Summary of Approved Research Projects

Project A-52   *Cyber Vulnerability of Automatic Vehicle Monitoring (AVM) and Health Monitoring Systems (HMS)*

Research Field: **Operations**
Allocation: **$400,000**
TCRP Staff: **Jamaal Schoby**

The increased focus on cybersecurity threats and attacks requires the transit industry to address critical vulnerabilities in interconnected systems throughout the lifecycle of new and existing systems. Traditionally, cyber vulnerabilities are addressed and mitigated in information technology (IT) networks with relative ease; however, this statement does not apply to operational technology (OT), which suffers from many complex challenges. OT describes many critical systems responsible for sustaining availability and ensuring safe, secure, and resilient operations.

With many transit agencies adopting automated fleet management, vehicle monitoring, and health status systems, it is important to understand the cyber implications of these OT systems. The utility of automated vehicle monitoring (AVM) and health monitoring systems (HMS) requires constant availability, real-time communications, remote connections, and dashboard reporting to ensure that the system properly functions. Many transit agencies are not aware that these systems are installed in their vehicles by the manufacturers. These built-in features can present a cyber risk and an avenue of attack for a motivated threat actor. For example, on November 3, 2022, a cyber-attack at Danske Statsbaner (DSB), the largest railway operator in Denmark, caused train operations to halt. A subcontractor of DSB had provided a critical component of the train control system and later reported that a criminal hacker had compromised their network, resulting in the complete shutdown of production servers and, thus, the halt of DSB operations.

Generally, the cyber vulnerability in OT systems is not addressed until well after a vulnerability has been exploited, which can impact the safety and security of riders, operators, and transit agencies as a whole. AVM and HMS rarely undergo cyber testing to identify critical vulnerabilities before they are deployed and used in vehicles. With threat actors aggressively targeting critical infrastructure and the transportation sector, vulnerabilities in on-vehicle systems are unknown, untested, and unmitigated.

Cyber incident response (IR) is a key process in a healthy cybersecurity program and contributes to the overall governance program. IR policies and processes must be aligned in accordance with compliance frameworks, federal security directives, and cyber best practices. Within the transit industry, there is a lack of guidance to frame how an IR process, and associated policies, should be codified for an effective response. A consistent and standard IR process is critical in identifying trends within the transit agency and the greater transit community. Identifying key metrics and reporting supports the

transit agency's compliance with regulatory mandates and captures trends over time to better understand policy, procedure, or technology gaps.

An important aspect of an IR plan involves each transit agency determining how to categorize events, incidents, and the associated reporting timelines and response activities based on severity or impact. Every day, thousands of events occur on a network, any one of which may lead to the identification of an incident. The response actions for an event versus an incident vary greatly, including how and when that information is reported to governing bodies such as the Transportation Security Administration (TSA), the Cybersecurity and Infrastructure Security Agency (CISA), the Federal Bureau of Investigations (FBI), or Information Sharing and Analysis Centers (ISAC).

Default event and incident categories are not institutionalized in the transit community, potentially leading to the overreporting of events or the underreporting of incidents. Overreporting events can cause undue stress on the agency's IR team and skew the metrics collected for future improvements to the IR process. The underreporting of incidents fails to meet the requirements of federal directives and may result in decreased IR support from external parties. Each of these scenarios results in an increased cost associated with investigating an incident, identifying the root cause, and remediating the impacts of a cyber-attack.

This research aims to (1) present best mitigation practices and improvements for cyber vulnerabilities in AVM and HMS, and (2) develop recommended practices for transit incident response utilizing the best practices and requirements in other critical infrastructure sectors.

Project B-54   *Paving the Way for Inclusion: Addressing Gaps in Measuring Disability within Transportation Data Systems*
Research Field: Service Configuration
Allocation: $300,000
TCRP Staff: Jamaal Schoby

To adequately measure the extent of inequities in current systems and identify interventions to address these inadequacies in transportation, specific, standardized demographic data that adequately accounts for the diversity of the population, including multiple dimensions of disability, must be collected. In 2023, 61 million Americans live with some form of disability (Centers for Disease Control and Prevention, 2023), including visual, hearing, mobility, and cognitive disabilities. Unfortunately, current systems for collecting data on disability are inadequate, perpetuating the existing inequities of transportation systems between those with and without disabilities and limiting the impact that transportation planners can make to reduce them. There are three main limitations in current national and local travel surveys in identifying disability populations and understanding the travel experiences of disabled travelers holistically:

Lack of Measurement Reflecting Diverse Types of Disability. Measures of disability in current surveys primarily focus on travel-limiting medical conditions and do not capture the diversity within the disability community (Levine and Karner, 2022). The exclusion of questions accounting for the diversity within the disability population leads to a critical gap in transportation surveillance, especially for disability subgroups, such as those on the autism spectrum.

Lack of Data on Travel Barriers. The social model of disability frames disability as a condition created within the context of the environment in which a person lives (Shakespeare, 2010). An individual's disability status is exacerbated or ameliorated by the physical places, policies, and resources available to them. For example, individuals with physical limitations are "disabled" by missing curb ramps rather than by their impairments. Similarly, individuals with hearing limitations are disabled by nonexistent visual notifications of upcoming bus stops. The absence of information about the disabling experience of interactions with such barriers limits our understanding of what shapes the decisions of people with disabilities regarding travel and ultimately where treatments and interventions can be most effective.

Lack of Appropriate Data Collection. Several travel surveys (e.g., NHTS) do not collect data on trips that are not taken but that are desired or needed. Accounting for these trips not taken is particularly salient as numerous research studies have identified how physical, social, and policy transportation barriers limit trip taking among the disabled population (Bezyak, 2017). Current methods in disability and transportation research tend to focus on cross-sectional research design, which limits our understanding of disability

and transportation as disability changes over time. Also, data is limited only to the utilization of certain services, such as paratransit, and does not capture the experience of the complete trip, which can be across service modes. Finally, current methods lack guidance on ensuring the inclusion of people with cognitive disabilities in the sample and fully participating in the data collection (Rios, 2016).

There is also a lack of systematized evaluation models that can be used to assess the quality of transportation, particularly regarding its ability to satisfy the needs of citizens with temporary or permanent disabilities. An immersive virtual environment (IVE) tool is proposed to support developing and applying inclusive, safe, resilient, and sustainable accessible qualities onto community public transportation systems. IVEs are computer-based, artificial, digital realms that users can access through specialized equipment. This equipment provides sensory stimuli, creating the illusion of immersion within the digital environment. IVEs would be a valuable evaluation tool for accessible mobility strategies, including in emergencies, allowing relevant stakeholders and end-users to observe and evaluate alternative implementation proposals (Soares, F. et al. 2021). To achieve the targeted transport improvements, the development of quality assessment tools is required to gauge and plan the level of service to be provided.

Project B-55   *Guidelines for Surveying Hard-to-Reach Populations for Small, Medium, and Large Transportation Agencies*

Research Field: Service Configuration
Allocation: $100,000
TCRP Staff: Mariela Garcia-Colberg

In January of 2022, the U.S. DOT released its Equity Action Plan, which describes key actions the department will engage in to expand access and opportunity to public transportation focusing on "underserved, overburdened, and disadvantaged communities" as well as "reinvigorating U.S. DOT's programmatic enforcement of Title VI of the Civil Rights Act." In research related to public transportation, we also endeavor to have equity in our ongoing customer survey work, which means there is a distinct need to develop protocols that engage hard-to-reach populations and ensure representation of minority and underserved populations in our research.

Hard-to-reach populations are any group of people who have been historically difficult to identify and are difficult to engage in research projects. This includes minority, low-income, and low English language–proficiency customers. Those who do not have access to technologies involved in newer forms of surveying, such as online research, are considered hard-to-reach in this context. Making sure that every customer, regardless of their income, race, or primary language, has an equal chance of participating in research leading to a meaningful engagement provides insights into these populations and provides data for Title VI reporting and service and fare equity analysis.

This research seeks to identify and understand potential barriers to participation, including mistrust of the research request, not understanding how the results will benefit them, fear of providing personal information, cultural beliefs that may prohibit participation, and low literacy levels.

As we expand participation among hard-to-reach populations such as minorities and customers with disabilities, we must develop approaches that ensure that the final research product includes enough responses to allow for a statistically valid analysis of the results. We must also develop best practices for writing survey questions that can be understood by someone with limited education and use language that is clear and concise. These hard-to-reach populations are more cost prohibitive to reach and engage than typical transit riders. This research also will provide guidance as to how to use research funds more efficiently.

The main objective is to create a resource of best practices that describes the necessary steps for conducting a successful survey of public transit customers that is inclusive, affording all customers a chance to have their voices heard, while taking cost considerations into account. This resource will provide public transportation market research professionals with a deeper understanding of how to provide the best quality

data to their organizations, based on the size of the operating agency and the scope of the operations, with the resources that are available.

Project B-56   *Using Market Segmentation to Increase Transit Ridership: An Updated Handbook*
Research Field: Service Configuration
Allocation: $300,000
TCRP Staff: Mariela Garcia-Colberg

To foster long-lasting satisfaction with and loyalty to their services, it is imperative that transit agencies understand, and make decisions in accordance with, customer needs and preferences. Since it is usually infeasible for agencies to tailor actions at the scale of the individual, an alternative strategy is to conduct a market segmentation analysis on one or more data sources to identify sufficiently similar groups of transit riders to consider within a decision-making process.

Challenges arise in terms of selecting both the variables to consider in a segmentation analysis and the methodological approach. One potential approach is to use predetermined (*a priori*) segments, identifying a set of characteristics at the outset that might represent important differences among transit customers, and creating segments based on these (for example, commuters versus non-commuters or suburban versus central-city riders). An alternative is to use market-defined (*post-hoc*) methods, using statistical clustering and classification methods to identify groupings that may not be apparent from surface-level examination. These data-driven strategies are useful in that they can assist decision-makers in discovering key differences within groups defined by one or more sociodemographic characteristics.

The quintessential TCRP report on this topic, published in 1998, is *TCRP Report 36: A Handbook: Using Market Segmentation to Increase Transit Ridership*. The purpose of this report was to introduce the "whats" and "whys" of market segmentation, including several case studies on how to appropriately plan for and research the development of a suitable segmentation scheme and then implement findings into actionable strategies that fulfill the transit agency's goals of increasing ridership, bringing in new customers, and boosting satisfaction levels of different groups of users. In the 25 years since the publication of the 1998 Handbook, scholars in the business, social, and mathematical sciences have published new research with relevance to this topic. Moreover, passive data collection and "big data" sources have become more widely implemented and available for profiling transit customers, and the rise in remote work, which has accelerated in the wake of the COVID-19 pandemic, has challenged conventional thinking about typical rider segments. A targeted census of approaches to collecting data, extracting and describing segments, and tailoring product and service decisions to the needs and preferences of transit market segments would allow for the dissemination of success stories and potential pitfalls surrounding forward-thinking market segmentation practices, in addition to how agencies might benefit from adopting certain practices under various scenarios.

The objective of this research is to deliver a comprehensive update on market segmentation strategies and best practices in the form of a handbook that mirrors and expands on the content of *TCRP Report 36*. This handbook will draw on both multidisciplinary academic literature and real-world case studies at public- and private-sector organizations in the public transit realm.

Project D-25   ***Preparation of a Manuscript for Publication of the Track Design Handbook for Light Rail Transit, 3rd Edition***
Research Field: **Engineering of Fixed Facilities**
Allocation: **$500,000**
TCRP Staff: **Mariela Garcia-Colberg**

The goal of this project is to update the various chapters of *TCRP Report 155: Track Design Handbook for Light Rail Transit*, 2nd Edition, to reflect the current state of the art in light rail track design.

Significant changes have occurred in railway track design since the second edition of the Handbook was published in 2012. Several new track components have made an appearance, especially in the field of direct fixation track. Advances in light rail vehicles, special trackwork (frogs), embedded track accommodations for pedestrians and bicyclists, prevention of stray current, requirements for track modulus of elasticity, rail/structure interaction on bridges, to name a few, are topics that need updating.

The influence of the Handbook cannot be overestimated. Entire new-start systems have been designed by inexperienced engineers almost entirely relying on the Handbook. Owners use the Handbook as a proof that the designers' recommendations are valid. It is of vital importance that a reference of that powerful an influence undergo periodic updating.

Major expansions of light rail and other rail transit systems continue unabated in North America. Given the influence that the Handbook exerts in the industry, it is very important that it be updated. Anecdotally, we are hearing reports of owners and engineers relying on outdated information to make important decisions. For example, the trackwork on an entire new-start streetcar system was designed solely by a junior engineer and constructed using a continuous stretch of embedded track out-of-crosslevel, designed to match the crown of the road in which it was embedded. While the occasional use of out-of-crosslevel track cannot be avoided, endorsement of a continuous length of canted track throughout the system was not intended by the authors of *TCRP Report 155* and is not considered to be prudent and reasonable practice. Another issue is leaving a junior engineer to interpret the Handbook without quality processes in place to have the design reviewed by a qualified senior trackwork engineer. Both issues—crosslevel and use of an experienced engineer—can be re-emphasized in an updated version of the Handbook. Another example involves vehicle loading parameters. It seems that the Handbook has outdated vehicle information that owners are relying despite the protests of contracted engineers.

A strong showing of support by the TRB will continue to keep the TCRP in the forefront of rail transit engineering.

Project D-26   *Rational Approach to Performing Rail Structure Interaction (RSI) Analysis and for Using the Results of the Analysis in Transit Bridge Design*
Research Field: **Engineering of Fixed Facilities**
Allocation: **$268,000**
TCRP Staff: **Mariela Garcia-Colberg**

Rail structure interaction (RSI) represents a significant load on longer bridges with continuous welded rail. These forces and effects are even more important on bridges with curved alignment or direct fixation track. Most transit agencies in the United States require that RSI analysis be performed on their bridges. However, the parameters and methodology for this analysis are not clearly defined. Further, most agencies do not indicate how these results are to be used once the analysis is completed and lack any acceptance criteria for the results. This gap in U.S. transit design guidelines was noted over thirty-five years ago but has not yet been addressed.

It is necessary to develop recommendations on the methodology for the analysis based on a rational approach and research. Criteria for judging the results and incorporating them into bridge design are also needed.

A huge expansion in transit systems in the United States is anticipated in the next few years. RSI analysis is currently performed without a uniform or rational basis. It is not known whether the structures are designed using unconservative or overconservative loads since there is no research basis for the various design criteria used by different transit agencies. It is considered a task of high to medium urgency, since it will improve safety and performance of transit structures.

There is high potential for cost savings, both in design/analysis and construction, through more rational methods. Reducing unnecessarily complex analysis and optimizing design with a rational basis can save agencies significant cost, amounting to millions of dollars across the country.

Research will include an RSI analysis that focuses on:

1. Conditions under which RSI analysis is needed, including need in ballasted track structures
2. Applicability of simplified TCRP equations and evaluation of limitations
3. Parameters to be included, including use of gross or cracked concrete section properties, inclusion or exclusion of rail lay temperatures, and need for rail break analysis
4. Acceptance criteria for rail stresses and/or rail gaps
5. Use of analysis results in structural design of bridges, including applicable load combinations

Project F-32   *Culture Reform: Psychological Health and Safety at the Workplace—The Missing Elements of Successful Workforce Retention and Recruitment in Transit*
Research Field: **Human Resources**
Allocation: **$350,000**
TCRP Staff: **Mariela Garcia-Colberg**

In March of 2023, APTA released a report addressing the workforce shortage. That study noted that 32% of former transit workers quit due to problems with management. These were detailed as transparency in decision-making, support during incidents, and general communication. Former transit workers ranked "listening to concerns" as the agencies' number one action to encourage workers to stay. The report's recommendations include building agency culture and morale improvement. Further, the report's toolkit emphasizes creating safe spaces for employees from marginalized groups and general employee engagement, recognition, and acknowledgment. Among the research gaps identified are "What have agencies tried to improve workforce morale, and what has been the most effective?" The transit industry can benefit greatly from focusing on psychological health and safety in the workplace and other questions concerning organizational culture.

Recent literature posits that psychological safety, mindfulness, and attention to dignity at work present concepts, pathways, and tools to improve retention and recruitment strategies as well as overall organizational culture. Research shows that attention to these subjects can increase productivity, innovation, employee satisfaction, and long-term retention. The additional benefits to agencies can be measured by reducing accidents, injuries, incidents, absenteeism, healthcare costs, and litigation. These nontechnical skills, often referred to as soft skills, are, in reality, critical skills that have an enduring effect on culture. Training in these skill sets can cure a multitude of negative interactions responsible for overly negative and toxic work cultures. At least three of the hot topics in the transit industry—DEI, safety, and retention—can be successfully addressed using these tools and skill development organization-wide. For example, all three can be addressed, in part, by enhancing communication skills up and down an organization's hierarchy and peer-to-peer. To a large extent, these skills have only recently been explored in transit research.

The transit industry has recognized and acted on workforce recruitment and retention issues for decades. However, little attention has been focused on identifying and reforming components of organizational culture that strongly influence recruitment and retention. As noted above, the current workplace research and literature have focused on various new concepts designed to address retention and employee well-being, safety, mental health, productivity, and creativity. The transit industry would benefit from research examining how this industry and others have begun implementing psychological health and safety, mindfulness-based practices, and similar initiatives.

The primary objective of this research is to identify and evaluate innovative methods and approaches for strengthening organizational culture. Culture reform aims to improve transit agencies' retention, recruitment, and organizational culture. This may include items that might not be labeled as features of organizational culture but nevertheless contribute to the culture, broadly defined as "the way things are done" in the organization, including mindfulness-based techniques and strategies that would improve listening, team and leadership communications, mindful organizing, and other approaches that help establish a sense of psychological safety in the workplace. The research should also identify, define, and quantify the relationship between the transit industry's safety culture and organizational culture.

Project F-33 **Enriching Transit's Workforce: Recruiting and Retaining Individuals with Disabilities**
Research Field: Human Resources
Allocation: $150,000
TCRP Staff: Dianne Schwager

The Transportation Research Board and the transportation industry have long recognized the need to attract, develop, and retain a diverse group of workers to fill the varied positions that enrich our industry. Especially now, as ridership rates increase and transit agencies struggle to fill open positions, innovative strategies are needed to ensure the recruitment and retention of a diverse transit workforce. This approach, recognizing the critical contributions made by individuals from diverse backgrounds, is also reflected in the federal government's Justice40 initiative.

Often overlooked in efforts to recruit a diverse transit workforce is the pool of potential employees who have disabilities. In 2021, the Bureau of Labor statistics reported that only 19.1 percent of persons with a disability were employed, while 63.7% of persons without a disability were employed. Additionally, 29 percent of workers with a disability were employed part time, compared with 16 percent for those with no disability, reflecting the persistent challenge of underemployment of this population. Individuals with disabilities represent a viable recruitment pool for the transportation sector. However, a lack of knowledge about how to recruit and retain individuals with disabilities, along with administrative structures that can tend to "silo" disabled workers into units disconnected from workforce development opportunities, may be a challenge for transportation hiring managers. In fact, in a recent study conducted by the National Center for Mobility Management, an FTA-funded national technical assistance center, researchers found little emphasis by university transportation programs on strategies to educate future transportation planners about disability topics. In addition, university professionals were not knowledgeable about strategies used by their department or university to recruit students with disabilities into transportation preparation programs.

Ron Brooks, founder and CEO of Accessible Avenue and a 30-year transit industry veteran and lifelong member of the disability community, stated: "As the public transit industry begins to fully embrace a true commitment to authentic equity, it is critical that people with disabilities are part of that picture. As an industry, we already know that effectively serving a diverse community means leadership and personnel that are similarly diverse, so if we're serving people with disabilities, we need people with disabilities to join us as leaders and employees. But we can't even begin when we don't know where we stand. It's that old adage: You can't manage what you don't measure. Truer words were never spoken."

Now is the time to expand our transit workforce pool. There is an alignment between the supply of potentially qualified yet overlooked transportation personnel across employment levels and the demand for skilled professionals in the tightest labor market in 40 years. Through a multi-stepped research process, this work will capture information about recruitment and retention strategies, aggregate findings into replicable models, develop and package learning to communicate to the field, and serve as the foundation for future research to facilitate a robust transit workforce that is benefited by the inclusion of individuals with disabilities.

This research seeks to:
1. Discover strategies and practices used across the transportation industry that focus on the recruitment and retention of individuals with disabilities.
2. Engage industry leaders with disabilities in developing recruitment and retention models, along with appropriately aligned internal organizational structures, that facilitate the representation of individuals with disabilities across the transportation workforce.
3. Identify and suggest replicable capacity-building tools that can be used by the industry to advance and enrich its workforce with employees with disabilities.
4. Determine what types of additional data collection may help advance further research and action in the field.

Project F-34   *CDL Requirements for Local and Regional Transit Drivers*
                     Needs Study
Research Field: **Human Resources**
Allocation: **$350,000**
TCRP Staff: **Dianne Schwager**

As noted on the Federal Motor Carrier Safety Administration (FMCSA) website, "FMCSA's Entry Level Driver Training (ELDT) regulations set the baseline for training requirements for entry-level drivers." These regulations govern how states issue commercial driver's licenses (CDLs). However, current FMCSA requirements to obtain a CDL are focused on trucking. The needs of transit vehicle drivers were not a primary consideration in the development of these regulations, which focus on vehicle size, loaded weight, and seating capacity. In addition, the major differences between work assignments and mechanicals are ignored. Local and regional transit work assignments, unlike trucking, involve a collection of much shorter one-way trips with built-in break times between. While some transit vehicles are heavy-duty and diesel-powered—rated for a minimum 12-year life similar to trucks—many are smaller gasoline- or propane-powered vehicles.

There are several consequences to vetting job candidates for long-haul trips and training that require them to pass a CDL test on a vehicle they will never drive, and grouping those drivers into a queue that includes all long-haul trucking candidates. These include:

- A lengthy lead time to vet applicants before accepting them as training candidates and the expense of paying them during the training period while waiting for the police and driving records. Many desirable candidates find other work during that interval, which can be six weeks.
- The loss of applicants (and existing drivers) who fail CDL physical examinations designed for long-haul trucking, have serious difficulty procuring an examination in the first place, or leave positions due to frustration with the frequency of examination appointments.
- A focus on mechanical abilities that many transit drivers are forbidden to use. Transit systems have maintenance technicians who can come to the vehicle or meet the vehicle at the end of the route or at a transit hub.
- An excessive focus on the vehicle, in what is a primarily customer service career. Transit drivers are not loading and unloading the vehicle, seldom service the vehicle, and will never have to back a tractor-trailer into a loading dock.

The transit industry needs an honest assessment of issues, impediments, needless expenditures, and other challenges with the current CDL acquisition process and suggestions for improvements with return on investment (ROI), including for safety. While

automated driving technologies have been promoted as a potential response to the public transportation labor shortage, the safety of these concepts, especially in mixed traffic, is still unproven. Trained and licensed drivers are necessary to safely negotiate mixed traffic at a reasonable speed, deal with unforeseen obstacles, assist riders with disabilities, respond to inquiries, and maintain order on board.

Can the vetting process before training commences be shortened and become more inclusive? What aspects of candidate backgrounds need to be reviewed for this combined customer service and driving position? How can citizens returning from incarceration become candidates? How can veterans be recruited when they leave the service? Should recruits receive paid classroom training while the motor vehicle and criminal record checks are in process? Overall, how can this process become more efficient while still safe?

Other issues to be examined include (1) should competencies be built into CDL training to ensure operators are proficient driving zero-emission buses/battery electric or hydrogen-powered buses (e.g., pre-trip inspection). (2) Since transit assignments involve a collection of short trips with built-in breaks, what are the minimum health requirements for a transit driver? Do these real requirements for safety match current DOT physical examination components and requirements for frequency of assessment? (3) How can access to physical examinations be expanded, particularly in rural areas? (4) As driving a transit vehicle is primarily a customer service position, many riders have disabilities, and some customers display an unproductive attitude, are the minimum training requirements for a passenger endorsement adequate? Which customer service training topics should be covered? (5) How can the minimum English proficiency of a transit driver be assessed? Many candidates with lower English proficiency have the driving skills and customer service ethic to be good candidates. (6) What types of organizations, including workforce intermediaries and transit agencies themselves, are engaged in CDL training, and to what extent does training serve as a mechanism to advance equitable career pathways and DEIA goals within public transit? (7) Are additional grant funds needed to expand state CDL administrative capacity?

Project H-62　　　*Innovations for Equitable Rural Transit Economic Benefit Analyses*
Research Field:　　Policy and Planning
Allocation:　　　　$300,000
TCRP Staff:　　　　Jamaal Schoby

Several limited cost–benefit analyses (CBA) studies have been conducted for rural public transportation over the years, with varying results. A core challenge is that rural transit provides services in larger areas of lower populations, often with minimal prior use of transit and long-established personal travel patterns. Inevitably, rural transit costs exceed revenues, build-up of usage will be slow, and the financial outcome exclusive of societal economic benefits will be weak.

The societal beneficiaries of rural transit are challenging to define, in part because areas are so large and target populations so diffuse and of many different types. The benefits are also difficult to quantify in part because of a lack of suitable methodologies and limitations of baseline data. Current standard appraisal schemes and available methodologies are seen as a barrier when quantifying benefits of rural transit. Additionally, little is known about any differing CBA impacts rural transit has for individuals with and without disabilities.

Public transportation access helps to promote equity and opportunity within communities for people who have been systematically divested for economic, physical, and social reasons. We need to better understand the equity issues and to incorporate them into the appraisal schemes when gauging the societal benefits that transit provides to rural communities (e.g., reduction in foregone trips, access to healthcare, mobility for persons with disabilities, social connectedness, aging in place). The economies of scale that are evident for urban transit may not apply for rural communities. Instead, the economic impacts manifest when quality transit services provide access to work and education, which promotes local businesses and bolsters labor supply in rural areas.

The objective of this research is to identify current and emerging practices in defining benefits and impacts associated with rural transit, in forecasting/quantifying them, and in assigning monetary values. This research will identify and develop new methods/tools to assess the broader benefits and impacts of public transit with consideration of mobility equity and other socioeconomic aspects for rural communities.

Project   *Drug Testing Science and Best Practices*
J-11/Task 48
Research Field: Special Projects
Allocation: $125,000
TCRP Staff: Dianne Schwager

Research into the workforce shortages faced by the transit industry has identified drug testing as a barrier to hiring and retaining transit workers, especially vehicle operators. This issue has become more acute over the last few years as fifteen additional states have legalized recreational cannabis since the beginning of 2018. In APTA's survey of transit agencies in 2022 (APTA, 2022), 47 percent of transit agencies volunteered in open-response questions that applicants were discouraged or disqualified from applying for jobs because of drug and alcohol testing. In total, 23 states, three territories, and Washington, DC, have legalized the recreational use of cannabis. An additional 15 states have legalized medical use. This has created a conflict between how people use cannabis and the requirements for commercial driver's licenses (CDLs) and other transit agency requirements for drug testing.

At issue is the fact that current tests for cannabis can detect the presence of Tetrahydrocannabinol (THC, the principal psychoactive constituent of cannabis) for weeks after use. There currently is no available test for THC impairment, though some are being developed (WMI Central, 2023).

The various federal agencies involved in drug policy are currently reviewing the status of cannabis as a Schedule I controlled substance (Washington Post, 2023). This could potentially impact how cannabis is treated by the various U.S. Department of Transportation agencies.

The objective of this study is to examine the landscape regarding transit workforce issues and cannabis use. The study should:

- Examine the current status of and potential future timeline for THC testing options.
- Examine the potential timeline for rescheduling cannabis at the federal level.
- Examine how rescheduling cannabis could impact drug testing in the transit industry.
- Examine drug testing regimes in the transit industry in other countries.

Project   *New Transit Service Delivery to Drive Ridership Growth*
J-11/Task 49
Research Field: Special Projects
Allocation: $150,000
TCRP Staff: Dianne Schwager

Public transportation ridership in the United States continues to recover from the effects of the COVID-19 pandemic. After reaching low levels of 20 percent of pre-pandemic ridership in April 2020, ridership has recovered nationally to 70 percent of pre-pandemic levels as of mid-2023. However, transit ridership recovery levels vary widely, with some systems experiencing higher ridership than before the pandemic, while others are well below the national average.

While some aspects of transit ridership recovery are outside of transit agency control, a number of agencies have found success in driving ridership growth through improving transit service. Changes to service levels at different times of day, improvements to transit service reliability, and focusing on specific populations have supported ridership growth at various transit agencies.

Previous TCRP and APTA projects examined transit ridership and service delivery and can be expanded on to provide the post-pandemic context. *TCRP Research Report 209* examines transit ridership trends in the period leading up to the pandemic. *TCRP Research Report 231* provides a deep dive into transit ridership declines and solutions. *TCRP Research Report 215* addresses improving bus transit reliability. *TCRP Research Report 207* examines tactical transit projects. And APTA's report *On the Horizon: Planning for Post-Pandemic Travel* examines transit agency responses to the pandemic and their plans for recovery.

The objective of this project is to develop a guide for transit agencies on successful strategies for increasing transit ridership in the post-pandemic era. The study should:

- Identify and examine successful strategies for growing transit ridership post-pandemic.
- Examine the impact of transit service changes at different times of day (e.g., midday service, early morning service, late night service).
- Compare the highest and lowest day of travel each week pre- and post-pandemic regarding total ridership and distribution through the day.
- Examine changes to infrastructure and operations that improve transit reliability.
- Examine transit service changes that target specific populations.
- Examine communities with high transit ridership recovery post-pandemic.
- Provide strategies for a range of transit agency and metropolitan area sizes.

Project	Transit Governance and Funding Models
J-11/Task 50	
Research Field:	Special Projects
Allocation:	$125,000
TCRP Staff:	Dianne Schwager

Public transit agencies experienced unprecedented decreases in ridership and fare revenue because of the COVID-19 pandemic. The U.S. Congress provided emergency funding as part of three separate laws in 2020 and 2021. This emergency funding helped public transit agencies avoid major service cuts or layoffs by replacing fare revenue and local and state funding that was lost due to the pandemic. Transit agencies have obligated more than 99 percent of these COVID-19 emergency relief funds. While transit ridership levels have recovered to more than 70 percent of pre-pandemic levels nationwide, those levels vary by agency, and there is some evidence that fare evasion has increased in the last three years. In addition, operating costs have increased substantially since 2019. As a result, transit agencies are facing a situation where COVID-19 relief funds are expended and operating costs have increased, but fare revenues have not returned, presenting a looming operating budget shortfall, or "fiscal cliff."

According to APTA's survey of public transportation agencies in June 2023, half of responding transit agencies say they are facing a fiscal cliff in the next five years, with 71 percent of agencies with operating budgets over $200 million saying so.

Addressing these funding challenges will require new approaches to funding and possibly governance of transit systems. TCRP Project J-11/Task 10, "Regional Organization Models for Public Transportation," examined the topic more than ten years ago. Of seven strategies for successful organizational transformation identified as part of that project, two stand out that apply particularly to the current situation: "It is important to recognize and capitalize on windows of opportunity for governance change" and "Governance and financing for public transportation are so closely inter-related, they must be addressed together."

The objective of this project is to identify governance and funding models that would be particularly effective in assisting transit agencies in recovering from the financial difficulties precipitated by the COVID-19 pandemic and provide for long-term funding reliability. The study should:

- Examine public transit governance and funding models inside and outside the United States.
- Identify strengths and weaknesses of various governance and funding models for public transit.
- Assess post-pandemic changes in governance and/or funding models implemented to address revenue shortfalls.

- Identify which governance and funding models work particularly well together and why.
- Identify the most effective governance and funding models for public transit based on system size and geographic coverage.
- Identify governance and funding models that may be particularly effective in the post-pandemic financial landscape.

Project   *Enhancing Transit Operations with Artificial Intelligence*
J-11/Task 51
Research Field: Special Projects
Allocation: $125,000
TCRP Staff: Jamaal Schoby

Public transit is a complex system that involves a network of people, equipment, and facilities in a geographical space. Transit agencies have notably adopted artificial intelligence (AI) as a tool with great potential to enhance various aspects of operations, both strategically as well as in real-time, to improve efficiency, safety, and service quality. AI's applications can be expanded toward transit signal priority systems, scheduling, route analysis, fleet and personnel optimization, vehicle automation, maintenance, transit safety, coordination with services provided by transit partners (e.g., transportation network companies and other micro-mobility modes), ticketing, and customer service (e.g., alternative trip planning when disruptions occur, or enhancing call center staff to respond to customer feedback and questions). This is shown to be the case in the existing use of different AI/machine learning technologies for transit, which include using reinforcement learning for coordinating operational control, or using supervised learning frameworks, like deep neural networks or language models, to monitor, analyze, and predict demand. In addition, generative AI, such as ChatGPT and Bard, could be used to enhance management efficiency in communication and coding.

For years, transit operators and agencies have collected and used data to analyze and improve service. This abundance of data includes second-by-second vehicle location data; sensors on assets that measure temperature, vibrations, and other variables; ticketing/fare gate information; and cameras monitoring operating status throughout the system, all of which could easily be leveraged for AI. This is particularly due to the nature of different machine learning models, which are unique in their ability to process diverse data types (e.g., numerical, image, natural language). Despite the noted potential benefits of AI, we have no structured knowledge of how it is adopted by transit agencies, who the adopters are, nor the extent of its benefits to agencies and transit users. There is also no catalog of opportunities to integrate AI into existing operations to enhance safety and service quality and to reduce costs (for example, could AI be used to address labor shortages in transit operations). Other questions include: What are the costs of adoption? What are the barriers to adoption? What are some of the associated risks of adopting AI, and how reliable are the outputs?

The research objectives are to:
1. Study the deployment of AI in transit operations and provide insights into existing and potential use cases of AI, success stories, challenges, and barriers that deter AI deployment.
2. Study the benefits and costs of AI adoption in transit operations.

3. Develop and establish a framework of common definitions, guidelines, and standards for AI adoption in transit.

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