VERMONT AGENCY OF TRANSPORTATION PAVEMENT CONDITION STUDY

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PREPARED FOR:
THE VERMONT AGENCY OF TRANSPORTATION

CONTENTS

List of Figures

List of Tables

List of Abbreviations

DMV	Department of Motor Vehicles
IRI	International Roughness Index
NHS	National Highway System
NRB	Nonresponse bias
VTrans	Vermont Agency of Transportation

1.0 EXECUTIVE SUMMARY

The purpose of this study is to gather feedback from the traveling public on the performance measures and targets that are used to guide decisions by the Vermont Agency of Transportation (VTrans) on the investment, timing and location of roadway paving projects. This study utilized an original smartphone app (programmed for both iPhones and Android devices) to gather 799 post-trip pavement condition ratings from 267 licensed Vermont drivers. Study participants were recruited through in-person intercepts at six DMV offices around the state. All 14 Vermont counties were represented in the study.

Significant findings include:

- Overall, study participants were quite positive about the current condition of Vermont roads. Approximately 70% indicated that the road segment of interest was at least in "acceptable" condition, and only 10% indicated that it was in "unacceptable" condition.
- Even road segments that were assigned low condition ratings by VTrans were generally deemed to be in reasonable condition by survey respondents. For example, 80% of segments that VTrans classified as being in "very poor" condition were rated as "good" or "fair" by survey respondents.
- Older respondents, infrequent drivers, and individuals driving cars and SUVs (as opposed to trucks) generally provided higher pavement acceptability and condition ratings.
- Survey respondents who had traveled over road segments that they considered to be in "poor" or "very poor" condition felt that the segments should be repaired relatively quickly. Nearly a quarter (23%) indicated that these segments should be repaired right away, while another 60% felt that they should at least be repaired within 1-2 years.
- The majority of respondents indicated that VTrans should have a target of no more than approximately 5% to 15% of roads in "very poor" condition, which is lower than VTrans' current target of 25%. Given the generally positive ratings provided by respondents, however, there is a mismatch between what respondents consider "very poor" and what VTrans classifies as "very poor." This mismatch leads to ambiguity in interpreting drivers' opinions regarding the 25% target. The fact that survey respondents rated only 3% of all segments as currently being in "very poor" condition indicates that VTrans is already exceeding its customers' targets of having approximately 5% to 15% of roads in "very poor" condition. These findings suggest if VTrans continues to manage to their current standard, they will likely continue to meet or exceed driver's standards for pavement quality in Vermont.
- VTrans uses several different engineering-based measures of road quality to develop its pavement condition ratings. These measures are all correlated with respondent acceptability, with higher acceptability ratings generally associated with higher average values for the indices.

Although other states have conducted studies where drivers were asked to rate pavement quality on specific road segments (e.g., Minnesota DOT 2015; Garvey, Pietrucha, and Poister 2003), this may be the first state-level study to use a real-time data collection app to gather data on drivers' perceptions of pavement conditions.

2.0   INTRODUCTION

This study was designed to gather feedback from the traveling public on the performance measures and targets that are used to guide decisions by the Vermont Agency of Transportation (VTrans) on the investment, timing and location of roadway paving projects.

In May 2016, the Vermont Agency of Transportation (VTrans) contracted RSG to conduct a real-time survey of Vermont drivers to learn about perceptions of pavement conditions. RSG subsequently developed a proprietary smartphone travel survey app ("rPlace") to implement the survey. The app requested that study participants complete a brief survey at the conclusion of any trip that covered specific, predesignated road segments. The survey asked the driver to rate the condition of the road segment, thus allowing for comparisons between respondents' pavement ratings and VTrans' pavement ratings.

The advantage of using the rPlace™ app for survey implementation was that it allowed for near real-time evaluations of road segments throughout the state. Traditional survey methods typically need to overcome challenges with recall error in obtaining respondent evaluations of pavement conditions. Although recall issues can potentially be addressed through trip diaries, these are burdensome for the respondent and require significant data entry and analysis effort. The rPlace app allowed for (1) automated identification of relevant trips (i.e., trips that included the predesignated road segments), (2) survey administration immediately following the conclusion of each trip, and (3) confirmation of the specific segment of road to be evaluated using an interactive route map.

This report begins with a description of the study methodology, including details related to survey design and implementation, participant recruitment, and the selection of road segments. We then present the detailed results of the analysis and conclude the report with a brief discussion.

3.0 METHODS

The pavement condition survey was administered via smartphone to a sample of adults possessing a valid Vermont driver's license. Study participants were recruited at six different Vermont DMV offices. Participants were asked to download and install the free rPlace app on their smartphone; the app then monitored the participant's driving trips for approximately two weeks. Every time the participant completed a driving trip that included at least one road segment from a set of predesignated segments located throughout the state, a notice would appear on the individual's phone requesting that they complete a survey about their driving experience on that segment.

This section of the report provides a detailed description of the study methodology, including the selection of road segments used in the survey, the development and testing of the survey itself, participant recruitment, and survey implementation.

3.1 | SELECTION OF ROAD SEGMENTS

The survey asks study participants to rate the condition of road segments over which they have recently driven. These segments are developed from a subset of the Vermont road network, focusing specifically on roads within the network that meet the following conditions:

- The road is a state road (city and town roads are excluded).
- The road is classified by customer service level as Tier 1 (national highway system (NHS) interstate), Tier 2 (NHS non-interstate), Tier 3 (regional corridor), or Tier 4 (local connector). Tier 5 roads are excluded.
- No construction is scheduled on the road in 2017.
- The road is included in the VTrans pavement condition database, which classifies pavement conditions by 0.1-mile segments.

The Vermont roadways meeting these conditions were divided into 1-mile (Tier 1 roads) and 0.5-mile (Tier 2, 3, and 4 roads) segments for use in the study (Table 1). Longer segments were used for Tier 1 roads due to significantly higher travel speeds on those roads. All road segments with consistent pavement conditions were included in the study. Consistency was defined using the ratings in the VTrans pavement conditions database. The condition of a segment was defined as consistent if (1) 80% of the segment had the same road condition in the database, and (2) the condition of the remaining 20% of the segment differed by no more than one category. Table 1 shows the number of segments included in the survey, by road class. The segments are well distributed throughout the state, with a large number of state highways included (Figure 1).

TABLE 1. CLASSIFICATION OF ROAD SEGMENTS INCLUDED IN STUDY

Classification	Segment Length (Miles)	Number of Segments	Number of Miles	Percentage of Miles
Tier 1	1.0	392	392.0	23%
Tier 2	0.5	420	210.0	12%
Tier 3	0.5	885	442.5	26%
Tier 4	0.5	1,310	655.0	39%

FIGURE 1. GEOGRAPHIC DISTRIBUTION OF ROAD SEGMENTS INCLUDED IN STUDY
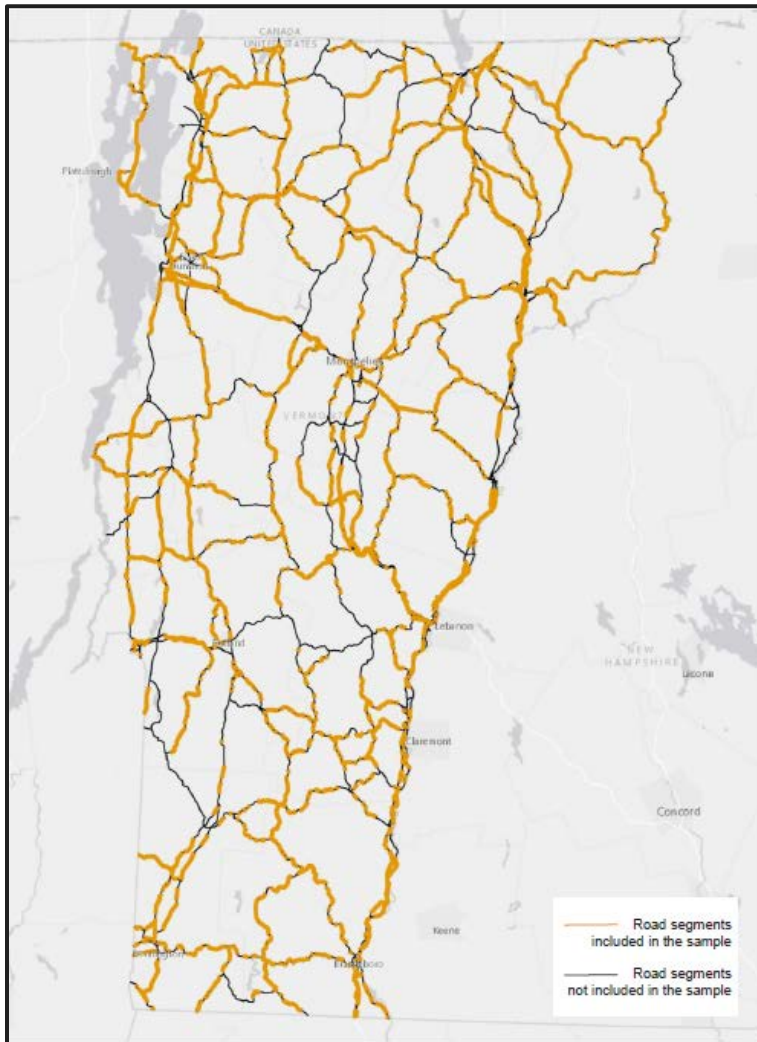
3.2 | SURVEY DEVELOPMENT AND PRETESTING

In February and March of 2016, four focus groups were conducted to gather information about the aspects of pavement conditions that are most important to Vermont drivers and to solicit feedback on potential approaches to implementing the road conditions survey. The focus groups took place in Manchester, Burlington, White River Junction, and Lyndonville, Vermont, and were moderated by RSG's Steve Lawson and Susie Irizarry. A total of 33 licensed adult drivers participated in these groups. Of the 33 participants, 24 were recruited via telephone from a sample of residential addresses in the U.S. Postal Service's Delivery Sequence File. The remaining nine participants were recruited by staff at regional planning commissions. Insights from the focus groups were used to help inform the development of the survey instrument (RSG, 2016).

The survey instrument was developed through a collaborative process between VTrans and RSG. An initial draft survey was developed by RSG. Comments from VTrans on this initial draft were incorporated in developing a revised draft suitable for programming and pretesting. Programmers at RSG then developed the rPlace app to implement the survey on both Android™ and iOS™

platforms. rPlace was designed to use device sensors, including the GPS, compass, Wi-Fi, and accelerometer, to passively collect travel data while running in the background on the device. The device's GPS location informed rPlace as to when to issue relevant surveys and data collected from the app was periodically sent to a secure server, minimizing any potential data loss.

A series of three field pretests were implemented to evaluate rPlace and identify any concerns with either the survey questions or the functionality of the app. In each round of testing, at least five RSG employees (working out of both the White River Junction and Burlington offices) installed and used the app over a period of several days. In the final round of testing, a few VTrans staff also installed and evaluated the app. Any problems identified during pretesting were communicated to the project team and addressed through modifications to the survey and to rPlace.

The final survey is reproduced through screen captures in Appendix A. The survey begins by confirming that the respondent drove on the road segment of interest. The respondent is given the option of viewing interactive maps of the specific road segment and of the overall trip to make this determination. After confirming that the respondent drove on the appropriate road segment, the survey asks a series of questions about the condition/acceptability of the segment, the frequency with which the respondent drives on the segment, the type of vehicle the respondent was driving, and the purpose of the trip. For the first survey that the respondent completes, additional questions are asked about the respondent's age, gender, driving experience, and opinion regarding the proportion of Vermont roads that should be in very poor condition. When the respondent rates a road segment as being in "poor" or "very poor" condition, the survey asks the respondent to indicate how long it is reasonable for the segment to remain in that condition (i.e., how quickly it should be repaired).

3.3 | PARTICIPANT RECRUITMENT

Study participants were recruited over a two-week period in September 2017 at the six Vermont DMV locations that have regular operating hours: Bennington, Montpelier, Newport, Rutland, Springfield, and South Burlington. Recruiting was conducted on five consecutive weekdays at each location (9/18/17 through 9/22/17 in Rutland, Springfield, and South Burlington; 9/25/17 through 9/29/17 in Bennington, Montpelier, and Newport), focusing on the hours of approximate peak visitor flow for the location as determined by DMV managers on site.

At each DMV location, RSG survey administrators recruited study participants in the waiting area using a "first-after-last" sampling approach. The first-after-last sampling approach involves contacting the first available visitor at the start of the sampling period, completing the recruitment process with that visitor, contacting the next available visitor, and so on throughout the entire sampling period. "Available visitors" were defined as visitors waiting for DMV assistance after checking in and completing necessary paperwork. Visitors were not recruited if they completed DMV business and departed while the survey administrators were speaking with another visitor.

The recruitment process involved greeting the visitor, describing the purpose of the study, then asking if they would be willing to participate. If the visitor was willing to participate, eligibility was established by confirming that the visitor (1) was 18 years old or older and (2) owned a smartphone with an Android™ or iOS™ operating system. Participants were offered a $10 Amazon e-gift card as a contingent incentive. They received the gift card if either (1) they completed at least three post-trip

surveys or (2) they were prompted to complete a post-trip survey fewer than three times and they completed every survey that they were prompted to complete. Upon agreeing to participate, the survey administrator walked the participant through the free app download process from the "App Store" (iOS™) or "Play Store" (Android™). A wireless internet device (i.e., a Verizon mobile hotspot) was provided at each DMV location for faster and easier downloads.[1] After the app was installed on the participant's phone, the survey administrator verbally guided the participant through the app, answered any questions, and provided an information sheet (Appendix B).

Of 1,567 visitors contacted by survey administrators, 707 were ineligible to participate because they did not have a smartphone available, could not remember their Apple ID to download rPlace, were under 18 years old, or did not have a driver's license. Of the remaining 860 eligible visitors contacted, 450 (52%) agreed to participate in the study. The participation rate at specific DMV locations generally ranged from 43% to 56%, except for Springfield, which had a participation rate of 80% (Table 2). These response rates are reasonable for intercept surveys conducted within a transportation context. For example, Schaller (2005) surveyed transit agencies throughout the U.S. regarding recently implemented customer surveys, finding that response rates for "the majority of on-board and intercept surveys ranged from 33% to 67%." The 52% response rate for the current study falls near the middle of this range, despite a general downward trend in survey response rates in recent decades (Groves 2007).

TABLE 2. PARTICIPATION RATE BY DMV LOCATION

Location	Total Eligible Contacts	Agreed to Participate	Refused to Participate	Participation Rate
Bennington	26	13	13	50%
Montpelier	117	105	12	48%
Newport	136	76	60	56%
Rutland	200	96	104	48%
Springfield	107	86	21	80%
South Burlington	174	74	100	43%
Total	860	450	410	52%

The potential for nonresponse bias was evaluated through a set of four brief "nonresponse bias" (NRB) questions posed to respondents and nonrespondents. Nonresponse bias can arise when individuals who refuse to participate in a survey differ systematically from individuals who agree to participate (Groves et al. 2004). The four NRB questions allow us to assess potential differences between respondents and nonrespondents. In general, concern about nonresponse bias is greater when differences between respondents and nonrespondents are larger. Suppose, for example, that younger drivers were more concerned about pavement quality than older drivers (i.e., provided lower ratings). If survey respondents tended to be much younger than nonrespondents, then estimates of drivers' perceptions of pavement quality based on the survey results would be biased downwards (i.e., towards lower ratings).

Survey administrators asked respondents the NRB questions while the rPlace app was downloading onto the participant's phone. They asked nonrespondents the NRB questions immediately after they

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[1] The Newport DMV location had internet problems through the sampling period. For this location, download instructions were printed on paper that participants could take home with them (see Appendix B).

indicated that they would not like to participate in the study. The following four questions are used for evaluation of nonresponse bias:

1. What type of vehicle do you typically drive; a motorcycle, scooter or moped, car or hatchback, SUV or van, pickup truck, box truck or semi, or some other type of vehicle?

2. For how many years have you been driving?

3. In general, what is the purpose of the majority of your trips? Is it commuting to and from work or school, running errands, recreation or leisure trips, or other trip purposes?

4. What is the ZIP Code of your primary Vermont residence?

In addition to these four questions, the survey administrator recorded the individual's gender. Responses to nonresponse bias questions are described in the Results section of the report.

3.4 | SURVEY IMPLEMENTATION

Once the rPlace app was installed and activated on the participant's phone, it remained active for a period of 7 to 12 days (through 9/29/17 for participants recruited at the Rutland, Springfield, and South Burlington DMV locations, and through 10/6/17 for participants recruited at the Bennington, Montpelier, and Newport DMV locations). During that period, rPlace tracked the participant's driving behavior. It prompted participants to complete a survey every time they had completed a trip that included one or more of the predesignated road segments and had safely stopped their vehicle. rPlace defined a vehicle "stop" as traveling less than 50 meters over a three-minute period. The survey began with a map that allowed the participant to verify the road segment of interest from among the road segments comprising their overall trip. The participant was then asked if he or she was the driver on the trip, and the survey terminated if the participant was not the driver. After verifying that the respondent drove over the road segment of interest, a series of survey questions was presented to the respondent. Upon completion of the survey, the data were automatically uploaded to RSG servers via Wi-Fi (if available) or the cellular network. The app allowed respondents to take the survey at any time within 18 hours of completing the trip.

In many cases, participants traveled over multiple road segments during a single trip. When this occurred, a single road segment was randomly selected for the survey, with the selection probability inversely proportional to the average annual daily traffic. This selection method was used to ensure that heavily-traveled road segments did not dominate the sample.

4.0   RESULTS

This section of the report describes the survey results. We begin by providing an overview of the survey respondents. We then summarize the trip surveys completed by these respondents, focusing on road segment condition and acceptability ratings. Finally, we compare the survey respondents' road condition ratings to engineering-based condition ratings assigned to road segments by VTrans.

4.1 | RESPONDENT CHARACTERISTICS

Of the 450 study participants recruited at Vermont DMV locations, 267 (or 59%) provided a condition rating for at least one road segment using the rPlace app. The remaining individuals either changed their mind and chose not to participate, did not drive over any of the preselected road segments during the survey implementation period, or were screened out during the initial post-trip survey questions.[2]

Survey respondents were quite diverse with respect to geographic location, age, gender, driving experience, and type of smartphone used. Residents of all 14 Vermont counties were represented in the study, with over half of the respondents living in Rutland (20%), Windsor (18%), Washington (13%), and Chittenden (13%) counties (Table 3). The age of respondents ranged from 18 to 83, with an average of 40 years old. Younger drivers were somewhat overrepresented relative to the licensed driver population, as one would expect given that younger drivers are more likely to own smartphones and to feel comfortable installing and using a smartphone app. The gender of respondents approximately reflects the 50-50 male/female split within the licensed driver population. The majority of respondents have at least 20 years of driving experience and over 85% drive more than six hours in a typical week (Table 4). Approximately 58% of the respondents used an iPhone to participate in the study, with the remaining 42% participating on an Android device.

TABLE 3. COMPARISON OF SURVEY RESPONDENTS TO LICENSED VERMONT DRIVERS

		Study Participants		Licensed Vermont Drivers	
		Number	**Percent**	**Number**	**Percent**
County					
Rutland		53	20%	46,874	8%
Windsor		48	18%	45,873	8%
Washington		36	13%	44,815	8%
Chittenden		34	13%	130,008	23%
Orleans		15	6%	20,685	4%
Orange		24	5%	21,944	4%
Windham		12	4%	32,956	6%
Caledonia		12	4%	22,453	4%
Addison		8	3%	27,795	5%
Lamoille		8	3%	19,238	3%
Bennington		5	2%	29,078	5%
Grand Isle		4	2%	6,107	1%
Franklin		3	1%	30,476	6%
Essex		3	1%	4,955	1%
Unknown		12	4%	69,972	13%
	Total	**266**	**100%**	**553,229**	**100%**

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[2] Participants were screened out if either (1) they were vehicle passengers rather than drivers when they drove over the segment or (2) they indicated that they did not drive over the entirety of the segment.

	Study Participants		Licensed Vermont Drivers	
	Number	Percent	Number	Percent
Age				
18 to 24 years	33	12%	47,453	9%
25 to 34 years	72	27%	95,322	17%
35 to 44 years	52	20%	86,179	16%
45 to 54 years	58	22%	92,853	17%
55 to 64 years	38	14%	103,894	19%
65 years or more	13	5%	127,528	23%
Total	**266**	**100%**	**553,229**	**100%**
Gender				
Male	126	47%	275,187	49.7%
Female	136	51%	278,042	50.3%
I'd rather not say	4	2%	N/A	N/A
Total	**266**	**100%**	**553,229**	**100%**

TABLE 4. DRIVING FREQUENCY OF SURVEY RESPONDENTS

Weekly Driving Hours	Number	Percent
6 or less	37	14%
7 to 13	106	40%
14 to 20	76	29%
21 to 27	14	5%
28 to 34	8	3%
35 or more	25	9%
Total	**266**	**100%**

Responses to NRB questions that were posed to both respondents and nonrespondents during the participant recruitment process are summarized in Table 5. We do not summarize zip code responses in Table 5 given that we have zip code data for the entire population of licensed drivers (summarized in Table 3). Overall, the types of vehicles typically used by respondents are similar to the types typically used by nonrespondents. The typical trip purposes are also similar between respondents and nonrespondents. The two groups differ with respect to driving experience, although this is expected given that younger respondents were generally more willing to participate in the study (Table 3). Finally, men were less likely to respond than women, but there were more men than women at the recruitment locations and the male/female split for respondents was ultimately relatively even.

**TABLE 5. COMPARISON OF RESPONDENTS TO NONRESPONDENTS**

	Respondents		Nonrespondents	
	Number	Percent	Number	Percent
Vehicle Type				
Motorcycle, scooter, or moped	8	2%	5	1%
Car or hatchback	226	51%	423	52%
SUV, van, or pickup truck	203	45%	366	45%
Box truck or semi	7	2%	6	1%
Other or multiple types selected	3	1%	12	1%
Motorcycle, scooter, or moped	8	2%	5	1%
Total	**447**	**100%**	**812**	**100%**
Trip Purpose				
Commuting to/from work or school	333	74%	544	69%
Errands	76	17%	172	22%
Recreation	31	7%	67	8%
Other	7	2%	11	1%
Total	**447**	**100%**	**794**	**100%**

	Respondents		Nonrespondents	
	Number	Percent	Number	Percent
Driving Experience				
20 or less years of driving experience	226	51%	238	30%
21 – 40 years of driving experience	175	39%	309	39%
41 or more years of driving experience	46	10%	253	32%
Total	**447**	**100%**	**800**	**100%**
Gender (Observed)				
Male	222	50%	604	55%
Female	225	50%	498	45%
Total	**447**	**100%**	**1,102**	**100%**

4.2 | TRIP CHARACTERISTICS

The 267 active study participants were prompted to complete 2,287 trip surveys during the two-week study period. A total of 799 trip surveys were ultimately completed, or an average of approximately three completed trip surveys per participant (3.0 = 799/267).[3] Figure 2 shows the number of trip surveys completed by the 267 participants. The road segments that were the focus of these surveys were approximately equally split between National Highway System (NHS) roads (49%) and non-NHS roads (51%). Just over half of the segments were classified by VTrans as being in "good" (37%) or "fair" (21%) condition, with the remainder classified as being in "poor" (27%) or "very poor" (15%) condition (Table 6).

FIGURE 2. NUMBER OF SURVEYS COMPLETED BY STUDY PARTICIPANTS

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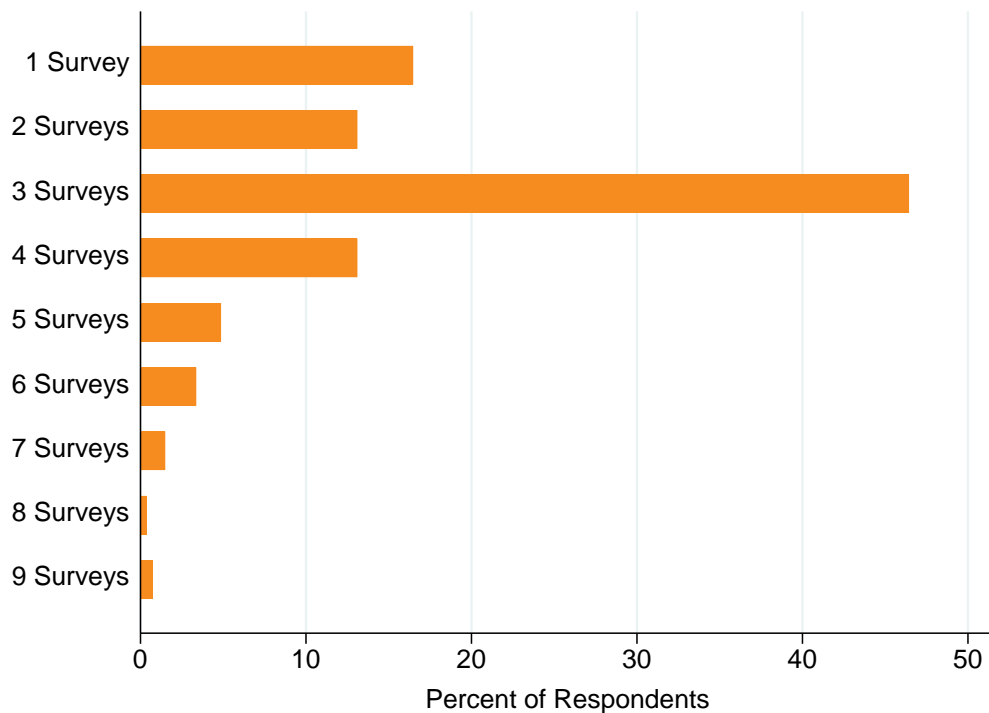
[3] The average of three completions per participant is clearly linked to the requirement that three surveys be completed to qualify for the $10 incentive. Nearly half of the respondents completed exactly three surveys.

TABLE 6. VTRANS CLASSIFICATION OF ROAD SEGMENTS SELECTED FOR SURVEYS

VTrans Classification	Number	Percent
Good	299	37%
Fair	167	21%
Poor	215	27%
Very Poor	118	15%
Total	**799**	**100%**

Of the 799 trips characterized through the surveys, 32% were commuting trips (to work or school), 40% were trips that involved running errands, 22% were recreation or leisure trips, and 6% were trips taken for some other purpose (Table 7). The trips were completed primarily in cars (50% of trips), SUVs (29%) or pickup trucks (18%) (Table 8). Respondents were generally familiar with the road segment they were asked to assess, with 64% indicating they traveled on the segment "very frequently" or "frequently." Only 3% of respondents indicated that the segment they were asked to assess was slick or wet when they drove over it.

TABLE 7. TRIP PURPOSE

Purpose	Number	Percent
Commuting to Work or School	253	32%
Running Errands	321	40%
Recreation or Leisure	173	22%
Other	49	6%
Total	**796**	**100%**

TABLE 8. VEHICLE USED ON TRIP

| Vehicle	Number	Percent
Motorcycle/Scooter/Moped	13	2%
Car	394	50%
SUV	227	29%
Pickup Truck	144	18%
Box Truck or Semi	13	2%
Other	5	1%
Total	**796**	**100%**

4.3 | PAVEMENT CONDITION RATINGS

Two survey questions asked the respondent to evaluate the pavement condition on the road segment over which they recently drove. The first asked the respondent to rate the condition on a four-level scale (good, fair, poor, or very poor), while the second asked the respondent to evaluate the acceptability of the segment on a five-level scale (very acceptable, acceptable, neutral, unacceptable, or very unacceptable). Overall, respondents reported that they were satisfied with the condition of the road segments, with 53% providing a rating of "good," 34% providing a rating of "fair," 10% providing a rating of "poor," and only 3% providing a rating of "very poor" (Figure 3). Similar results were obtained for acceptability, with 70% selecting "very acceptable" or "acceptable," only 10% selecting "very unacceptable" or "unacceptable," and 21% selecting a "neutral" response (Figure 4).

FIGURE 3. RESPONDENT RATING OF PAVEMENT CONDITION
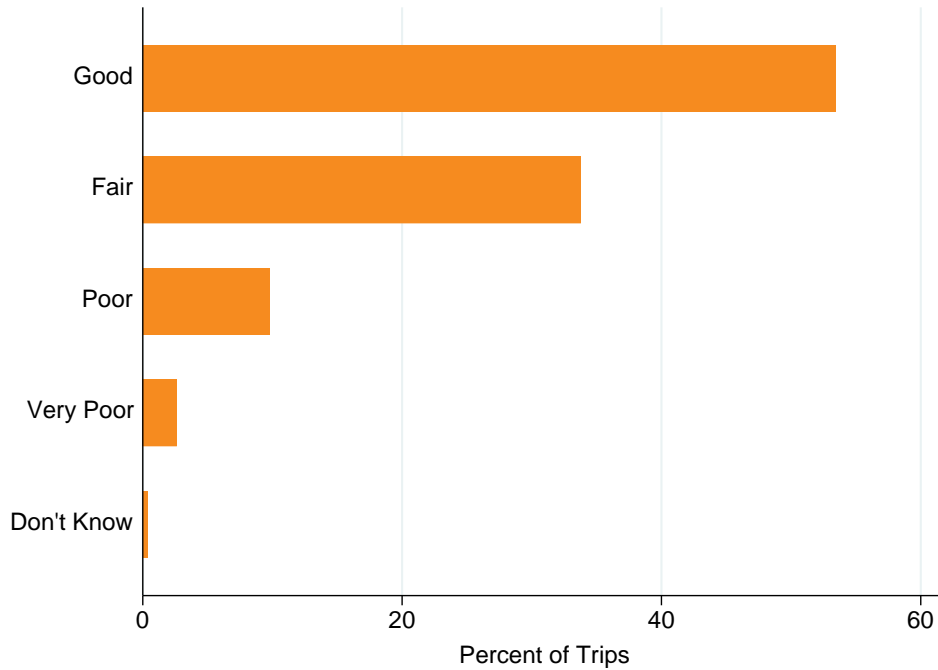
FIGURE 4. RESPONDENT ACCEPTABILITY OF PAVEMENT CONDITION
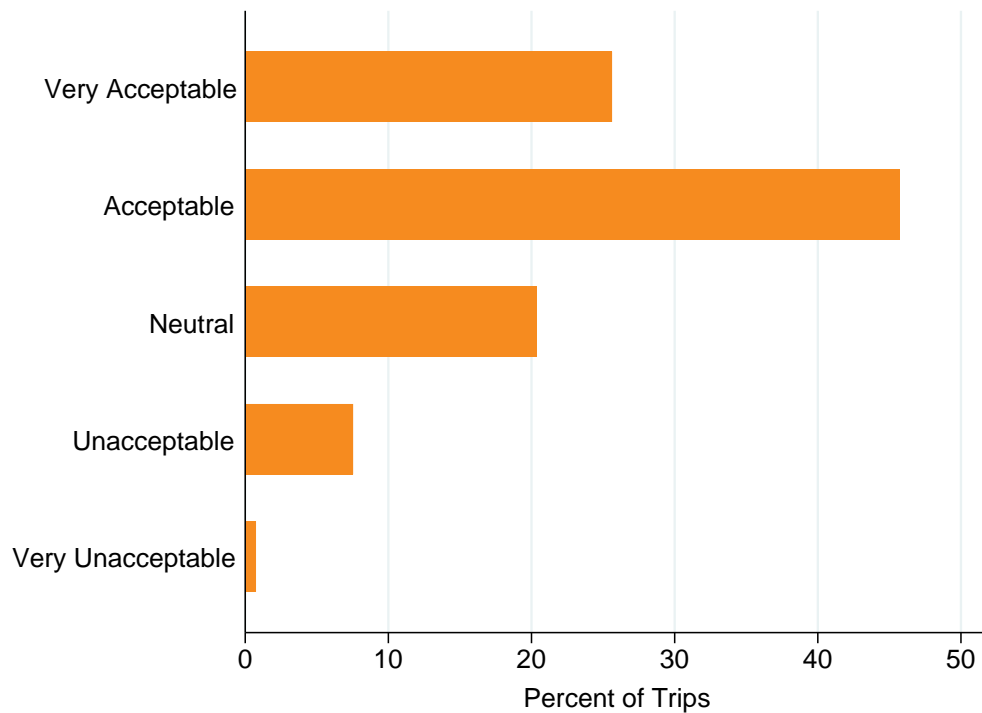
A comparison of the condition evaluation and acceptability ratings indicates that the two questions generally provide information about the same underlying construct, with the acceptability rating providing somewhat greater resolution than the condition rating (Table 9). Specifically, 99% of respondents who rated the segment as "good" provided an acceptability rating of "very acceptable" or "acceptable," 94% of the respondents who rated the segment "fair" provided an acceptability rating of "acceptable" or "neutral," 94% of the respondents who rated the segment as "poor" provided an acceptability rating of "neutral" or "unacceptable," and 100% of the respondents who rated the segment as "very poor" provided an acceptability rating of "unacceptable" or "very unacceptable." Given this close correspondence between condition rating and acceptability, we focus primarily on acceptability in the remainder of the report to avoid unnecessary duplication.

TABLE 9. CONDITION RATING VERSUS ACCEPTABILITY

Condition Rating	Acceptability Rating					Total
	Very Acceptable	Acceptable	Neutral	Unacceptable	Very Unacceptable	
Good	48%	51%	1%	0%	0%	**100%**
Fair	1%	50%	44%	5%	0%	**100%**
Poor	0%	5%	52%	42%	0%	**100%**
Very Poor	0%	0%	0%	76%	24%	**100%**

The respondent acceptability ratings were generally somewhat higher for road segments within the NHS (i.e., Tier 1 or Tier 2 road segments). Among NHS road segments, only 5% were classified as "unacceptable" or "very unacceptable" versus 11% for non-NHS road segments (i.e., Tier 3 or Tier 4 road segments) (Table 10). Similarly, 77% of NHS road segments were classified by respondents as "acceptable" or "very acceptable" versus 66% of non-NHS road segments.

TABLE 10. ACCEPTABILITY OF NHS ROAD SEGMENTS VERSUS NON-NHS ROAD SEGMENTS

Acceptability	NHS		Non-NHS	
	Number	Percent	Number	Percent
Very Acceptable	105	27%	99	25%
Acceptable	196	50%	168	42%
Neutral	70	18%	92	23%
Unacceptable	19	5%	41	10%
Very Unacceptable	2	1%	4	1%
Total	**392**	**100%**	**404**	**100%**

The relationship between pavement acceptability ratings and respondent/trip characteristics is explored in Table 11 and Table 12. It appears that women, older respondents, and individuals who drive infrequently provide somewhat higher acceptability ratings. In addition, respondents who were commuting, who were traveling in cars and SUVs (rather than trucks), and who drove very frequently on the road segment provided higher acceptability ratings. It is important to note, however, that these comparisons focus on only one characteristic at a time. For example, the gender comparison ignores the respondent's age, driving frequency, trip purpose, and vehicle type.

TABLE 11. RESPONDENT CHARACTERISTICS VERSUS PAVEMENT ACCEPTABILITY RATINGS

	Very Acceptable	Acceptable	Neutral	Unacceptable	Very Unacceptable	Total
Gender						
Male	26%	39%	23%	11%	1%	**100%**
Female	26%	50%	17%	6%	1%	**100%**
Age Group						
18 to 24 years	18%	37%	38%	7%	1%	**100%**
25 to 34 years	25%	43%	24%	8%	0%	**100%**
35 to 44 years	21%	48%	18%	12%	2%	**100%**
45 to 54 years	27%	46%	17%	9%	0%	**100%**
55 to 64 years	32%	51%	9%	8%	0%	**100%**
65 years or more	45%	32%	13%	9%	0%	**100%**
Hours Driven per Week						
6 hours or less	35%	42%	20%	2%	1%	**100%**
7-13 hours	25%	42%	23%	8%	1%	**100%**
14-20 hours	26%	50%	17%	7%	1%	**100%**
21 hours or more	20%	43%	20%	17%	0%	**100%**

TABLE 12. TRIP CHARACTERISTICS VERSUS PAVEMENT ACCEPTABILITY RATINGS

	Very Acceptable	Acceptable	Neutral	Unacceptable	Very Unacceptable	Total
Trip Purpose						
Commuting	32%	43%	13%	12%	0%	**100%**
Running errands	20%	46%	25%	7%	1%	**100%**
Recreation or leisure	25%	44%	23%	7%	1%	**100%**
Vehicle Type						
Car	27%	45%	21%	7%	0%	**100%**
SUV/Van	29%	48%	16%	6%	1%	**100%**
Truck	21%	39%	24%	16%	1%	**100%**
Driving Frequency on Road Segment						
Very frequently	36%	40%	12%	12%	0%	**100%**
Frequently	19%	48%	23%	8%	2%	**100%**
Occasionally	23%	49%	23%	4%	1%	**100%**
Rarely	10%	40%	40%	11%	0%	**100%**

The relationship between VTrans pavement condition ratings and survey respondents' acceptability ratings is summarized in Table 13. There appears to be only a modest decrease in acceptability ratings as VTrans ratings decline. In the case of road segments that VTrans classifies as "good," approximately 77% of respondents considered these segments to be "acceptable" or "very acceptable." This percentage declines to 72% for road segments that VTrans classified as "fair," 58% for road segments VTrans classifies as "poor," and 57% for road segments VTrans classifies as "very poor." Overall, very few respondents considered segments to be unacceptable, regardless of the VTrans condition rating. For example, only 17% of respondents considered segments that VTrans rated as "very poor" to be unacceptable and only 13% of respondents considered segments that VTrans rated as "poor" to be unacceptable.

TABLE 13. VTRANS RATING VERSUS RESPONDENT ACCEPTABILITY RATING

VTrans Rating	Respondent Acceptability Rating					Total
	Very Acceptable	Acceptable	Neutral	Unacceptable	Very Unacceptable	
Good (n = 296)	29%	48%	15%	7%	0%	**100%**
Fair (n = 167)	25%	47%	22%	6%	1%	**100%**
Poor (n = 215)	18%	40%	30%	11%	2%	**100%**
Very Poor (n = 118)	28%	29%	26%	16%	1%	**100%**

An analogous comparison of VTrans pavement condition ratings and survey respondents' pavement condition ratings is presented in Table 14. There is a modest decrease in respondent condition ratings as the VTrans ratings decline from "good" to "very poor." Overall, survey respondents' condition ratings were much more positive than the ratings provided by VTrans: regardless of the VTrans condition rating, fewer than one quarter of respondents classified pavement conditions as "poor" or "very poor." Even for the subset of segments that VTrans rated as "very poor," for example, 80% of respondents rated the segments as "fair" or "good."

TABLE 14. VTRANS RATING VERSUS RESPONDENT RATING

VTrans Rating	Respondent Rating				Total
	Good	Fair	Poor	Very Poor	
Good (n = 296)	63%	27%	8%	2%	**100%**
Fair (n = 167)	56%	36%	7%	2%	**100%**
Poor (n = 215)	46%	39%	10%	5%	**100%**
Very Poor (n = 118)	41%	39%	18%	3%	**100%**

When respondents rated a road segment as "poor" or "very poor," they were asked what they felt was a reasonable timeframe for repairing the segment. The question wording was as follows:

> *You rated the pavement condition of the red highlighted section of road as Poor/Very Poor. Given that transportation funding is limited, how long is it reasonable for the pavement on the red highlighted section of road to remain in Poor condition?*

Sixty percent of respondents felt that a 1- to 2-year repair timeframe (but not longer) would be reasonable, although 23% felt that the segment should be repaired right away (Table 15).

TABLE 15. RESPONDENTS' OPINIONS REGARDING REASONABLE TIMEFRAME FOR REPAIRING ROADS IN POOR OR VERY POOR CONDITION

Timeframe	Number	Percent
Right away	23	23%
1-2 years, but not longer	59	60%
3-4 years, but not longer	12	12%
5-6 years, but not longer	3	3%
7-9 years, but not longer	2	2%
10 or more years	0	0%
Total	**99**	**100%**

Finally, respondents were asked to indicate what percentage of Vermont roads they felt it would be reasonable to have in "very poor" condition. The wording of the question is as follows:

> *Given that transportation funding is limited, it is inevitable that some Vermont roads will have Very Poor pavement condition. Vermont's current target is no more than 25% of roads in Very Poor condition. What do you think is the maximum percentage of roads that is reasonable for Vermont to have in Very Poor condition?*

Approximately 27% of respondents indicated that target should remain at 25% of roads (Table 16). However, the majority of respondents preferred a target that is more aggressive, with 16% preferring a target of 5% of roads and 42% preferring a target of 15% of roads. Only 15% of respondents indicated that the target should be more relaxed, at 35% or 50% of roads. Note, however, that these targets are linked to what *respondents'* consider to be "poor" and "very poor" roads. Given that respondents' condition ratings were generally much better than VTrans' condition ratings, roads that respondents' classified as "poor" or "very poor" were likely in very bad condition.

TABLE 16. RESPONDENTS' OPINIONS REGARDING THE MAXIMUM PERCENTAGE OF ROADS THAT SHOULD BE IN VERY POOR CONDITION

Maximum Percentage of Roads	Number	Percent
5% or less	42	16%
15% or less	112	42%
25% or less	72	27%
35% or less	20	8%
50% or less	18	7%
Other	2	1%
Total	**266**	**100%**

4.4 | RESPONDENT RATINGS VERSUS VTRANS CONDITION INDICES

This section of the report explores the relationship between segment characteristics and respondent acceptability ratings. The following objective measures of pavement condition are incorporated in the analysis:[4] For all of these indices, a higher number reflects better pavement conditions.

- IRI Index: a measure of roughness obtained from longitudinal road profiles (international roughness index).
- RUT Index: a measure of the severity of longitudinal depressions in the wheel paths.
- STRC Index: a measure of longitudinal cracking (parallel to the direction of travel).

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[4] The VTrans Comp Index was not evaluated, as it is calculated as a function of these four underlying indices. The raw IRI and RUT values were also analyzed, and the results were qualitatively similar to results associated with the corresponding index.

- TRAN Index: a measure of transverse cracking (perpendicular to the direction of travel).

An indication of the strength of the relationship between these four objective ratings and respondent acceptability is obtained by calculating the mean value of the objective rating across the five acceptability categories. These mean values are graphed in Figure 5, with the "very unacceptable" category combined with the "acceptable" category due to a small sample size (only six respondents classified a segment as "very unacceptable").

There is a general trend across all indices towards higher average index values as the respondent acceptability rating increases. The largest increase is associated with the IRI Index, which has a mean value of 51.4 for respondents providing a "very unacceptable" or "unacceptable" rating and a mean value of 68.9 for respondents providing a "very acceptable" rating.

FIGURE 5. AVERAGE PAVEMENT CONDITION INDEX VALUES BY RESPONDENT ACCEPTABILITY RATING
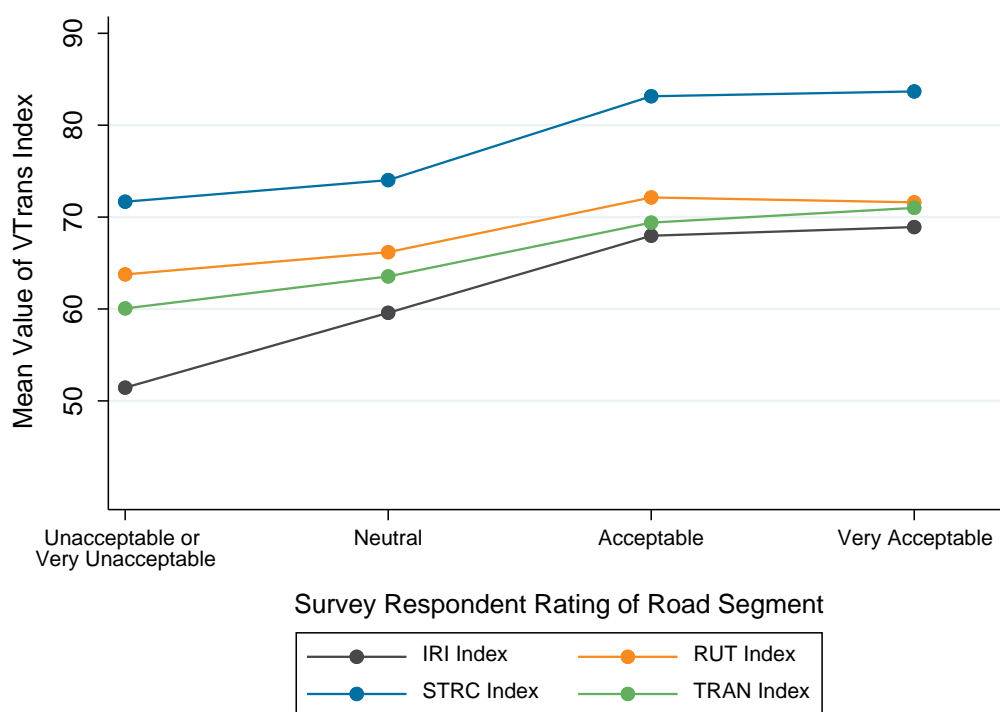
An alternative approach to analyzing the relationship between respondents' ratings and VTrans ratings is to group road segments by VTrans condition rating (e.g., 0-20, 20-40, 40-60, 60-80, and 80-100) and calculate the percentage of respondents finding a segment "acceptable" or "very acceptable" within each group. Figure 6 shows the results of this analysis for the four different indices. As expected, the proportion of respondents classifying a road segment as "acceptable" or "very acceptable" generally increases with the value of each of the indices. The increase is most pronounced for the IRI and RUT indices and less pronounced for the STRC and TRAN indices. Acceptability does not always consistently increase with the value of each index, but occasional inconsistencies are to be expected given small sample sizes within some index ranges (see Appendix C for graphs with confidence intervals).

FIGURE 6. PERCENT ACCEPTABLE BY PAVEMENT CONDITION INDEX
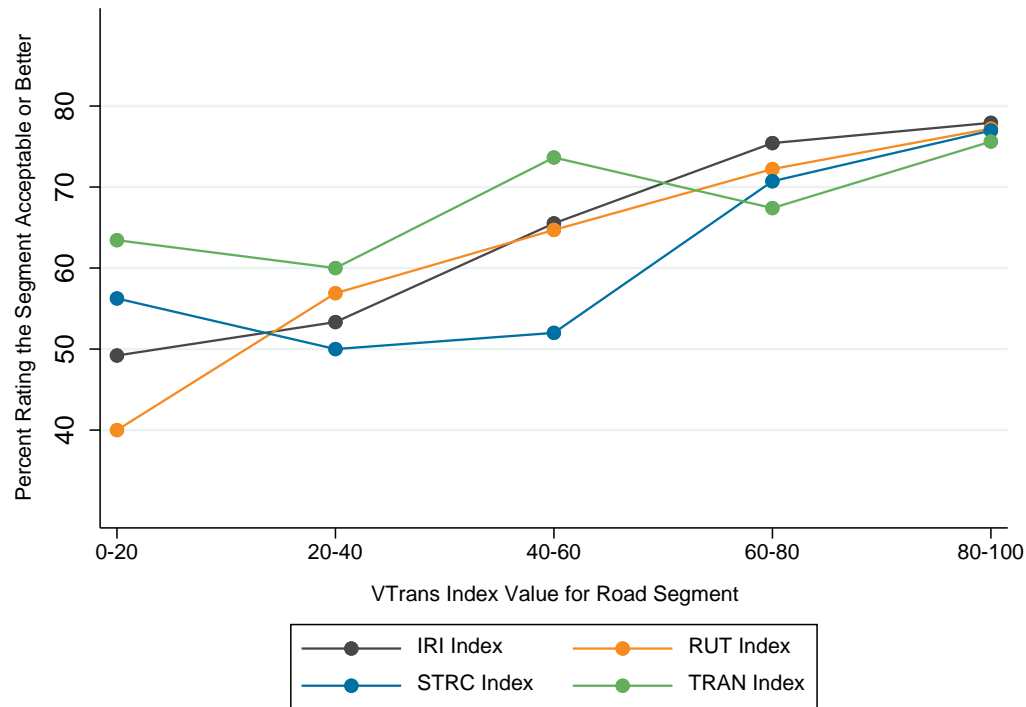
Finally, the relationship between the IRI index and driver acceptability is examined by converting the acceptability ratings into integer values (very unacceptable = -2, unacceptable = -1, neutral = 0, acceptable = 1, and very acceptable = 2) and plotting mean acceptability against the IRI index (Figure 7).[5] This component of the analysis focuses on a single index (IRI) given that all four indices displayed a similar relationship to respondent acceptability ratings (see Figure 5). While mean acceptability declines as pavement conditions decline, the decline is relatively gradual, and mean acceptability never dips below zero. This flat acceptability curve is consistent with the results presented earlier, and it indicates that respondents are not particularly sensitive to pavement conditions across the range of pavement conditions they evaluated in this study.

[5] Converting the acceptability responses to integer values requires that we assume the magnitude of the difference between each acceptability category is identical. That is, the difference between "very unacceptable" and "acceptable" is assumed to be the same as the difference between "acceptable" and "neutral," etc. In addition, acceptability is treated as a continuous variable when calculating the 95% confidence intervals.

FIGURE 7. MEAN ACCEPTABILITY BY IRI INDEX
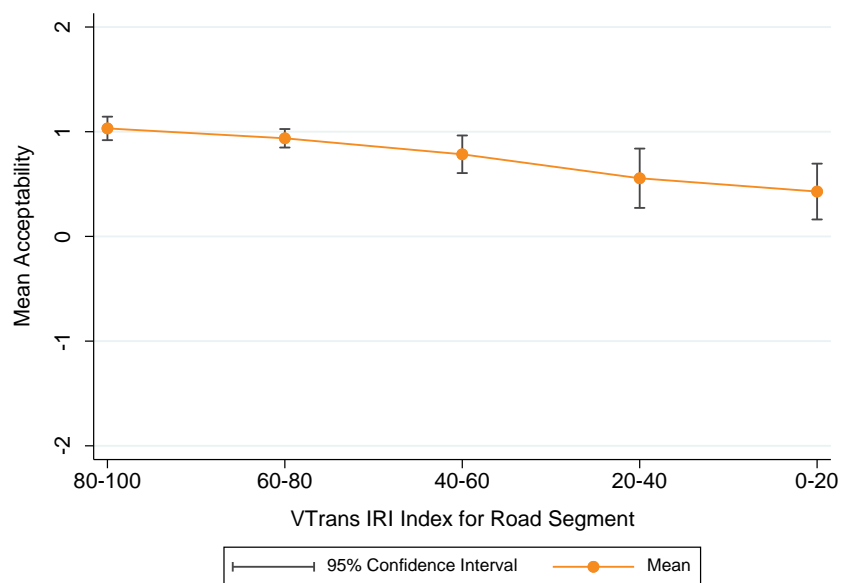
5.0   DISCUSSION

This study successfully applied a new smartphone app (iPhone and Android) to gather 799 post-trip pavement condition ratings from 267 licensed Vermont drivers. All 14 Vermont counties were represented in the study.

Overall, study participants were quite positive about the current condition of Vermont roads. Approximately 70% indicated that the road segment of interest was at least in "acceptable" condition, and only 10% indicated that it was in "unacceptable" condition. Even road segments that were assigned low condition ratings by VTrans were generally deemed to be in reasonable condition by survey respondents. For example, 80% of segments that VTrans classified as being in "very poor" condition were rated as "good" or "fair" by survey respondents. For segments classified by VTrans as "poor" this percentage increased to 85%, and for segments classified by VTrans as "fair" it increased further, to 92%. Older respondents, infrequent drivers, and individuals driving cars and SUVs (as opposed to trucks) generally provided higher pavement acceptability and condition ratings.

These results may conflict with perceptions of driver satisfaction based on direct feedback that VTrans receives from residents. However, if VTrans receives a significant number of driver complaints about road conditions, it is possible that the individuals contacting VTrans simply represent outliers within the driver population. Alternatively, these drivers may be confusing the condition of local roads with the condition of state roads.

Although drivers may indeed be satisfied with the overall condition of Vermont roads, it may also be the case that road condition is simply not a particularly salient indicator of the overall quality of the respondent's experience while driving. While respondents were specifically asked to rate pavement conditions, their responses may have been influenced by their overall experience on the trip. A variety of other factors are likely to influence the respondent's driving experience, including traffic, weather, music, phone conversations, and scenery. These other factors may serve to attenuate the impact of pavement conditions on acceptability, making it more difficult to identify a strong relationship.

Further, results of the focus groups that were conducted to inform this survey suggest that when asked about pavement condition on roads that are less familiar to drivers, they may be inclined to do some type of "mental averaging" of the pavement condition across the entire drive when providing a pavement condition rating. This could moderate respondents' evaluation of pavement condition to some extent. That said, most respondents provided favorable acceptability ratings for road segments they reported driving very frequently or frequently; this reinforces the conclusion that Vermont drivers generally consider pavement condition on state roads to be favorable.

Study participants who had traveled over road segments that they considered to be in "poor" or "very poor" condition felt that the segments should be repaired relatively quickly. Nearly a quarter (23%) indicated that these segments should be repaired right away, while another 60% felt that they should at least be repaired within 1-2-years.

Consistent with this sentiment, the majority of respondents indicated that VTrans should have a target of no more than approximately 5% to 15% of Vermont roads in "very poor" condition, which is lower than VTrans' current target of 25%. Given the generally positive ratings provided by

respondents, however, there is a mismatch between what respondents consider "very poor" and what VTrans classifies as "very poor." This mismatch leads to ambiguity in interpreting drivers' opinions regarding the 25% target. The fact that survey respondents rated only 3% of all segments as currently being in "very poor" condition indicates that VTrans is already exceeding its customers' targets of having approximately 5% to 15% of roads in "very poor" condition. These findings suggest if VTrans continues to manage to their current standard, they will likely continue to meet or exceed driver's standards for pavement quality in Vermont. An additional phase of work may be warranted to work through the policy and planning implications of these results.

Comparisons with DMV data on the licensed driver population indicate that younger drivers are overrepresented in our sample, as would be expected with a smartphone survey. Given that older drivers provided more positive ratings than younger drivers, this would likely have the effect of biasing our condition ratings downwards, towards less positive ratings. Thus, younger drivers being overrepresented in our sample further reinforces the conclusion that Vermont drivers are generally satisfied with road conditions in the state. In addition to respondent age, comparisons with DMV data indicate that Chittenden County is underrepresented in our sample, while Rutland, Windsor, and Washington counties are overrepresented. Chittenden County respondents had higher than average acceptability ratings (90% "acceptable" or "very acceptable" versus the sample average of 70%), while Rutland/Windsor/Washington counties had acceptability ratings only slightly higher than the sample average (72% versus 70%). Thus, similar to age, the overall impact of these county-level differences in sampling rates would be to reinforce the conclusion that the state's drivers are generally satisfied with road conditions.

Finally, VTrans uses several different engineering-based measures of road quality to develop its pavement condition ratings. These measures are all correlated with respondent acceptability, with higher acceptability ratings generally associated with higher average values for the indices.

6.0   ACKNOWLEDGMENTS

We thank the Vermont Agency of Transportation and staff of the Department of Motor Vehicles throughout the state of Vermont for their assistance and support with this pavement condition study.

7.0 LITERATURE CITED

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APPENDIX A. THE SMARTPHONE APPLICATION

The following are screenshots taken from the smartphone application that respondents used during the survey.
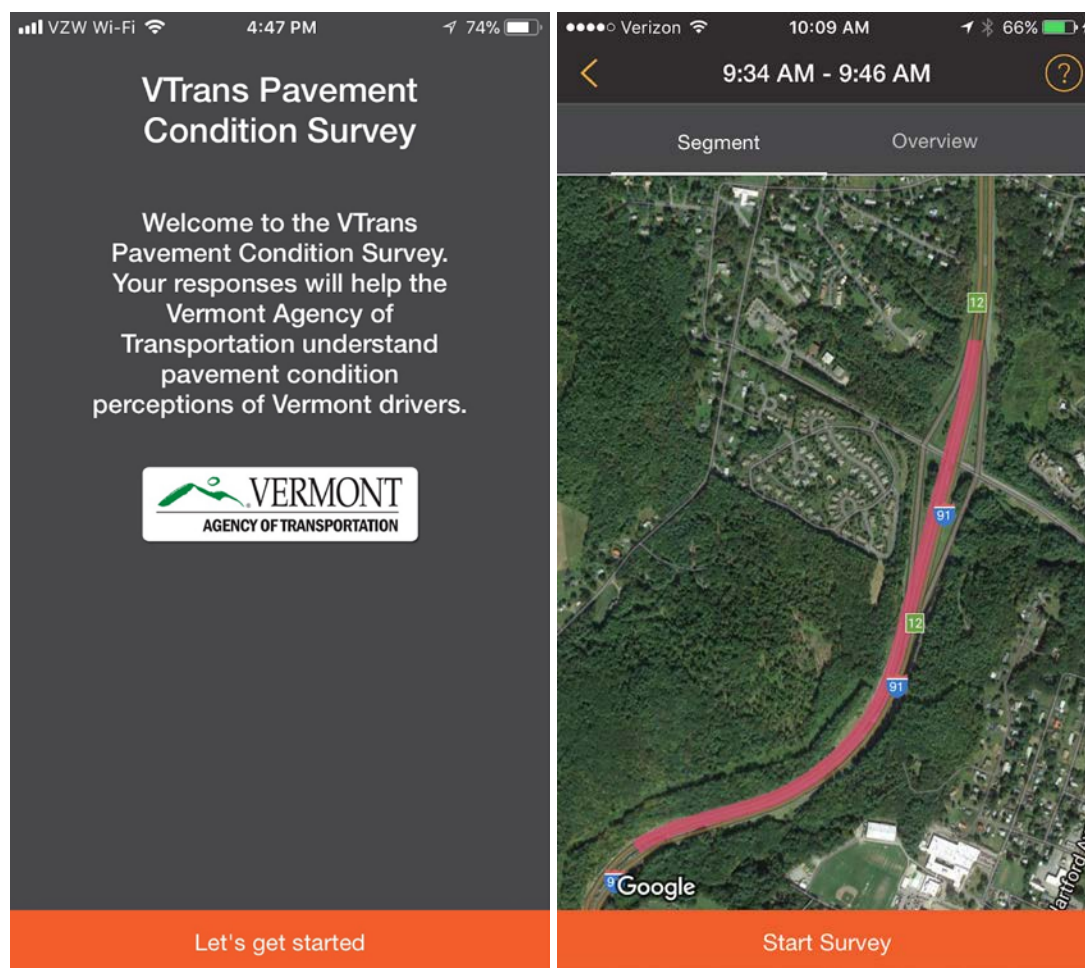
Left screen:

Carrier 📶   11:44 AM   📍 🔋⚡

9:34 AM-9:46 AM

How would you rate the condition of the pavement on the red highlighted road segment?

Good

Fair

Poor

Very poor

Don't know/Can't recall

Previous   🏠   Next

Right screen:

Carrier 📶   11:44 AM   📍 🔋⚡

9:34 AM-9:46 AM

How acceptable or unacceptable would you rate the condition of the pavement on the red highlighted road segment?

Very acceptable

Acceptable

Neutral

Unacceptable

Very unacceptable

Previous   🏠   Next

Left Screen

Carrier 11:45 AM

9:34 AM-9:46 AM

Was the pavement on the red highlighted section of road wet or slick on your trip?

Yes

No

Previous | Next

Right Screen

Carrier 11:45 AM

9:34 AM-9:46 AM

What type of vehicle were you driving on this trip?

Motorcycle/Scooter/Moped

Car/Hatchback

SUV/Van

Pickup Truck

Box Truck or Semi

Other

Previous | Next

Carrier	11:45 AM		Carrier	11:46 AM
	9:34 AM-9:46 AM			9:34 AM-9:46 AM

What 'other' type of vehicle were you driving on this trip?

What was the purpose of this trip?

Commuting to/from work or school

Running errands

Recreation or leisure

Other

| Previous | | Next | | Previous | | Next |

Screen 1 (left):

Carrier 📶   12:58 PM   ➤ 🔋⚡

9:34 AM-9:46 AM

Please specify the 'other' purpose for this trip?

Previous   🏠   Next

Screen 2 (right):

Carrier 📶   11:46 AM   ➤ 🔋⚡

9:34 AM-9:46 AM

You rated the pavement condition of the red highlighted section of road as Poor.

Given that transportation funding is limited, how long is it reasonable for the pavement on the red highlighted section of road to remain in Poor condition?

The pavement should be fixed right away

1 - 2 years, but not longer

2 - 3 years, but not longer

3 - 5 years, but not longer

5 - 7 years, but not longer

7 - 9 years, but not longer

10 or more years

Previous   🏠   Next

Carrier 📶	11:47 AM	
🗺	9:34 AM-9:46 AM	

You rated the pavement condition of the red highlighted section of road as Very Poor.

Given that transportation funding is limited, how long is it reasonable for the pavement on the red highlighted section of road to remain in Very Poor condition?

The pavement should be fixed right away

1 - 2 years, but not longer

2 - 3 years, but not longer

3 - 5 years, but not longer

5 - 7 years, but not longer

7 - 9 years, but not longer

Previous   🏠   Next

Carrier 📶	11:50 AM	
🗺	9:34 AM-9:46 AM	

The next set of questions will only need to be answered once. They will not appear in future surveys.

Previous   🏠   Next

Screen 1:

Carrier 📶 — 11:51 AM

9:34 AM-9:46 AM

Given that transportation funding is limited, it is inevitable that some Vermont roads will have Very Poor pavement condition.

Vermont's current target is no more than 25% of roads in Very Poor condition.

What do you think is the maximum percentage of roads that is reasonable for Vermont to have in Very Poor condition?

50% or less

35% or less

25% or less

15% or less

5% or less

Previous   🏠   Next

Screen 2:

Carrier 📶 — 12:54 PM

9:34 AM-9:46 AM

What is the maximum percentage of roads that is reasonable for Vermont to have in Very Poor condition?

[   ] %

Previous   🏠   Next

Carrier	11:51 AM		Carrier	11:51 AM	
	9:34 AM-9:46 AM			9:34 AM-9:46 AM	

For how many years have you been driving?	**On average, how many hours do you spend driving each week?**
5 years or less	6 hours or less
6 - 10 years	7 - 13 hours
11 - 20 years	14 - 20 hours
21 - 30 years	21 - 27 hours
31 - 40 years	28 - 34 hours
41 - 50 years	35 - 41 hours
51 years or more	42 - 48 hours
	49 hours or more

Previous	🏠	Next	Previous	🏠	Next
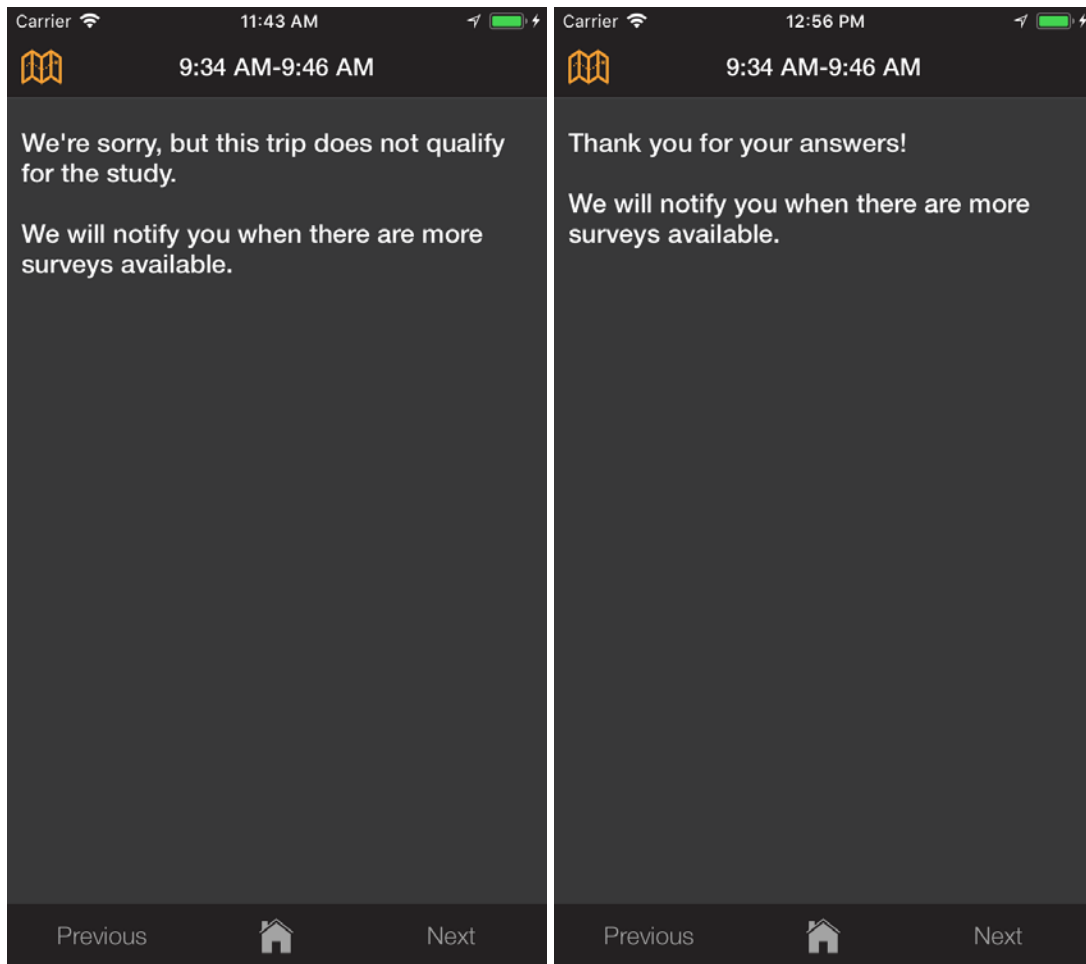
APPENDIX B.   SURVEY HANDOUTS

This appendix provides supplemental documents that were given to individuals who agreed to participate by the survey administrators. The first document is a handout given to study participants recruited at the Rutland, Springfield, and Burlington DMVs. A nearly identical handout was provided to study participants recruited at the Bennington, Montpelier, and Newport DMVs, except that the study end date was specified as October 6, 2017 rather than September 29, 2017. The second document is a handout with rPlace download instructions. This handout was provided to participants recruited in Newport.

FIGURE 8. HANDOUT PROVIDED TO ALL STUDY PARTICIPANTS DURING RECRUITMENT

rPlace

Study Period –
Through September 29, 2017

▶ Thank you for your participation in this important study!

Your responses will help the Vermont Agency of Transportation improve pavement condition management across the state.

How rPlace Works

- rPlace is a smartphone data collection application designed to collect information from Vermont drivers about the pavement condition of roads across the state.

- To participate in this study, all you have to do is download rPlace on to your smartphone and drive around as you normally do. Once you have driven over a portion of road that is part of the study, rPlace will display a notification that a survey is ready to complete. rPlace will send you this notification about three minutes after you have stopped driving. When you see this notification, open the rPlace app to complete the survey.

- rPlace will ask you to confirm the details of your trip, including the section of road on which you drove. To confirm the details of your trip, look at the red highlighted road segment **A**. Use the **"Segment"** and **"Overview"** buttons to look at a close up view and overall view of your trip **B**. Once you have a good sense for the section of road selected for the survey, click the **"Start Survey"** button **C**.

- After you have completed your first survey, continue driving as you normally would and look for another survey notification from rPlace. Some survey questions will only be asked once, so each subsequent survey is a little shorter than the first. We encourage you to continue completing surveys through the end of the study period. **Your responses are very important to our study!**

As a Reminder...

iPhone / Android
- Make sure your **"Location Services"** are **ON** (using the "High" accuracy setting for Android and "Always" using the services for iPhone).

- Make sure your **WIFI Is ON** (WIFI does not need to be connected to a network, just ON).

- Try to keep your phone **fully charged**. rPlace may affect battery life.

- **Pay close attention to the road conditions** you drive over during the study period as you may be asked to rate their quality!

- **Try to complete surveys as soon as possible** after a trip so you have the best chance of remembering pavement conditions.

- **Only one survey at a time will be available for your completion.** To be eligible for additional surveys, please complete any surveys existing within rPlace.

- **You may not be asked to complete a survey each time you take a trip.** Don't worry - rPlace is still working and will send a survey notification when it is available.

- Only the driver of the vehicle will be asked to rate pavement conditions.

- Only roads administered by the State of Vermont are included in this study. Local roads managed by municipalities are not included in this study.

GIFT CARD ELIGIBILITY

Full participation will grant you a $10 Amazon gift card, which is earned in one of two ways:

- **Complete at least three surveys within the study period.**
- **If you are not prompted to complete three surveys in the study period, complete all surveys you are prompted to complete.**

For more information about rPlace, visit https://rplace.rsginc.com

Have question about the rPlace app? Please email rplace-support@rsginc.com to get your question answered! *Questions will be answered within 24-48 hours of receipt.*

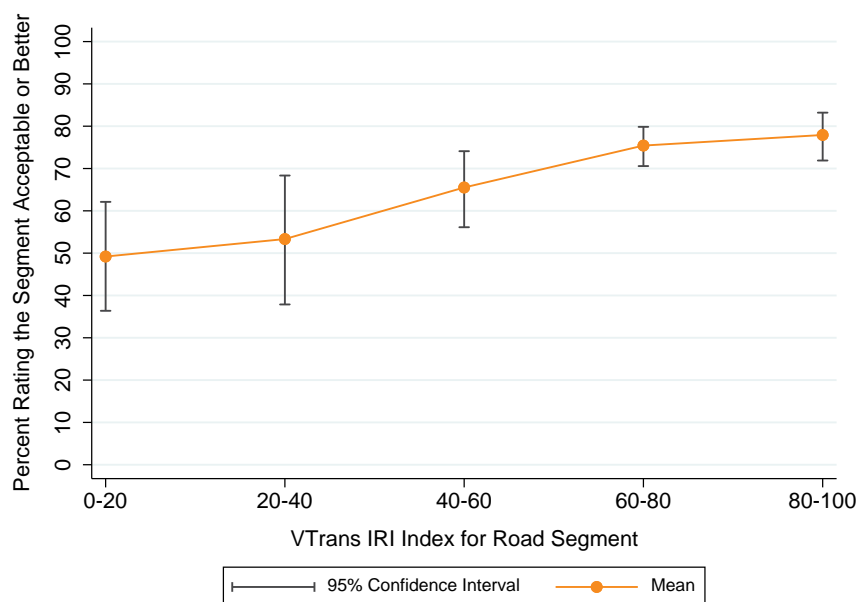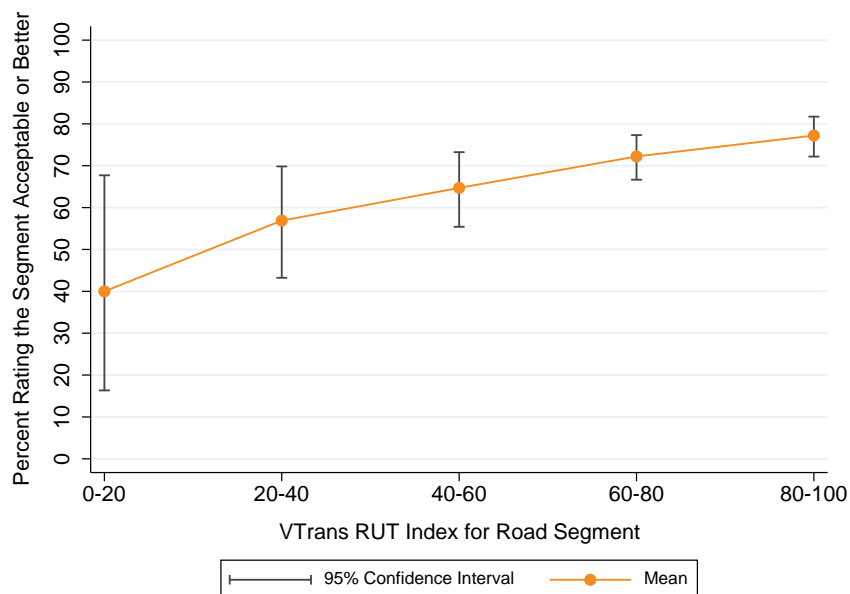**FIGURE 9. DOWNLOAD INSTRUCTIONS PROVIDED TO NEWPORT PARTICIPANTS**

APPENDIX C.   CONFIDENCE INTERVALS

This appendix provides confidence intervals associated with selected estimates presented in the main body of the report.
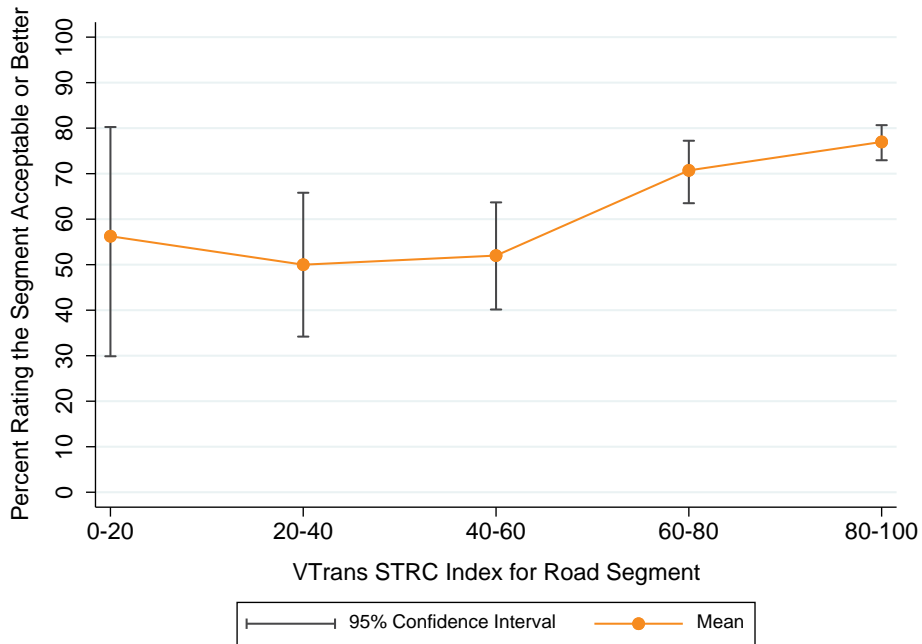
FIGURE 10. RESPONDENT ACCEPTABILITY BY IRI INDEX RANGE

FIGURE 11. RESPONDENT ACCEPTABILITY BY RUT INDEX RANGE

FIGURE 12. RESPONDENT ACCEPTABILITY BY STRC INDEX RANGE

FIGURE 13. RESPONDENT ACCEPTABILITY BY TRAN INDEX RANGE