Summary of Approved Research Projects

Project A-47 **Transit Capacity and Quality of Service Manual, 4th Edition**
Research Field: **Operations**
Allocation: **$400,000**
TCRP Staff: **Dianne Schwager**

The Transit Capacity and Quality of Service Manual (TCQSM) was initially produced in 1999 by TCRP Project A-15. The manual was intended to serve as a comprehensive resource document presenting information on principles and practices related to transit capacity for all transit modes, and quality of service from the passenger's point-of-view. The manual was designed to serve as the transit counterpart to the *Highway Capacity Manual* (HCM), an authoritative, regularly updated document presenting highway capacity and quality of service principles and practices.

TCQSM 1st Edition primarily synthesized existing research, with the quality of service material being its primary original material. TCQSM 2nd Edition was produced by TCRP Project A-15A and published in 2003 as *TCRP Report 100*. The production of the 2nd Edition filled gaps in knowledge, added a quality of service framework for demand-response transit, incorporated capacity procedures for less common transit modes, and made improvements throughout the manual in response to user feedback.

TCRP Project A-15C produced TCQSM 3rd Edition of the manual, published in 2013 as *TCRP Report 165*. This edition incorporated the findings of research completed during the previous 10 years and addressed new trends in the transit industry, such as the widespread interest in bus rapid transit, changes in vehicle technology, and an increased emphasis on security.

Over the years, TCQSM has been one of TCRP's best-accessed document and remains a cornerstone of the TCRP report series. It is being used by numerous universities as a basic transit education tool in various courses. Also, TCQSM has become known and applied throughout the world, having been downloaded in more than 116 countries, requested to be translated into Chinese, and serving as the foundational reference for a World Bank guide on transit capacity principles and practices for cities in developing countries.

Throughout its history, TCQSM has served as an implementation tool for other TCRP research. A total of 47 TCRP research reports and syntheses contributed to the 3rd Edition in some way, either as foundational research for capacity and quality-of-service methods, as key references for a section within a chapter or for material used across multiple chapters, or presented as sources for additional information. Since the 3rd Edition was published, a number of TCRP research efforts have been completed or are underway that can contribute updated material to TCQSM; these are listed in Section VIII.

In addition to incorporating the wealth of research that has occurred, TCQSM needs to address new trends in the transit industry. Numerous new transit technologies and practices have emerged in the industry. For example, topics such as transit automation, micromobility, TNCs, shared-use services, electric buses, and the use of big data to measure service quality need to be addressed. In addition, the capacity and quality of service effects of the COVID-19 pandemic can provide lessons for similar events that may occur in the future.

The objective of the research is to develop an updated 4th Edition of TCQSM to reflect the latest transit capacity and quality of service applications and research.

Project A-48 **Strategies to Mitigate and Reduce Assaults Occurring on Public Transit Vehicles and Property**
Research Field: **Operations**
Allocation: **$250,000**
TCRP Staff: **Mariela Garcia-Colberg**

In response to the Moving Ahead for Progress in the 21st Century Act (MAP-21) and its successor, the Fixing America's Surface Transportation Act (FAST), the Federal Transit Administration (FTA) established the Safety Management Systems (SMS) framework as the basis for their National Public Transportation Safety Program. A key aspect of the SMS approach, according to FTA, is for transit agencies to build on their existing safety foundation to detect and correct safety problems early in the process and analyze safety data in a holistic manner to ensure resources are applied effectively to mitigate risks. One such risk that the transit industry is facing is related to a growing problem with the number of assaults occurring on many transit systems throughout the United States.

An analysis of the National Transit Database (NTD) Safety & Security data reveals that between 2008 and 2020, transit assaults accounted for 12 percent of all transit safety and security events, and more than 9 percent of all transit injuries. Furthermore, assault injuries have increased an average of 80 additional injuries per year, since 2008. While there have been improvements in guidance made available to reduce transit vehicle operator assaults, the majority of assault-related injuries are sustained by transit vehicle riders and people waiting or leaving. This reveals an issue that will require comprehensive mitigation measures beyond those that are being implemented to reduce operator assaults.

The objective or this research is to produce industry guidance that includes strategies to reduce the number of assaults on public transit vehicles or property. The guidance will include risk mitigation strategies such as different types of environmental designs that deter criminal activity, advanced surveillance technology to improve criminal response time, reporting systems, increased penalties for repeat offenders, and other strategies to combine risk mitigation efforts. Additionally, other mitigation strategies such as instituting a rider code of conduct or similar type of guidance may prove beneficial. Barrier design considerations, and alternative variations of designs, may be useful for agencies that have unique challenges associated with their operating environment. The guidance will also include an emphasis on employee training, including dispatch response to emergency training, situational awareness training, verbal judo, and other de-escalation techniques.

Project B-50 **Public Transportation Information Systems for Passengers who are Vision Disabled**
Research Field: **Service Configuration**
Allocation: **$350,000**
TCRP Staff: **Mariela Garcia-Colberg**

Successful use of public transit requires access to accurate, timely information at every step along the way—from the public way, to the stop/station/ferry terminal/transit center, to the vehicle, to the desired stop/station/ferry terminal/transit center, and to the public way again. A successful trip can involve planning the trip, finding and negotiating the bus stop/station/ferry terminal/transit center, negotiating the fare purchase/payment system, negotiating a fare barrier, anticipating when the bus/train/ferry will arrive, boarding the correct conveyance, getting off at the correct location, exiting the station/ferry terminal/transit center, and knowing the correct action in case of a service disruption. Transit information is typically conveyed in a variety of ways including static maps, digital interactive maps, in-car digital displays, audio announcements, over-the-phone trip planning, website and app-based tools, all of which generally rely on visual cues that are unavailable or difficult to use for people who are vision disabled. People who are vision disabled typically cannot drive, so most of them depend on public transit to travel for work, school, shopping, medical services, to visit family and friends, and for recreation in order to live productive, healthy, and independent lives. The usability of the public transit system is therefore of crucial importance for people who are vision disabled. When traveling to unfamiliar areas or needing to deviate from familiar routes to regular destinations, the task is especially difficult without accessible, timely, user-friendly information.

Passenger information is conveyed by various public transit operators in inconsistent ways, many of which are inaccessible to vision disabled passengers, or which may be usable only with special technology that varies in the complexity of the user-interface. Yet accessible passenger information is required by section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) as amended, to the end that no otherwise qualified individual with a disability in the United States shall, solely by reason of his or her disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance. On the other hand, standards and guidance for providing accessible wayfinding information in such documents as Title 49 Transportation, Part 37—Transportation Services for Individuals with Disabilities and Part 38—Accessibility Specifications for Transportation Vehicles, have little to say about how accessible information should be provided.

There is no guidance for transit operators to use to determine the most accessible ways to provide traveler information to passengers who are vision disabled, and no tool for evaluation of the accessibility of traveler information. Consequently, there is a need for a comprehensive, up-to-date guidance document to help transit operators make all aspects of their passenger information systems accessible to their passengers who are vision disabled. There is also a need for a measurement or audit tool to help agencies quantify and understand accessibility of traveler information for their systems, and to determine priorities in improving accessibility.

The end product of this research will be a guide for making passenger information accessible to and usable by passengers who are vision disabled, including information provided on websites, audible and tactile information provided in stations, and information available via smartphone apps (including GPS). The guide will include information for route planning, as well as traveling all the route segments between the public way and the transit vehicle. The primary focus will be on transit, but the guidance should be applicable to other modes also.

Project D-22 **Evaluating Frog Design to Minimize Noise and Vibration and Improve Life-Cycle Costs**
Research Field: **Engineering of Fixed Facilities**
Allocation: **$300,000**
TCRP Staff: **Stephan Parker**

The frog is a component of special trackwork where one rail crosses another. Openings called flangeways are provided in standard frogs so that the flanges on the vehicle wheels can pass through. When the wheel passes through the open flangeway at the point of the frog, the wheel tread and frog wing rail surface locations produce high impact forces, noise, and vibration. When frogs must be located near noise- and vibration-sensitive land uses, they are often identified as a noise or vibration impact during the environmental process and require mitigation. Low-impact frog designs can be an effective mitigation measure because reducing the impact also reduces the resulting noise and vibration levels. However, there is almost no data on how much low-impact frog designs reduce noise and vibration levels. In addition, many agencies are hesitant to adopt new frog designs.

The primary objective of this research is to determine the reduction in noise and vibration provided by alternative low-impact frog designs. The secondary objective is to provide guidance to transit agencies on how to select appropriate frog designs for noise and vibration mitigation and how to maintain good noise and vibration performance through necessary maintenance practices.

Project E-14 **Electric Bus Fire Prevention and Risk Management**
Research Field: **Maintenance**
Allocation: **$350,000**
TCRP Staff: **Stephan Parker**

Lithium-ion battery fire risks are currently undermanaged in transit operations. At current fleet scales the magnitude of these risks is relatively small; however, there is no widespread understanding of how these risks will be magnified when fleet size increases. Lithium-ion battery fires, while less probable than fires due to combustion engines, are far more difficult to extinguish and may be many times more destructive and dangerous. Damaged cells in the battery can lead to thermal runaway, a phenomenon in which a failure in the architecture of a battery cell (e.g., a short) causes the heat of the battery to rapidly increase, releasing flammable gas, which then ignites, triggering similar events in adjacent cells. The ensuing fires are exceedingly difficult to extinguish and must be addressed with significant quantities of specialized fire suppressants. Moreover, there are several documented instances of stranded energy remaining after the fire is extinguished, causing batteries to reignite even after being initially suppressed by first responders.

The industry has largely addressed this risk by incorporating rigorous early detection and protection protocols in battery management systems that prevent thermal runaway when the battery pack is physically compromised through improper use or external impact. However, some fires still occur spontaneously and there is little consensus in the transit or Electric Vehicle (EV) communities regarding the best practices for managing this risk. Moreover, a greater risk of fire may arise when numerous electric buses are consolidated in a confined bus garage. In this scenario, the probability of a fire compounds with the introduction of additional buses as the resulting impact of such a fire would increase dramatically should a single bus fire spread to an adjacent vehicle. Furthermore, exogenous fires could initiate a fire in a nearby bus, turning a conventional fire into a lithium-ion battery fire of much greater severity.

With national news reporting on several instances of high-profile electric vehicle models catching fire in recent months, the risk of lithium-ion battery fires is a valid concern for transit agencies that are considering whether to electrify their bus fleets. At present, there is no comprehensive review of these risks, best practices for their mitigation on the part of fleet operators, strategies for suppressing and containing the spread of fires when they do arise, or policies for managing electric vehicles after the fire is extinguished to prevent reignition. Among the existing research, there has never been a focus on transit bus fleets or thermal events that occur within a bus maintenance or storage facility. Such a review would assuage agency concerns by objectively evaluating the risk of such fires, providing concrete steps to lessen this risk, and preparing transit agencies for the unlikely event that such a fire occurs on their premises. It would also help to lessen the risk of a high-profile lithium-ion fire that could take an incalculable toll on the industry-wide effort toward fleet electrification.

The objective of this research is to identify, evaluate, and summarize best practices for fire risk mitigation and suppression with regard to battery electric buses, with a particular focus given to agencies that store and charge their buses in indoor facilities, as well as the technical, economic, and institutional barriers to implementing these solutions. The anticipated products will be a guide to the potential origins of battery electric bus fires, an analysis of the potential of such fires to spread to other vehicles or reignite after suppression, an evaluation of various risk mitigation efforts, and recommended best practices for fire risk management.

Project H-61 **Resilience and Emergency Response Planning for Zero-Emission Fleets**
Research Field: **Policy and Planning**
Allocation: **$215,000**
TCRP Staff: **Stephan Parker**

The transit market in the United States is undergoing a significant shift from predominantly fossil fuel–powered vehicles to zero-emission vehicles in the future. When transit operators consider introducing these types of vehicles into their fleets, the primary concern is always whether or not the vehicles can meet the agency's service requirements. This concern exists both at the individual route level and at the fleet level. What happens if a charger goes down? What happens if the grid loses power? How will an operator ensure their buses are fully charged and able to go into revenue service? If there is a natural disaster, and an agency needs to provide emergency transportation services, how will they do so without a functioning power grid?

The industry is exploring a number of solutions to the challenges that occur if the power grid goes down or if there is a natural disaster, but there is no clear answer yet.

This research would survey proposed technologies and strategies for improving resilience of a zero-emission transit fleet, such as on-site power generation, microgrids, backup utility feeds, local liquid hydrogen storage, and vehicle-to-grid technologies. It would summarize these technologies, including identifying ideal applications of the strategy and estimating costs for implementation. It would also seek to assess the roles such technologies may play in the disaster response plans of communities and states.

Project **Analysis of Public Transportation Health Impacts and Benefits**
J-11/Task 43
Research Field: **Special Projects**
Allocation: **$125,000**
TCRP Staff: **Dianne Schwager**

Public transportation's benefits are far-reaching. Previous research has identified benefits such as greenhouse gas reduction, increased personal savings, reduced deaths from automobile crashes, and benefits to the wider economy. These subjects offer various metrics on measuring public transportation's performance and effectiveness.

One element of public transportation's impact that has taken on new importance is the health benefits of public transportation. The COVID-19 pandemic showed the importance of public transportation in transporting essential healthcare workers, as well as providing access to hospitals, urgent care centers, and doctors' offices. The pandemic also exposed the equity challenges in serving those trips.

In a recent request for information, the FTA indicated that they intend to include direct and indirect benefits to human health as part of measuring project benefits for Capital Investment Grant projects, see https://www.federalregister.gov/d/2021-15079/p-25. As a result, health benefits will be of particular interest to public transportation agencies going forward.

The public transportation industry seeks to better understand the connection between public transportation and health outcomes, both in terms of public transportation's health benefits compared to other modes and the ability of public transportation to connect people to heath care.

The objective of this research is to prepare a report on the ways public transportation impacts health and healthcare. The final deliverable should assist public transportation agencies in understanding and communicating the health benefits of public transit as well as the best practices for connecting public transit users to health care jobs and services. The final deliverable should address:

- Physical activity levels of public transit riders
- Pollution reduction from public transit use
- Reduced traffic injuries and deaths due to mode shift to public transit
- Health impacts of transit-oriented land use
- Access to medical care
- Access to healthy food
- Potential metrics agencies can use to measure health benefits in their own communities
- A focus on equity in analysis

The final deliverable should not focus on greenhouse gas emissions, as this topic was already addressed in TCRP J-11/Task 36, published as *TCRP Research Report 226*.

Project J-11/Task 44 Improving Access to Public Transit with Transit-Oriented Streets
Research Field: Special Projects
Allocation: $125,000
TCRP Staff: Dianne Schwager

Public transit's ridership recovery presents a unique opportunity to rethink ways to maximize access and availability. There is the potential to make big changes to the streets and neighborhoods served by public transit to ensure that public transit is competitive with other modes.

Recent research has covered several ways in which public transit agencies and local governments have worked to improve public transit service and ridership, such as tactical transit projects, bus network redesigns, transit priority projects, and micro-mobility services. One gap that remains is examining the infrastructure that riders use to access public transit services.

Street infrastructure like sidewalks and bike lanes enable first- and last-mile connections to public transportation. Some communities, especially historically underserved communities, lack even the most basic infrastructure for public transit access and face conditions hostile to walking and bicycling. Improving access to public transit has the potential to increase the use of public transit.

In order to fully leverage public transit services and infrastructure, communities must connect the places where people live, work, and play to public transportation stops and stations. In the coming years there may be several funding sources that public transit agencies, communities, and states can take advantage of to fund these changes.

The objective of this research is to prepare a report on the best practices to improve access to public transit. The final deliverable should assist public transit agencies and communities to understand how to connect people and places to public transit services and infrastructure, by combining existing research with new research into transit-oriented street designs and other practices that enhance access to public transportation. The final deliverable should address:

- Modes public transit riders use to access transit (e.g., walking, biking, micro-mobility)
- Infrastructure for accessing public transportation (e.g., sidewalks, bike lanes)
- Examples of projects and best practices for public transit stop/station access, especially to bus services
- ADA accessibility
- Wayfinding
- Equity impacts of increasing access
- Practices examined in a wide variety of communities
- Other complete streets initiatives that provide benefits to public transit
- Potential funding sources for public transit access projects
- Combining the above with previous research on stop design, tactical transit, transit priority projects, bus network redesigns, and micro-mobility