimization programs at over 30 of the 80 agencies initially targeted. Programs ranged from consolidation on a segment of a single bus corridor to system wide consolidation and optimization. Several agencies also were found to have BRT or rapid bus programs, which typically include some level of bus stop consolidation and optimization.

I then contacted transportation planners and public outreach coordinators with experience in implementing bus stop consolidation and optimization programs. Out of the 28 potential interviewees contacted, 18 responded with 16 completing an interview (see Table 4 in the appendix for more information about the interviewees). The participants work at 13 different transit agencies which have either completed (10), unsuccessfully attempted (2), or are planning (1) a bus stop consolidation process (see Table 1 for an overview of agencies that participated in this study). An additional participant is employed by a metropolitan planning organization that provided technical support for a transit agency during their consolidation effort, which was ultimately unsuccessful. Unfortunately, I was unable to complete an interview with a planner whose agency had not pursed consolidation, despite several attempts to do so.

I also spoke with Kurt Luhrsen, Vice President of Planning at Houston Metro, in order to develop a better understanding of the characteristics of Houston's transit network, as well as the technical capabilities of the agency. Mr. Luhrsen also acted as an advisor for this applied planning research project.

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4 Major transit agencies were identified as any transit operator with 20,000 or more daily bus boardings in 2014 Q3 (American Public Transportation Association, 2014).

## Review of Associated Materials

Nearly all agencies participating in this study have previously published documents detailing their stop consolidation and optimization process. Additionally, many agencies have published service standards or bus stop design manuals that were often used to inform their consolidation and optimization efforts. Publicly accessible documents were reviewed before each interview. Each interviewee was also asked about the availability of additional documents, which were later examined if available.

## Interview Process

Interviews were completed by telephone using a semi-structured process. Each participant was asked a basic set of questions, with follow-up questions developed based on discussion content or previously reviewed documents specific to the associated agency. Interviews lasted an average of 25 minutes and ranged from 14 minutes to 41 minutes. All conversations were recorded with interviewee consent and then transcribed. Participants were given the opportunity to clarify and edit the direct quotations used in this report via email. Additionally, each participant was given the opportunity to request that I remove identifiable information from this report or paraphrase, rather than directly quote, from their interview transcript. All transcripts were destroyed upon the completion of this study in order to ensure the confidentiality of each interview.

All participants chose to accept the opportunity to review and edit the quotations presented in this report. The majority of these alterations were edits to improve grammar or clarity. Several participants also redacted a section or the entirety of quotes originally proposed for inclusion. None of these edits or redactions altered the initial findings of this report. Additionally, one interviewee requested that all references to their interview be paraphrased and that their name and position be redacted.

*Table 1: Agency Profiles*

| Agency | Service Area | Urbanized Area Population (2010) | | Urbanized Area Population Density (2010) | | Transit Ridership (Annual Unlinked Passenger Trips) | | Bus Stop Consolidation | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Rank | Total | Rank | Total | Rank | Status | Comments |
| Metropolitan Transit Authority of Harris County (Houston Metro) | Houston, TX | 4,944,332 | 7 | 2,979 | 66 | 82,485,882 | 20 | N/A | N/A |
| Santa Monica Big Blue Bus | Santa Monica, CA (Part of Los Angeles, CA UZA) | 12,150,996 | 2 | 6,999.3 | 1 | 19,319,086 | 60 | Ongoing | • Plans to study and implement consolidation system wide over a three year period.<br>• Groups of stops based on route or target area are consolidated during each service shakeup.<br>• Also plans to combine local and rapid services on a corridor by adding a limited number of stops to the rapid and eliminating all local service. |
| Central Ohio Transit Authority (COTA) | Columbus, OH | 1,368,035 | 35 | 2,680 | 93 | 18,472,039 | 62 | Ongoing | • Started evaluating consolidation opportunities on express bus services in 2009, then moved on to local routes in more recent years.<br>• Ongoing study and implementation of stop consolidation on routes system wide. |
| Charlotte Area Transit System (CATS) | Charlotte, NC | 1,249,442 | 37 | 1,685 | 311 | 28,478,330 | 48 | Ongoing | • Has completed bus stop consolidation on five highest ridership routes<br>• Plans to increase the total percentage of stops with improved amenities |
| Clark County Public Transit Benefit Area Authority (C-TRAN) | Vancouver, WA (Portland, OR Northern Suburbs) | 1,849,898 | 23 | 3,528 | 34 | 6,260,280 | 127 | Ongoing | • Currently completing fifth stage of bus stop consolidation program.<br>• In final planning stages of adding signal priority to a corridor that previously underwent stop consolidation. |
| Greater Cleveland Regional Transit Authority (RTA) | Cleveland, OH | 1,780,673 | 24 | 2,307 | 136 | 48,501,787 | 31 | Ongoing | • Currently consolidation stops across entire bus network<br>• Program includes the replacement of signage at all remaining stops |
| King County Metro | Seattle, WA | 3,059,393 | 14 | 3,028 | 62 | 122,002,305 | 13 | Ongoing | • Most stop consolidation has come through the transformation of local bus services into rapid bus routes.<br>• Rapid services have 1/3-1/2 mile stop spacing. The agency does not retain local bus services on corridors where rapid service is implemented. |
| Long Beach Transit | Long Beach, CA (Part of Los Angeles, CA UZA) | 12,150,996 | 2 | 6,999 | 1 | 28,597,870 | 47 | Ongoing | • Completed a consolidation project on a section of a single corridor; may expand program.<br>• Utilized a bus stop ranking methodology to identify potential stops for consolidation.<br>• Plan on using bus stop ranking to prioritize bus stop infrastructure improvements. |
| Massachusetts Bay Transportation Authority (MBTA) | Boston, MA | 4,181,019 | 10 | 2,232 | 149 | 393,145,108 | 5 | Complete | • Received federal grant to improve stop amenities along the 15 highest ridership bus routes.<br>• Consolidated and relocated stops as part of this amenity enhancement program. |
| Port Authority of Allegheny County (Port Authority) | Pittsburgh, PA | 1,733,853 | 26 | 1,916 | 235 | 61,837,788 | 27 | Planning | • Eliminated unsigned stops that remained in the agency's bus stop database.<br>• Considering bus stop consolidation program. |
| Southeastern Pennsylvania Transportation Authority | Philadelphia, PA | 5,441,567 | 5 | 2,746 | 88 | 356,725,629 | 7 | Discontinued | • Eliminated half of stops on a route segment as part of a larger service enhancement strategy pilot<br>• Reinstated most stops after program failed to achieve cost savings |
| City and County of Honolulu Department of Transportation Services (TheBus) | Honolulu, HI | 802,459 | 53 | 4,716 | 8 | 69,242,214 | 27 | Discontinued | • Attempt to conduct consolidation through their system<br>• Ended consolidation program after significant negative community and political response |
| Transit Authority of Northern Kentucky (TANK) | Covington, KY (Cincinnati, OH Southern Suburbs) | 1,624,827 | 29 | 2,063 | 190 | 3,545,445 | 179 | Ongoing | • Consolidating stops on the three highest ridership corridors; plan to expand program.<br>• Removed almost 45% of stops on highest ridership route.<br>• Working to enhance amenities are remaining stops. |
| Washington Metropolitan Area Transit Authority (WMATA) | Washington, DC | 4,586,770 | 8 | 3,470 | 39 | 411,606,781 | 4 | Ongoing | • Initial attempts to consolidate stops were controversial and ultimately heavily modified based on community input.<br>• Revamped process with focus on political outreach, now implementing consolidation on one or two routes at a time. |

Sources: 2010 United States Census, American Public Transit Association, Interviews with planners from listed agencies

# What have planners learned about bus stop consolidation?

Based on interviews with planners and outreach coordinators, it appears that most stop consolidation programs follow a similar development pattern:

1. Agencies first set goals for their programs and develop phasing and implementation strategies.
2. They then establish a set of criteria used to evaluate stops considered for consolidation.
3. Once formalized consolidation lists are developed, planners present their proposals to political and community constituents, which are sometimes received coolly.
4. With consideration given to these outreach processes, consolidation proposals are implemented.

In this report, interview findings are presented chronologically, based on each of these steps in the typical consolidation process.

## Program Initiation and Goals

Despite an overwhelming acceptance of bus stop consolidation as a tool to improve bus service, agencies across the United States vary significantly in the goals motivating their programs. That said, eliminating stops whose spacing does not follow guidelines was the primary goal of nearly all stop consolidation processes. Most agencies also specifically targeted low ridership stops for removal or consolidation. Rationales for elimination of these stops can be broken down into two sub-categories, operational efficiency goals and stop quality goals. Most agencies targeted improvements in at least one category, many in both.

Operational efficiency goals have traditionally been the focus of bus stop consolidation research. Unsurprisingly, planners at 11 of the 13 agencies surveyed identified at least one operational efficiency objective. Most interviewees did not specify which aspect of bus operations they hoped to make more efficient, but tended instead to refer to reducing operational inefficiencies more broadly. Representatives of five agencies singled out increasing average operating speeds or reducing travel times as a primary goal. Surprisingly, only one interviewee, Greg Krykewycz, Manager in the Office of Transit, Bicycle, and Pedestrian Planning at the Delaware Valley Regional Planning Commission[5] (DVRPC), mentioned potential operating costs savings as a driver behind the attempt to improve operational efficiency:

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[5] The Delaware Valley Regional Planning Commission (DVRPC) is an interstate metropolitan planning organization serving the Greater Philadelphia metropolitan region, including counties in Pennsylvania and New Jersey. While DVRPC does not operate or directly control planning for a public transit agency, they do provide ongoing technical assistance for the Southeastern Pennsylvania Transportation Authority (SEPTA). DVRPC provided technical and community outreach support for SEPTA’s Transit First project, which included bus stop consolidation.

*"…I think it's always good to look at stop consolidation, stop location and stop frequency because that's a no cost change. And so if you do it right you're achieving travel time savings and that provides potentially an operating cost savings and... you're doing that at no expense…"*

In contrast, Greg Strangeways, Manager of Service Planning at the Massachusetts Bay Transportation Authority (MBTA) in Boston, expressly noted that planners at his agency did not expect to see cost savings as a result of stop consolidation:

*"Cost savings were never the goal… [Our goal was] to improve operations, but not save money. We told everyone that upfront and we don't think the improvement will be enough to really save a bus here and there, it will just make service more reliable and a little bit faster."*

Removing underutilized bus stops was also widely seen as a method to increase overall stop quality. Planners at 10 of the 13 agencies surveyed identified at least one stop quality improvement goal. These specific stop quality goals included both operational and safety improvements, as well as stop amenity improvements. Six planners noted that removing underutilized bus stops would allow their agency to more effectively utilize capital resources to fund upgrades, and increase the overall percentage of stops with benches or shelters. Five identified either increasing safety at stops or eliminating those that were unsafe for riders to access as a goal of their stop consolidation program. Interviewees at three agencies specifically cited the ability to make ADA accessibility improvements, and increase the total percentage of bus stops that are ADA compliant[6], as a goal of their programs. Several planners I interviewed noted that these stop improvements would likely increase customer satisfaction with transit services.

## Program Strategy and Phasing

The analyzed transit agencies utilized several different phasing and implementation strategies in their efforts to consolidate bus stops. In terms of phasing, two main patterns emerged. Several agencies studied stop consolidation in groups of routes, and carried out proposed changes as part of regularly scheduled service updates. These agencies typically planned to consolidate at least some stops on most or all of their routes over the long term. Timothy McCormick, the Transit Planning Administrator at Santa Monica Big Blue Bus in Southern California noted that a phased implementation strategy may reduce opposition to what will ultimately be a system wide change:

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6 The Americans with Disabilities Act of 1990 includes specific requirements for the design of public transit access points, including bus stops. To be ADA compliant, bus stops must meet specific design standards for sidewalks, curb ramps, and landing pads. In a 2013 study, over one third of major transit agencies surveyed stated that less than 50% of their bus stops were ADA compliant. The same study found that installing an ADA compliant bus landing pad, one of the most common projects required to make a bus stop ADA complaint, cost an average of $6,995 per stop (Suksawang et al., 2013).

> *"…I would say on the re-spacing we're keeping it under 50 [stops] at any one time. So it takes time because we don't want to have the phone at City Hall ring of the hook. If you take out too many bus stops at once, it's… too many people at once complaining about the policy decision."*

Some planners I spoke with also noted that their agencies pursued a phased implementation strategy due to the significant staff time commitment required to complete a consolidation study. High ridership routes were often included in the initial phases of a consolidation effort. Alternatively, some planners opted to target a specific geographic location such as a downtown neighborhood, and consolidate stops only on the sections of routes that entered that area. The size of each phase varied somewhat, with most agencies targeting less than six routes or one neighborhood per service update.

Using an alternate approach to phasing, several other agencies have focused, at least initially, on individual routes. SEPTA, for example, initiated a pilot stop consolidation program on just a single short route segment. The segment was chosen due to high utilization and because it was located within a single political jurisdiction. Conversely, the Washington Metropolitan Area Transit Authority (WMATA) in Washington, D.C. implemented their first successful stop consolidation effort on a longer route that crossed several neighborhood boundaries. Clark County Public Transit Benefit Authority (C-TRAN) in Vancouver, Washington initially targeted only their most popular bus route for consolidation, and then began utilizing a phased strategy to evaluate wider geographic areas, such as Downtown Vancouver.

Agency practices with regards to the implementation strategy also varied significantly. Several introduced stop consolidation programs independently of other service enhancement strategies. The majority however, studied and implemented stop consolidation in coordination with and/or in anticipation of other proposed improvements. Greg Krykewycz, Manager at DVRPC, noted the benefits of coordinated implementation:

> *"Really our idea was with all of these things whether as part of a Transit First project in the city or as part of a regional initiative are that if you can achieve a couple percent here and a couple percent there through these different sorts of low hanging fruit —low cost moderate impact strategies— that in combination can have a pretty considerable impact and result in a much more attractive surface transit operating experience at only a marginally higher cost. So I guess as a general rule I would recommend not considering any of these strategies in isolation unless you know for a particular transit agency they've got an issue that's really severe on one of them and not on any of the others. Because generally speaking if when you combine multiple strategies kind of smartly that you get the best overall bang for your buck."*

The most common potential companion service enhancement strategy considered when restructuring bus stops was the future introduction of transit signal priority. Planners also simultaneously designed or implemented a variety of bus stop enhancements, including bus stop pad and shelter installation, ADA accessibility improvements, real-time countdown clocks, and off-board fare collection. Signage was also frequently replaced or enhanced at remaining bus stops.

Big Blue Bus, TheBus in Honolulu, and King County Metro in Seattle all implemented rapid bus services that feature longer bus stop spacing. Similar services have also been implemented in Los Angeles and Vancouver, British Columbia (IBI Group, 2003; Transportation Management & Design Inc., 2002). TheBus and Big Blue Bus maintained local bus service on corridors where rapid bus service was implemented, while King County Metro removed local service, but maintained somewhat narrower stop spacing. Rapid bus overlays on corridors that maintain existing local service may allow agencies to obtain some of the benefits of stop consolidation without actually eliminating existing local bus stops.

## Stop Spacing Standards

Conventional wisdom in the U.S. transit industry holds that transit users will typically walk about a quarter mile to access a local bus service and about a half mile to access higher quality transit, such as rail or rapid bus (El-Geneidy et al., 2014; Walker, 2012). Ideal spacing is generally considered to be around a quarter mile between local bus stops. At this spacing, most potential riders near a corridor will be within walking distance of one stop. Narrower spacing may result in most riders being within walking distance of multiple stops, which provides minimal benefit while reducing operating speeds. Wider spacing may leave some riders, especially those originating farther away from the corridor, without an easily accessible bus stop. Typical stop spacing on existing bus lines in the United States is almost exclusively narrower than this recommended quarter mile spacing (Walker, 2012).

Most public transit systems in the United States are the descendants of private streetcar operators. These companies often generated a significant portion of their revenues from purchasing land on the outskirts of existing urban areas, extending their transit lines out to their new land holdings, and then selling the newly subdivided land as suburban housing (Jones Jr, 1985). Some services in outlying operated use flag stops, where riders could board or alight anywhere along the line, while others used fixed stops that were typically close together. Bus services and their associated bus stops emerged from these early streetcar lines.

Over the succeeding decades, many transit systems added new stops without considering the effect on transit operations. Patrice A. Brady, a Service Planner at the Central Ohio Transit Authority in Columbus, Ohio, commented,

> *"At that time I think it was literally if somebody called us for a stop to be installed, they just put it in the ground without any spacing consideration at all."*

As a result, many agencies have numerous stops with little to no ridership, often serving destinations that no longer exist. Scott Vetere, Director of Service Planning, Scheduling, and Evaluation at the Port Authority of Allegheny County (Port Authority), said, *"Developments that have been there for some of these stops in our system are probably 70 years old, and so they probably haven't been looked at in 70 years either."*

*Table 2: Stop Spacing Standards at Selected Agencies*

| Agency | Local Bus | | | Rapid Bus |
|---|---|---|---|---|
| | Low Density | Moderate Density | High Density | |
| Santa Monica Big Blue Bus | 1000-1320 | 1000-1320 | 1000-1320 | 2640 |
| Central Ohio Transit Authority | 850-1200+ | 700-850 | 500-700 | N/A |
| Clark County Public Transit Benefit Area | 600-2640 | 500-1200 | 300-1000 | N/A |
| Greater Cleveland Regional Transit Authority | 880 | 880 | 880 | N/A |
| King County Metro | 1320 | 1320 | 1320 | 2640 |
| Port Authority of Allegheny County | 500-1000 | 500-700 | 500-700 | 900-1300 |
| Southeastern Pennsylvania Transportation Authority | 1000 | 500-1000 | 500-1000 | N/A |
| Washington Metropolitan Area Transit Authority | 1056-1320 | 1056-1320 | 1056-1320 | 1760-2640 |

Note: Agencies used various definitions of neighborhood density
Source: Service standards manuals provided by listed agencies

Bus stop spacing standards have emerged as a primary tool to guide the rationalization of bus stop placement. All but one of the transit agencies analyzed for this study has published service guidelines that feature minimum or ideal bus stop spacing standards. At least three agencies have or are in the process of updating their stop spacing standards as part of their bus stop consolidation program. Spacing guidelines varied widely in terms of recommended distances between stops (see Table 2). Certain agencies provide further refinements that take neighborhood density into account. Three transit operators where I conducted interviews base stop spacing guidelines entirely on service type, only differentiating shorter spacing for local routes and longer for rapid bus services. All other agencies varied stops spacing based on density, with lower density areas have wider stop spacing and narrower stop spacing in higher density residential areas and CBDs.

Only one agency surveyed recommended quarter mile or greater stop spacing on the majority of bus services and locations. This suggests that even when enacting stop consolidation programs, access to transit services is preferred by planners over speed (Walker, 2012). Additionally, it is likely that many agencies make context specific exceptions to spacing standards, even if the ability to make these modifications is not expressed in their service guidelines. Timothy McCormick, the Transit Planning Administrator at Big Blue Bus, described narrowing stop spacing near major destinations, *"So the one place where we accept a much higher density of stops is where the individual volume at a stop is so high you have considerable sidewalk congestion at that stop. So if I was to go every 1,300 feet in downtown Santa Monica the sidewalk would have hundreds of people. So we have a more frequent bus stop placement also at the stops around Santa Monica College, like we'll have three stops 600 feet apart, because any one of those three bus stops can be jammed…. so we use side walk congestion as a way to make a decision about mitigating and allowing a closer spacing…"*

Stop spacing standards may also be modified based on topography and street network connectivity, rather than just density. Scott Vetere, Director of Service Planning, Scheduling, and Evaluation at the Port Authority, noted that in Pittsburgh:

*"... in some cases there's no way easy or obvious way to get from one stop to another due to geographic barriers, grade issues and factors like that."*

Ultimately, most agencies appear to utilize their stop spacing standards as guidelines rather than regulations. In other words, stop spacing minimums are aspirational goals that present transit agencies with the opportunity to better rationalize stop spacing, without limiting the ability to fully consider local context.

## Stop Evaluation: Data Collection

The transit agencies analyzed for this study relied on a variety of methods to accumulate the data necessary to make bus stop consolidation recommendations. Most agencies used data collected from APC systems, bus stop inventories, and various fieldwork methods to inform their consolidation decisions. Ridership data collected from APC systems were utilized by all but one of the analyzed agencies. APC systems automatically count bus boardings and alightings, typically using sensors positioned near bus doors. When paired with a location-tracking device, such as an AVL system, transit agencies can determine ridership at the stop level (Boyle, 2008).

Of the six agencies that provided data, five had functioning APC systems. Three[7] agencies had APCs installed on all of their buses. With this level of coverage, agencies should be able to accurately estimate ridership at the stop level. The other two agencies had APC installed on between 10 and 20 percent of their buses. These agencies typically rotated APC equipped vehicles between different bus routes in order to develop a ridership sample for each route in the system. This method provides line level ridership estimates, but reduces the accuracy of stop level data. The agency without a functioning APC system hired a consulting firm to conduct manual passenger counts, which was common practice before the widespread usage of APC data.

The growing use of APC and AVL systems may contribute to the apparent increased interest in bus stop consolidation in the past decade. In order to install these systems, agencies generally have to develop or organize an inventory of their bus stops. These inventories potentially decrease the staff time needed to identify consolidation candidates on a given route,

[7] As of early 2015, the Port Authority of Allegheny County had APCs installed on 92% of their vehicles. They expect to have APCs installed on all vehicles by the end of the year.

and also allow agencies to analyze all stops in their system simultaneously. Increased usage of visualization tools, including Geographic Information Systems (GIS) and vehicle tracking apps, may also encourage agencies to consider stop consolidation. Scott Vetere, Director of Service Planning, Scheduling, and Evaluation at the Port Authority, noted,

> *"…we have a new staff member that can do a lot of GIS and other layers that are available to do analysis based on walkability and things like that. It's just factoring all of those into the final composition of … how things are going to rank out - what's more important when you get down to which one stays and which one goes. That's something that we've never had before. The individual stop information of the passenger counters, they really went active in the beginning of 2012. It's nothing we've had for years and just within the last few years, we've brought all of these things online. The other thing you can tell that makes a big difference now is we just turned on our real time information system last year. The one thing you can't see on that is there's (sic) a lot of stops on every route. But, you will see that there's a lot of buses that'll show they're within two minutes of the stop and there's three or four of them in a row. This tells you how close the bus stops are to one another. So, that kind of points out the need to do something."*

While APC and AVL usage was prominent among planners in this study for analyzing ridership, no interviewee specifically mentioned using this technology to analyze other efficiency factors, such as dwell times. This finding suggests that there are additional applications for using APC, AVL, and GIS technology to identify inefficient route sections or stops that should be targeted for intervention.

Long Beach Transit in California uniquely utilized APC data to conduct a system wide analysis of potential stop consolidation targets. Stops were assigned points based on ridership, and received additional points if they were a transfer stop. Chris MacKechnie, a Service Planner at Long Beach Transit, described this stop analysis:

> *"We've categorized all of our 1,935 bus stops into six categories based on how important they are to the overall system. So tier one are our busiest bus stops and tier six are our less busy bus stops. If it's a low ranking tier, we can either remove the stop or relocate it to try to make it get more ridership. With the tier one stops, we're looking to focus our implementation of bus stop amenities like nice shelters and maybe in the future, we'll have ticket vending machines for TAP cards and maybe more of those signs that tell you when the next bus is coming. So by categorizing them in different tiers, we're better able to focus our efforts when we do get funding for bus stop improvements on the right stops that would benefit our passengers the most."*

Long Beach Transit's stop evaluation process is further documented in Ma et al. (2014), a study discussed earlier in this report.

Several agencies supplemented automatic data collection and computer-based analysis with fieldwork methods. Fieldwork was primarily utilized to validate or add additional information to bus stop inventories. While such inventories provide important information for transit agencies during the consolidation process, they are not always reflective of actual conditions. Patrice A. Brady, a Service Planner at COTA, noted,

> *"…we also do field visits because what we may have in our GIS system may not match up with what's in the field. For example, here recently I did analysis on some stops and at least five of them either disappeared or got hit by a car, I don't know what happened to them..."*

The transit planners interviewed also used fieldwork to better understand the relationship between stop spacing and the built environment, as well as to identify factors, such as lack of crosswalks, that are not registered in all bus stop inventories. A planner from the Greater Cleveland Regional Transit Authority in Ohio uniquely noted that her agency uses internet-connected tablets to assist the fieldwork process.

SEPTA, with the assistance of DVRPC, conducted a far more extensive fieldwork operation than was typical at the other agencies analyzed for this study, collecting data not utilized by any other agency as part of their evaluation processes. Their analysis included fieldworkers who measured dwell times, which were then associated to specific bus stops using a GPS system. This analysis allowed SEPTA to more accurately determine the factors associated with stop-related delays.

Some agencies did not routinely conduct fieldwork, utilizing other methods to generate some of the data typically recorded through physical examination of stops. For example, Timothy McCormick, Transit Planning Administrator at Big Blue Bus, noted that planners at his agency used Google Maps to provide supplemental data about bus stop conditions:

> *"…we have Google Street View up, and we're looking at the site conditions, cross walks. You know, what would make someone want to board here or alight here or not because sometimes you're in a dense area and you notice there is almost no boarding, so then you go or no wonder it's at a blind corner of a fast moving road with no cross walk. No wonder no one comes here okay, let's take it out…."*

Long Beach Transit was able to use fare box data to generate a more in-depth ridership demographic profile at the stop level, without having to do manual surveys. Chris MacKechnie, a Service Planner at Long Beach Transit, said,

> *"…our fare box data tell us what kind of person boards at each stop. So if someone puts 60 cents, and then it's a senior disabled fare, we know that it's senior disabled person boarding at that stop. So we got all the necessary information from the types of riders based on the fare box data that we get."*

These data collection methods may provide a more time efficient and cost effective strategy to analyze bus stop consolidation candidates.

## Stop Evaluation: Consolidation Criteria

Rather than setting firm standards for identifying consolidation candidates, each agency where I conducted interviews developed criteria to guide but not dictate the evaluation process. The weighted importance of a given factor varied among agencies, and thus differently affected the probability that a stop would be eliminated or moved. Low ridership was almost universally considered as a major, and often the primary, metric that increased the likelihood that a stop would be consolidated. Several agencies also mentioned that stops seen as unsafe for operators or riders were significantly more likely to be eliminated. The absence of crosswalks in the immediate vicinity of a stop, a characteristic common to midblock locations, was specifically noted as an unsafe feature that could be reduced through stop relocation. One planner I interviewed suggested that ridership data could help identify unsafe stops, as riders tend to avoid locations that are difficult to access.

Interviewees indicated that poorly designed stops were more likely to be eliminated, regardless of ridership. Poor stop design qualities mentioned included lack of curb space, which increases the difficulty of pulling into and out of the stop, and poor sight lines, which reduces the ability for operators to see waiting passengers. Several planners also mentioned that they had eliminated "nearside" (of the intersection) stops, in favor of establishing or maintaining stops on the far side of intersections. Far side stop locations were seen enhancing the benefits of potential future signal priority systems. They may also reduce interactions between buses and alighting riders, as most pedestrians will cross the street at the crosswalk behind the bus, instead of in front of the bus as with the nearside configuration (Fitzpatrick, Hall, Perkinson, Nowlin, & Koppa, 1996).

Planners also identified several characteristics that decreased the likelihood of a stop being consolidated. Stops that functioned as transfer points between different lines or transit services were almost never eliminated, regardless of ridership. A majority of agencies where I interviewed staff attempted to identify low ridership stops that served a higher rate of senior or disabled passengers or were located near vital social services. Some planners had difficulty identifying these stops due to the way wheelchair ramp deployment data were tabulated. Patrice A. Brady, a Service Planner at COTA, noted,

> *"…one of the downsides with the wheelchair deployment data… is that it's a button that the operator has to push, so it is not automatically counted when a deployment is made."*

Several planners noted that the existence of bus stop improvements, like street furniture, shelters, or ADA accessibility improvements, reduced the likelihood that a low ridership stop would be consolidated. Patrice A. Brady, however, said that the furniture installed by COTA was highly moveable and that this type of infrastructure placement was not a factor in their analytical process. As noted previously, Big Blue Bus planners consider potential sidewalk congestion when determining whether to increase stop spacing near major destinations.

## Political Engagement

Local political officials often function as a primary interface between transit agencies, riders, and other constituents. On balance, it appears that planners at the agencies analyzed for this study adjusted their outreach strategies based on existing political relationships and practices. Some agencies chose to have only limited or even no outreach to political officials. Elad Mokadi, Manager of Planning at the Transit Authority of Northern Kentucky (TANK), which serves the southern suburbs of Cincinnati, Ohio, said,

> *"I would say the location of bus stops is primarily a professional decision rather than a political issue. Therefore, it is not a major concern for the political leaders here in Northern Kentucky."*

Conversely, several interviewees asserted that informing and involving political officials can be beneficial to the stop consolidation process and that failure to do so can contribute to confusion and distrust. WMATA indicated that a past attempt at bus stop consolidation was hindered by a lack of political outreach before the proposal was announced. Political officials reacted negatively when constituents reached out to their offices about stop removal proposals that they were never informed of. WMATA now contacts political officials before a consolidation proposal is announced, which has greatly reduced political opposition and allowed officials to better address constituent concerns (Cepler, 2014). Roger Morton, President and General Manager of TheBus, whose proposals were ultimately not implemented, also suggested that increased political outreach may have reduced community opposition to the agencies' efforts,

> *"…I think having some descriptions to the city council maybe making themselves available for TV coverage and those kinds of things would have been probably I think that is a better way to get word out into the community and maybe they get some partners and some supporters."*

Political outreach strategies were generally focused on providing information regarding the reasoning behind and potential benefits of bus stop consolidation. The most common outreach strategy was sending letters to political officials representing areas designated for consolidation. On some occasions, politicians reached out to planning agencies in response to these letters. Two agencies, WMATA and MBTA, held more in-depth meetings with political officials. During and after these meetings, some officials commented on specific aspects of the consolidation proposals, and adjustments were made in response.

Ultimately, it appears that for agencies that accurately anticipated political response, or lack thereof, to their consolidation proposal, the outreach process pursued, whether aggressive or perfunctory, did not significantly alter the stop consolidation programs. For agencies that did not correctly assess the level and energy of opposition, however, failure to effectively reach out to political officials may well have dramatically hindered consolidation efforts.

## Community Engagement

Many transit planners assume that negative community pushback will be a major obstacle to successfully implementing a bus stop consolidation program (Boyle, 2013). All of the agencies analyzed for this study anticipated some negative responses to their consolidation efforts, and thus incorporated some form of public outreach process. Nearly all began community outreach efforts after stops had been selected for consolidation, rather than soliciting public input during the development stages. Timothy McCormick, Transit Planning Administrator at Big Blue Bus, noted,

> *"We had a public hearing to implement the policy, but a stop re-spacing policy is not… anything that's going to make anybody think oh that means my stop is in danger I better come out and speak up. I mean until you tell them their stop is going away, they don't think that they need to comment on your re-spacing policy."*

Once a consolidation strategy was developed, however, agencies differed in their approach to community engagement. Engagement approaches can be ranked on a spectrum from least to most intensive. The least intensive, and most common, community outreach method was the posting of notices on affected bus stops. These notices typically provided a short explanation of why the agency was pursuing consolidation and the locations of alternate stops. The notices were typically installed several weeks before scheduled elimination. Most agencies provided a phone number or website where the public could submit feedback.

Several agencies that relied primarily on posted notices at bus stops also integrated additional, and somewhat more intensive, activities into their outreach process. The most common additional outreach activity was the mailing of letters to local neighborhood associations or citizen advisory boards. Planners invited these groups to submit written comments, as well as comments by telephone. In at least two circumstances, planners decided to meet with community groups in response to negative comments.

All agencies pursuing these less intensive approaches retained some stops scheduled for elimination based on feedback received from the comment process. None of planners I interviewed felt that the modifications they made in response to community comments significantly affected their overall program. Katie Nelson, Capital Projects Coordinator at C-TRAN, noted,

> *"We have left stops in place, if [the public had significant] concerns about the removal of it. We also have pulled stops from the project or added stops, due to the concern of neighbors' interactions. So, we definitely, take what their concerns are into consideration."*

Elad Mokadi, Manager of Planning at TANK, said,

*"…we proposed to consolidation about 55% of the bus stops along the route…. At the end of process [we removed] 45%. Following the process, we've listened to our patrons through the Service Request process and accommodated reasonable requests for stop reinstatements"*

Jack Whisner, a Service Planner at King County Metro, discussed his experience during a local bus to rapid bus conversion,

*"There was some, but not a lot of [public complaints about stop removal]…. For example on the former routes 230 and 253 in Bellevue, there were stops about every two blocks. And we closed more than half of them, and not much protest was heard."*

Additionally, two interviewees who utilized the notice approach felt that more substantial public meetings were unlikely to attract additional community perspectives on the proposals. WMATA noted that the comments made at the public meetings for a past consolidation effort focused on the quality of the bus system overall, rather than the specific stop removal and relocation proposals. The interviewees expressed that the public notice approach concentrated comments on the consolidation proposals and provided the information needed to augment their initial stop evaluations.

Three of the 13 agencies in my sample developed significantly more intensive public outreach processes for their stop consolidation efforts. These agencies held many public events and scheduled meetings with numerous local neighborhood groups and businesses. Interestingly, each of the agencies pursuing this strategy integrated other service changes or infrastructure investments along with their consolidation programs. Greg Krykewycz, Manager at DVRPC, noted the importance of public outreach in regards to stop consolidation:

*"…early and often is sort of the best way to go…. it's a much heavier lift than you would think on the surface because it's really easy to say, 'Jeez our blocks are very small, can't people walk an extra block.' And the short version is that yeah most people can walk an extra block, but it ends up being a really sticky thing to implement because if one person is happy to walk an extra block but their neighbor isn't; they get to keep their stop. Or if the rider asked to walk the extra block is an older person who has been riding forever and maybe has relationship with the driver of the bus that they've developed over time. It's just really hard to kind of manage that and to take all of those kind of different kinds of measurables and immeasurables into account when you're developing a plan… When you're talking about trying things tomorrow they're gonna impact people's quality of day to day life tomorrow, you need to be much more sort of hands on and human about it."*

C-TRAN utilizes a public notification and comment process for their successful bus stop consolidation program. This outreach strategy has resulted in only minimal modifications to their initial lists of proposed stop relocations and eliminations. In contrast, C-TRAN relied heavily on public meetings as an outreach strategy while planning the conversion of a high ridership local bus corridor to BRT. Chuck Green, the Bus Rapid Transit Project Manager at C-TRAN, noted,

> *"Our public involvement to date involved 120 meetings… We've been meeting with a variety of stakeholders, neighborhood groups, business groups, Vancouver City council, C-TRAN board. Basically, anyone that wants to have a meeting, we'll be there."*

Unlike the response to their stop consolidation program, community comments voiced at the BRT public meetings encouraged C-TRAN to significantly modify their original proposal. Mr. Green stated,

> *"…there was an alternative that came out of a previous study that would have been a fixed guide-way alternative with stops every half to three-quarters of a mile apart. In the involvement process, we found there a lot of people are very protective of their service and their access. So, we ended up with pretty much keeping most of the stops and stops being, based on the community recommendation, one quarter to one-third of a mile apart at the maximum."*

That being said, Mr. Green felt that the outreach process helped planners better understand how riders were using the existing local service and that the final BRT plan better reflects community needs.

Like C-TRAN, SEPTA relied extensively on meetings with neighborhood and business interest groups. While the agency did not significantly modify initial consolidation proposals as a result of public outreach, they did make a commitment to restore removed stops if the program did not result in consistent travel time savings after six months. After failing to meet these goals during the pilot period, SEPTA restored nearly all removed or modified stops in their original condition. Greg Krykewycz, Manager at DVRPC, which advised SEPTA on the consolidation project, indicated that presenting the program as a pilot benefited city agencies more broadly:

> *"…that the agencies were very transparent about what they were gonna try, where, why to achieve travel time savings and… a faster end to end trip for riders. And that if it didn't work they said they were gonna put the stuff back the way it was. And it turned out because of the operating context and the variety of other reasons, they didn't achieve the travel time savings from the stop consolidation that they were hoping to and they did what they said. They put the stops back, with I think maybe a couple of other exceptions where stops were unusually close together. And that so kind of being completely transparent with the community at the ground level about what you're trying to do, why you're trying to do it and then doing honoring your commitment to change your mind based on the data to make a transparent data based decision. I think really has helped the city and SEPTA in our case kind of build credibility to try more things in the future."*

The MBTA also held extensive public meetings while proposing and implementing its Key Bus Route Improvement Program. Unlike C-TRAN and SEPTA, however, the MBTA did not have to significantly alter lists of proposed stop modifications or reinstate stops after implementation. Instead, the MBTA made only a few changes to their consolidation list and was able to maintain their spacing goal, similar to agencies that only posted notices. It is not possible to firmly conclude that more extensive public outreach strategies result in greater alterations to proposed consolidation programs solely based on the experiences of these three agencies. However, it does appear that under certain circumstances, planners that hold more extensive public meetings chose to make more changes to their initial proposals.

All planners interviewed for this study said that concerns related to elderly and disabled passengers were among the primary objections to bus stop consolidation. As noted previously, many transit agencies anticipated these concerns, and attempted to identify stops with potential value to these ridership bases. It appears that the public outreach process can help agencies pinpoint stops providing access to destinations considered vital for elderly and disabled riders, but are not flagged during the analysis process. Roger Morton, President and General Manager of TheBus, highlighted the importance of outreach to seniors as a lesson from his agency's efforts,

> *"…maybe [we should have] pre-partner[ed] with groups like AARP to explain the rationale for the stop realignments because in the end I think it was primarily the senior citizens that were the loudest voice in opposition. I think some going to a neighborhood board is a good idea and it's a necessary idea, but the reality is that not as many citizens or seniors go to those meetings."*

Apart from elderly and disabled riders, no particular ridership or neighborhood demographic was specifically noted by planners as widely objecting to bus stop consolidation. Other concerns expressed during the outreach process reflected general resistance to a specific bus stop removal. Wendy Green-Harvey, formally a Constituent Relations Coordinator, Public and Government Affairs Department at SEPTA, noted,

> *"Some community members were okay with it, some weren't. You know, if you have a bus stop right outside your front door for the past 20 years and all of a sudden it's gone, you're not too happy about that."*

Some homeowners and business owners also reacted negatively to the placement of relocated bus stops in front of their homes or stores. Greg Strangeways, Manager of Service Planning at the MBTA, noted that these constituents were the primary group expressing continued concerns after stop consolidation occurred:

> *"…in the end after everything was said and done, none of the enduring issues have been about people having to walk a little bit further to the bus stop. It's all been abutters who never had a bus stop in front of their home or business before and don't like having it now. There was 800 and some stops involved here and we got rid of maybe 170 of them… and moved a whole bunch of the remaining ones and there is probably about ten or fifteen that are still real sticking points with abutters…"*

Some planners also noted a few business owners expressed concerns over lost parking when a stop was placed near their establishment. In most cases, however, planners said that stop consolidation does not result in a net loss of parking along a given corridor. In fact, some programs resulted in a net increase in parking.

Ultimately, while the intensiveness of outreach processes and the specific strategies utilized varied among agencies, there appears to be a general consensus that some form of public outreach is necessary and beneficial.

## Staff Engagement

Staff input into the consolidation process is typically informal and does not appear to be a priority, at least at the agencies analyzed for this study. No interviewee noted that they specifically incorporated operator feedback when determining which stops to move or consolidate. Several agencies did, however, have formal and informal meetings or methods where operator feedback is gathered more generally. Patrice A. Brady, a Service Planner at COTA, described this process,

> *"Operators informally and formally communicate potential safety or operational hazards. Operators approach Planning Division staff and supervisors if there is an issue. Also Transportation Directors and Superintendents and the Scheduling Director and Schedulers host 'Shop Days' where they visit the Dayrooms and discuss any issues with the operators. The issues may include bus stops, running time, etc. We also have an Operator Feedback Form where operators can address any issues. After the form is completed, it is forwarded to the appropriate person to research and resolve. If it is a bus stop the appropriate person may be me or our Service Program Manager."*

Planners I interviewed did not generally solicit staff evaluation of the effects of implemented stop consolidation programs. In their evaluation of SEPTA's Route 47 Transit First project, Flint et al. (2014) note that some operators continued serving removed stops at the request of long-term passengers. The study authors believe that this practice may have affected their post-evaluation of the service changes. None of planners interviewed for this study reported that operators at their agency continued serving removed or relocated stops after program implementation. In fact, several planners noted that bus operators (drivers) felt that consolidation improved their work environment. Elad Mokadi, Manager of Planning at TANK, said,

> *"…feedback from the drivers were very, very positive… in the beginning there were concerns that [bus stop consolidation] would harm the service and is unnecessary… about two or three months after the stop consolidation, several operators indicated they like the change since it allows them to stay on time and drive "more smoothly". . The scheduling manager indicated the consolidation has significantly improved on-time performance and reduced delay complaints."*

## Post-Evaluation

As stated above, most agencies implemented bus stop consolidation programs with the goal of achieving operational efficiency and/or stop quality benefits. Theoretically, these goals could be operationalized into variables, for example on-time service or passenger boardings, which could be evaluated after completion of a consolidation project. Nearly all agencies analyzed in this study, however, did not formally track any operational metrics, apart from the number of stops removed through consolidation and the resulting average stop spacing. SEPTA, which ultimately retracted most stop eliminations after not meeting operational improvement goals, was the only agency that attempted a formal post evaluation analysis that focused on additional operational metrics.

There are multiple explanations for this overall lack of formalized before and after analyses. Some planners I interviewed noted a general expectation that stop consolidation would have operational benefits and thus post-evaluation was not needed. For example, Timothy McCormick, Transit Planning Administrator at Big Blue Bus, said,

> *"I mean you don't need a degree to know that wider stop spacing speeds up travel…You know what I mean, it's been well studied."*

Alternatively, agencies may not have formalized practices to establish the effects of service alterations, apart from analysis required by Title VI[8]. Planners I interviewed at two different agencies also noted that their stop consolidation programs coincided with other major service alterations. It therefore may be difficult to isolate the specific effects of bus stop consolidation on operations.

Some planners employed by agencies that have completed bus stop consolidation provided evidence of the effects of their program, but did not conduct more complex analysis or controlled studies. The variables mentioned generally reflect data that most agencies regularly track for National Transit Database reporting required by the Federal Transit Administration, rather than detailed cost savings or revenue evaluations. Planners at four of these agencies reported positive effects on either ridership or operational performance. For example Elad Mokadi, Manager of Planning at TANK, noted operational efficiency benefits:

> *"There were two major objectives of the stop consolidation: (1) improving on-time performance and schedule reliability, and (2) eliminating underutilized stops that degrade passenger experience. Of-course, the ultimate goal is, as always, was increasing ridership. In terms of ridership, there hasn't been a significant increase on the #1 Route, which serves the corridor. However, we*

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8 Title VI of the Civil Rights Act of 1964 prohibits transit agencies, and other government entities, that receive funding from the Federal Government from discriminating against on the basis of race, color, or national origin. To comply with Title VI, transit agencies must conduct equity analysis when adjusting fares or implementing major capital projects, among other actions, to determine whether these protected classes will be "adversely affected" by the action or change (Federal Transit Administration, 2012).

> *improved on-time performance and improved passengers experience by consolidating the stops and cutting travel time. It is our hope that these improvements, together with the investment in street amenities along the Dixie Corridor, will attract more passengers to ride the bus."*

Greg Strangeways, Manager of Service Planning at the MBTA, commented on some potential benefits related to stop consolidation, but noted that he had not yet performed a more substantial analysis:

> *"…we haven't been able to do a full analysis yet. Our early returns look like it's a bit faster and a bit better for on time performance. But we are going get a consultant in to really dig into this (using probably our APC data which is much more fine grain but it isn't on every single bus) and figure out wherever we made the most improvement and is there correlation between better performance in that segment. We did a few queue jumps as well so we need to do more analysis on that."*

Only one planner I spoke with said that his agency had not measured any noticeable operational improvements related to their consolidation efforts. Despite this, that planner still views consolidation as beneficial towards efforts to improve service and stop quality, and has thus continued to pursue consolidation opportunities.

Based on both the review of the research literature summarized at the outset as well as the qualitative evidence gathered through my interviews, it appears that stop consolidation can have a positive effect on bus operations – but that such effects are not guaranteed. In tandem with other service improvements, stop consolidation may also lead to increased ridership – though this too is not guaranteed. However, without a more formalized post-evaluation process, it is not possible to ascribe specific benefits to the stop consolidation programs reported on here.

# Discussion and Recommendations

The study detailed above gives a comprehensive review of bus stop consolidation plans, implementation alternatives, successes and failures. What is clear from the literature, as well as specific agency experiences, is that there are many ways to approach this process. Based on these findings, I will now provide a series of recommendations relating to a potential Houston Metro bus stop consolidation program. I will first detail what specific goals the agency should aim to achieve though stop consolidation. I will then examine a pre-implementation evaluation process that could be used to help the agency fulfill these objectives. I will then detail a political and public outreach plan that will best incorporate community concerns, while maintaining the underlying goals of the program. Finally, I will examine the potential options for a meaningful post-evaluation analysis.

## Program Goals

All of the planners interviewed for this study targeted stops with (1) spacing that fell below adopted guidelines, (2) low ridership, or (3) both for consolidation or removal. Through this process, they sought to achieve goals that can be grouped into two broad categories, operational efficiency goals and stop quality goals.

Operational efficiency goals primarily focused on improving average bus speeds and on-time performance. These goals reflect the findings of the academic literature on optimal bus stop spacing models, which suggest that increasing the distance between stops results in increased service speed and reliability. Post-implementation studies of stop consolidation programs, however, have found more mixed results. Both the TriMet and SEPTA programs resulted in service speed increases, though SEPTA actually saw services speeds decrease during some time periods. Neither program resulted in increased service reliability. No other agency analyzed for this study has completed a formal post-analysis of their program, though many planners indicated that they believed consolidation had increased speeds and reliability. None of these agencies were ultimately able to measure cost savings through consolidation.

In contrast to most previously published works on stop consolidation, many of the planners I spoke with highlighted stop quality improvements, rather than operational improvements, as the primary goal of their efforts. Several planners noted that removing underutilized stops would allow their agencies to more efficiently improve stop quality throughout their network. Stop improvements included the installation of shelters, benches and improved signage, as well as ADA accessibility improvements. Many planners noted that they believed that these improvements would increase customer satisfaction with their services. Yoh et al. (2011) also found that some stop improvements can reduce transit rider's perception of wait time in certain circumstances.

Like most agencies analyzed for this study, I recommend that Houston Metro seek to improve both bus operations and stop quality through bus stop consolidation. From the outset, the agency should set a goal to increase average stop spacing to distances that reflect stop spacing standards (which are discussed in detail below). However, as the specific operational benefits of consolidation remain more speculative than assured, the agency should be wary about publically articulating specific speed, reliability, or cost savings goals from stop consolidation – as these performance outcomes are a function of many factors beyond the location and number of stops. Instead, Houston Metro should internally monitor how these metrics are affected by the consolidation program. The nature of and potential challenges related to this monitoring program are discussed below. If initial efforts result in consistent speed or reliability benefits, the agency could develop more specific improvement goals for the program.

Houston Metro's bus stop consolidation program should also be integrated with a broader stop infrastructure investment program. This approach reflects several programs analyzed in this study, most notably the MBTA's Key Bus Routes Improvement Program. As part of this effort, Houston Metro should develop a bus stop improvement plan with design guidelines based on location and ridership targets. This plan could function as an extension of the existing Passenger Bus Shelter Program, which usually includes a 35 daily boarding threshold for consideration of shelter installation. The agency should set specific goals related to the number of stops with improvement amenities and/or are ADA compliant. Such coordination between programs will allow the agency to best leverage potential benefits of stop consolidation, while also demonstrating to riders that the program will lead to valuable investments in stop infrastructure.

## Stop Spacing Standards

As noted previously, ideal stop spacing for local bus services is generally considered to be a quarter mile (Walker, 2012). Existing stop spacing standards utilized by Houston Metro reflect, or even exceed, this industry best practice. With the exception of so-called coverage routes, all local bus services are expected to have stop spacing ranging from a quarter to a half mile on average. Rather than basing standards on local area population density, like many other agencies analyzed in this study, Houston Metro guidelines include standards based on service type. The variation in spacing standards prioritizes speed on higher ridership routes and access on routes designed to provide coverage service targeting transit-reliant riders. Based on evidence from this study, existing Houston Metro bus stop spacing standards do not need to be modified in preparation of a consolidation program.

As noted above, actual spacing on many Houston Metro bus network do not reflect these standards. Current average stop spacing on many local routes is significantly below the quarter to half mile target. As stated previously, any consolidation effort should in part focus on increasing bus stop spacing to better reflect existing standards.

*Table 3: Houston Metro Stop Spacing Standards*

| Frequent | Secondary Ridership | Quickline | Coverage | Flex | Park & Ride | Express |
|---|---|---|---|---|---|---|
| 1,300'-2,600' | 1,300'-2,600' | 2,600' | 800'-1300' | N/A | Every Other Block (Distribution) | 1,300'-2,600' (Collection); Every Other Block (Distribution) |

## Program Strategy and Phasing

Most agencies evaluated in this study have completed stop consolidation in phases, focusing initially on their highest ridership routes. This strategy reflects the significant time commitment many planners I interviewed reported was required to complete a consolidation effort. Additionally, by focusing on the highest ridership corridors, more passengers experience the potential benefits of consolidation. Two of the agencies that were analyzed for this study are in the fifth phase of their consolidation program, and several others are currently in earlier phases. Planners at these agencies said that they have found this phasing strategy was effective.

Accordingly, I recommend that Houston Metro pursue bus stop consolidation using a phasing strategy. The agency should study and implement consolidation and optimization on groups of routes, likely four or five at a time depending on staff availability. The initial route groups should include services that make up the planned Frequent Network. As these routes have the highest ridership and lowest headways, they likely stand to achieve the greatest benefits from stop consolidation. Additionally, consolidating lower ridership stops on these corridors will concentrate great levels of boardings and alightings at the remaining stops. Houston Metro can then justify more significant stop amenity enhancements at these locations.

## Stop Evaluation

Most agencies surveyed for this report relied primarily on ridership data collected through APC systems, as well as location data registered in bus stop inventories, to analyze stops for consolidation. Planners also worked to identify stops located near sensitive services like senior homes or schools. This data analysis was sometimes supplemented with fieldwork to confirm stop location, amenities, and potential safety or operational hazards. Data and fieldwork evaluations were typically conducted separately for each line or area undergoing consolidation, rather than analyzing the entire system simultaneously.

Planners at two agencies, Big Blue Bus and Long Beach Transit, used new technology and data analysis methods to replace most in-person fieldwork. Big Blue Bus relied on Google Street View to more quickly identify stop amenities and safety hazards. Long Beach Transit developed an innovative ranking system, initially based solely on ridership, to prioritize stops for both consolidation and amenity improvements. Ma et al. (2014) and Stewart (2014) show that this ranking system can be used to identify and rank stops based on demographic characteristics, as well as by accessibility to social services. These innovations represent an opportunity to refine the consolidation evaluation process, while also potentially reducing needed staff time.

Before Houston Metro identifies specific neighborhoods, corridors, or routes to target for stop consolidation, the agency should complete a system wide bus stop ranking evaluation. This will allow the agency to identify those routes that may achieve significant benefits from consolidation, as well as inform which stops should be eliminated or moved when individual routes are subsequently analyzed. Houston Metro is extremely well positioned to develop a strong bus stop ranking system. The agency has already installed APC and AVL systems fleet-wide. Additionally, Houston Metro has relatively detailed information about the location and characteristics of active stops.

Based on past industry experience, as well as Houston Metro's technological capabilities, the following variables should be included in the stop ranking process: total ridership, senior and, total wheelchair ramp deployments, existence of street furniture and shelters, availability of transfer opportunities, and stop spacing. Each of the variables described above can be calculated using existing Houston Metro technologies. They also address a common goal, like increasing the percentage of stops with improved amenities, or community concern, like ensuring access for elderly riders, expressed during previously analyzed bus stop consolidation processes.

Total ridership by bus stop data is already regularly calculated using the APC system. This ridership data will allow Houston Metro to identify significantly underutilized stops, in line with a primary goal of most stop consolidation efforts. Houston Metro's fareboxes register which type of smartcard, including elderly-specific cards, are used to board a bus. Unfortunately, this fare technology does not allow the agency to recognize riders using cash fares or determine when specific riders exit the bus. Despite these limitations, extrapolating smartcard data should allow Houston Metro to pinpoint stops with high rates of elderly boardings. Wheelchair ramp deployments are also registered by the APC system, which permits the agency to identify stops important to riders with disabilities. Combined usage of ridership, farebox, and wheelchair ramp deployment data will result in a better informed decision regarding stops to be excluded from this process, reducing possible customer concerns and negative reactions.

Houston Metro currently has a bus stop inventory that can be utilized as part of the bus stop ranking process. The inventory includes information about existing stop furniture and shelter investments. The stop ranking system should give preference to maintaining stops with preexisting infrastructure, as relocating these fixtures is expensive. Unfortunately, the bus stop inventory does not have information related to ADA accessibility and crosswalk availability. As stated previously, many agencies manually inspect stops for these factors during each route's consolidation evaluation process. Houston Metro could conduct a system wide ADA and pedestrian accessibility analysis before initiating the bus stop ranking process. However, this strategy would be a unique practice and is likely prohibitively cost and time intensive. Costs could be reduced, however, if the agency uses the initial ranking process to eliminate groups of stops from consideration and then conduct the analysis only on stops that will be reviewed.

To finalize the bus stop ranking process, Houston Metro should apply a point value to each of the characteristics described above. For example, bus stops could be assigned a point value from one to four based on ridership quartile. Then, using GIS data on stop location, the agency should identify all stops whose spacing falls below agency guidelines. After eliminating transfer locations from consideration, the agency should use the bus stop ranking points to determine which stop in a closely spaced pair should be eliminated. In some circumstances, the agency could alternatively consolidate both stops to an optimized location. The process of determining which stops to remove or relocate could be automated in GIS, as described by Stewart (2014). Once the stop consolidation list has been prepared, the agency should manually inspect proposed new stop locations. This inspection could be completed using Google Street View, supplemented with fieldwork in locations where conditions are unclear. This process should result in a consolidation list that reflects Houston Metro's goals for the program, and adequately anticipates and considers community concerns.

## Engagement Strategies

The agencies analyzed for this study engaged in a wide spectrum of political, community, and staff engagement strategies. In regions with strong political investment in transit, planners frequently contacted and met with political officials to discuss consolidation proposals. Some planners felt this political outreach helped counterbalance community opposition, while others felt political officials were less invested in transit policy decisions and that outreach was not necessary. All planners that implemented their consolidation programs successfully utilized some form of community outreach strategy. These strategies ranged in intensity, from the solicitation of public comments through bus stop notice postings to large scale public meetings. Most planners I spoke with made some changes to their initial proposals based on community comments, though none felt these changes significantly altered the intentions of their programs.

Before implementing a bus stop consolidation program, I recommend that Houston Metro evaluate existing relationships with local political official representing the affected corridors. In all cases, the agency should send an informational packet to officials representing neighborhoods where consolidation is scheduled to occur, and follow-up with telephone calls to answer questions about the proposal in advance of any public announcements. The packet should detail the potential benefits of consolidation, as well as the measures the agency undertook to identify safer stop locations and ensure that transit-reliant riders maintain access to transit services. Furthermore, elected officials, especially those that have previously taken an active role in transit policy, should be offered the opportunity to meet with Houston Metro planners to discuss the intent of the consolidation program. Two planners with whom I spoke expressed the view that these types of meetings helped generate political support and allowed political offices to better respond to community concerns.

Most planners with whom I spoke noted that reducing access for elderly and disabled riders was the dominate community concern about consolidation. Business and homeowners also often expressed concerns when new stops were located in front of their properties. Based on my interviews, it does not appear that a more intensive community engagement strategy, such as public meetings, generates additional beneficial insights about local preferences. Therefore, like the majority of agencies pursuing bus stop consolidation, Houston Metro should rely on public notices as the primary community outreach method. The notices should be posted at affected stops in the weeks preceding planned consolidation. Each notice should have an explanation for why Houston Metro is implementing consolidation, information about nearby stop locations, and a phone number and website where riders can submit comments. The website could also include information about potential bus stop improvements, and provide riders the opportunity to submit comments about amenities they would like to see at their local stop. These practices reflect those of the planners I interviewed and were generally seen as effective.

Comments received from political officials and community members will likely identify stop characteristics that will not have been fully considered in the stop ranking analysis discussed above. Houston Metro should reconsider and adjust consolidation only in circumstances where feedback suggests an oversight of the bus stop ranking process, such as not identifying a senior center or an unsafe bus stop. If staff time permits, the agency should post responses to constituents whose suggestions cannot be accommodated. This feedback will potentially reduce constituent frustration, while also providing further justification for the consolidation decision making process. Ultimately, these outreach methods should improve the program, increase community buy in, and reduce significant deviations from the intended goals.

Staff engagement was not viewed as a vital part of the consolidation process, though several planners noted that their agency has existing formal and informal practices to solicit bus operator comments and concerns. These comments sometimes related to stop safety, and were considered when analyzing consolidation targets. Several planners noted that bus operator feedback on consolidation was generally positive. If Houston Metro does not already have a formal outreach program for staff, one should be established. However, based on the interviews collected for this report, the agency does not need to establish a specific outreach program for the consolidation effort.

## Post-Implementation Evaluation

Most agencies analyzed for this study have not completed a formal evaluation of their stop consolidation programs. The primary metric that was officially tracked by planners I spoke with was the number of stops removed during the consolidation process. Several planners, however, also noted that they had informally monitored ridership, on-time performance, and the average running time of services that had undergone consolidation. In most circumstances, these planners reported that these metrics had remained unchanged or improved after they implemented their programs. However, several also noted that they had made other significant changes to affected services that may obfuscate these informal findings.

Houston Metro's *System Reimagining Plan*, as well as the ongoing rail capital program, will significantly alter how users interact with the transit network. Such a dramatic change in the transit network will have ongoing effects on service reliability, efficiency, and effectiveness metrics. It will likely be difficult to isolate the effects of bus stop consolidation, especially if the program is implemented in the months following the network restructuring. From the outset, Houston Metro should track the number of stops eliminated or moved, as well as the resulting average stop spacing across the network. The agency should also evaluate ridership, on-time performance, and run time data on services that have undergone consolidation. The evaluation, however, should be conducted with the understanding that the results may be affected by other network and service changes. Information gathered through this process could provide evidence of the effects of consolidation, and may also provide insight on which bus stop enhancement strategies are most effective.

## Conclusion

Transit operators across the United States face pressures from limited revenues, deteriorating infrastructure, and competing claims for service. Many transit systems are relics of 20$^{th}$ century private operators and fail to provide access to more recent commercial centers and residential developments. Houston Metro has responded to these challenges through the *System Reimagining Plan*. By redesigning its bus network without increasing operating costs, the agency aims to efficiently increase mobility within the rapidly developing Greater Houston metropolitan region. Bus stop consolidation provides an opportunity to complement this effort by prioritizing capital resources and improving bus stop quality, while also potentially increasing service reliability and speed.

The planners interviewed for this study all expressed that bus stop consolidation has been beneficial for their agencies. Many also noted that consolidation has facilitated bus stop amenity improvements that they view as valuable for transit riders. Recent improvements in data collection technology, such as APC and AVL systems, appears to have reduced the monetary and time costs related to pursuing a consolidation program. Bus stop ranking may further reduce these costs, while also providing valuable data to prioritize infrastructure investments.

While this study provides valuable insights into bus stop consolidation, additional research is needed to fully understand the dynamics of such programs. I was unable to analyze agencies that have chosen not to pursue stop consolidation. Interviews with officials at these agencies may provide valuable insights into the barriers planners face when considering consolidation, as well as why planners may not feel the strategy is necessary. Additionally, I hoped to interview more planners from agencies that had experienced significant opposition to their consolidation proposals. Interviews with planners that have had this experience will likely enhance understandings of how the framing of consolidation projects to the public, as well as outreach methods, can affect program outcomes. Finally, additional research is needed to better understand how agencies have integrated stop improvement projects alongside consolidation, as well as how, and if, these practices provide complementary benefits. As stop consolidation and optimization becomes an increasingly utilized technique to improve public transportation, such analyses are essential to ensure the efficient maximization of potential benefits for both transit operators and riders.

# Appendices

*Table A1: Planners Interviewed for this Study*

| First Name | Last Name | Agency | Position | Interview Duration |
|---|---|---|---|---|
| Heather | Bates | Greater Cleveland Regional Transit Authority | Manager of Service Planning | 25 |
| Patrice A. | Brady | Central Ohio Transit Authority | Service Planner | 23 |
| Robert | Cerrato | Charlotte Area Transit System | Transit Planner | 41 |
| Chuck | Green | Clark County Public Transit Benefit Area Authority | Bus Rapid Transit Project Manager | 27* |
| Wendy | Green-Harvey | Southeastern Pennsylvania Transportation Authority | Constituent Relations Coordinator; Public and Government Affairs Department | 17 |
| Larry | Ham | Clark County Public Transit Benefit Area Authority | Operations Planning Supervisor | 27* |
| Greg | Krykewycz | Delaware Valley Regional Planning Commission | Manager; Office of Transit, Bicycle, and Pedestrian Planning | 29 |
| Chris | MacKechnie | Long Beach Transit | Service Planner | 14 |
| Timothy | McCormick | Santa Monica Big Blue Bus | Transit Planning Administrator | 21 |
| Elad | Mokadi | Transit Authority of Northern Kentucky | Manager of Planning | 29 |
| Roger | Morton | TheBus | President and General Manager | 23 |
| Katie | Nelson | Clark County Public Transit Benefit Area Authority | Capital Projects Coordinator | 27* |
| Greg | Strangeways | Massachusetts Bay Transportation Authority | Manager of Service Planning | 26 |
| Scott | Vetere | Port Authority of Allegheny County | Director of Service Planning, Scheduling, and Evaluation | 21 |
| Jack | Whisner | King County Metro | Service Planner | 36 |
| - | - | Washington Metropolitan Area Transit Authority | - | 18 |

*Planners from the Clark County Public Transit Benefit Area Authority were interviewed as a group
Note: Washington Metropolitan Area Transit Authority asked to redact the name and position of the interviewee

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