Bus Transit Service Reliability and Improvement Strategies: Integrating the Perspectives of Passengers and Transit Agencies In North America

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1. Abstract

Transit agencies are consistently trying to improve service reliability and attract new passengers by employing various strategies. Previous literature reviews have focused on either passengers' or transit agencies' perspectives on service reliability. However, none of the earlier reviews have simultaneously addressed these differing perspectives on service reliability in an integrated manner. In response to this gap in the literature, this paper first reviews previous work on passengers' perspectives of transit service reliability and their response to service adjustments made by different agencies. Second, it analyzes transit agencies' plans and reports regarding their reliability goals and used strategies in order to improve service reliability, while looking at the impacts of these strategies on service. Reviewing these two parts together provides a needed contribution to the literature from a practical viewpoint since it allows for the identification of gaps in the public transit planning and operations field in the area of reliability and provides transit planners and decision makers with effective and valuable policy-relevant information.

2. Introduction

Public transit systems are essential services to the sustainability, equity, and livability of any city. In fact, during the past decade, transportation planning has shifted its focus from car mobility goals to embrace broader environmental and social goals, in particular, by providing and improving transport alternatives that provide access to destinations regardless of car ownership (Jabareen, 2006; Lucas et al., 2007). This shift in paradigm has encouraged operators to incorporate various strategies to improve transit service operation with the goal of attracting new passengers and retaining existing ones. This shift is supported by enormous funding commitments from federal, state and local governments in order to improve transit service. For example, in the United States, total government spending increased at an annual average inflation-adjusted rate of about 3% between 1997 and 2012, from $26.1 billion to $ 58.5 billion (NTD, 2013).

Transit agencies are responsible for providing an efficient, productive and reliable service that is positively perceived by the public (Vuchic, 2005). It is clear that providing a reliable transit services is necessary in order to maintain an efficient and attractive system, which increases users' satisfaction and loyalty. Reliability is also important for operators because it can easily improve internal efficiency, reduce operating costs, and improve revenues by retaining and attracting users. Therefore, improving reliability is a win-win situation for both users and transit agencies and enables cities to achieve their broader goals. The present review of the literature aims to understand transit service reliability from different perspectives. More specifically, it attempts to identify passengers' and transit agencies' perspectives, while linking both perspectives to empirical studies that investigate the impacts of service improvement strategies. This paper uses a systemic review method to identify the international literature that covers the passengers' perspective, while analyzing North America's transit agencies' perspectives regarding service reliability.

Within the transportation setting, there are a wide range of definitions for the concept of reliability. It can be defined as the availability and stability of transit service attributes at certain locations, affecting people and operators' decision-making (Abkowitz et al., 1978; Cham, 2006). On the other hand, reliability can also be defined in terms of performance measures. Kimpel

(2001) defined it as "a multidimensional phenomenon in that there is no single measure that can adequately address service quality." (p. 3) Different measures have been identified by researchers and range from minimizing schedule delays, running time delays and headway delays to achieving on-time performance (OTP) standards (Kimpel, 2001; Strathman et al., 1999; Turnquist, 1981). Other researchers used a holistic standpoint to define reliability from the passengers' perspective. Passengers perceive the service as reliable when it (a) decreases their efforts to access the service, (b) has short and consistent travel times, and (c) arrives predictably, resulting in short waiting time (El-Geneidy et al., 2011; Koenig, 1980; Murray and Wu, 2003).

Researchers argue that public transport patronage growth can result from service reliability improvements whereas it can decay due to unreliable service (Bates et al., 2001; Nam et al., 2005; Noland and Polak, 2002; Vuchic, 2005). A lively discussion about the importance of reliability issues for passengers can be found throughout the literature. Peek and Van Hagen (2002) suggested an approach based on Maslow's pyramid, which represents passengers' priorities. This approach argues that safety and reliability are the foundation of traveler satisfaction, and accordingly, must be provided. The upper part of the pyramid includes additional aspects of quality such as comfort. Hensher, Stopher and Bullock (2003), and Brons and Rietveld (2007) confirm this hierarchal importance of prioritization for both regular and non-regular users. Other researchers have argued that reliability is the second most important transit attribute after arriving safely at destinations (Iseki and Taylor, 2010; Perk et al., 2008; Taylor et al., 2007; Yoh et al., 2011).

3. Methodology

This section describes the methodology used in the analysis, and contains two sections. The first section describes the review of academic literature concentrating on the passengers' perspective and reliability improvement strategies, while the second section focuses on the analysis of transit agencies' plans and reports in order to understand their perspective.

3.1 *Literature Review*

A systematic literature review is an important and useful approach to identify and analyze all relevant research on a given topic. The present study uses a Realist method to understand the literature concerning: (a) passengers' perspective, and (b) reliability improvement strategies. This method builds on the conventional systematic review template to provide a more explanatory rather than a solely judgmental focus (Pawson et al., 2005). For each section of the literature review, a search strategy consisting of two phases is conducted. The first phase includes a search of the Web of Knowledge, Scopus and TRID online article databases in November of 2013. TRID is a comprehensive database that includes more than one million records of transportation research worldwide (TRID, 2013). Only results yielding full articles and papers are included in the analysis. Additionally, the search is also restricted to include only publications in English related to transportation, urban studies, social sciences and engineering. There were no date restrictions on the results of the search. The second phase of the search strategy began once the database search had identified the relevant articles based on a predetermined set of inclusion and exclusion criteria. Table 1 shows the criteria. The reference lists of all articles were examined, and articles found through this method were subject to the same exclusion criteria after their full texts had been read.

3.1.1 Passengers' perspective

The search consisted of the following terms within the ‘‘title’’ search field: *“(Bus OR Transit) AND perception or time value”, OR “(bus OR transit) AND satisfaction or demand or ridership.”* The first phase of the search yielded 340 papers in total, of which 316 were excluded due to irrelevance and application of exclusion criteria. The second phase of the search strategy began once the database search results had been reduced to 22 relevant articles based on the predetermined set of exclusion criteria. Then, the reference lists of all articles were examined and yielded an additional 7 articles. Finally, articles that passed this review process were read in their entirety (see Appendix 1). The studies range in publishing date from June 1987 to November 2013. The studies selected for the review focused on one or more aspects of transit users’ point of view in terms of their perception, estimation of their time value, demand and satisfaction.

3.1.2 Reliability improvement strategies

The search consisted of the following terms within the ‘‘title’’ search field: *"(Bus OR Transit) AND improvement strategies or Automatic data collection or AVL or APC or AFC” OR "(Bus OR Transit) AND Reliable or Reliability or On-time performance”, OR"(Bus OR Transit) AND travel time or dwell time.”* The first phase of the search yielded 230 papers in total, of which 218 were excluded due to irrelevance and application of exclusion criteria. Studies using the actual automatic operational data e.g. extracted from Automatic Vehicle Location (AVL) and Automatic Passenger Counting (APC), and Automated Fare Collection (AFC), were included if the results were based on empirical model-driven analyses. Strathman and Hopper (1993) demonstrate the importance of the emergence of these automatic data collection technologies in the 90s. They provide researchers and agencies with a rich and accurate source of information, facilitating extensive and detailed analysis of transit operations (Feng and Figliozzi, 2011; Furth et al., 2006; Furth and Muller, 2007; Hickman, 2004; Peng et al., 2008; Uniman et al., 2010) . The second phase of the search strategy was based on the reference lists of the 12 relevant articles and yielded one additional article. Appendix 3 presents these studies. The studies range in publishing date from June 2000 to July 2013. Findings from these studies are discussed in the transit agencies’ perspective section following the introduction of what measures agencies use to improve the service.

Table 1. Inclusion and Exclusion Criteria for Literature Review

Inclusion criteria	Exclusion criteria
Passengers' perspective	
• Uses surveys or real-world observations	• Focuses on private automobile
• Focuses on passenger-related issues (i.e. demand, perception, satisfaction and time value)	• Focuses on other public transport modes, e.g. trams and trains, planes, undergrounds, and ferries
• Investigates the factors impacting passengers’ perception.	• Focuses on vehicle emissions and economics, and users’ life satisfaction issues
• Empirical analysis	• Focuses on simulation techniques and mathematical optimizations methods.
• Published up to November 2013	• Not peer reviewed

Inclusion criteria	Exclusion criteria
• Peer- reviewed • Full articles only • English language only	• All languages other than English
Reliability improvement strategies*	
• Uses automatic data collection (e.g. AVL, AFC, APC) • Analyzes the impact of improvement strategies (e.g. bus type, reserved lanes, TSP ...etc) • Focuses on one of the service operational aspects (e.g. running time, on-time performance, dwell time) or their variation • Empirical model-driven analyses • Published up to November 2013 • Peer- reviewed • Full-articles only • English language only	• Focuses on private automobile • Focuses on other public transport modes, e.g. trams and trains, planes, undergrounds, and ferries • Focuses on vehicle emissions and contracting • Focuses on simulation techniques, mathematical optimizations methods and visualization • Only a summary statistics study • Not peer reviewed • All languages other than English

* AVL: Automatic Vehicle Location, APC: Automatic Passenger Counting, AFC: Automated fare collection, TSP: Transit Signal Priority System

3.2 *Transit Agencies' Plans*

The existing literature rarely discusses how transit agencies define and resolve reliability issues or realize their reliability objectives and employ strategies to achieve these objectives. Previous studies focus solely on aspects such as understanding transit agencies’ performance measures (Bates, 1986; Benn, 1995; Kittelson & Associates et al., 2003b), employing archived AVL-APC data to improve transit performance and management (Furth et al., 2006), or planning processes (Mistretta et al., 2010). This section reviews 15 of the largest bus transit agencies' plans and reports in the U.S. and Canada, which are ranked by annual ridership (American Public Transportation Association, 2011a, b). The search criteria regarding plans and reports were as follows: large transit agencies with recent documents published after 2004 available from an agency’s official website. Appendix 2 shows the results of transit agencies’ plans that were reviewed.

Transit agencies’ plans and reports represent one of their main outputs illustrating their guidelines, policies and approaches, and are used to communicate these to the public. The purpose of this approach is not only to understand their performance measures, but also to understand the main reliability goals these agencies articulated, and strategies they use to achieve them. The idea of transportation plan analysis and examination is well-established in the literature. Researchers have employed this approach to understand existing policies regarding various goals, including agencies' sustainability orientations and approaches, or their social goals (Berke and Conroy, 2000; Feitelson, 2002; Geurs et al., 2009; Stanley and Villa-Brodrick, 2009).

Finally, the study identifies the areas of overlap, disconnect and mismatch between the perspectives of transit agencies and passengers, regarding service reliability and the impacts of service improvement strategies. The areas of disconnect represent the important gaps in understanding that need to be integrated and addressed to enable transit agencies to achieve better service that is positively perceived by passengers.

4. Passenger Perspectives

4.1 *Passengers' Time Value*

A sizable body of literature has developed around how users value their time during a transit trip and has attempted to assign a dollar value to passenger time, with an underlying assumption that the value of time is equal to its opportunity cost, usually defined as the wage rate (Wardman, 2004). These studies tend to focus on the relationship between out-of-vehicle time and in-vehicle time. For example, Mohring et al. (1987) estimate the value associated with in-vehicle time as half of an hourly wage whereas waiting time is valued at a level two to three times that of in-vehicle time. One example is Wardman's (2001) study that uses a regression model to analyze evidence drawn from 143 British academic and consultancy studies conducted between 1980 and 1996. He estimated that walking time, waiting time, and combined walking and waiting time are respectively valued 1.66, 1.47, and 1.46 times as much as in-vehicle time. Later, Wardman (2004) suggested that previous estimations for waiting time values were too low, and it is reasonable to value waiting time at 2.5 times as much as in-vehicle time. However, some studies he referenced indicated that the waiting time is valued up to 4.5 times more than walking time, which is valued at two times that of in-vehicle time. Similarly, several studies reviewed by Reed (1995) indicate a significantly different estimation for waiting time value, ranging from less than 1.5 times to as much as 12 times that of travel time value. It is important to note that the calculated values of waiting time vary by income, location, trip distance and purpose, and by survey method (Abrantes and Wardman, 2011; Chang and HSU, 2003; Lam and Morrall, 1982; Wardman, 2004). Shires and de Jong (2009) indicate similar factors that impact the value of travel time savings. However, it is rare to find empirical studies in the literature investigating the value of time savings that come as a result of service improvements.

Nevertheless, from the perspective of behavioral decision research, the value of time is subject to context effects. Most human behavior is analogous in its relation to both time and money; however, it differs completely for all situations involving risk (or uncertainty) (Leclerc et al., 1995). Behavioral decision researchers more recently have extended the previous argument in the context of time versus money and have stated that there are quantitative and qualitative differences in how people process temporal information in relation to monetary information to arrive at judgments and decisions (Monga and Saini, 2008; Soman, 2001; Zauberman and Lynch, 2005). While most of the studies regarding the cost of travel time reliability focused on car users' perceptions (Carrion and Levinson, 2012; Chen et al., 2003; Li et al., 2010; Small et al., 1999), it is rare to find studies focused specifically on transit users' perceptions. One of the rare examples is an empirical analysis done by Pinjari and Bhat (2006) which indicates that transit users, during the first 15 minutes of a trip, place a small value on travel time while placing a higher value on travel time reliability. However, the value of travel time increases rapidly after the first 15 minutes while the valuation of travel time reliability falls radically.

4.2 *Passengers' Time Perception*

Research indicates that passengers perceive waiting time differently from the actual time for reasons such as being exposed to adverse weather conditions, the surrounding environment, and the experience of being stressed by waiting anxiety (Daskalakis and Stathopoulos, 2008). Mishalani et al. (2006) used linear regression to investigate the relationship between passengers' perceptions of waiting time and actual time. In this study a surveyor went to a bus stop, noted the arrival time of a passenger, and then asked him or her about their time perceptions. The results of this study indicate an overestimation of waiting time by 0.84 minutes. Psarros et al. (2011) used the same data-collection technique and revealed that for all trip purposes – work, education, shopping and personal affairs – there appears to be a strong positive effect on the length of perceived waiting time by 27%, 43%, 30% and 30%, respectively. However, these estimates may not present the actual case because perception of waiting time tends to differ significantly from the actual measured waiting time depending on whether passengers make a conscious decision to wait compared to when the wait is imposed on them by others, such as transit agencies (Moreau, 1992).

Hall (2001) indicated that passengers who knew the schedule were more inclined to believe the bus was late than those who did not know the schedule. Hess, Brown and Shoup (2004) report that passengers overestimate their waiting time by a factor of two compared to the actual wait time when it is imposed by others (e.g. transit system) whereas they accurately estimate their waiting time when they themselves chose to wait (e.g. for a free bus). Other researchers indicate that this tendency to overestimate waiting time is further affected by the individual's personal experience in terms of whether the passenger is experiencing *time drag* or not. Time drag occurs when a passenger perceives his time spent at a stop as unproductive and useless, which occurs when the passenger is not involved in other activities such as reading a book while waiting. In this case, waiting time can seem much longer (Dziekan and Vermeulen, 2006; Moreau, 1992; Reed, 1995). However, no study explicitly focused on understanding the impacts of bus delay or arrival variation on transit users' waiting time perception.

Regarding travel time perception, the Transit Capacity and Quality Service Manual (TCQSM) (2003a) suggests that perceived travel time is equal to actual travel time. However, this does not provide understanding about how passengers perceive travel time variability, which is clearly an added time cost that passengers must account for during their trip planning (Daskalakis and Stathopoulos, 2008). According to the scheduling approach theory, transit users' preferred departure time would change (later or earlier) in response to transit schedule constraints and structures and their perceptions about travel time variation. Hollander (2006) confirms that the impacts of travel time variability on passengers is best explained through scheduling considerations. Nam et al. (2005) indicates that, at the same level of improvement, policies designed to decrease travel time variability are more beneficial than policies designed to reduce travel time. In addition, there is some empirical evidence that suggests there is an inherent disutility associated with a failure to adhere to the schedule for both the early and the late arrival, particularly if there is a transfer point in the trip (Bates et al., 2001; Noland and Polak, 2002). In other words, arriving early at destinations (e.g. a transfer point) is not as good as arriving late because time cannot be restored and used for other purposes, and users will regard the time spent due to the early arrivals as a wasted time that they may have used it better if they had taken the following trip instead. In short, passengers overestimate their waiting time at bus stops and value this waiting time more than any other time component of their trip.

4.3 *Transit Strategies Impact on Passengers' Perception*

A number of studies examined the immediate impacts of the implementation of different strategies on users' perceptions, and they generally indicated that passengers tend to perceive the service more positively after the implementation of a new strategy (Cain et al., 2010; Conlon et al., 2001; Currie, 2006; 2010). For instance, using a before-and-after rating system survey in Chicago after the implementation of a limited stop service running parallel to a bus route, users indicated a high satisfaction level in many areas including the overall satisfaction, satisfaction of travel time and waiting time, at both the regular and the limited stop service routes (Conlon et al., 2001). Dziekan & Vermeulen (2006), Dziekan & Kottenhoff (2007) and Watkins, et al. (2011), among others, have investigated the impact of the introduction of real-time information on passenger' waiting time perception. Results from these studies indicated that the perceived waiting time decreased after the implementation, without reporting any actual improvement in the service frequency. El-Geneidy & Surprenant-Legault (2010) focused on users' travel time perception after the implementation of a new limited stop service, indicating that users overestimate their perceived travel savings compared to the actual time savings.

Cain, et al.(2010) revealed that the implementation of express lanes significantly improved users' travel time and service reliability ratings. Diab & El-Geneidy (2012) investigated the impact of a combination of strategies on passengers' travel time perception, indicating that passengers tend to overestimate the travel time savings associated with the implementation of this combination of strategies, while there was almost no actual saving in buses' running time. This indicates a positive attitude towards the implementation of improvement strategies. However, previously mentioned studies in this subsection focused on measuring users' perceptions and/or satisfaction immediately (at one time point) after the implementation of a new measure or route. Thus, it is rare to find studies that investigate how these perceptions change over time. Only Dziekan & Vermeulen (2006) investigated the effects of the introduction of real-time information on people's waiting time perception changes over time, using surveys one month before, and three months and 16 months after the system implementation. However, their study suffered from a limited study sample size.

4.4 *Section Summary*

To summarize, several studies investigated how users value their time during a transit trip and indicated that the relative value of waiting and travel times varies with income, location, trip distance and purpose, and survey method. Nevertheless, it is infrequent to find empirical studies that investigate the value of time savings and their reliability for transit users. It is common to find studies investigating passengers' waiting time perception, however, no study explicitly focused on understanding the impacts of bus delay or arrival variation on transit users' waiting time perception. Finally, although, several studies indicate a positive impact of service improvement strategies on user's perception after the immediate implementation of a new strategy, it is rare to find studies that investigate why exactly these strategies impact perception and how these perceptions change over time.

5. Transit Agency Perspectives

Across the U.S. and Canada, transit services are funded in part through public subsidies (American Public Transportation Association, 2011a). In addition, in each country, there is a national organization that tracks and supports public transit service, which requires transit agencies to file annual reports, to develop future plans, and to comply with various other requirements in order to receive federal funds (FTA, 2012; Transport Canada, 2012). Therefore, and due to the spatial, political and financial contexts similarities, this study focuses solely on industry practice in North America. The following section discusses transit agencies' perspectives on reliability. The discussion provides insight into the following questions:

- how do transit agencies understand and realize reliability;
- how and to what extent do they measure riders' perceptions of service reliability;
- what reliability indictors do they use; and,
- what are their service improvement strategies?

A systematic evaluation method for transit agencies' plans was applied to identify each agency's definition of reliability, and reliability goals, objectives and strategies. A key word search for "reliability, "punctually", "transit", "bus", "perception", and "satisfaction" was performed to allocate the sections that needed to be reviewed. If agencies used words such as "mission", "goal" and "task", or employed key verbs, such as "define", "refer", or the verb 'to be' (e.g. reliability is….), the sentences' purpose were considered as a goal or as a definition, respectively. While if agencies used words such as "target", "objective", or contained key verbs, such as "aim', "intent", and "require", the sentences" purpose were considered as an objective. Then, the related paragraphs were checked to make sure that the used word was related to reliability and bus and/or transit service. If the agency indicated reliability as a main goal, the strategies used to improve the service were collected. For each transit agency, more than one report is included in the analysis to give more holistic ideas about its perspectives.

5.1 *Transit Agencies' Understanding of Reliability*

All the transit agencies included in this review indicate reliability as a priority. Most of them mentioned reliability in their broad mission statement or president's message as one of the most important strategic goals to be achieved. Among the examples, the chairman of NJ TRANSIT, New Jersey, stated that their mission is to "enhance reliability and safety" of transit services (NJ TRANSIT, 2012). In Chicago, the CTA president stated that his charge is to make sure that "(the service) is operating as reliably and efficiently as possible, … to strive to evolve and improve and to deliver on-time… service each and every day"(p.7) (Chicago Transit Authority (CTA), 2011). Similar examples of commitment to improve transit service reliability can be found across the reviewed transit agencies' plans.

Transit agencies define reliability in different ways. Among those who provided a definition of reliability, nearly all agencies define and operationalize reliability in term of measures, particularly those related to OTP. As an example, reliable service for TransLink, Vancouver, is regarded to be "*designed to ensure OTP, avoiding being early & minimizing running late"* (p.3) (TransLink, 2004). WMATA, Washington, is "*dedicated to delivering service on time… to improve reliability"* (p.4) (WMATA, 2012). Other transit agencies including the King County Metro Transit, Seattle, defined it in terms of the overall availability of service. Regarding the objective of achieving reliability, around 80% of the reviewed transit agencies consider reliability as an objective in order to increase customer convenience, or as the measure that should be monitored in order to keep them satisfied and to improve ridership. For example, MTA in New York city, regards service reliability as the key factor to increase ridership (Metropolitan Transportation Authority (MTA), 2008). NJ TRANSIT (2011) stated that reliability is an important measure to *"meeting customers' needs."* OC-Transpo, Ottawa, stated that *"reliability is a key factor"* in building customer satisfaction (OC Transpo, 2012).

5.2 *How Transit Agencies Measure Riders' Perceptions of Service Reliability*

It is important to understand how transit operators view and recognize transit users' responses to service quality changes, particularly regarding their perspectives concerning reliability. Despite the fact that most of the reviewed transit agencies regard reliability as a key factor in building customer satisfaction, only 20% of transit agencies (3 out of 15) reported users' satisfaction about service reliability (or schedule adherence and OTP). For example, Miami-Dade Transit, Miami, indicated that the percentage of respondents satisfied with the reliability of bus service is 35% in 2008, while their target is 45%. The MTA indicated the passenger satisfaction level for their local buses' OTP reached 6.6 out of 10 in 2008 (Metropolitan Transportation Authority (MTA), 2008).

On the other hand, approximately 12% of the sampled agencies reported changes in the passenger complaint rate concerning reliability of service, including the MBTSA in Massachusetts and Metrolinx in Toronto. Other transit agencies reported overall customer satisfaction of transit service along with other measures without reporting satisfaction with reliability. For example, the STM, Montreal, in their 2009 report, stated that "*the average level of customer satisfaction about all aspects of service is 86%"* (p.8). In addition, the STM in 2008 reported the level of overall customer satisfaction with transit (82%), the level of satisfaction with driver courtesy (81%) and safety (91%), without reporting reliability separately. It should be noted that a rating system (e.g. 1=Poor to 10=Excellent) was the major tool reported by transit agencies to indicate changes in passengers level of satisfaction.

5.3 *Transit Agencies Reliability Indicators*

Indicators are the quantitative measurement tools used to assess progress toward a desired outcome or objective (Maryland Department of Transportation, 2009a). Bates (1986), Benn (1995), and Kittelson & Associates et al., (2003b) reviewed operators' performance measures. They report that OTP is the most commonly recognized and employed measurement used by transit operators in order to understand and achieve reliability. Along with previous research, our study indicates that most transit agencies define reliability in terms of OTP and are still using OTP-related measures. A few transit agencies use other measurements besides OTP, that relate to service interruption percentages, the percentage of delivered trips, or the mean distance between failures (MDBF). However, it is rare to find measurements related to headway adherence (the importance of these measures will be discussed later). Only 20% of reviewed transit agencies (3 out of 15) used the percentage of big gap intervals and bunched intervals, headway adherence percentage and waiting time assessments as measures of reliability.

OTP is commonly expressed as the percentage of buses that depart or arrive at a given location within a predetermined range of time. The acceptable percentage threshold varies from one agency to another according to the target goal and the measured range of acceptable delay or earliness that an agency assumes would be acceptable for passengers to wait. For example, a transit agency can set a goal that requires 78% of their buses to be on time, using an acceptable range from 2 minutes early to 7 minutes late, like the WMATA. Another agency's goal can be the same (78%), using an acceptable range of from 1 minute early to 4 minutes late, such as in the case of SEPTA in Philadelphia. In addition, while the majority of transit agencies measure

OTP as the bus arrival time at a number of points along the system, such as the last stop of some routes, the NJ TRANSIT measures OTP as the bus *departure time* within 1 minute early and 5 minutes late from a few time points along the system (i.e. layover points mainly). On this basis, the NJ Transit achieved 94% in 2010 (NJ TRANSIT, 2010).

5.4 *Agencies Strategies to Improve Service Reliability*

Regarding the strategies that agencies use to enhance their service reliability, several are reported. These strategies are different from one transit agency to another according to the level of improvement required or provided by what has already been implemented (Hemily and King, 2008; Smith et al., 2005). These strategies, by decreasing frequency of appearance order, are: transit signal priority (TSP), bus rapid transit (BRT) or BRT-like systems (rapid transit system or networks), new buses (low-floor buses and articulated buses), reserved bus lanes, limited-stop services (express buses), intelligent transportation system (ITS) and (AVL/APC) systems, and smart cards. Because BRT and BRT-like systems that combine more than one approach are more attractive than conventional transit routes operating with less speed and reliability, these systems are considered one of the most effective tools to increase service reliability, efficiency and ridership (Currie, 2006; The Canadian Urban Transit Association (CUTA), 2007). About 20% of transit agencies (3 out of 15) considered reviewing their bus stop location, route design and structure, and driver training.

5.5 *Impact of Strategies on Service*

A number of studies discussed the impacts of different improvement strategies on transit service. These studies are presented in Appendix 3. Most of the studies are done in response to the cooperation between transit agencies and researchers to understand the impacts of their actions on service. Thus, these studies are evaluational studies that use a before-and-after design to assess and provide evidence of the impacts of interventions. Other studies not included in the review generally focused on understanding the general factors impacting the service, such as distance, weather, time periods, number of passengers and land use (Mazloumi et al., 2010; Patnaik et al., 2004; Rajbhandari et al., 2003).

The majority of the study concentrated on running time improvements that resulted from implementing these strategies. Several studies agreed that limited-stop bus service and reserved bus lane decrease running time (El-Geneidy et al., 2006; El-Geneidy and Surprenant-Legault, 2010; Surprenant-Legault and El-Geneidy, 2011), while low-floor buses decrease dwell time (Dueker et al., 2004). Strathman et al. (2000) indicates buses' running times are significantly shorter due to the implementation of the dispatch system. The use of articulated buses along a transit corridor is expected to have a mixed effect on running time (El-Geneidy and Vijayakumar, 2011). It decreases running time due to the existence of the buses' third door, while also increasing it due to the longer acceleration and deceleration time. The use of the smart card increases running time compared to using the traditional flash passes (Diab and El-Geneidy, 2012), while it decreases the running time compared to magnetic strip tickets, but only when the bus is not crowded (Milkovits, 2008). Kimpel et al. (2005b) indicate that the expected benefits of TSP are not consistent across routes and time periods.

Concerning the service variation, few studies indicated that driver experience and behavior are important factors affecting transit service running time and its variability (Abkowitz et al., 1978; El-Geneidy et al., 2011; Levinson, 1991; Strathman and Hopper, 1993; Strathman et al., 2002). El-Geneidy et al. (2006) analyzed the impacts of bus stop consolidation on bus performance. They indicate that while bus running time improves due to implementation, this does not impact the service running time variation nor headway variation. Yetiskul and Senbil (2012) indicate that new buses decrease running time variation. Finally, Diab and El-Geneidy (2002; 2003) provided two detailed studies that explore the impact of a combination of service improvement strategies on service running time and its variaiton. They indicated that strategies may have unexpected impacts when they are implemented together. Therefore, understanding the synergies and the collective impacts of strategies is needed.

5.6 *Section Summary*

To summarize, transit agencies consider reliability to be a priority, defining it in terms of OTP measures to achieve the objective of increasing customer satisfaction. They do not frequently report users' satisfaction regarding service reliability despite its perceived importance. Additionally, the majority of transit agencies use OTP measures with differing standards. Finally, no transit agency indicated using only one improvement strategy; they often employ TSP and BRT or BRT-like systems that combine a few strategies in order to enhance the service. On the other hand, discussion of the impact of improvement strategies focused on understanding the effect of only one or two strategies on the service running time and dwell time. Only a few studies focused on exploring the impact of a set of strategies on the service variation.

6. DISCUSSION AND CONCLUSIONS

The main objective of this paper is to address simultaneously, within the scope of reliability, passengers' and transit agencies' perspectives. Figure 1 illustrates the research structure and the key findings. The shaded area within the arrows shows the overlap in the understanding and linkage areas. The area outside the arrows presents the disconnect area, which signifies the important gaps and mismatches in the understanding of reliability. The factors in this area need to be integrated and addressed to enable transit agencies to achieve better service that is positively perceived by passengers. The following section discusses this paper's key findings in detail.

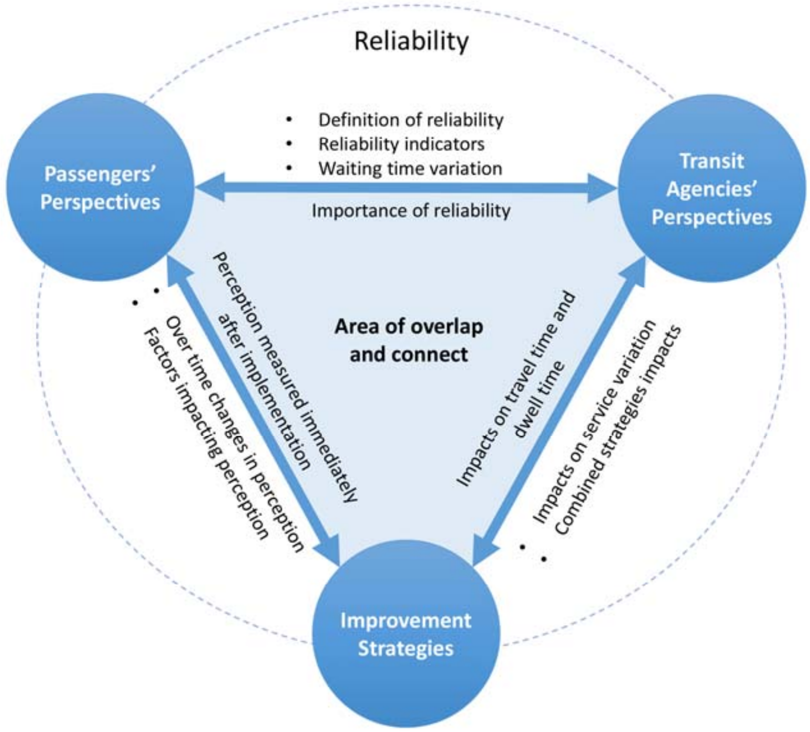


Figure 1. Research Structure and Main Findings

6.1 *Passengers and Agencies Perspectives*

The overlap between passengers' and transit agencies' perspectives on reliability centers on agreement about its importance to the service provided. The key differences between both perspectives are related to the definition of reliability, to the standard viewpoint regarding OTP, and to the unaddressed waiting time variation.

Passengers think about reliability in terms of consistently minimizing their overall waiting time and traveling time. They consider waiting and running times and their variation as reliability measures since they affect their decision of departure time (Hollander, 2006) and daily activity planning (Leclerc et al., 1995). In contrast, operators mainly define reliability in terms of on-time performance standards (or adherence to schedules). From a passenger's perspective, there are few drawbacks related to an OTP standard because it only introduces a number or percentage of vehicles located within a fixed tolerance based on the schedule. OTP does not take into account the amount or severity of delay or the bandwidth of arrival deviation from schedules (Camus et al., 2005). Therefore, it does not provide much information about the changes that occur in passengers' waiting times.

In addition, particular attention must be given to the main aspect of passengers' views relating to the reliability of transit planning: their response to waiting time variation due to bus delays. In fact, capturing and isolating waiting time variations experienced by users due to late buses is difficult. Researchers simply cannot know when users' actual waiting time starts in correlation with how much longer they waited behind the schedules (for the late buses). This is because researchers have to interrupt users to ask them about their perception, which is not capturing the full impact of delays on perception. Therefore, in the literature, it is still unclear how people perceive wait time variation and how they act during that experience. Thus, transit planners should support the concept that measurement of service variation can fundamentally address the quality of service, which can then decrease service variations and, consequently, users' waiting time variations. Variation can be expressed using various measures including headway variation and travel time variation. These measures are more relevant to a passenger's experiences of daily changes and delays than a discrete on-time window that may be practical for evaluating the reliability of the system's operational plan from a transit agency's perspective.

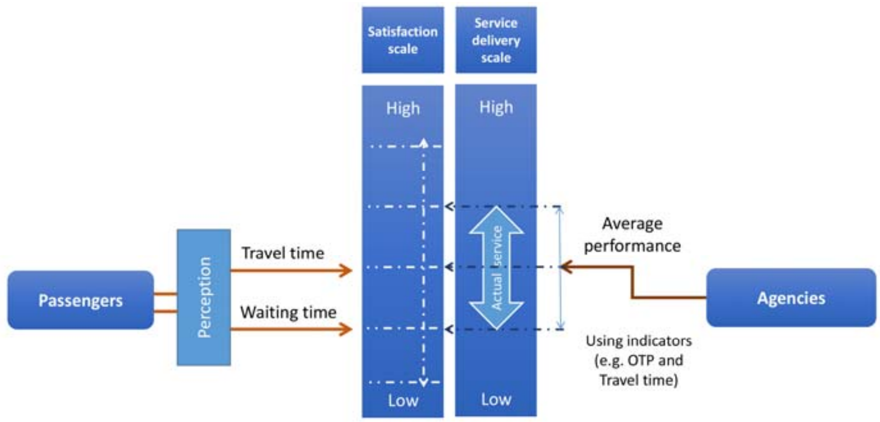
Accordingly, given the classic dilemma of valuing passenger time, transit agencies should account for passengers' waiting time more carefully by determining and addressing the difference between *expected* waiting time values for passengers and the *added* waiting time imposed by operators due to delays. Waiting imposed by operators makes passengers spend time stressed because they experience anxiety related to the fear of not meeting their target arrival time at their destination. Therefore, the value of waiting time can reach as much as 12 times the value of in-vehicle time and it changes according to users' preferences, time planning and their situations, as stated earlier (Iseki et al., 2006; Reed, 1995).

The majority of transit agencies indicate using passengers' surveys to measure user's perception. Nevertheless, these surveys should not only be utilized to track changes in service quality but also to help prioritize future improvements for service quality initiatives and strategies. Rather than using a satisfaction rating system, these surveys should consistently require users to quantify their waiting time and travel time (and their changes). This would give a better connection between passengers' perceptions and improvement efforts made by agencies, which may lead to more accurate integration between users' perceptions and policy making during the service planning and operation process.

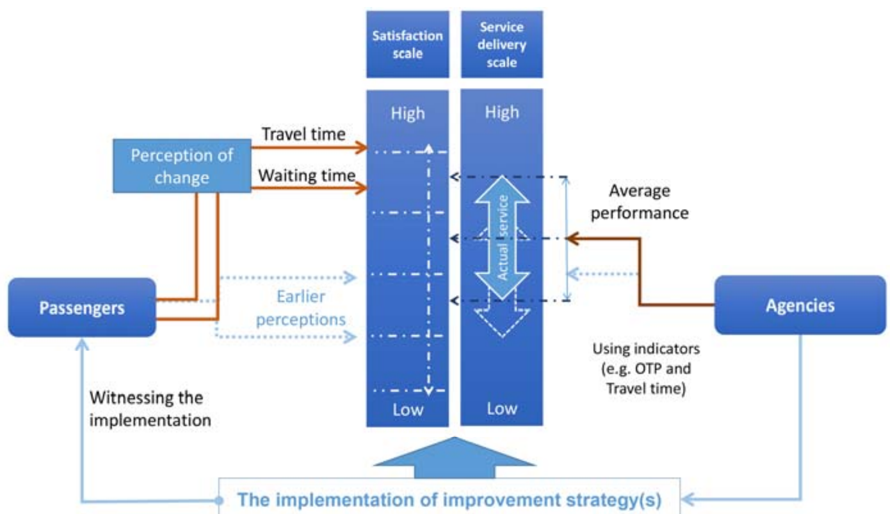
6.2 *Passenger Perspective Relative to Service Improvement Strategies*

A number of studies examined the immediate impacts of the implementation of different strategies on users' perceptions, and they generally indicate that passengers tend to perceive the service more positively after the implementation of a new strategy (Cain et al., 2010; Conlon et al., 2001; 2010). Figure 2-A shows a conceptual framework of how transit agencies measure their performance, and the nature of the passengers' perception of the *regular* or *standard* service attributes. It shows that while agencies measure and capture the actual average service, passengers perceive it differently, particularly concerning their waiting time (Kittelson & Associates et al., 2003a). The main conflict is related to passengers' perception when the agency implements strategies in order to improve the service. Figure 2-B shows this conceptual framework related to when transit agencies implement an improvement strategy. In this case, transit users tend to be satisfied and significantly overestimate their benefits (ICF Macro, 2011). This bias may occur because users are witnessing the implementation of such measures, as well as the related time cost saving that they experience. However, the question of why 'exactly' users overestimate these benefits is not presented in the literature. In addition, it is rarely discussed how these positive estimated perceptions can change over time (shifting back from Figure 2-B to Figure 2-A).

Unfortunately this tendency to be satisfied is yet to be successfully quantified and put to use, and will remain that way as long as transit agencies and researchers are capturing passengers' satisfaction and perception using mainly customer satisfaction rating techniques. The traditional rating techniques' results are devoid of specific insight into how people are overestimating and quantifying their time changes according to changes in service quality. In fact, the availability, affordability and accuracy of AVL/APC systems data offers a good opportunity to understand and to present better estimations of how passengers estimate and perceive actual time changes in relation to implemented strategies. This is an important policy-relevant issue, since agencies should not only understand the quantitative effects of their policy and implemented strategies on their performance, but also on passengers' perception. Such knowledge will provide an understanding of the link between passengers' perception and the benefits of using a specific strategy, which may lead to more accurate measures and predictors of behavioral responses and, as a result, improved cost-benefit evaluations of transportation projects.



(A)



(B)

Figure 2. (A) Perception of Regular Service; and (B) Perception after the Implementation of Improvement Strategies**.**

6.3 *Transit Agencies Perspective Relative to Service Improvement Strategies*

It is essential to assess to what extent the academic literature provides transit agencies with useful information related to the impacts of various strategies. The impacts of various strategies on run time and dwell time have long been discussed in the literature. However, it appears that less attention has been given to the impact of various strategies on service variation, particularly related to dwell time variation. Furthermore, it is rare to find studies that provide a comprehensive analysis of the impacts of implementing a set of strategies on service reliability as well as passengers’ perception of these changes. These are important issues since strategies may have unexpected impacts when they are implemented together. Therefore, understanding the synergies and the collective impacts of these strategies is needed (Diab and El-Geneidy, 2012, 2013). This is particularly relevant to transit agencies’ practice, since no transit agencies indicated using only one strategy to improve their service, and they often employ BRT or BRT-like systems (that combine a few strategies in order to improve the service).

This knowledge is important to help transit agencies prioritize one strategy or a set of strategies over the others. The current literature’s limited focus on transit agencies’ knowledge needs may be limiting the latter’s ability to correctly anticipate the impacts of their efforts on the service, and accordingly, on passengers’ perception. Therefore, it is suggested that researchers should provide more in depth studies regarding the comprehensive impacts of improvement strategies while understanding how these may function together to affect the transit performance and its variation. This level of complexity can be investigated using different automatic data collection systems, thereby giving transit agencies a better idea about the impacts of efforts on service and on passengers. Finally, while this research has focused on the North American experience regarding transit agencies’ perspective, lessons can be learned and applied across different areas in the world, enabling transit agencies to achieve better service reliability that is positively perceived by the public.

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Appendix 1. Summary of Studies on Passengers' Perspectives Included in Review

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Passenger time value						
Mohring et al. (1987), Singapore	Wage, and waiting and travel time values	on-board survey	11,438	Maximum likelihood estimates	• Travel time • Waiting time	• The value associated with time is usually higher than the fare. • The value associated with in vehicle time is around half the equivalent of an hourly wage, waiting time is valued at 2-3 times that of in-vehicle time.
Leclerc et al. (1995), New York, USA	Risk behavior, money and time value	8 surveys	756	Descriptive statistics	• Waiting time	• The value of consumers' waiting time is not constant but depends on contextual characteristics of the decision situation • Respondents preferred risk-averse choices with respect to decisions in the domain of time
Wardman (2001), England	Time and service quality value	Meta-anlysis using various data sources	143 studies	Regression models	• Walking time Waiting time • Travel time	• Walking time, waiting time, and combined walking and waiting time are valued 1.66, 1.47, and 1.46 respectively times as much as in-vehicle time.
Wardman (2004), England	Value of Walk time, waiting time	Meta-anlysis using various data sources	171 studies	Regression models	• Walk time • Wait time • Headway • Travel time	• Waiting time is valued at 2.5 times as much as in-vehicle time, while walking time is valued at 2.5 times travel time • The value of headway depends upon journey purpose and distance
Nam et al. (2005), na	Importance of travel time reliability	On-site survey	na	Multinomial and Nested Logit model	• Travel time	• The value of reliability is greater than values of travel time. Reliability was expressed in terms of standard deviation.
Pinjari & Bhat (2006), Austin, USA	Value of Travel time and travel time variation	Web-based survey	317	Mixed logit model	• Travel time	• The values of travel time and travel time unreliability were found to be nonlinear. • During the first 15 minutes of a trip, passengers place a small value on travel time while placing a higher value on travel time reliability. The value of travel time increases rapidly after the first 15 minutes while the valuation of reliability falls radically
(Shires and de Jong, 2009)	Value of travel time savings	Meta-anlysis using various data sources	77 studies	Panel data models	• Travel time	• The value of travel time savings varies by income, country, travel purpose, mode, distance and by survey method.

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Politis et al. (2010), Thessaloniki, Greece	The value of real time Information System	On-site survey	300	Descriptive statistics	• Waiting time • Number of trips	• Users value real time information services at, on average, 24.0% of the current fare. • Women value the service more than men. • About 20 % of the overall sample stated that they have undertaken more trips as a consequence of the information system.
Abrantes & Wardman (2011), England	The value of travel time	Meta-anlysis using various academic and reports	226 studies	Regression models	• Travel time	• The ratio between walk and wait time and in-vehicle time was found to be lower than the commonly used value of two. • There is a large and significant difference between the results from studies based on different types of Stated Preference survey presentation.
Passenger perceptions regarding time						
Strathman et al. (1999), Portland, USA	Automated Bus Dispatching impacts	On-board survey (Rating 1-4 scale)	1815	Descriptive statistics	• Reliability • Satisfaction	• Users rated a frequent service as the most reliable and gave it the highest overall satisfaction rating, while it has the lowest reliability (in terms of the coffecient of variation of running time and headways).
Hall (2001), Los Angeles, USA	Perception of Waiting time	On-site survey & AVL data	1199	Regression models and logit models	• Waiting time	• Perceived waiting time varies according to age group, destination, primary language, as well as for first-time users. • People who knew the schedule were more inclined to believe the bus was late than those who did not know the schedule.
Hess et al. (2004), Los Angeles, USA	Perception of Waiting time	On-site survey & manual headway data	281	Descriptive statistics	• Waiting time	• Riders overestimated their wait time by a factor of two when it was imposed by the transit system, but accurately estimated their wait time when they chose to wait for the free bus ride.
Hollander (2006), city of York, England	Travel time variability and trip time choice	Web-based survey	244	Multinomial logit	• Travel time variability	• The influence of travel time variability on bus users is best explained indirectly through scheduling considerations. • The penalty placed on early arrival to the destination is found to be similar to the penalty on travel time itself; late arrivals are much more heavily penalized.
Mishalani et al. (2006), Ohio, USA	Perception of waiting time	On-site survey	83	Regression models and descriptive statistics	• Waiting time	• Their results indicated an overestimation of waiting time by passengers compared to their actual waiting time at stops by 0.84 minutes.

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Daskalakis & Stathopoulos (2008), Athens, Greece	Perception of waiting time and headways	On-site survey	300	Mathematical models	• Waiting time	• The greater the headway, the greater the deviation the users perceive, but at a diminishing rate. • A reliable service, meaning smaller deviations, is more appreciated by the public than any service of shorter headways and less reliability.
Fan & Machemehl (2009), Texas, USA	Waiting time and Arrival pattern	Observation & video recording	2237	Linear regressions	• Waiting time • Arrival pattern	• They identified a threshold of 11 minutes that passengers begin to coordinate their arrivals to the bus stops as predetermined as at schedules
Dell'Olio et al. (2010), Santander, Spain	How perception of quality varies according to the available information	Focus groups, on-board and on-site survey	768	Ordered probit models	• Waiting time • Travel time • Reliabilty	• The perception of quality is shown to change with the category of user (frequency of use, income, gender, age, car ownership) • Users tend to be more critical in terms of perception of Overall Quality until they are stimulated into thinking more deeply about other influential variables. • As a general rule, the number improving their score is practically double the number reducing it for the same situations.
Eboli & Mazzulla (2011), Italy	Asymmetric user perception	Survey (Rating 1 to 10)	470	Mixed logit model	• Service quality	• Users' perceptions of transit services are heterogeneous: for many reasons: the qualitative nature of some service aspects, the different users' socioeconomic characteristics, the diversity in tastes and attitudes towards transit.
Psarros et al. (2011), Athens, Greece	Perception of waiting time	On-site survey	1000	Hazard-based duration models	• Waiting time	• For all trip purposes – work, education, shopping and personal affairs – there appears to be a strong positive effect on the length of perceived waiting time comapred to actual waiting time by 27%, 43%, 30% and 30%, respectively. • Younger people estimate their waiting time more correctly than older people
Transit strategies impacts* on passengers' perception						
Conlon et al. (2001), Chicago, USA	Express service	On-site survey (Rating 1 to 5)	1,178, 1,006, and 730	Descriptive statistics	• Travel time • waiting time	• Customer satisfaction and loyalty measures, as measured by before-and-after customer satisfaction surveys, increased significantly for both local and express customers due the implementation of new express service.

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Dziekan & Vermeulen (2006), Hague, Netherlands	Real-time information displays impacts	Three mailed survey	53	Descriptive statistics	• Waiting time	• Passenger waiting time perception decreased after the implementation by 20% (1.30 minutes) without reporting any actual improvement in service, with no significant change in perception on the long term
Dziekan & Kottenhoff (2007), Stockholm, Sweden	Real-time information displays impacts	Several studies review	11 studies	na	• Waiting time	• Only 4 studies report that users' perceived wait times were reduced due to the real-time information system implementation.
Cain et al. (2010), Miami, USA	Reserved lanes impacts	Two on-board surveys (Rating 1 to 5)	572 and 349	Descriptive statistics and t-tests	• Travel time • OTP	• Express lanes, as measured by before-and-after surveys, have improved user perceptions of travel time and service reliability. • Travel time and rating increased by 0.23 points • Service reliability increased by 0.16 points • 63.9% perceived a 5- to 29-min, while the actual saving was 17 min.
Barr et al. (2010), New york, USA	BRT system impacts	Na	Na	Na	• Travel time	• 89% said that BRT is better than the limited services, and 30% said that they were riding more frequently than before, • 84% said that BRT is faster than the limited.
El-Geneidy & Surprenant-Legault (2010), Montreal, Canada	Express service impacts	On-site survey & AVL/APC data	340	Linear regressions and t-test	• Travel time	• Implementing a limited-stop service yielded 4.6 minutes savings (13% compared to the local service) in running time for the new limited service. • Passengers tend to overestimate the savings associated with the implementation of the new limited-stop service by 4 to 7 minutes more than the actual savings.
Yoh et al. (2011), California, USA	Relative importance of stop amenities on perception	On-site survey (Rating 1 to 4) and a value for waititng time	900	Regression models	• Waiting time	• Regardless of waiting time, safety and on-time performance were paramount to riders • Lighting, cleanliness, information, shelter, and the presence of guards were less important to travelers when waits were short, but were more important with longer wait times.

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Watkins et al. (2011), Seattle, USA	Real-time information via devices impacts	On-site survey	655 (13% are real-time users)	Linear regression models	• Waiting time	• Measured wait time, real-time information, PM peak period, bus frequency, and aggravation level impact users perception. • Real-time information users' perceived wait time = measured wait time. The addition of real-time information decreases the perceived wait time by 0.73 min.
Diab & El-Geneidy (2012), Montreal, QC, Canada	A set of strategies impacts	AVL/APC & On-site survey	60,973	Linear regression models	• Travel time	• The combination of a set of strategies led to a 10.5% decline in running time along the limited stop service compared to the regular service. However, the regular route running time increased by 1% compared to the initial time period. • Users tend to overestimate the savings associated with the implementation of this combination of strategies by 3.5–6.0 min and by 2.5–4.1 min for both the regular route and the limited stop service, respectively.

Appendix 2. Summary of Transit Agencies Plans Included in Review

Agency	Reliability definition/goal	Objective or expected benefits	Performance measures*	Strategies, and policies	Users Perception	Reference
South Coast British Columbia Transportation Authority (TransLink), Vancouver, Canada	• Improve OTP • Avoid being early • Minimize running late	• Increase customer satisfaction	• OTP (0 min +3 min) • Delivered trips (%) of scheduled trips	• Transit priority system (TSP, bus lanes, queue jumpers) • Express service • Bus bays improvements • Articulated buses	• Overall satisfaction ratings (e.g. 7.3 out of 10 in 2009)	(TransLink, 2004, 2009, 2012)
Toronto Transit Commission (TTC), Toronto Canada	• Increase OTP and decrease cancellations	• Compete effectively with the automobile	• OTP • Monitored monthly	• BRT • Rapid Transit Network • TSP, Bypass, Shoulders ITS	• Less complaints about reliability every three months • Customer satisfaction rating	(Metrolinx, 2008; Toronto Transit Commission (TTC), 2009, 2013)
Société de transport de Montréal (STM), Montréal, Canada	• Increase bus punctuality	• Improve customer experience	• OTP (-1min +3 min) • Target: 83%, (82.6 in 2008 and 83.6% in 2009)	• TSP and ITS • Express service • Reserved bus lanes • Street layout	• Overall customer satisfaction (81 in 2008 and 86% in 2009)	(Société de transport de Montréal, 2009, 2010, 2011)
OC Transpo, Ottawa, Canada	• Achieve scheduled service availability • OTP		• OTP (0 min +5 min) at time points • Cancelled trips (%) of scheduled trips • Average transit vehicle speed	• Rapid transit system • TSP • Road geometry changes • Reserved lanes • Queue jumps	• Using customer satisfaction surveys	(OC Transpo, 2009, 2012; The City of Ottawa, 2008)

Agency	Reliability definition/goal	Objective or expected benefits	Performance measures*	Strategies, and policies	Users Perception	Reference
Metropolitan Transportation Authority (MTA), New York, USA	• Improve performance	• Ridership	• Mean Distance Between Failures (MDBF) • Bus wait assessment percentage for high-volume bus lines and limited stop service	• Express service • New Buses • TSP • BRT (off-board fare collection, TSP, Real time bus information) • New Fare collection system • Managing fleet defects • Improved schedules	• Ridership • Customer satisfaction rating (1 to 10) For OTP, Safety, and Overall	(Metropolitan Transportation Authority (MTA), 2008, 2009, 2011)
San Francisco Municipal Transportation Agency (SFMTA), San Francisco, USA	• Meets core operational agency performance objectives (e.g. achieve OTP)	• Ability to speed transit • Meet Transit Effectiveness Project (TEP) objectives	• OTP (-1 min +4 min) • Headway adherence (as a secondary measure)	• BRT • Reserved bus lanes • All-door boarding • Stop spacing • TSP and signal timing • Articulated buses • Improving fare collection system	• Using customer satisfaction surveys	(San Francisco Municipal Transportation Agency (SFMTA), 2011, 2013; SFMTA and Nelson\Nygaard Consulting Associates, 2008)
Chicago Transit Authority (CTA), Chicago, USA	• Minimize system delays manage rail and bus intervals	• Decrease delay and bus bunching	• Percentage of Big Gap Intervals • Percentage of Bunched Intervals	• BRT • TSP • Articulated buses. • Bus arrival information	• Number of complaints	(Chicago Transit Authority (CTA), 2011, 2013)
Maryland Transit Administration (MTA), Maryland, USA	• Quality of service/ efficiency • OTP	• Ridership	• OTP • Target: 87% in 2010 out of 90% target	• AVL system and centralized control center • CharmCard smart card • Express service • Fleet replacements	• Using customer satisfaction rating (1 to 5)	(Maryland Department of Transportation, 2009b, 2011)
Massachusetts Bay	• Service	• Decrease	• OTP	• BRT	• Rider	(Massachusetts

Agency	Reliability definition/goal	Objective or expected benefits	Performance measures*	Strategies, and policies	Users Perception	Reference
Transportation Authority (MBTA), Boston, USA	should be operated as scheduled	unpredictable wait and/or travel times.	• Headways ≥10 min: OTP at start (0 min +3 min), mid (0 min +7 min), and at end (-3 min +7 min) • Headways <10 min: OTP within 1.5 times of scheduled headway, and OTP at end within 20% of run time	• AVL/APC • Newer buses (Low-floor buses)	complaints • Public meetings feedback	Bay Transportation Authority (MBTA), 2008, 2009; MassDOT, 2013)
Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia, USA	• Improve OTP		• OTP (-59 sec +4min) • Bus arrival • Target 78% in 2011 (75% in 2010) • MDBF: target 9125 in 2012 (7,066 in 2010) • Report every 6 months	• New Technologies • New payment methods • Evaluate schedules • Route adjustments	• Reliability for all modes (7.8 in 2012 out of 10) • Using customer satisfaction rating (1 to 10)	(Southeastern Pennsylvania Transportation Authority (SEPTA), 2010, 2011, 2013)
NJ TRANSIT, New Jersey, USA	• Achieve OTP	• Decrease delays	• OTP (-59 sec +5min) • Bus departure at few main stations • 94% in 2010 (No target)	• Newer full-size buses • low-floor buses • "Tap & Go" system	• Using customer satisfaction rating (1 to 10)	(NJ TRANSIT, 2010, 2012)
Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C. USA	• OTP	• Meet customer expectations by consistently delivering quality service	• OTP (-2 min +7 min) • Arrival time at a time point • Target 78% in 2013 (77.5% in 2012) • MDBF: Target 8100 miles in 2013 (8485 miles in 2012) • Reported quarterly	• Priority Corridor Network (TSP and exclusive bus lanes) • Management actions • Express service • Route adjustments	• Reliability (73% in 2012) • Overall customer satisfaction (81% in 2013)	(WMATA, 2010, 2012, 2013)

Agency	Reliability definition/goal	Objective or expected benefits	Performance measures*	Strategies, and policies	Users Perception	Reference
King County Metro Transit – Department of Transportation, Seattle, USA	• Decrease late trips	• Improve satisfaction	• OTP (-1 min +5 min) • Target 80% in 2013 (77.5% in 2012) • PM Peak period 65 % • Reported monthly • Measured at time points	• Rapid transit • Schedule revisions • TSP • Bus reserved lanes • Queue bypass • Stop consolidation	• Customer Satisfaction of OTP • Customer complaints	(King County Metro Transit, 2007, 2013a, b)
Denver Regional Transportation District (RTD), Denver, USA	• On-time as scheduled service	• Decrease users' waiting time • Ridership • Riders deserve on-time service	• OTP (-1 min +5 min) • Max 30 minutes delay	• TSP • Bus lanes • BRT		(City of Denver, 2008; RTD, 2011, 2012)
Miami-Dade Transit, Miami, USA	• Improve OTP	• improve riders satisfaction	• OTP (-2 min +5 min) • Target 80% (79% in 2009 and 80% in 2012)	• TSP	• % of users satisfied with the service reliability (35% in 2008, target 45%)	(Miami-Dade Transit, 2009, 2012a, b)

***OTP**: on-time performance; **MDBF:** mean distance between failures; **Big Gap interval:** An instance when the time in between buses is more than double the scheduled interval, or a gap of more than 15 minutes; **The percentage of bunched intervals:** The number of bus intervals (time between two buses at a bus stop) that are 60 seconds or less divided by the total number of weekday bus intervals traveled during the month; **Bus wait assessment:** The percent of actual intervals between vehicles that are no more than the scheduled interval plus 25% of the headway.

Appendix 3. Summary of Studies on Service Improvement Strategies Included in Review

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Strathman et al. (2000) Portland, USA	Bus dispatching system (BDS) impact	Manual and AVL/ APC	830	Linear regression models	• Running time	• The implementation of bus dispatching system (BDS) decreased running time by 1.45 minutes (around 3% of the running time before BDS).
Strathman et al. (2002) Portland, USA	Drivers experience impact	AVL/ APC	110,743	Linear regression models	• Running time	• Bus operators are an important source of running time variation after controlling for such factors as route design, time of day and direction of service, and passenger activity. • Operators' relative running time decreases by 0.57 seconds for each month of additional experience
Dueker et al. (2004), Portland, USA	Low-floor buses impact	AVL/ APC	353,552, 2,347, 16,504, 18,098	Linear regression models	• Dwell time	• The dwell time model for the without lift operation sub-sample yields an estimated effect of a low-floor bus of -0.11 seconds (-0.93%) per dwell. • A low-floor bus reduces dwell time for lift operations by nearly 5 seconds (-4.74 or 5.8 %).
Kimpel et al. (2005a), Portland, USA	Transit signal priority (TSP) impact	AVL/APC	18,132	Summary stats & and a regression model	• Running time	• The study shows that the expected benefits of TSP are not consistent across routes and time periods, nor are they consistent across the various performance measures (e.g. running time, running time variation, headway and OTP)
El-Geneidy et al. (2006), Portland, USA	Stop consolidation impact	AVL/APC	332	Linear regression models	• Running time • Running time variation	• The results indicate that bus stop consolidation had no significant effects on passenger activity, whereas bus running times improved by nearly 6%. Running time improvements may have been limited by insufficient schedule adjustments. No evidence was found about the impact of stop consolidation on running time variation or headway variation.

Study	Issues addressed	Data source (s)	Sample size	Analysis methods	Measures used	Key findings
Milkovits (2008), Chicago USA	Smart cards and bus type impact	AFC/AVL/ APC	165,000	Linear regression models	• Dwell time	• Smart cards are estimated to have a 1.5-s faster transaction time than magnetic strip tickets, but only in uncrowded situations. When the number of onboard passengers exceeds the seating capacity, there is no statistically significant difference between the fare media types.
El-Geneidy et al. (2011), Minneapolis, MN, USA	Drivers Experience impact	AVL/APC	21,275, and 97	linear regression models	• Running time • Running time variation	• Drivers' experience decrease run time by 0.34 for each additional year of experience. • A 1% variation in drivers' experience leads to 5% decline in the run time coefficient of variation.
Surprenant-Legault & El-Geneidy (2011), Montreal, Canada	Reserved lanes Impacts	AVL/APC	4,384	Linear regression and logit models	• Running time • OTP	• The reserved bus lane yielded savings of 1.3% to 2.2% in total running time, and benefits were more significant for northbound afternoon peak trips than for southbound morning peak trips because of congestion levels northbound. • The introduction of a reserved lane increased the odds of being on time by 65% for both routes.
El-Geneidy & Vijayakumar (2011), Montreal, QC, Canada	Articulated buses impact	AVL/APC	253,260 and 9,235	linear regression models	• Running time • Dwell time	• Operation of articulated buses yielded savings in dwell time, especially with high levels of passenger activity and the use of the third door in alighting. • However, these savings were not reflected in running time, since articulated buses are generally slower than regular buses.
Yetiskul & Senbil (2012), Ankara, Turkey	New buses in the fleet impact	AFC data	3,150, 2,481 and 7,424	linear regression models	• Running time variation	• Three main causes of travel-time variability have been identified and tested in this study: temporal dimension, spatial dimension, and service characteristics. • Model results indicate that all of these factors affect travel-time variability.
Diab & El-Geneidy (2013), Montreal, QC, Canada	A set of strategies impacts	AVL/APC	255,000 and 447	linear regression models	• Running time variation • Running time deviation variation	• The introduction of a smart card fare collection system increased bus running time and service variation compared to the initial situation. • Articulated buses, limited-stop bus service and reserved bus lanes have mixed effects on variation in comparison to the running time changes, while TSP did not show an impact on variations.