Research and Development of a 3-Item Transportation Security Index Mobility Measurement Tool

Final Report

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16. Abstract

Departments of Transportation need measurement tools to (1) assess and track over time populations and geographies where mobility investments are needed, (2) assess what is driving the mobility needs of different populations and geographies so as to identify possible interventions, and (3) evaluate the impact of department investments on mobility. The Transportation Security Index (TSI) enables planners to do just this. Modeled after the Food Security Index, the TSI is a validated measure designed to capture the experience of transportation insecurity at the individual level. Informed by qualitative research, items in the TSI ask respondents to report how often in the past 30 days they have experienced a given symptom of transportation insecurity (e.g., skipping trips, not being able to leave the house). Currently, there is a validated 16-item longform TSI and a validated 6-item shortform. However, the ability of DOTs to use the TSI to assess where investments are needed and evaluate the impact of such investments on transportation insecurity is stymied by the length of the index. To increase the utility of the TSI for assessment, planning, tracking, and evaluation purposes, a shortened 3-item TSI (TSI-3) was developed and validated using data from nationally representative surveys and content expert feedback and following a similar methodology used in abbreviating the original 16-item TSI to 6-items. Results indicate that the validated TSI-3 is comparable to the TSI-6 with respect to their psychometric properties, the prevalence estimates they generate, and their predictive validity, using health outcomes. Shorter than the TSI-6 and TSI-16, the TSI-3 is more efficient and cost effective to administer. The biggest substantive difference between these measures is the categories of transportation insecurity they can identify: whereas the TSI-6 identifies three categories of insecurity (secure, marginal/low insecurity, moderate/high insecurity), the TSI-3 can only identify 2 (transportation secure/transportation insecure). This project concludes by offering several use cases for the TSI. In an appendix we detail how the TSI-3 can be implemented and point to an analysis of transportation insecurity in the City of Detroit as an illustration.

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DISCLAIMER

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EXECUTIVE SUMMARY

Those who are unable to get from place to place in a safe or timely manner because of a lack of resources are considered to experience "transportation insecurity," a condition that has implications for individual wellbeing. Recently, researchers developed The Transportation Security Index (TSI), a validated survey instrument that measures transportation insecurity at the individual level. The TSI enables Departments of Transportation (DOT) to identify and quantify those who experience transportation insecurity, where it exists, and assess its causes and consequences. However, the ability of DOTs to use the TSI to assess where investments are needed and evaluate the impact of such investments on transportation insecurity is stymied by the length of current versions of the index (the original version consists of 16 items, a shortened version consists of 6 items). To increase the utility of the TSI for assessment, planning, tracking, and evaluation purposes, an even more abbreviated TSI is needed.

This report details efforts to develop and validate an abbreviated TSI consisting of 3-items (TSI-3) that is (1) more cost efficient and more concise/less burdensome than, and (2) similarly effective in identifying transportation insecurity and predicting its associated outcomes of interest as the existing TSI tools (the TSI-16 and the TSI-6). To put this project in context, we begin by reviewing why existing mobility measurement tools are unable to measure transportation insecurity, review the logic underpinning the design of the TSI, provide details about the development of the TSI, and discuss the index's added value in assessing the mobility needs of individuals.

Next, we report on the data and methods used to develop and validate the TSI-3. Following a similar technical approach that was used in abbreviating the TSI-16 to a score with 6-items, in this exercise we considered the TSI-6 only and identified a preliminary TSI-3 using both statistical and content approaches to analyze previously collected nationally representative survey data as well as feedback from content experts. To validate the preliminary TSI-3, we fielded a new, nationally representative survey that included a split-ballot experiment wherein random halves of the sample received identical questionnaires including either the longer TSI-6 or TSI-3. Using a statistical approach, we analyzed this data to establish the consistency of the TSI-6 across surveys, identify categories of insecurity using the TSI-3, and assesses whether the TSI-3 performed similarly to the TSI-6, examining how they compared in terms of their respective psychometric properties, prevalence estimates, and associations with two health outcomes. The result of these efforts is that a 3-item TSI that performs similarly to longer TSI versions and has face validity among potential users was developed and validated. Shorter than the longer TSI versions, the TSI-3 is more efficient and cost effective to administer. The biggest substantive difference between these measures is the categories of transportation insecurity they can identify: whereas the TSI-6 identifies three categories of insecurity (secure, marginal/low insecurity, moderate/high insecurity), the TSI-3 can only identify 2 (transportation secure/transportation insecure).

We conclude this report by suggesting future avenues for research and measurement validation and detail several use cases of the TSI, specifically describing how the Michigan Department of Transportation (MDOT) might use the TSI to (1) assess and track over time populations and geographies where mobility needs are high (thus identifying where investments are needed), (2)

assess the causes of transportation insecurity among different populations and geographies (allowing for the identification of possible interventions), and (3) evaluate the impact of department investments (assessing whether they move people from “transportation insecurity” to “transportation security”). In an Appendix, we provide step-by-step guidance on how the TSI-3 should be implemented in survey research and refer to the paper “Transportation Insecurity in the Motor City” which offers both an illustration of how to implement the TSI as well as a demonstration of the utility of the TSI in understanding transportation insecurity in one Michigan local context.

INTRODUCTION[i]

Background

The ability to get from place to place in a safe or timely manner is critical to individual economic, social, physical, and psychological wellbeing. Those who are unable to get from place to place in a safe or timely manner are considered to experience "transportation insecurity," a condition that can be shaped by a variety of factors from not having the financial resources to own or repair a car or pay for a bus pass, to not having the physical health for walking, to living in a neighborhood without sidewalks or access to public transit, to not having friends and family able to provide rides (Gould-Werth et al. 2018; Murphy et al. 2021). Until recently, no measurement tool existed that could identify people experiencing transportation insecurity. This made it impossible to quantify the extent of the problem. It also made it impossible to understand what demographic groups and spatial geographies were experiencing this condition, thereby hindering state Departments of Transportation (DOTs) from being able to assess who and where mobility investments are most needed or evaluate the extent to which their investments are effectively moving people from "transportation insecurity" to "transportation security" (or, conversely, evaluate whether investments are having a negative impact on the transportation insecurity of specific subgroups and/or communities).

To address this gap, researchers recently developed the Transportation Security Index (TSI), a validated survey measure designed to capture the experience of transportation insecurity at the individual level, regardless of mode or geography (Gould-Werth et al. 2018; Murphy et al. 2021). Fielding an original, nationally representative survey that included the TSI, researchers documented that in 2018 one in four Americans over the age of 25 experienced transportation insecurity. They also found that over half of those living below the poverty line experience transportation insecurity and that the prevalence of transportation insecurity differs by demographic characteristics, car ownership, and geography (Murphy et al. 2022). Using this same survey researchers also found strong associations between transportation insecurity and both physical and mental health (McDonald-Lopez 2023).

As this prior research illustrates, the TSI is a useful tool to identify who experiences transportation insecurity, where it exists, and assess its causes and consequences – information of great value to the planning and evaluation work of state DOTs. However, the two versions of the TSI that currently exist are somewhat long (the original validated measure, the TSI-16, is comprised of 16 items (Murphy et al. 2021); an abbreviated validated measure, the TSI-6, is comprised of 6-items (Murphy et al. 2024)). Given that questionnaire length directly impacts survey costs, respondent burden, response rates, and data quality, the existing versions of the TSI may be prohibitive to be included on most surveys, limiting their potential usefulness to state DOTs. Because of this, it is valuable to identify and validate an even more abbreviated TSI than those versions that currently exist.

To reliably measure a latent construct like transportation insecurity, a minimum of three survey items is necessary. Therefore, this project aimed to produce a validated 3-item index that would be easier and more cost effective to administer than the other versions of the TSI. If implemented in future data collection efforts of the Michigan DOT (MDOT), the TSI-3 could provide the department with an effective tool to (1) assess and track over time populations and geographies

where mobility needs are high (thus identifying where investments are needed), (2) assess the causes of transportation insecurity among different populations and geographies (allowing for the identification of potential interventions), and (3) evaluate the impact of department investments (assessing whether they move people from "transportation insecurity" to "transportation security").

Objectives

This research project had three primary objectives:

> ***Objective #1:*** Develop and validate an abbreviated TSI – one consisting of 3 items (TSI-3) – that is (1) more cost efficient and more concise/less burdensome than, and (2) similarly effective in identifying transportation insecurity and predicting its associated outcomes of interest as the existing validated TSI tools (the TSI-16 and the TSI-6). To accomplish this objective, we built on existing research and followed a similar technical approach that was used in abbreviating the original TSI-16 score to a score with 6-items (see Murphy et al. 2024 for details).
>
> ***Objective #2:*** Demonstrate the utility of the TSI in assessing mobility needs and illustrate how the TSI may be implemented to achieve this goal. To accomplish this objective, we used data generated from the TSI-6 that was included on a 2023 survey sample representative of the Detroit metropolitan region as a case to publish a paper detailing the prevalence and descriptive characteristics of transportation insecurity among Detroiters.
>
> ***Objective #3:*** Identify and recommend future use cases for which MDOT might utilize the validated TSI-3 to determine and assess future mobility infrastructure investments. Through our research, several use cases for the TSI were identified with those most pertinent to the MDOT being outlined in the conclusions portion of this report.

Figure 1: Q-Line M-1 Rail on Woodward Ave in Detroit. Credit: MDOT Photography Unit

LITERATURE REVIEW

To assess the mobility needs of populations and/or communities, planners and researchers across different disciplines use a range of different measurements. At the individual level, common tools include car ownership, mode use, commute time and other kinds of travel behavior measures (see, for example, Fitzpatrick and Ploeg 2010, Smart and Klein 2015). At the neighborhood level, planners often use place-based metrics that are created by some combination of census, land use, transit, destination, and survey data to measure communities along scales of "transit richness," "neighborhood accessibility" or "proximity to destinations" (Grengs 2012; Tomer et al. 2011; Grengs 2003; Cervero et al. 2006; Allen et al. 1993; Siddiq and Taylor 2021).

While useful, these quantitative measures do not always correlate with qualitative assessments of transportation insecurity (Gould Werth et al. 2018; Murphy et al. 2021) nor do they "address whether a person's needs have been met," as does indicators of transportation insecurity (National Academies of Sciences, Engineering, and Medicine 2025, p. 108). For example, while car ownership is sometimes used as a proxy for transportation security, car owners can experience transportation insecurity when they cannot afford gas, car repairs, or car insurance, when their license is suspended, or when they have to share their vehicles with others in the household (Blumenberg and Agrawal 2014; Pendall et al. 2014). Conversely, there are people without cars who are able to regularly get around in a safe or timely manner via public transit, social networks, or Uber. Similarly, people in neighborhoods deemed "transit rich" or in neighborhoods assessed to have multiple destinations, like jobs and healthcare, in close spatial and temporal proximity may be transportation insecure when they cannot afford bus fare, do not feel safe using public transit, or have health conditions that make walking or public transit use not possible. Place-based measures used by planners do not capture these individual-level differences (Gould Werth et al. 2018; National Academies of Sciences, Engineering, and Medicine 2025). Additionally, existing measures that capture people in transit, like commute times, do not capture trips not taken or people for whom transportation insecurity is so severe that they barely get around at all – those who have "unmet demand" (Murphy et al. 2021).

To create a measure explicitly designed to capture individuals who experience transportation insecurity, researchers developed the TSI. Because it is impossible to catalogue every mode of transportation that someone might have access to (the inputs of transportation insecurity) and every destination someone might like to go, in designing the TSI, researchers modeled their approach after the development of the Food Insecurity Index (FSI). The FSI is a multidimensional measure capturing "uncertain, insufficient, or unacceptable availability, access or utilization of food" at the individual level (National Research Council 2006, p.4) and has been widely adopted in nationally representative surveys to generate national estimates of the prevalence of hunger as well as in a causal inference framework to capture the causes and consequences of food insecurity (see, for example, Kushel et al. 2006). Instead of attempting to measure the content of what people eat (i.e. the inputs of food insecurity), the FSI was explicitly designed to "measure food insecurity based on the way people actually experience it" (Frongillo 1999: 507S). It does so by measuring the *symptoms* of experiences with food insecurity, asking questions such as: "In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food."

Following this model, and informed by extensive qualitative and quantitative data, the TSI measures an individual's experience with transportation insecurity by asking how often (never, sometimes, often) in the past 30 days respondents have experienced several unique symptoms of transportation insecurity observed in qualitative research (see Table 1: the TSI-16 asks about 16 unique symptoms of transportation insecurity; the TSI-6 (in bold font) asks about 6 unique symptoms of transportation insecurity). Symptoms fall into two broad categories that prior psychometric analyses (Murphy, Gould-Werth, and Griffin 2021) demonstrate are indicators of a single latent trait (i.e., transportation insecurity): (1) material symptoms that reflect the difficulties people have getting from place to place in a safe or timely manner (e.g., skipping trips, arriving places late) and (2) relational symptoms that reflect the emotional toll and social strain of experiencing transportation insecurity (e.g., being embarrassed, worrying about inconveniencing ride givers).[ii] Importantly, in developing the TSI, researchers intentionally omitted references to the causes (e.g. lack of bus fare, unreliable transit) and consequences (e.g. inability to look for work or access healthcare) of transportation insecurity so as to ensure that the TSI could be used as both an independent and dependent variable in a causal inference framework (Transportation Security Index website 2025).

The original validated TSI (TSI-16) consists of 16-items (Gould-Werth et al. 2018; Murphy et al. 2021). Recognizing that 16-items may be too costly and burdensome to easily administer, researchers developed an abbreviated validated TSI (TSI-6) derived from the original TSI (Murphy et al. 2024). Both the TSI-16 and the TSI-6 perform similarly in identifying individuals experiencing transportation insecurity and are able to generate comparable prevalence estimates (Murphy et al. 2024). The primary difference between them, aside from length of the measure, is that whereas the TSI-16 is able to identify five categories of transportation insecurity (secure, low, minimal, moderate, high insecurity) (McDonald-Lopez et al. 2023), the TSI-6 is only able to identify three categories of transportation insecurity (secure, low/minimal, moderate/high insecurity) (Murphy et al. 2024).

By measuring symptoms rather than trying to paint a holistic picture of all variables that affect an individual's level of transportation security (e.g. neighborhood context, mode of travel, destination) this single measure is not only able to accurately identify people experiencing transportation insecurity (and differentiate people experiencing different degrees of insecurity) but also offers several unique strengths not available in other individual-level measures that seek to capture mobility needs. First, it can be used to differentiate car owners who can and cannot afford gas; people who can walk to the places they need to go and people who are stranded without a car; and transportation secure residents and their transportation insecure neighbors (Gould-Werth et al. 2018). Second, the fact that it is immune to changing modes of transit makes it uniquely able to assess how future mobility technologies, like connected and automated vehicles, impact transportation insecurity (Gould-Werth et al. 2018). That it is "mode agnostic" also enables users of the index to examine how transportation insecurity is shaped by different modes and features of the built environment and transportation systems. Finally, because the measure was intentionally crafted to include some index items tailored to those for whom getting around is most difficult, who find themselves stuck at home, unable to leave the house, forced to skip a lot of trips, the TSI is one of the only – if not the only – existing measure that captures "unmet demand."

Table 1. The Transportation Security Index (items in the TSI-6 are in bold font)

1. To get to the places they need to go, people might walk, bike, take a bus, train or taxi, drive a car, or get a ride. In the past 30 days, how often were you late getting somewhere because of a problem with transportation?
2. In the past 30 days, how often did it take you longer to get somewhere than it would have taken you if you had different transportation?
3. There are times when we need to wait for transportation to pick us up. In the past 30 days, how often did you spend a long time waiting because you did not have the transportation that would allow you to come and go when you wanted?
4. In the past 30 days, how often did you have to arrive somewhere early and wait because of the schedule of the bus, train, or person giving you a ride?
5. **In the past 30 days, how often did you have to reschedule an appointment because of a problem with transportation?**
6. **In the past 30 days, how often did you skip going somewhere because of a problem with transportation?**
7. **In the past 30 days, how often were you <u>not</u> able to leave the house when you wanted to because of a problem with transportation?**
8. In the past 30 days, how often did you worry about whether or not you would be able to get somewhere because of a problem with transportation?
9. In the past 30 days, how often did you feel stuck at home because of a problem with transportation?
10. In the past 30 days, how often do you think that someone did not invite you to something because of problems with transportation?
11. In the past 30 days, how often did you feel like friends, family, or neighbors were avoiding you because you needed help with transportation?
12. In the past 30 days, how often did you feel left out because you did not have the transportation you needed?
13. **In the past 30 days, how often did you feel bad because you did not have the transportation you needed?**
14. **In the past 30 days, how often did you worry about inconveniencing your friends, family, or neighbors because you needed help with transportation?**
15. **In the past 30 days, how often did problems with transportation affect your relationships with others?**
16. In the past 30 days, how often did you feel embarrassed because you did not have the transportation you needed?

The value of the TSI for planning, tracking, research, and evaluation has been recognized by researchers, planners, and government officials. For example, in 2024 the Minnesota Department of Transportation added the TSI-6 to its biennial "Omnibus Survey." A coalition of King, Pierce, and Snohomish Counties in Washington State added the TSI-6 to a 2024 regional mobility survey. The TSI-6 was used in a Community Health Needs Assessment of Taylor County, WV (Hartley Health Solutions 2024). Washington D.C.'s Department of Transportation (DDOT) used the TSI-6 to evaluate their District E-bike Incentive Program (Email correspondence with

DDOT planner 3.3.25). And a 2025 consensus study report of the National Academies of Sciences, Engineering, and Medicine has recommended Congress and the U.S. Department of Transportation to "provide resources to states, local jurisdictions, regional planning organizations, and other recipients of federal surface transportation funds" to both "pilot test tools that directly measure transportation insecurity as it is experienced and related by people" and to measure, among other things, transportation insecurity-related "outcomes of their transportation investments and plans using the metrics and tools that were successfully piloted" (pgs. 143-144).

Yet while the value of measuring transportation insecurity using the TSI has been recognized, broader use of the TSI is stymied by the length of current versions of the index. Therefore, to increase the utility of the TSI for assessment, planning, tracking, evaluation, and research purposes, this project aimed to develop and validate an abbreviated index comprised of three items that would be easy, efficient, and cost effective to administer.

Figure 2: Amtrack Pontiac Transportation Center. Credit: MDOT Photography Unit

METHODOLOGY

Data

Survey Data

Survey data were gathered from two similar data collections administered in November 2022 and 2024. The 2022 survey was fielded to validate the TSI-6 (see Murphy et al. 2024) and to develop a preliminary TSI-3. Because the 2022 survey included a split-ballot design, only respondents to Ballot Two (n=1,118) were administered the full TSI-6 (respondents to Ballot One were administered the TSI-16).

The 2024 survey was fielded to validate the TSI-3 scale and was modeled after the 2022 survey data collection. Specifically, the 2024 survey included a split-ballot experiment wherein one random half-sample (analytic sample size = 1,110) received the TSI-6, and the other random half-sample (analytic sample size = 1,090) received the proposed abbreviated scale (See Appendix A for the 2024 survey questionnaire).

For both the 2022 and 2024 surveys, we contracted with the survey firm, Ipsos. Ipsos maintains the KnowledgePanel®, an online research panel that is representative of the U.S. population. Panel members are randomly recruited using probability-based sampling and provided with Internet access and a web-enabled device, if necessary. Samples from the panel have been demonstrated to closely resemble U.S. Census demographic benchmarks (Yeager et al. 2011), and Ipsos uses a patented methodology to ensure that all general population samples are fully self-weighting (i.e., each sample member is assigned a design weight of unity). Study-specific design weights are adjusted to account for any departure from a general population sample (e.g., stratified design, oversampling) and any differential nonresponse. The KnowledgePanel® is particularly well-suited for this project because the sample frame, generated via address- based sampling, has been demonstrated to have improved coverage of subpopulations that are particularly vulnerable to transportation insecurity (Knowledge Networks 2010; Murphy et al. 2021).

Each survey was administered to a distinct sample of Ipsos' KnowledgePanel® members. Each sample was restricted to U.S. adults aged 25 years or older to minimize the impact of the potentially unique transportation behaviors of college-aged young adults, and respondents living in households at or below the federal poverty line were oversampled. Demographic characteristics of respondents were preloaded from the panel and provided by Ipsos. Our sample design permits the generation of both national prevalence estimates and sub-group differences.

In addition to the TSI, the survey also included questions important for assessing and comparing the predictive validity of the TSI-3. In particular, self-rated health and depressive symptoms were gathered using standard self-report measures. These measures have been shown to be associated with transportation insecurity (McDonald-Lopez et al. 2023). Respondents were asked, "In general, how would you rate your health?" with "excellent, very good, good, fair, poor" as response options. Responses were dichotomized into fair/poor versus excellent/very good/good. Depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale 7-item short form (Radloff 1977, Levine 2013). Specifically, respondents were asked how often, during the past week, they had poor appetite, had trouble keeping their mind on what they were doing, felt depressed, felt that everything they did was an effort, had restless sleep, felt sad, and could not get "going" (1=rarely or none of the time, 2=some or a little of the time, 3=occasionally or a moderate amount of the time, 4=most or all of the time). Respondents with sum scores greater than 20 were classified as experiencing major depression syndrome.

All survey data were weighted. Survey weights, provided by Ipsos, accounted for differential selection probabilities due to the low-income oversample, any differential nonresponse probabilities, and a post-stratification to the 2023 Current Population Survey (March Supplement). See Appendix B for additional survey data collection details and respondent descriptive statistics for each survey.

Content Expert Feedback Data

To ensure the abbreviated TSI had face validity, we consulted with potential users of the index. Specifically, we solicited feedback from 23 individuals who either had familiarity with the TSI already or who might be interested in using it sometime in the future. These content experts included public transportation officials, planners, transit advocates, transportation researchers, and material hardship scholars. In soliciting feedback, we shared with these experts three potential versions of a 3-item TSI, communicated that each version had demonstrated a similar ability to identify people experiencing transportation insecurity, and asked them to share with us which version they would choose as the final TSI-3, explaining their decision.

Methods

Here we detail the methods we used in the two phases of measurement development: (1) identifying a preliminary 3-item TSI and (2) validating the preliminary 3-item TSI (for an overview of the steps involved in such efforts broadly, see Murphy et al. 2024).

Identifying a Preliminary 3-Item TSI

Transportation insecurity is a unidimensional condition with both relational and material manifestations. Because both the TSI-16 and TSI-6 contain items that reflect both manifestations, a desirable 3-item index will do the same, specifically retaining those manifestations that are most likely to be encountered across a variety of contexts (content validity). Additionally, a desirable 3-item index will have face validity among respondents (thereby increasing respondent motivation and the quality of data collected) and users of the index (thereby facilitating use of the scale).

To determine which items to include, we used both content and statistical approaches and considered only those items that were included in the TSI-6 (which performs as well as the TSI-16; see Murphy et al. 2024). We began by using the 2022 survey data (Ballot Two only) to examine all potential three-item combinations derived from the TSI-6. For each combination, we examined R-squared values from linear probability models that estimate the association between TSI questions and severity of transportation insecurity. Such estimates revealed which combinations have the best “model fit” and would be useful in eliminating combinations with poor fit.

Next, we considered how respondents who experience different levels of severity of transportation insecurity (secure, marginal/low, moderate/high) endorse each of the 6 items in the TSI-6. A desirable set of items in a 3-item form should be able to pick up respondents spanning these categories of transportation insecurity.

We then evaluated the individual item characteristics of all 6 items in the TSI-6 as estimated by a graded response model. Graded response models estimate the probability that a respondent will endorse a particular item response given the respondent’s location on a latent continuum (here, transportation insecurity), the ability of the item to differentiate among respondents at different locations on the latent continuum (item discrimination), and the location on the latent continuum

at which the respondent has a 50 percent chance of endorsing a particular item response (item location). A desirable set of items will have high discrimination values while adequately covering the content space (i.e., spanning the range of item difficulty).

After conducting these analyses of individual items, we next arranged the remaining items under consideration into a series of possible 3-item scales, ensuring that at least one material and one relational item appeared in each scale. Because an abbreviated score should be able to classify individuals as secure and insecure in a manner that is similar to the longer score, we then used the 2022 data to examine the individual distributions of the candidate scales to assess whether one candidate scale would emerge as being better or worse than the others.

Our final step was to consult with potential users of the index (researchers, policymakers, planners). We provided potential users with the remaining combinations under consideration and requested feedback on what items are important (and least important) to retain in terms of content and what combinations are preferred, including their justification for their responses. In this step, we sought to garner external input on what items are most important to retain as well as what items are needed to cover the content of the dimension or trait in terms of the conceptual model of transportation insecurity. Doing so helps ensure that the final TSI-3 has face validity among potential users.

Validating the proposed TSI-3 using the newly collected nationally representative survey data

To validate the proposed TSI-3, we used the 2024 survey data and began by evaluating the consistency of the TSI-6 over time to ensure that this scale performs as expected in the new independent sample. To do so, we compared the prevalence estimates derived from the TSI-6 in 2022 and 2024 survey data.

Next, we evaluated the psychometric properties of the TSI-3. For an abbreviated scale to work, it should preserve the TSI-6's psychometric properties. Specifically, we evaluated the internal reliability of the scale as measured by Cronbach's alpha.

We then created cut points for the proposed TSI-3 using 2024 survey data. Such cut points will enable us to evaluate whether the TSI-3 reproduces the prevalence estimates of the categorical TSI-6. To create these cut points, we conducted a *k*-means cluster analysis using data from TSI-3 respondents only. *K*-means cluster analysis is a non-deterministic partitional clustering method wherein observations are iteratively clustered into *k* mutually exclusive and exhaustive categories using their continuous TSI sum scores as input (MacQueen 1967). Our goal is to identify a *k* which provides as much description of the population as can generally be reproduced. Because the TSI-6 can identify three categories of insecurity, we examined between one and three distinct categories of transportation insecurity and re-estimated each model ten times.

Once a preliminary categorical TSI-3 was defined, we calculated the level of agreement between the TSI-6 and TSI-3. To estimate the concordance between these two scales, we calculated the percent agreement between the two using the 2024 survey data. Because simple agreement

between two measures does not consider chance agreement, we also estimated the Kappa statistic between the categorical TSI-6 and the categorical TSI-3.

Next, we determined whether the TSI-3 is able to classify people in the same way as the TSI-6 by comparing the prevalence estimates derived from the two scales. To do this, we created a single 3-category variable across the entire 2024 data such that respondents who received the TSI-6 were assigned their 3-category TSI-6 score and respondents who received the TSI-3 were assigned their 2-category TSI-3 score. To examine whether there is a significant difference in prevalence estimates between the two, we conducted a chi-square analysis.

Finally, we examined whether the TSI-3 has similar predictive power as the TSI- 6. To do this, we used logistic regressions and the 2024 survey data to compare how each is associated with our outcomes of interest, controlling for sociodemographic characteristics: self-rated health and depressive symptoms. A high degree of agreement between the TSI-6 and TSI-3 across these analyses would suggest that the TSI-3 is a sufficient proxy for the TSI-6 (and the TSI-16) when estimating transportation insecurity's prevalence and predictive power.

All survey data were analyzed using Stata version 15.1 (StataCorp LP, College Station, TX).

Figure 3: US-31 in Traverse City. Credit: MDOT Photography Unit.

FINDINGS

Identifying a Preliminary 3-Item TSI

There are twenty possible three-item combinations derived from the TSI-6. Table 2 illustrates the R-squared values from linear probability models estimating the association between each three-item TSI and severity of transportation insecurity. Each TSI question is coded as a binary variable where "yes/1" means they answered either "sometimes" or "often" to the TSI question and "no/0" means they answered "never." The outcome variable captures severity of transportation insecurity (1 = "more severe" and 0 = "less severe"). Notably, as indicated by the average R-squared across both models, all three-item combinations performed similarly, with each combination explaining between 67 and 76 percent of the variability in response. Therefore, all twenty combinations remained under consideration.

Table 2. R-Squared values from linear probability models estimating the association between TSI questions and severity of transportation insecurity

Questions Forming All Possible 3-Item Combinations from TSI-6	Marginal/Low vs. Secure	Moderate/High vs. Marginal/Low	Average R-Squared (across the two models)
Q7,15,17	0.76	0.76	0.76
Q8,15,17	0.73	0.78	0.76
Q7,8,15	0.79	0.71	0.75
Q7,9,15	0.79	0.69	0.74
Q7,9,17	0.71	0.76	0.74
Q7,15,16	0.78	0.69	0.74
Q7,8,17	0.68	0.78	0.73
Q8,15,16	0.76	0.7	0.73
Q8,9,17	0.68	0.77	0.73
Q8,16,17	0.66	0.79	0.73
Q9,15,17	0.71	0.74	0.73
Q7,9,16	0.74	0.69	0.72
Q15,16,17	0.69	0.74	0.72
Q7,8,16	0.71	0.71	0.71
Q7,8,9	0.73	0.68	0.71
Q8,9,15	0.74	0.67	0.71
Q9,15,16	0.75	0.66	0.71
Q8,9,16	0.72	0.69	0.71
Q9,16,17	0.66	0.74	0.70
Q7,16,17	0.59	0.75	0.67

To determine whether any of the candidate items were more or less frequently endorsed by respondents experiencing various levels of transportation insecurity, we next examined the proportion of respondents answering *sometimes* or *often* to each item by their transportation security score. For example, as illustrated in Table 3, 2 percent, 57 percent, and 98 percent of

respondents classified as “secure,” “marginal/low insecurity,” and “moderate/high insecurity,” respectively, endorsed the item about rescheduling appointments because of problems with insecurity. The ratio of the proportions for moderate/low vs. marginal/low illustrates whether any given item is more or less likely to be endorsed by those with greater levels of insecurity. As expected, a greater proportion of those with greater levels of insecurity endorse each of the six items. Notably, nearly five times as many of those experiencing moderate/high insecurity endorse *relationship effects* than those experiencing marginal/low insecurity, indicating that *relationship effects* might be particularly important to retain in the TSI-3 (see also McDonald-Lopez et al. 2023 which shows that experiences with the relational symptoms of insecurity begin to appear the more severe a person’s transportation insecurity is).

Table 3. Proportion of respondents endorsing each TSI-6 item by TSI score

Questions	**Secure** TSI Score = 0-1 N = 801	**Marginal/low** TSI Score = 2-5 N = 168	**Moderate/high** TSI Score = 6-12 N = 149	Ratio for moderate/high vs. marginal/low
In the past 30 days, how often did you have to reschedule an appointment because of a problem with transportation?	0.02	0.57	0.98	1.72
In the past 30 days, how often did you skip going somewhere because of a problem with transportation?	0.01	0.52	0.99	1.90
In the past 30 days, how often were you not able to leave the house when you wanted to because of a problem with transportation?	0.00	0.64	0.99	1.55
In the past 30 days, how often did you feel bad because you did not have the transportation you needed?	0.00	0.74	1.00	1.35
In the past 30 days, how often did you worry about inconveniencing your friends, family, or neighbors because you needed help with transportation?	0.03	0.60	0.94	1.57
In the past 30 days, how often did problems with transportation affect your relationships with others?	0.00	0.18	0.89	4.94

Results of the graded response model, including item discrimination and difficulty, and our rationale for retaining or striking an item from consideration in the TSI-3 are illustrated in Table 4. We began by striking *reschedule* from consideration because it was one of the least discriminating items and presupposed respondents had an existing appointment to reschedule. We then removed *inconvenience* from consideration because it overlapped, semantically, with *relationship effects*, yet was easier to endorse.

Table 4. TSI-6 question stems, graded item response model parameters, and TSI-3 decision criteria

Item label (question number)	Question stem	Item discrimination (SE)	Item difficulty (SE) Never to Sometimes/Often	Reason struck (S)/retained (R) for TSI-3 consideration
Reschedule (Q3)	In the past 30 days, how often did you have to reschedule an appointment because of a problem with transportation?	6.00 (1.11)	1.08 (.05)	Low discrimination and requires having prior appointment (S)
Skipped 9 (Q4)	In the past 30 days, how often did you skip going somewhere because of a problem with transportation?	7.83 (1.49)	1.12 (.05)	High discrimination (R)
Not able to leave house (Q5)	In the past 30 days, how often were you **not** able to leave the house when you wanted to because of a problem with transportation?	14.50 (2.79)	1.06 (.03)	High discrimination (R)
Felt bad (Q6)	In the past 30 days, how often did you feel bad because you did not have the transportation you needed?	13.08 (1.81)	1.01 (.03)	High discrimination (R)
Inconvenience (Q7)	In the past 30 days, how often did you worry about inconveniencing your friends, family, or neighbors because you needed help with transportation?	5.49 (1.12)	1.06 (.05)	Less information than *relationship effects* and easier to endorse (S)
Relationship effects (Q8)	In the past 30 days, how often did problems with transportation affect your relationships with others?	5.46 (1.06)	1.40 (.10)	Greatest difficulty and semantically broader than *inconvenience* (R)

Note: SE=standard error, final TSI-3 in bold font
Response options: Never, sometimes, often

The remaining four items under consideration reflected both the material (*skipped, not able to leave house*) and relational (*felt bad, relationship effects*) manifestations of transportation insecurity. These items were arranged into the following three candidate 3-item scales, ensuring that at least one material and one relational item appeared in each scale: (1) *skipped, felt bad, relationship effects,* (2) *skipped, not able to leave house when you wanted to, relationship effects,* (3) *felt bad, not able to leave house when you wanted to, relationship effects.*

Using the 2022 survey data, we examined the individual distributions of the three candidate scales and found that they performed similarly. For example, the forms classified between 82.8 and 83.8 percent of respondents as transportation secure (i.e., a sum score of 0). Contingency tables of each form with the original TSI-6 demonstrated that all respondents classified as secure using the TSI-6 had sum scores of 0 or 1 on each TSI-3 (with nearly all of them having a sum score of 0). Together, these results suggest that the three candidate TSI-3 forms were very closely aligned with the TSI-6 and that, on these metrics, no single TSI-3 emerged as much better or much worse than the others.

To ensure that the final TSI-3 had face validity, 23 content experts reviewed these three possible 3-item scales and stated their preference among them. While there was support for each of the 3-item combinations across the group, a sizeable share of respondents expressed a preference for retaining the two items reflecting the material manifestations of transportation insecurity (*skipped* and *not able to leave house when you wanted to*), noting that doing so would increase the face validity of the scale. Further, several expressed that *felt bad* might be potentially stigmatizing in the absence of other relational items that provide greater context. Therefore, the following 3-item scale was selected: *skipped, not able to leave house when you wanted to, relationship effects*.

Validating the proposed TSI-3

We began by examining the consistency of the TSI-6 over time. The national prevalence of transportation insecurity per the TSI-6 was 17.1% and 15.6% in 2022 and 2024, respectively, suggesting that the TSI-6 performed consistently over time and in an independent sample (see Figure 4).

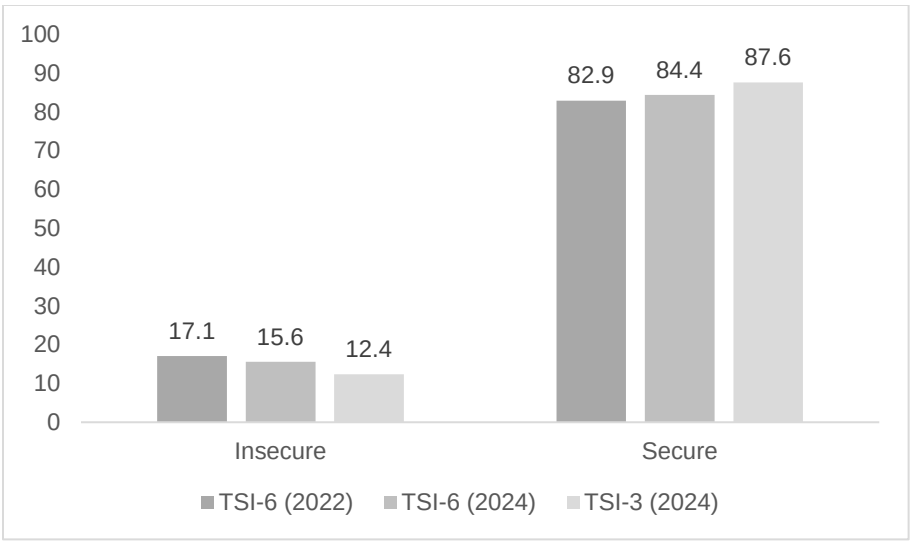

Figure 4. Prevalence of transportation security as measured by the TSI-6 and TSI-3 in 2022 and 2024

Second, we evaluated the psychometric properties of the TSI-3 as measured in Ballot Two, finding that the TSI-3 was internally consistent with a Cronbach's alpha estimate of 0.81.

Next, we compared the classification of Ballot One respondents using the TSI-6 and the TSI-3 (extracted from Ballot One). Although the TSI-6 is a three-category measure, the *k*-means cluster analysis of the TSI-3 found that a dichotomous version of both the TSI-3 (sum scores of 0 and 1 defined as secure, 87.6%, and sum scores of 2 through 6 defined as insecure, 12.4%) and TSI-6 (sum scores of 0 and 1 defined as secure and sum scores of 2 through 12 defined as insecure) yielded the greatest percent agreement in respondents classified as secure (see Table 5 for *k*-means results).

Table 5. k-means cluster analysis of the TSI-3 (2024 data)

	k=2	
Iteration	1	2
1	0-2	3-6
2	0-1	2-6
3	0-1	2-6
4	0-1	2-6
5	0-1	2-6
6	0-1	2-6
7	0-1	2-6
8	0-1	2-6
9	0-1	2-6
10	0-1	2-6

As illustrated in Table 6, 91.4% of respondents to Ballot One were similarly classified using the TSI-6 and the TSI-3 (70.9% secure, 20.5% insecure). Furthermore, the only misclassification was the 8.6% of respondents classified as insecure using the TSI-6, but secure using the TSI-3. This pattern of misclassification is to be expected given that longer measurement forms increase the likelihood of item endorsement and, thus, classification as insecure. The kappa statistic, accounting for any agreement due to chance, was 0.82 and indicated 92.0% of agreement.

Table 6. Weighted percent agreement between original and abbreviated scales using 2024 survey data (N=1,110)

	TSI-3	
TSI-6	secure	insecure
secure	70.9	0
insecure	8.6	20.5

To compare the performance of the independently measured TSI-6 (Ballot One) and TSI-3 (Ballot Two), we created a collapsed variable reflecting the TSI classification of respondents per their TSI-6 (Ballot One respondents) or TSI-3 (Ballot Two respondents) score. A chi-square analysis evaluating whether the prevalence of transportation insecurity varied by ballot found no significant difference (uncorrected $X^2(1)=4.74$, design-based $F(1, 2199)=2.488$, $p=0.115$): 15.6% insecure per the TSI-6 and 12.4% per the TSI-3 (see Table 8).

Table 7. Weighted prevalence of collapsed TSI category by ballot using 2024 survey data (N=2,200)

	Ballot	
Collapsed TSI Classification	One (TSI-6)	Two (TSI-3)
secure	84.4	87.6
insecure	15.6	12.4

Lastly, to examine the association between transportation insecurity and key outcomes of interest, we estimated two logistic regression models in which being in fair or poor health and being very depressed were regressed on the collapsed dichotomous measure of transportation insecurity, including an interaction with which ballot the respondent completed and a set of demographic control variables (see Table 8). Notably, the main effect of transportation insecurity was significant in both models such that being transportation insecure was a significant predictor of being in fair or poor health and being very depressed. Further, the interaction between transportation security and ballot was not significant; indicating that the effect of transportation insecurity on these outcomes does not depend on whether the TSI-6 or TSI-3 was used to measure transportation insecurity. For example, the predicted probabilities of experiencing each outcome for the reference group are illustrated in Figure 5.

Table 8. Logistic regression results for models predicting (1) whether in fair or poor health and (2) whether very depressed

	Fair/Poor Health (N=2,186)						Very Depressed (N=2,190)					
	Odds Ratio	Standard Error	t	P>|t|	95% Confidence Interval		Odds Ratio	Standard Error	t	P>|t|	95% Confidence Interval	
Whether insecure per combined TSI-3 variable (*referent = no*)	2.94	0.87	3.64	0.00	1.65	5.26	3.96	1.57	3.47	0.00	1.82	8.64
Ballot (*referent = Ballot One (TSI-6)*)	1.17	0.22	0.82	0.41	0.80	1.70	0.57	0.21	-1.55	0.12	0.28	1.16
Whether insecure per combined TSI-3 variable (*referent = no*) x Ballot (referent = Ballot One (TSI-6)) interaction	0.48	0.20	-1.76	0.08	0.21	1.09	0.99	0.57	-0.02	0.98	0.31	3.09
Presence of personal vehicle in household (*referent = no*)	1.24	0.24	1.09	0.28	0.84	1.82	0.81	0.27	-0.64	0.52	0.42	1.56
Household Income (*referent = less than $15,000*)												
$15,000-$29,999	0.66	0.18	-1.54	0.12	0.39	1.12	0.83	0.34	-0.46	0.64	0.37	1.85
$30,000-$49,999	0.38	0.11	-3.43	0.00	0.22	0.66	0.37	0.19	-1.94	0.05	0.13	1.01
$50,000-$74,999	0.39	0.12	-3.18	0.00	0.22	0.70	0.47	0.23	-1.57	0.12	0.18	1.21
$75,000 or more	0.28	0.06	-5.53	0.00	0.18	0.44	0.37	0.15	-2.50	0.01	0.17	0.81
Age (*referent = 25-39*)												
40-64	1.21	0.26	0.87	0.38	0.79	1.85	0.59	0.19	-1.68	0.09	0.31	1.09
65 or older	1.48	0.34	1.69	0.09	0.94	2.34	0.12	0.05	-4.78	0.00	0.05	0.29
Education (*referent = less than high school*)												
High school diploma or GED	0.49	0.16	-2.17	0.03	0.26	0.93	0.72	0.37	-0.64	0.52	0.26	1.99
Some college or Associate's degree	0.60	0.20	-1.55	0.12	0.31	1.15	1.38	0.73	0.62	0.54	0.49	3.87
Bachelor's degree or higher	0.41	0.14	-2.59	0.01	0.21	0.80	0.58	0.33	-0.96	0.34	0.19	1.75
Race (*referent = white*)												
Black	1.56	0.39	1.81	0.07	0.96	2.54	0.54	0.24	-1.39	0.16	0.23	1.29
Hispanic	1.04	0.26	0.15	0.88	0.63	1.70	0.47	0.20	-1.74	0.08	0.20	1.10
Other	1.28	0.42	0.75	0.45	0.67	2.45	0.16	0.08	-3.69	0.00	0.06	0.42
Whether married (*referent = no*)	0.64	0.12	-2.29	0.02	0.44	0.94	0.93	0.31	-0.23	0.82	0.48	1.79
Gender (*referent = male*)	0.86	0.14	-0.89	0.37	0.62	1.20	1.34	0.37	1.05	0.30	0.78	2.30
Constant (*baseline odds*)	0.62	0.25	-1.17	0.24	0.28	1.38	0.32	0.18	-1.97	0.05	0.10	0.99

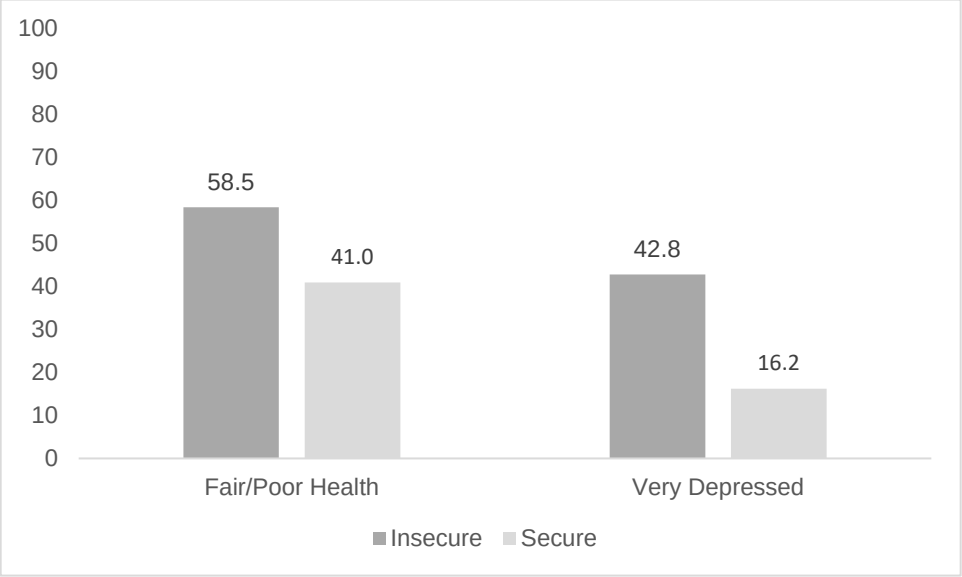

Figure 5. Predicted prevalence of outcomes by transportation insecurity status for referent group

Together, these results suggest that the TSI-3 is concordant with the TSI-6 and, thus, a reasonable proxy for generating both prevalence estimates of transportation insecurity and measures of association between transportation insecurity and outcomes of interest (here, those outcomes were physical and mental health). Furthermore, response time paradata demonstrate that using the TSI-3 in place of the TSI-6 decreases median index response times by 56% (Ballot One TSI-6 median completion time = 51.1 seconds; Ballot Two TSI-3 median completion time = 28.5 seconds).

DISCUSSION

Using nationally representative survey data and content feedback from experts, we developed and validated a 3-item TSI. The TSI-3 is comprised of three questions that capture both the material and the relational symptoms of transportation insecurity and that, together, can be used to identify whether an individual is experiencing transportation insecurity. We have demonstrated that the TSI-3 and TSI-6 are comparable in a number of ways: they share similar psychometric properties, they generate comparable prevalence estimates, and they are similarly predictive of two health outcomes that have been demonstrated to be associated with transportation insecurity: self-reported health and depressive symptoms. We have also demonstrated that the TSI-3 has face validity with potential users. That the TSI-3 takes less time to complete demonstrates that it is less costly and burdensome to administer than the TSI-6. The biggest tradeoff between the two is related to how many categories of transportation insecurity each index can identify: whereas the TSI-6 identifies three categories of insecurity (secure, low/marginal, moderate/high), the TSI-3 is only able to identify two (secure vs insecure).

Factors affecting the results & implications

Although we successfully developed and validated a 3-item TSI, the data collection methods used and outcome variables considered during the scale validation might have affected the results and, thus, the generalizability of our findings, highlighting avenues for future research. Beginning with the first quantitative survey conducted as part of this measurement development research program and following gold-standard shortening practices that require keeping data collection similar across studies, all surveys in this program have been administered using a well-regarded online panel. Although the survey data presented in this report were weighted to account for differential selection probabilities due to the low-income oversamples and any differential nonresponse probabilities and were post-stratified to national benchmarks, national prevalence estimates of transportation insecurity generated by these survey data could be biased if panel members differ systematically from non-panel members. That being said, the design of the split-ballot experiment used in both 2022 and 2024 does protect against any such bias affecting the results of the comparisons between original and abbreviated versions of the index. Future research could compare results from a similar online survey among people who are not part of an online panel.

Because all surveys in this program have been online surveys, it is important that future research replicate these findings using other data collection modes, both self- and interviewer administered. For example, respondents to online surveys, particularly those in online panels, might be prone to satisficing, speeding, or other suboptimal response behaviors. To the extent that DOTs are interested in using the TSI in an interview or focus group setting, it is important to evaluate its performance in both self- and interviewer-administered modes.

The data collection period for the 2024 survey data presented in this report (May 17 – June 3) included Memorial Day weekend (Friday, May 24 – Monday, May 27), a weekend with an increase in travel due to the holiday. To the extent that Memorial Day travel experiences were atypical for respondents in the panel compared to their usual travel experiences, national prevalence estimates of transportation insecurity could be biased. (Again, the design of the split-ballot experiment does protect against any such bias affecting the results of comparisons between the original and abbreviated versions of the index.) The Memorial Day weekend comprised four of the eighteen days of the data collection period and occurred in the latter half of the data collection period. Because respondents were asked to report on transportation experiences in the past 30 days, only those who began the survey after the start of the holiday weekend would have been possibly affected. As it turns out, the vast majority of respondents (82.4%) started the survey before the holiday weekend. Furthermore, there was no significant difference in rates of transportation insecurity as measured by the TSI-6 between those who started before or during/after the holiday weekend. Together, this suggests that our results are not impacted by potential changes in travel due to the holiday weekend.

To validate the TSI-3, we examined the extent to which the respective short forms replicated the patterns of association with two outcomes of interest: self-reported physical and mental health. Although we found that the associations between the shorter form and these outcomes did not differ from those found between the longer form and these outcomes, it might be the case that the two indices are differentially associated with other outcomes of interest, thus calling into

question their interchangeability. To test for this, we used the 2024 survey data to examine the association between transportation insecurity and whether a respondent was working now, a common employment outcome of interest related to transportation insecurity, using the TSI-6 and TSI-3. Although not reported in the present study, we found that both indices performed similarly in predicting whether a respondent was working now, suggesting that the TSI-3 has predictive validity beyond the health outcomes examined here.

Figure 6: Location M-3, Gratiot Ave. Credit: MDOT Photography Unit.

CONCLUSIONS

In a review of the Transportation Security Index, the authors of a 2025 consensus study published by the National Academies of Sciences, Engineering, and Medicine wrote, “A measure such as the TSI is essential for expanding the usual focus of physical performance of infrastructure to understand whether transportation is meeting people’s needs. Such a measure can be applied to decisions about any mode or across modes” (p. 113) and “can be used to identify less obvious transportation solutions” (p. 108). To enable DOTs to use the TSI for these purposes, among others, in an efficient and cost-effective manner, with this project we have delivered a validated, abbreviated TSI that is comparable to the TSI-6 in its performance but that consists of 3-items that can be used to measure transportation insecurity at the individual level.

It is important to note that while the TSI-3 may be more efficient and cost-effective to use than the TSI-6, there are instances where a DOT may want to use the TSI-6. For instance, there are times where it may be useful to be able to differentiate between not just those who are transportation insecure versus those who are transportation secure (which the TSI-3 can do), but those who are insecure versus those who have low levels of insecurity and those who have high levels of insecurity (which the TSI-6 can do). It is likely the case that the causes and consequences of those experiencing low transportation insecurity versus those experiencing high transportation insecurity may differ, suggesting different kinds of programs and investments may

be needed to alleviate the insecurity experienced by these two groups. Having a greater number of categories of insecurity is especially useful when the TSI is used to evaluate the effectiveness of DOT investments and initiatives. For instance, it may be useful to know whether an investment is moving someone from "high insecurity" to "low insecurity." Such alleviation of the severity of insecurity may suggest a particular program is effective and yields high returns on investment. But this would not be detectable with an instrument that is only able to distinguish between those who are transportation insecure versus those who are transportation secure. Another instance where using the TSI-6 may be preferred is in those cases where a DOT would like to evaluate the individual items within the index to understand how residents experience a wide range of symptoms associated with transportation insecurity. In these cases, it may be more illuminating to use the TSI-6 where six symptoms of insecurity (vs 3) can be examined individually.

Recommendations for further research

DeVellis (2017) writes that measurement development is an ongoing process. As we have written elsewhere (Murphy et al. 2024), as much is exemplified by the Food Security Index. First developed in 1995, psychometric research related to this index continues to this day (see, for example, Tanaka et al. 2020). In regard to the TSI, future research should explore how the TSI performs with other data collection modes, various subpopulations of interest (e.g., those living in rural areas, aging populations), and various visual questionnaire design elements (e.g., grid formats).

Given that all TSI development and validation efforts have focused on adults 25 and older, future work should examine how the TSI performs with people under 25 years of age.

All versions of the TSI currently exist in English only. Future work might involve translating the TSI to other languages and validating such translations so that the TSI can be used with non-English speakers.

Finally, transportation insecurity has been defined as a condition experienced by individuals. Accordingly, the TSI was developed as an individual level measure. Yet there are numerous surveys interested in the experiences of households, asking individual respondents to respond on behalf of the experience of the entire household. Future research should examine the degree to which transportation insecurity can be considered a household-level experience and, if so, consider whether the TSI can be used as a household-level measure.

Recommendations for implementation

There are several use cases for the TSI. Here we focus on those most pertinent to MDOT:

> ***Establish a baseline & track prevalence change over time:*** To understand the prevalence of transportation insecurity in the State of Michigan, the TSI could be included on statewide surveys representative of the State of Michigan, thereby establishing a baseline prevalence estimate. If included on reoccurring statewide surveys, changes in the prevalence of insecurity could be tracked over time, alongside other changes likely to

impact transportation insecurity including changing demographics, changing car, gas, and insurance costs, and changes in investments in transportation infrastructure. The Minnesota Department of Transportation has begun to use the TSI in precisely this way, including it on their 2024 biennial Omnibus Statewide Survey, with plans to continue to include it in the future surveys. MDOT could consider including the TSI on their MI Travel Counts Survey as well as their Attitudes and Perceptions Survey. The TSI can be also used in this way at lower-geographic levels as well, including counties, cities, and census tracts.

Identify geographic "hot spots" of transportation insecurity: If included on surveys that collect data at fine-grained spatial scales (i.e. census tracts, block groups), the TSI can be used to identify spatial "hot spots" where transportation insecurity spatially clusters. Such information can be used in decisions about how to allocate transportation resources and investments to areas most in need of such interventions. By identifying such areas, MDOT might also work with other state agencies to coordinate the delivery of important social services to such areas.

Investigate the causes of transportation insecurity so as to identify solutions: When included on surveys with other questions about mode use, travel patterns, finances, among other things, MDOT can examine what factors are driving transportation insecurity across different demographic groups and geographic areas. Such information enables MDOT to identify potential solutions that can be tailored towards specific demographic groups and geographies.

Investigate attitudes and perceptions by transportation insecurity: If included on the MI Attitudes and Perceptions Survey, MDOT could examine how the attitudes of Michigan residents towards the state's transportation systems differ by whether residents are transportation insecure versus those who are transportation secure. Such differences could help MDOT in long-range planning efforts by considering the perspectives of those whose needs are not being met (i.e. those experiencing transportation insecurity).

Evaluate whether investments are effectively moving residents from "transportation insecurity" to "transportation security:" MDOT could use the TSI to evaluate whether their programs, systems, and investments are alleviating residents' experiences with transportation insecurity. For instance, MDOT could use the TSI in a "pre" and "post" evaluation framework to evaluate programs such as the Mobility Wallet Challenge. Collecting data on participant's transportation insecurity before participation, during participation, and after, MDOT can assess how well the program is ameliorating transportation insecurity. Such data is useful in determining whether such programs should be continued and expanded and what kinds of returns on investments they are producing. Similarly, the TSI could be used in ridership surveys. Understanding what is shaping public transit riders' experience with transportation insecurity may illuminate where improvements could be made such that the public transit system ameliorates transportation insecurity.

Screen potential participants into pilot programs: For pilot programs that aim to alleviate experiences with transportation insecurity, MDOT can use the TSI as a screening tool to screen whether potential participants qualify for participation.

In conclusion, the TSI is a novel tool that not only offers new insights into who is experiencing transportation insecurity but also sheds light on the severity of that experience. As outlined here, the TSI could be utilized by MDOT to (1) assess populations and geographies where mobility infrastructure investments are needed, (2) evaluate the impact of department investments on mobility approaches, and (3) trace the progress the department is making on serving the transportation needs of Michigan residents (for step-by-step instructions on how to use the TSI-3 in surveys, see Appendix C).[iii] Moreover, the TSI is also a potentially useful tool that could assist MDOT in identifying travel behavior trends and patterns to inform future mobility investments that seek to move all Michiganders towards transportation security.

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APPENDICES

Appendix A : Transportation Security Index 2024 Survey Questionnaire

Note to Reader: Bold font is used to identify the three items that comprise the TSI-3. Importantly, for Q5 that asks, "In the past 30 days, how often were you **not** able to leave the house when you wanted to because of a problem with transportation?" the question is presented to respondents as it appears here, with the word "**not**" in bold font. [S] denotes items where only one response was allowed. [M] denotes items where multiple responses were allowed. Question 1 technically consists of several questions that gather updated information about household size and household income. No question number was assigned to these questions, however.

Screener

SCRIPTER: PLEASE DO NOT OVERRIDE EXISTING PROFILE VARIABLES HHSIZE AND PPINCIMP. RECORD BELOW VARIABLES (HHSIZE/HHINCIMP) AS NEW VARIABLES.

[DISP_INTRO]
Before we begin the survey, we'd like to ask you some questions about your household. Please keep in mind that your answers are confidential and your personal information will also be kept private. We appreciate your participation in this important study!

Base: All respondents
[PPT18OV]
QHHSIZE_adults [Q]
Including yourself, how many people are 18 years of age or older and currently live in your household at least 50% of the time?
[SPACE]
Please include unrelated individuals (such as roommates), and also include those now away traveling, away at school, or in a hospital.

[PROMPT]
Your answer will help represent the entire U.S. population and will be kept confidential. Thank you!

Type in the number of adults 18 years of age or older.

SCRIPTER: min.=1, max.=10. Prompt following nonresponse. Show on same screen as Q5b.

Base: All respondents
[PPKID017]
QHHSIZE_kids [Q]
Next, how many people are 17 years of age or younger and currently live in your household at least 50% of the time? If none, enter "0".
[SPACE]
Include babies and small children.

[PROMPT]
Your answer will help represent the entire U.S. population and will be kept confidential. Thank you!

Type in the number of children 17 years of age or younger.

SCRIPTER: min.=0, max.=10. Prompt following nonresponse.

Base: All respondents

[PPHHSIZE]
QHHSIZE [Q]

SCRIPTER: Create DOV: QHHSIZE=QHHSIZE_adults + QHHSIZE_kids. Compute if QHHSIZE_adults and QHHSIZE_kids are not refused.

Base: all respondents
[PPINCIMP]
QINC [S]
How much is the combined income of all members of YOUR HOUSEHOLD for the PAST 12 MONTHS?
[SPACE]
Please include your income PLUS the income of all members living in your household (including cohabiting partners and armed forces members living at home). Please count income BEFORE TAXES and from all sources (such as wages, salaries, tips, net income from a business, interest, dividends, child support, alimony, and Social Security, public assistance, pensions, or retirement benefits).

Select one answer only.

1. Below $50,000
2. $50,000 or more

SCRIPTER: Prompt once if question is skipped. Do not show 'Don't know' initially. Show 'Don't know' only with the prompt if question is skipped initially.

[PROMPT]
Your answer will help represent the entire U.S. population and will be kept confidential. Thank you!

Base: respondents with household income below $50,000 (QINC=1)
QINC2 [S]
We would like to get a better estimate of your total HOUSEHOLD income in the past 12 months before taxes. Was it...

[PROMPT]
Your answer will help represent the entire U.S. population and will be kept confidential. Thank you!

Select one answer only.

1. Less than $5,000
2. $5,000 to $7,499
3. $7,500 to $9,999
4. $10,000 to $12,499
5. $12,500 to $14,999
6. $15,000 to $19,999
7. $20,000 to $24,999
8. $25,000 to $29,999
9. $30,000 to $34,999
10. $35,000 to $39,999
11. $40,000 to $49,999

Base: respondents with household income of $50,000 or more (QINC=2)
QINC3 [S]
We would like to get a better estimate of your total HOUSEHOLD income in the past 12 months before taxes. Was it...

[PROMPT]

Your answer will help represent the entire U.S. population and will be kept confidential. Thank you!

Select one answer only.

3. $50,000 to $59,999
4. $60,000 to $74,999
5. $75,000 to $84,999
6. $85,000 to $99,999
7. $100,000 to $124,999
8. $125,000 to $149,999
9. $150,000 to $174,999
10. $175,000 to $199,999
11. $200,000 to $249,999
12. $250,000 or more

SCRIPTER: Create Data-only variables below.

Variable name: PPINCIMP [S]
Variable Text: HH income
Response list:
1. Less than $5,000
2. $5,000 to $7,499
3. $7,500 to $9,999
4. $10,000 to $12,499
5. $12,500 to $14,999
6. $15,000 to $19,999
7. $20,000 to $24,999
8. $25,000 to $29,999
9. $30,000 to $34,999
10. $35,000 to $39,999
11. $40,000 to $49,999
12. $50,000 to $59,999
13. $60,000 to $74,999
14. $75,000 to $84,999
15. $85,000 to $99,999
16. $100,000 to $124,999
17. $125,000 to $149,999
18. $150,000 to $174,999
19. $175,000 to $199,999
20. $200,000 to $249,999
21. $250,000 or more

QINC2	QINC3	PPINCIMP
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10		10
11		11
	3	12

	4	13
	5	14
	6	15
	7	16
	8	17
	9	18
	10	19
	11	20
	12	21

if pphhsize = 1 and ppincimp le 4 FPL100 = 1.
if pphhsize = 2 and ppincimp le 5 FPL100 = 1.
if pphhsize = 3 and ppincimp le 6 FPL100 = 1.
if pphhsize = 4 and ppincimp le 7 FPL100 = 1.
if pphhsize = 5 and ppincimp le 8 FPL100 = 1.
if pphhsize = 6 and ppincimp le 9 FPL100 = 1.
if pphhsize = 7 and ppincimp le 10 FPL100 = 1.
if pphhsize = 8 and ppincimp le 10 FPL100 = 1.
if pphhsize = 9 and ppincimp le 11 FPL100 = 1.
if pphhsize = 10 and ppincimp le 11 FPL100 = 1.
if pphhsize = 11 and ppincimp le 12 FPL100 = 1.
if pphhsize = 12 and ppincimp le 12 FPL100 = 1.
if pphhsize = 13 and ppincimp le 12 FPL100 = 1.
if pphhsize = 14 and ppincimp le 13 FPL100 = 1.
if pphhsize = 15 and ppincimp le 13 FPL100 = 1.
if pphhsize = 16 and ppincimp le 13 FPL100 = 1.

if pphhsize = 1 and ppstaten = 94 and ppincimp le 5 FPL100 = 1.
if pphhsize = 2 and ppstaten = 94 and ppincimp le 6 FPL100 = 1.
if pphhsize = 3 and ppstaten = 94 and ppincimp le 7 FPL100 = 1.
if pphhsize = 4 and ppstaten = 94 and ppincimp le 9 FPL100 = 1.
if pphhsize = 5 and ppstaten = 94 and ppincimp le 10 FPL100 = 1.
if pphhsize = 6 and ppstaten = 94 and ppincimp le 10 FPL100 = 1.
if pphhsize = 7 and ppstaten = 94 and ppincimp le 11 FPL100 = 1.
if pphhsize = 8 and ppstaten = 94 and ppincimp le 12 FPL100 = 1.
if pphhsize = 9 and ppstaten = 94 and ppincimp le 12 FPL100 = 1.
if pphhsize = 10 and ppstaten = 94 and ppincimp le 12 FPL100 = 1.
if pphhsize = 11 and ppstaten = 94 and ppincimp le 13 FPL100 = 1.
if pphhsize = 12 and ppstaten = 94 and ppincimp le 13 FPL100 = 1.
if pphhsize = 13 and ppstaten = 94 and ppincimp le 14 FPL100 = 1.
if pphhsize = 14 and ppstaten = 94 and ppincimp le 14 FPL100 = 1.
if pphhsize = 15 and ppstaten = 94 and ppincimp le 15 FPL100 = 1.
if pphhsize = 16 and ppstaten = 94 and ppincimp le 15 FPL100 = 1.

if pphhsize = 1 and ppstaten = 95 and ppincimp le 5 FPL100 = 1.
if pphhsize = 2 and ppstaten = 95 and ppincimp le 6 FPL100 = 1.
if pphhsize = 3 and ppstaten = 95 and ppincimp le 7 FPL100 = 1.
if pphhsize = 4 and ppstaten = 95 and ppincimp le 8 FPL100 = 1.
if pphhsize = 5 and ppstaten = 95 and ppincimp le 9 FPL100 = 1.
if pphhsize = 6 and ppstaten = 95 and ppincimp le 10 FPL100 = 1.
if pphhsize = 7 and ppstaten = 95 and ppincimp le 11 FPL100 = 1.
if pphhsize = 8 and ppstaten = 95 and ppincimp le 11 FPL100 = 1.
if pphhsize = 9 and ppstaten = 95 and ppincimp le 12 FPL100 = 1.
if pphhsize = 10 and ppstaten = 95 and ppincimp le 12 FPL100 = 1.
if pphhsize = 11 and ppstaten = 95 and ppincimp le 12 FPL100 = 1.

if pphhsize = 12 and ppstaten = 95 and ppincimp le 13 FPL100 = 1.
if pphhsize = 13 and ppstaten = 95 and ppincimp le 13 FPL100 = 1.
if pphhsize = 14 and ppstaten = 95 and ppincimp le 14 FPL100 = 1.
if pphhsize = 15 and ppstaten = 95 and ppincimp le 14 FPL100 = 1.
if pphhsize = 16 and ppstaten = 95 and ppincimp le 14 FPL100 = 1.

All else, FPL100=0.

SCRIPTER: IF XRIDE=2 AND FPL100=0, TERMINATE AND INSERT STANDARD CLOSE.

Main survey

Base: all respondents

SCRIPTER: Split sample survey into two groups. Split sample xride=1 and 2 separately. Create DOV:

SPLIT_SAMPLE
1 = Ballot 1
2 = Ballot 2
3 = Ballot 3

Each question will be asked to all respondents Ballot 1, 2 and 3unless specified in base logic.

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)

[DISPLAY 1]
Thank you for participating in this survey about how you get from place to place. The goal of this study is to understand people's experiences with transportation and how these experiences shape their daily lives. We'll start off by asking some questions about the focus of this survey: transportation.

Base: (SPLIT_SAMPLE=1 and 2)

Q2 [S per statement] [ACCORDION GRID]
How often do you use each of the following to get from place to place? If the type of transportation is not available to you, please select "Not available to me."

Statements in rows:
1. Walking
2. Biking
3. Riding a motorcycle or moped
4. Your own personal vehicle (e.g., car, truck, SUV)
5. Borrowing the personal vehicle of a friend, family member, neighbor, coworker, or acquaintance
6. Getting a ride from a friend, family member, neighbor, coworker, or acquaintance (including carpooling)
7. Taking a taxi service or rideshare (e.g., Uber, Lyft)
8. Using a rental car or car sharing service (e.g., zipcar, Car2go)
9. Taking the bus
10. Taking the train or subway
11. Using paratransit (that is, specialized, door-to-door transport service for people with disabilities)

Statements in columns:
1. Daily
2. A few times a week
3. A few times a month
4. A few times a year
5. Never
6. Not available to me

Base: ask if SPLIT_SAMPLE=1 (Ballot 1)

Q3 [S]

To get to the places they need to go, people might walk, bike, take a bus, train or taxi, drive a car, or get a ride. In the past 30 days, how often did you have to reschedule an appointment because of a problem with transportation?

1. Often
2. Sometimes
3. Never

Base: all respondents (SPLIT SAMPLE=1 and 2 and 3)

Q4 [S]

[If SPLIT_SAMPLE=1 and 2: To get to the places they need to go, people might walk, bike, take a bus, train or taxi, drive a car, or get a ride.] In the past 30 days, how often did you skip going somewhere because of a problem with transportation?

1. Often
2. Sometimes
3. Never

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)

Q5 [S]

In the past 30 days, how often were you not able to leave the house when you wanted to because of a problem with transportation?

1. Often
2. Sometimes
3. Never

Base: ask if SPLIT_SAMPLE=1 (Ballot 1)

Q6 [S]

In the past 30 days, how often did you feel bad because you did not have the transportation you needed?

1. Often
2. Sometimes
3. Never

Base: ask if SPLIT_SAMPLE=1 (Ballot 1)

Q7 [S]

In the past 30 days, how often did you worry about inconveniencing your friends, family, or neighbors because you needed help with transportation?

1. Often
2. Sometimes
3. Never

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)

Q8 [S]

In the past 30 days, how often did problems with transportation affect your relationships with others?

1. Often
2. Sometimes
3. Never

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)

Q9 [S]
Do you or does anyone else in your household own or lease a car or other vehicle for personal use?

1. Yes
2. No

Base: ask if Q9=1 or refused
Q10 [NUMBOX, 0-50]
Altogether, how many vehicles are owned, leased, or available for regular use by the people who currently live in your household? Please be sure to include motorcycles and mopeds.

__ __ Number of vehicles

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q11 [S]
In general, how easy or difficult is it for you to get to the places you want or need to go?

1. Very easy
2. Somewhat easy
3. Neither easy nor difficult
4. Somewhat difficult
5. Very difficult

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q12 [O] [PROMPT]
Please describe how you get from place to place and any problems you have with transportation.

[LARGE TEXTBOX]

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
[DISPLAY2]
Next, we would like to know a bit about your health and wellbeing.

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q13 [S]
In general, how would you rate your health?

1. Excellent
2. Very good
3. Good
4. Fair
5. Poor

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q14 [S per statement] [ACCORDION GRID]
Below is a list of ways you might have felt or behaved recently. How often have you felt or behaved in each of the following ways **during the past week**?

Statements in row:
1. I did not feel like eating; my appetite was poor.
2. I had trouble keeping my mind on what I was doing.
3. I felt depressed.
4. I felt that everything I did was an effort.
5. My sleep was restless.
6. I felt sad.

7. I could not get “going.”

Statements in column:
1. Rarely or none of the time (less than 1 day)
2. Some or a little of the time (1-2 days)
3. Occasionally or a moderate amount of the time (3-4 days)
4. Most or all of the time (5-7 days)

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
[DISPLAY3]
The next questions are about whether you have difficulty with certain daily activities.

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q15 [S per statement] [BANKED GRID]

Statements in a row:
1. Do you have serious difficulty hearing?
2. Do you have serious difficulty seeing even when wearing glasses?
3. Do you have serious difficulty walking or climbing stairs?
4. Do you have difficulty dressing or bathing?

Statements in a column:
1. Yes
2. No

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q16 [S per statement] [BANKED GRID]
Because of a physical, mental, or emotional condition, do you have:

Statements in a row:
1. Serious difficulty concentrating, remembering, or making decisions?
2. Difficulty doing errands **ALONE** such as visiting a doctor's office or shopping?

Statements in a column:
1. Yes
2. No

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q17 [M]
Now a question about what you do. Are you…?

1. Working now
2. Only temporarily laid off, or on sick or parental leave
3. Looking for work, unemployed
4. Retired
5. Permanently or temporarily disabled
6. Keeping house
7. A student
8. Other (please specify) [O]

Base: all respondents (SPLIT_SAMPLE=1 and 2 and 3)
Q18 [S]
In the past 12 months, has lack of reliable transportation kept you from medical appointments, meetings, work or from getting things needed for daily living?

1. Yes
2. No

Base: ask if xppp20197=5 (missing)
QEG22 (S)
Are you a citizen of the United States?

1. Yes
2. No

SCRIPTER: Prompt following nonresponse.

Base: ask if QEG22=1 or xppp20198=5 (missing)
QEG23 [S]
Were you born a United States citizen or are you a naturalized U.S. citizen?

1. Born a U.S. citizen
2. Naturalized U.S. citizen

Show KP closing question QF1

Appendix B: Additional Data Collection Details and Sample Characteristics

Appendix Table 1. Survey data collection details

	Field Start	Field End	N Fielded	N Completed (%)	N Qualified (%)	Analytic Sample
2022	11/14/22	11/21/22	5701	2702 (47.4%)	2224 (82.0%)	2217
Ballot One (TSI16)					1101	1099
Ballot Two (TSI6)					1123	1118
2024	5/17/24	6/3/24	6081	3909 (64.3%)	3325 (85.1%)	3317
Ballot One (TSI6)						1110
Ballot Two (TSI3)						1090
Ballot Three (TSI3)						1117

Demographics preloaded from the panel include gender (male, female), race (Non-Hispanic White, Non-Hispanic Black, Hispanic, Non-Hispanic Other), marital status (currently married, collapsed other), age (25-39, 40-64, 65+), and education status (no high school diploma or GED, high school graduate, some college or Associate's degree, Bachelor's degree or higher).

Self-reported demographics include household vehicle status (whether anyone in household owns or lease car or other vehicle for personal use; yes, no) and household income (back-coded <$15k; $15k-$29,999; $30k-$49,999; $50k-$74,999; $75k or more).

Appendix Table 2. Weighted survey respondent characteristics

	2022	2024		
	Ballot Two (N=1,118)	Ballot One (N=1,110)	Ballot Two (N=1,090)	Combined (N=2,200)
Age				
25-39	27.6	28.5	28.9	28.7
40-64	48.6	46	46.6	46.3
65+	23.9	25.6	24.5	25.1
Gender (% male)	48.5	48.7	48.7	48.7
Race/Ethnicity				
White	63.5	62.5	62.8	62.6
Black	11.7	11.9	11.6	11.7
Hispanic	16.3	16.7	16.6	16.7
Other	8.6	9	9	9
Education				
Less than high school diploma	8.8	8.6	8.6	8.6
High school diploma	28.4	27.8	27.7	27.8
Some college	25.1	25.2	25.1	25.1
Bachelor's degree	37.7	38.5	38.6	38.5
Urbanicity (% rural)	13.3	13.3	13.6	13.5
Household income				
< $15,000	8.2	7.4	8	7.7
$15,000 - $29,999	7.1	6.9	7.5	7.2
$30,000 - $49,999	12.5	11.2	10.2	10.7
$50,000 - $74,999	16.5	15.6	15.7	15.7
$75,000 or more	55.7	59	58.5	58.7
Presence of personal vehicle in household[1]	74.1	74.3	77.9	76.1
Whether in fair or poor health[2]	16.0	15.5	15.3	15.4
Whether very depressed[3]	3.9	7.2	4.1	5.7

[1] Q21 (2022); Q9 (2024): Someone in household owns or leases car or other vehicle for personal use

[2] Q28 (2022); Q13 (2024)

[3] Q29_1 - Q29_7 (2022); Q14_1 - Q14_7 (2024)

Appendix C: Step-by-Step Instructions for Implementing the TSI-3 on Surveys

In this appendix, we provide step-by-step instructions for how the TSI-3 may be implemented in survey contexts. The guidance provided follows that pertaining to longer versions of the TSI, though identifying categories of insecurity is somewhat different (see McDonald-Lopez et al. (2023) and Murphy et al. (2024) for specific instructions on scoring those indices). For a specific illustration of implementation in action, that follows the steps laid out here, we encourage readers to refer to the 2025 White Paper "Transportation Insecurity in the Motor City." This paper draws on survey data representative of the City of Detroit that included the TSI-6 to demonstrate the utility of the TSI in understanding transportation insecurity in one Michigan local context.

Step 1: Add the TSI-3 to a survey questionnaire. In adding the TSI to a survey questionnaire, there are several things to keep in mind. First, the questions should appear in the order in which the index has been validated (see below). Second, the wording of the questions should not be altered (note: in the second question of the TSI the word "not" is bolded). Any such changes threaten the validity of the index. Third, the response options for each of the questions should remain: Often, Sometimes, Never.[iv] This enables the user to use the scoring method detailed below. Developers of the TSI developed a preamble that precedes the TSI which asks about mode use and frequency of mode use. This preamble was designed to prime respondents to think about all the many ways they may get around. A yet-to-be published analysis of responses with and without this preamble has shown that the use of this preamble does not affect the results generated by the TSI. Thus, this question can be omitted without harming the integrity of the tool.

In terms of where the TSI should be placed on a survey questionnaire, that is up to the discretion of the author. However, the author should be mindful to not place the TSI after questions that might be perceived as similar and thus priming. That is, if the author wishes to include questions such as "In the last 30 days, how often have you been satisfied with your transportation," such questions should come after the TSI, not before.

In addition to the TSI, survey questionnaires should include other questions of interest. For instance, if interested in the causes of transportation insecurity, questions pertaining to mode use and individual finances may be useful. If interested in how transportation insecurity differs across the population, questions pertaining to demographics should be included. If interested in the consequences of transportation insecurity, questions pertaining to outcomes of interest should be included (e.g. access to destinations, health outcomes, employment, experiences with food insecurity). To understand how the built environment shapes transportation insecurity, surveys that use the TSI will also want to collect the latitude and longitude of survey respondents.

Preamble to the TSI (Optional)
How often do you use each of the following to get from place to place? If the type of transportation is not available to you, please select "Not available to me."

Statements in rows:
1. Walking
2. Biking
3. Riding a motorcycle or moped
4. Your own personal vehicle (e.g., car, truck, SUV)
5. Borrowing the personal vehicle of a friend, family member, neighbor, coworker, or acquaintance
6. Getting a ride from a friend, family member, neighbor, coworker, or acquaintance (including carpooling)
7. Taking a taxi service or rideshare (e.g., Uber, Lyft)
8. Using a rental car or car sharing service (e.g., zipcar, Car2go)
9. Taking the bus
10. Taking the train or subway
11. Using paratransit (that is, specialized, door-to-door transport service for people with disabilities)

Statements in columns:
1. Daily
2. A few times a week
3. A few times a month
4. A few times a year
5. Never
6. Not available to me

Validated TSI-3 Question Ordering, Wording, and Response Options:

1. To get to the places they need to go, people might walk, bike, take a bus, train or taxi, drive a car, or get a ride. In the past 30 days, how often did you skip going somewhere because of a problem with transportation?

1. Often
2. Sometimes
3. Never

2. In the past 30 days, how often were you **not** able to leave the house when you wanted to because of a problem with transportation?

1. Often
2. Sometimes
3. Never

3. In the past 30 days, how often did problems with transportation affect your relationships with others?

1. Often
2. Sometimes
3. Never

Step 2: Scoring the TSI. Once the data has been collected, the TSI-3 needs to be scored. To score the TSI, look at responses to the main questionnaire, assign each "never" response a score 0, each "sometimes" response a score of 1, and each "often" a score of 2.

For those interested in using the TSI-3 as a continuous variable, sum the scores to arrive at the respondent's continuous transportation insecurity score (0-6).

For those interested in using the TSI as a categorical measure, to assign the respondent to a transportation insecurity category, use the following scheme:

- Sum score 0-1: No insecurity/secure
- Sum score 2-6: Insecure

Note: to score the TSI, all items in TSI must be used. That is, any one individual item or any subset of items cannot be scored and used as a measure of transportation insecurity. Individual items can be examined for the responses on those items, but only the index in full can capture the latent construct: transportation insecurity.

Step 3: Analyzing survey data using the TSI. Once the TSI has been scored, the survey data can be analyzed in several different ways depending on the interest of the user. As an illustration, we refer readers to the White Paper "Transportation Insecurity in the Motor City" which illustrates the following:

- How the TSI can be used to generate prevalence estimates of transportation insecurity for a specific location.
- How individual items in the TSI can be used, and analyzed individually, to understand how respondents experience different symptoms of insecurity and how such responses may differ by the severity of their insecurity (i.e. category).
- How the TSI can be used, in conjunction with demographic data, to examine transportation insecurity by different demographic groups (i.e. age, income, employment status, disability, etc....).
- How the TSI can be used, in conjunction with mode use data, to examine how transportation insecurity is related to transportation access and mode use and how this may differ by the severity of a respondent's severity of insecurity.
- How the TSI can be used, in conjunction with the latitude and longitude of respondents, to examine how transportation insecurity is associated with features of the built environment, including physical proximity to public transit stops.

- How the TSI can be used, in conjunction with data on the costs associated with transportation, to examine how transportation insecurity is associated with various transportation-related costs (i.e. bus far, car insurance, car repairs, rideshare expenses, etc..) and how this may differ by the severity of a respondent's severity of insecurity. Such analyses can include whether transportation insecure residents forego certain costly expenses, such as car insurance, which may increase their insecurity.
- How the TSI can be used, in conjunction with public opinion data, to examine how perceptions and attitudes break down by transportation insecurity category. In this instance, respondents' satisfaction with their ability to get around was considered.

It is important to note that this illustration provides an example of how the TSI can be used for descriptive analysis. Again, depending on the project and design of data collection, the TSI can also be used in causal analysis frameworks, if, for example, deployed in a pre- and post-evaluation framework or if included in a longitudinal panel survey.

[i] As this project is a continuation of previous work developing and validating and abbreviating the Transportation Security Index, much of the material that appears in this report is drawn heavily from previously published work authored by the authors of this report. Specifically, this report draws on the writing and analyses that appears in the following papers (which we cite throughout the report where appropriate): Gould-Werth, Alix, Jamie Griffin, and Alexandra K. Murphy. 2018. "Developing a New Measure of Transportation Insecurity: An Exploratory Factor Analysis." Survey Practice 11, no. 2: 3706. McDonald-Lopez, Karina, Alexandra K. Murphy, Alix Gould-Werth, Jamie Griffin, Michael M. Bader, and Nicole Kovski. 2023. “Establishing Discrete Categories of Transportation Insecurity Using the Transportation Security Index” American Journal of Epidemiology, pp. 1-10. Murphy, Alexandra K., Alix Gould-Werth, and Jamie Griffin. 2021. “Validating the Sixteen Item Transportation Insecurity Index in a Nationally Representative Sample: A Confirmatory Factor Analysis” Survey Practice, 14:1. Murphy, Alexandra K. and Alix Gould-Werth. Spring 2021. “The Transportation Security Index: A New Measure to Deepen Our Understanding of the Relationship Between Transportation Insecurity and Poverty” ASA Section on Poverty and Inequality Newsletter. Murphy, Alexandra K., Karina McDonald-Lopez, Natasha Pilkauskas, and Alix Gould-Werth. 2022. "Transportation insecurity in the United States: A descriptive portrait." Socius, 8: 1-12. Murphy, Alexandra K., Alix Gould-Werth, and Jamie Griffin. 2024. “Using a Split-Ballot Design to Validate an Abbreviated Categorical Measurement Scale: An Illustration Using the Transportation Security Index.” Survey Practice 17.

[ii] Given that the relational symptom category includes symptoms that can be considered emotional, transportation insecurity could be considered to have three broad categories of symptoms: material, relational, and emotional.

[iii] In addition to surveys, the TSI may also be used in interviewing and focus group efforts. In these cases, the individual items can be an effective way to probe people’s transportation challenges and their experiences with the symptoms of transportation insecurity. Using these questions, respondents can then be scored so as to assess their experiences with different levels of severity of transportation insecurity.

[iv] Can the TSI be used in a survey grid format? We suspect that it can, but, as suggested by our recommended steps for future research, this has not been tested and validated.