A Study on Road Users' Overall Perceptions of Highway Maintenance Service Quality and the Variables that Define the Highway Maintenance Service Quality Domain

by

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University in partial
fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Civil Engineering

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October 20, 2008
Blacksburg, Virginia

Keywords: Highway Maintenance, Service Quality, Service Delivery, Public Opinion

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Abstract

The concept of involving the public in the development of transportation solutions was built in the Federal-Aid Highway Act of 1956, the legislation that authorized the construction of the Interstate Highway System. Better plans, transparent process, and public support are some of the benefits that road managers can obtain by educating and involving the general public. During the last two decades the volume of research performed related to the topic of customer-driven highway maintenance suggests an increasing level of interest in the field. Most research concentrates on gathering information from road users to assess the performance level of highways. However, public opinion can also be collected for measuring the quality of the service delivered by maintenance units. Assessing product and service delivery performance is important for determining the overall performance of highway maintenance programs. The present study examines the relationship between road users' overall perceptions of the quality of highway maintenance services and the variables that define the highway maintenance service quality domain. The results of the study indicate that two service dimensions, Safety and Reliability, explain about half of the variance in overall perceptions of highway maintenance service quality. The procedures developed for the study provide an initial step for further improvement of the highway maintenance service quality measurement.

This work is dedicated

To my teachers

Acknowledgement

I would like to thank my committee members for their guidance and assistance during the past four years. Special thanks to Dr. Jesus M. de la Garza, the committee chairman, for the opportunity of pursuing the doctoral degree. This research was possible thank you to the financial support provided by the Virginia Department of Transportation.

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1. CHAPTER ONE - INTRODUCTION

1.1. Overview

A highway maintenance management system is a tool to optimize the allocation of available resources and assist highway maintenance personnel in delivering optimal levels of service. In the past, the complexity of these maintenance management systems has evolved from simple accounting controls to more elaborate performance measurement systems. The following chronology summarizes the key features of different approaches adopted by road managers from 1950 to the present.

1950s: Fiscal Approach - This approach to maintenance management consisted of controlling annual expenditures and allocating resources on the basis of historic cost adjusted by changes in material prices and labor rates. The approach soon became inadequate for resource allocation mainly because of increasing labor cost and design complexity (Leslie et al. 1968).

1960s: Systems Approach - This approach originated from the need to rationalize maintenance operations. Grounded on the four managerial functions of planning, organizing, executing, and controlling, the systems approach provided information that allowed road managers to allocate resources on the basis of need. The new approach introduced objective measures of productivity, resource requirements, work accomplished, and maintenance costs of maintenance activities into the highway maintenance-management process (Leslie et al. 1968).

1980s: Quality Revolution - Quality plans were added to current maintenance-management practices to improve public perception of the quality provided by transportation agencies. Also, the change in focus from infrastructure design and construction to maintenance and rehabilitation significantly increased the amount of maintenance work. Most work was performed by subcontractors, so agencies adopted quality plans to confirm that work was performed according to maintenance standards (Miller 1989).

1990s: Performance-Based Road Maintenance – The traditional way of subcontracting road maintenance was based on work items paid for through agreed rates. By contrast, performance-based contracts specified the minimum level of service for roads, bridges, etc. that the subcontractor had to meet without indicating what materials, methods, or quantities were required. Payments were based on how well the contractor complied with the performance requirements (Piñero 2003).

These transformations have most certainly been spurred by changing environments and other circumstances such as shrinking budgets, new technologies, new legislation, and changes in highway programs. Thus far, changes in highway management systems have reflected the availability of technology, material, and engineering judgment within transportation agencies and each change has been sought as a step toward a better use of maintenance resources.

The measurement systems for highway maintenance management have also evolved and increased in complexity. **Figure 1** shows how measurement has moved from simple productivity measurement (outputs *over* inputs) to more elaborate customer-oriented measures such as customer value added.

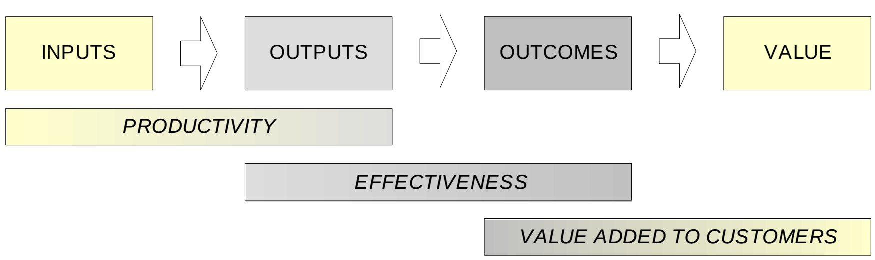

Figure 1 Measures in Highway Maintenance Management
(Hyman, 2004, p. 46)

The first two measures in **Figure 1**, inputs and outputs, are associated with the Systems Approach of the 1960s. Inputs are “the resources used to deliver a product or service, perform an activity, or undertake a business process” (Hyman, 2004, p.45). These resources basically consist of labor, material, and equipment. Other resources, as well as intangible resources like experience or knowledge, may be considered as inputs. Outputs are measures of everything that has being accomplished by the maintenance activity, such as the number of potholes that have been patched or the number of bags of litter gathered. The ratio between inputs and outputs is the productivity of the maintenance effort.

The next measure in **Figure 1** is outcomes. Outcomes are “the results, effects, or changes that occur due to delivering a product or service, conducting an activity, or carrying out a business process” (Hyman, 2004, p.46). In the early 1990s, road managers started to measure outcomes of maintenance activities with the introduction of performance measurement systems. Examples of outcomes include smoother pavement after resurfacing or improved roadside aesthetics after mowing. The ratio between outputs and outcomes is the effectiveness of the maintenance effort.

The last measure in **Figure 1** relates to the value added to the customer by the agency or the maintenance unit. Value added is a “customer-oriented outcome measure expressed in term of the value received by the customer” (Hyman, 2004, p.47). The definition of value added implies that the judge of value added is the road user. Measuring customer value added requires direct communication with road users.

Since the early 1990s, several state agencies have turned their attention to customer-oriented measures, seeking a better understanding of road users. The next three applications of customer-oriented measures can be identified from the literature: highway performance assessment, performance target definition, and perceived service quality.

Highway performance assessment is the most frequent application of customer-oriented measures in highway maintenance programs. Information collected from road users is used to predict the extent to which highway current levels of service meets road users' expectation and the improvements that can be achieved based on road users' perception of the condition of the highway.

Performance target definition relates to the level of service at which highway assets must be maintained. Customer input can be used for determining adequate levels of service from the road user's perspective. For example, Poister et al. (2005) compared Pennsylvania Department of Transportation's current standards for ride quality with Pennsylvania road users' perception of satisfactory levels of service to find the level of the service at which ride quality shifts from unsatisfactory to satisfactory.

Perceived service quality relates to the sequence of events that a road user expects when driving through a work area or nearing maintenance operations. The measure focuses on the service delivery method and the manner in which the service is provided by the transportation agency or its subcontractors; hence, the title of highway maintenance service delivery. The conditions or quality of the individual elements of the highway do not play a role in the assessment of the quality of the service delivery.

The main components of maintenance service delivery are equipment, people, and the communication process deployed by the service provider during the execution of the maintenance work. **Figure 2** shows the three main components of highway maintenance service delivery.

People[1] **Equipment** **Communication**[2]

Figure 2 Highway Maintenance Service Delivery Components

Existing research related to customer-oriented measures in highway maintenance suggests increasing interest in public opinion concerning different aspects of highway maintenance. Customer-oriented measures provide valuable information regarding how well a service is functioning, where changes are most needed, and whether modifications are likely to produce improvements from the user's perspective.

The growing tendency is supported by government agencies, academic institutions, and road managers and practitioners. However, most research still remains focused on highway performance and levels of service. However, the manner in which the service is provided should not be overlooked.

1.2. Background of the Research

In 1995, the Commonwealth Legislature of Virginia enacted the Public-Private Transportation Act (PPTA) that allows local government and certain other political entities to enter into agreements authorizing private entities to acquire, construct, improve, maintain, and/or operate qualifying transportation facilities.

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[1] Photograph used by permission from www.vermont .gov

[2] Photograph used by permission from Michigan State University (source: Public Roads magazine, May/June 2008)

In 1996, the Virginia Department of Transportation (VDOT) accepted an unsolicited proposal from a private company for maintaining 250 miles of Virginia's interstate network. The contract became the first Performance-Based Road Maintenance (PBRM) contract awarded in the United States by a public agency enabled by the PPTA.

In 2000, the Joint Legislative Audit and Review Commission (JLARC) reviewed the PBRM initiative to assess progress. JLARC uncovered flaws in the evaluation method of the interstate maintenance contract and recommended VDOT strengthen the current routine monitoring system (JLARC 2001).

1.2.1. Framework for Monitoring Performance-Based Road Maintenance

In 2001, VDOT implemented a monitoring system based on five dimensions of highway maintenance performance.

- **Level of Service Effectiveness** assesses the condition of each asset to determine if minimum acceptable quality levels are being met.
- **Cost-Efficiency** assesses cost savings of performance-based contracts compared to traditional methods.
- **Timeliness of Response** assesses the contractor response to service requests related to incidents that place the traveling public at risk.
- **Safety Procedure** assesses the contractor's compliance with safety requirements to determine the contractor's overall commitment to safety.
- **Quality of Service** assesses the customer, users, and employee perceptions with respect to the condition at which road assets are maintained by the contractor.

Since transportation agencies emphasize the economic utilization of personnel, equipment, and material, the monitoring system was strongly oriented toward evaluating the level and cost efficiency of the service provided by private contractors (Piñero 2003). The assessment of service delivery did not receive much attention despite the fact that transportation agencies need to "see the big picture" in terms of cost benefits, cost effectiveness, and service quality.

1.3. Quality of Service in the Construction Industry

In the construction industry, the contractor always provides the client a service product, in addition to the physical product. The client evaluates both the quality of the service and the physical product. For example, the client expects the project to be delivered by the contractor on time, within budget, and according to the agreed-upon plans and specifications. The main challenges for the contractor are to properly identify the critical factors of the project and to understand the client's expectations within those factors. If the contractor meets the expectations within the factors of the project, the client will feel satisfied (Maloney 2002).

In general, the client requires several instances to fully perceive the quality of the service provided by the contractor. These are "service encounters" and they can occur any time and many times during a project as indicated in **Figure 3**. On each encounter, the client can perceive some aspect of the service quality and compare this perception against expectations. After each encounter, the client can feel satisfied or dissatisfied and ultimately, the client will form an opinion of the quality of the service provided by the contractor.

In highway maintenance, a crew performing maintenance will likely experience some kind of interaction with the road users who will certainly perceive the delivery of the maintenance service as an anomaly of the flow of traffic and will assess the quality of the encounter by evaluating the manner in which the anomaly is handled by the maintenance contractor. The final perception of the quality of the maintenance service will emerge from all the individual encounters experienced by the road user.

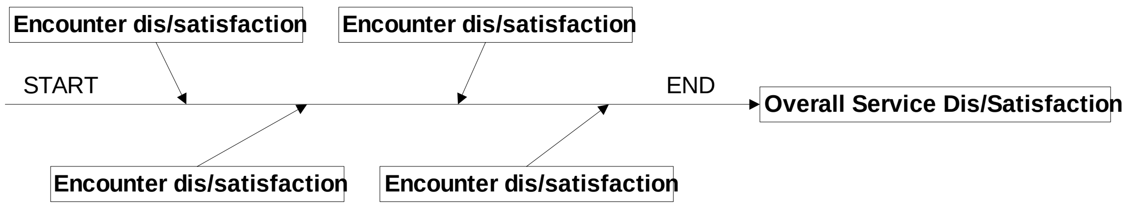

Figure 3 Overall Service Satisfaction

(Maloney, 2002, p.523, with permission from ASCE)

It is important to recognize that both physical and service products are relevant and both products play a role in the evaluation of the contractor. In highway maintenance, the quality of the maintenance product is represented by the level of service of each individual component of the highway and the quality of the maintenance service is represented by the levels of the critical factors or attributes of the service. The quality of the maintenance product plays an important role in the analysis of the efficiency of maintenance operations and so does the quality of the maintenance service.

1.4. Objective of the research

The main objective of the research is to examine the relationship between road users' overall perceptions of the quality of highway maintenance services and the variables that define highway-maintenance service quality.

1.5. Hypothesis of the research

One important assumption of the study refers to the service quality measure. It was considered that highway maintenance service delivery has service attributes similar to those possess by other services such as retailing and banking. Products and recommendations found in previous studies on service quality were adopted for the measurement of service quality. In particular, the structure of the multiple-item scale developed by Parasuraman et al. (1988) was adopted for measuring highway maintenance service quality.

The structure of the highway maintenance service quality measure was hypothesized as follows:

- one tangible dimension for measuring the physical facilities, equipment, and appearance of personnel
- one reliability dimension for measuring the ability to perform the service dependably
- one assurance dimension for measuring the knowledge of employees and their ability to inspire trust and confidence

1.6. Merit of the research

The present research focuses on two aspects of highway maintenance: the service delivery domain and users' perceived service quality. These two aspects have been extensively researched in many fields such as retailing, banking, telecommunications, and healthcare. This research would be the first study conducted specifically on highway maintenance service delivery.

Most research done in this field uses customer-oriented measures and focuses on the physical product - not the service delivery. The present research will contribute to the body of knowledge by exploring highway maintenance service delivery and the role of customer-oriented measures in its assessment. Looking at critical factors of highway maintenance service delivery and how they relate to user perceptions is the first step toward defining service quality measurement.

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2. CHAPTER TWO – LITERATURE REVIEW

2.1. Objectives

Customer-oriented measures associated with product and service quality are the subject of a large number of publications both in the private and the public sector. Due to such extensiveness, this literature review is selective and focuses on public sector and highway maintenance services. Most papers in the literature review have been recently published in academically reviewed journals.

The following are the objectives for the literature review.

- Shape a theoretical background for customer-oriented measures with particular emphasis on highway maintenance services.
- Identify common research methodologies and analysis techniques.

The chapter is divided in four parts. The first part focuses on highway maintenance definition and highway condition assessment. The second part discusses public involvement in infrastructure development with particular attention on transportation programs. The third part focuses on existing research related to customer-oriented measures in highway maintenance services. The fourth part discusses alternative approaches for measuring service quality and presents examples of these measures applied in the transportation sector.

2.2. Highway Services and Highway Maintenance Services

The National Highway System consists of three types of highways: Interstates, Primary, and Secondary roads. State transportation agencies (DOTs) are responsible for operating and maintaining all facilities within the right-of-way of these highways. The objectives of DOT operation and maintenance units are maintaining the free flow of traffic and preserving the capital investment in the network. Though important, operation and maintenance is not the only service provided by these agencies.

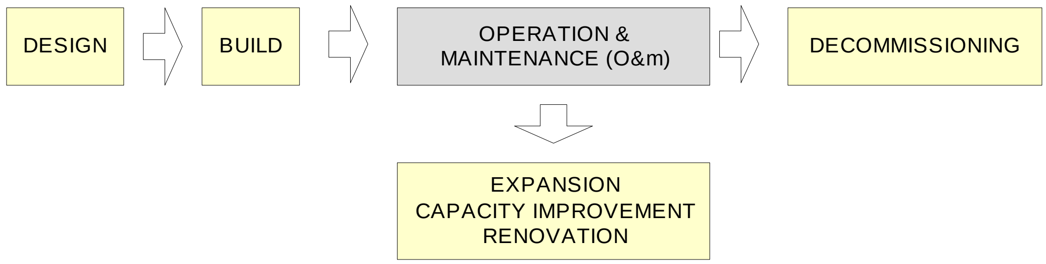

Figure 4 Transportation Facility Lifecycle

Figure 4 shows the lifecycle of a transportation facility. DOT personnel may be involved in every phase indicated in the sequence either as planners, executers, or controllers. In most cases, highways facilities are delivered following the traditional design-bid-build approach. Facilities such as bridges or pavements are designed and built in response to highway user needs. Once constructed, the facilities are operated and maintained for a certain period of time before decommissioning. During the operation period, the agency responsible for maintaining and operating the facility may perform several other services. These services include, but are not limited to, expansion, capacity improvement, and renovation (AASTHO 1999).

2.2.1. Operation and Maintenance Services

Operation and maintenance is an important phase in the lifecycle of a transportation facility in terms of expenditures and facility performance. The American Association of State Highway and Transportation Officials (AASHTO) defines operation and maintenance as "all the activities and services required to maintain infrastructure assets and provide services to the traveling public" (AASHTO 2005, p.50). Decisions during this phase impact the planning and budgeting process of highway maintenance units and the consequences of such decisions also impact the overall performance of transportation facilities. Operation and maintenance activities can be divided into the following three categories:

- Maintenance: any work task that prolongs the life of the facility without increasing its capability, strength, or capacity.
- Repair and Replacement: the restoration of the facility or any of its elements to its original condition in a short period of time.
- Customer Services: a systematic business process for responding to transportation customer needs.

Another way to view maintenance and repair activities is to consider maintenance as activities "on schedule" and repairs as activities "on demand." Also, the definitions of maintenance and repair activities presented above respectively match to some extent the definitions of preventive and reactive maintenance presented below.

- Preventive Maintenance: a planned strategy of cost-effective treatments to an existing facility that preserve the facility, retard future deterioration, and maintain the functional condition of the facility3 (AASHTO 1999).
- Reactive Maintenance: an activity that usually has a significant effect on the performance of the facility and is applied when an undesirable performance state is reached or is nearly reached (Neves et al. 2006).

Since 1960, a reactive philosophy best described by the adage "If it isn't broken, don't fix it," has governed highway maintenance, which was viewed as a response to problems. During the

[3] In some cases, preventive maintenance will improve the functional condition of the facility without substantially increasing capability, strength, or capacity.

last 20 years, maintenance managers have increasingly became more aware of the advantages of preventive maintenance and shifted to a more rational way of maintaining highway facilities. Current management systems consider both preventive and reactive maintenance actions when defining and adopting maintenance policies.

2.2.2. Road Assets Condition and Deterioration

The performance of a highway facility is determined primarily by the degree of deterioration of its individual components, known as road assets. Each type of road asset will deteriorate differently from the other. **Figure 5** shows the variation over time of the performance corresponding to a generic road asset. The physical deterioration of the asset causes its performance to decline. This variation in performance is represented by a curve line. The deterioration curve can be obtained by measuring the physical condition of the road asset at different points in time (Neves et al. 2006).

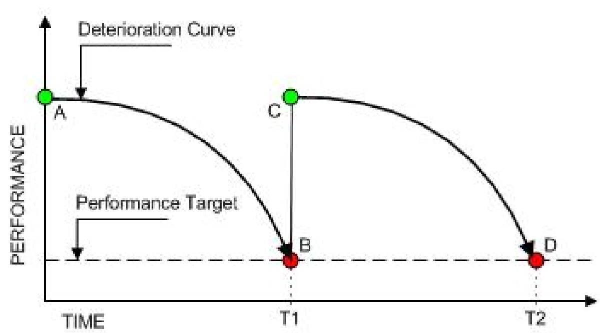

Figure 5 Road Asset Deterioration Cycle

Point A in **Figure 5** indicates the initial level of asset performance after the construction of the facility. The horizontal dashed line is the lowest performance level at which the asset is allowed to perform. This lower limit is called the performance target and it is usually defined during the development phase. Right after construction, the road asset starts deteriorating and its performance declines. The decline continues until it reaches point B at time T1. At this point, the asset is restored to its original conditions, point C, and the deterioration cycle restarts.

2.2.3. User Perception of Road Assets Condition

The road manager must know the condition of all road assets for planning maintenance operations. The options for assessing the condition of the highway are: (i) making a thoughtfully evaluation of the condition of the assets and (ii) evaluating a sample of the assets for determining the performance condition of the entire highway. Either way, the road manager assesses the condition of road assets by comparing the asset observations with specific requirements. Each requirement consists of a criterion and a target, as indicated below:

- Criterion, i.e. "Erosion present less than one foot deep."
- Target, i.e. "Ninety percent of inspected items comply with the criterion."

The criterion is the threshold at which the condition of the individual asset meets the corresponding quality standards. The target is the threshold at which the condition of all assets of the same kind present within the evaluation section meets the corresponding quality standards (NCHRP 14-12 1997).

Regardless of the assessment adopted by the road manager, the manner in which road managers determine the condition of road assets is different from the evaluation process followed by the road users. The user perceives the performance of the asset in relation to certain adapted standards. The primary difference between user's standards and agency's performance targets is that the former are subjective and vary over time and among users while the latter are objective and remain the same after successive evaluations.

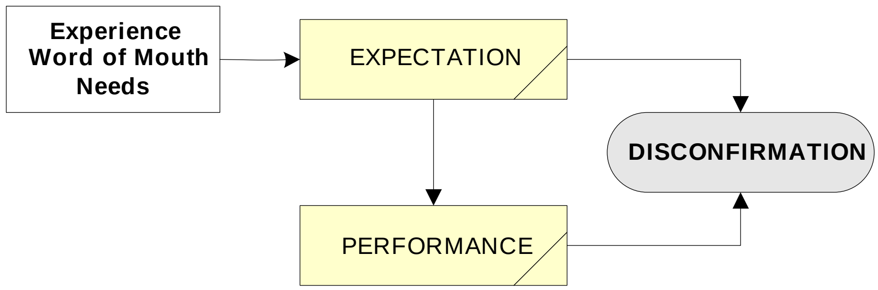

Figure 6 Cognitive Model of Perceived Performance

Figure 6 shows the cognitive process followed by users in evaluating asset performance. Users perceive and evaluate the performance of the asset in relation to certain expectation levels or standards (Oliver 1980). Disconfirmation results from comparing perceived performance with the expectation level. The outcome of the disconfirmation process updates the expectation with the asset creating a new standard or new level of expectation. The user will use this new standard in future performance evaluations.

A road manager will follow a systematic approach when inspecting and evaluating the performance of the assets of the highway. For a deterministic approach, the inspection sample is the entire population and no inferences are made. The performance condition of the road assets is obtained directly from the results of the inspection. For a probabilistic approach, the inspection sample is a subset of the entire population. The performance condition of the entire population is inferred from the results of the sampled population.

The highway user estimates the overall performance condition of a group of assets based on the Critical Incident Approach (Hayes 1998). Critical incidents are specific events. The road user will hardly remember the exact location at which the incident occurred. Only the result of the cognitive evaluation remains vivid. Hence, the evaluation of the condition of the road is totally based on selected events or critical incidents and has no statistical value. Knowing road users' perceptions with respect to the condition at which road assets are maintained can help verify to what extent this perception is aligned with agency's perception.

In addition, the scope of the evaluation also differs when road managers and road users are examining the condition of the highway. While the road manager assesses all assets within the right-of-way of the highway, the user assesses only those assets that are visible from the car. During daytime, the driver sees assets such as the pavement, markings, guardrails, the slopes and the grass on the roadside, shoulders, signs, debris, road killers, and litter. During nighttime this list shortens and some assets are excluded from the user's view such as under drainages and pipes.

2.3. Public Involvement in Infrastructure projects

In 2006 the U.S. Department of Defense requested the Army Corps of Engineers to develop the Mississippi Coastal Improvement Plan (MsCIP) for hardening the Mississippi Gulf Coast against storms like Hurricane Katrina. Instead of working alone, the MsCIP team involved the general public in the development of the plan. With frequent travels and extended hearings, the MsCIP team gathered valuable input from the public and used it to develop construction proposals. The transparency of the process was the main factor for getting the public involved in the initiative and supporting the outcomes produced by the MsCIP team (Bergeron 2007 p. 11).

The Corps of Engineers' approach for the MsCIP is characteristic of context-sensitive design. "Context Sensitive Design (CSD) is a collaborative, interdisciplinary approach to identifying and solving transportation problems, in which consensus building extends from defining the project needs and purpose, concept evolution, design and construction through maintenance and operation" (Dresnack and Golub, 2004, p.1).

The New Jersey Department of Transportation (NJDOT) has experimented with CSD since 2000. One project was the construction of the missing section of Route 21 in Clifton, N.J. The NJDOT developed the initial project documentation with the participation of local communities and businesses affected by the project. The baseline document, which studied several areas like socioeconomic impact analysis and visual enhancement, was intended to reflect the opinion of the public regarding the impact of the project on the community.

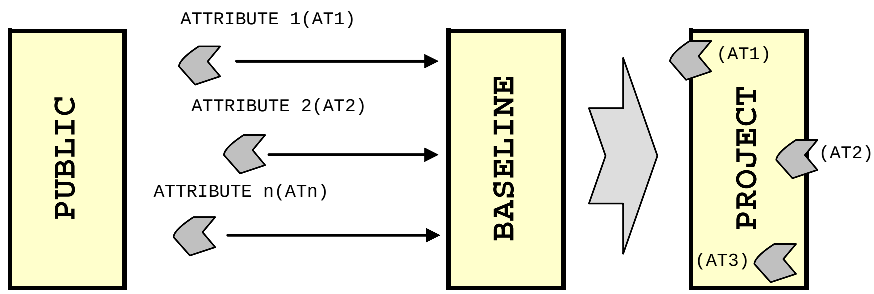

Figure 7 Public Involvement in Context-Sensitive Design

Figure 7 illustrates a generic CSD approach like that adopted by the NJDOT for the construction of the missing section of Route 21. Through public hearings and citizen committees, the project team obtains vital information about how the public perceived the impact of the project on the community. The design engineers convert this information into attributes of the project. Each attribute satisfies a public concern or need. Having these attributes identified in the final design enables road managers to evaluate the impact of the project from a user's perspective.

Today, highway users increasingly express their thoughts regarding highway maintenance and the value created by transportation agencies. The public is more knowledgeable and sophisticated in many aspects of the service, from road aesthetics to safety and environmental issues. Listening to the public is increasingly "*the*" best practice in highway maintenance services.

2.3.1. The Role of Metropolitan Planning Organizations

Notwithstanding the importance of maintaining a continuous line of open communication between the public and the Department of Transportation, a direct link is not always necessary. Other institutions, like metropolitan planning organizations (MPOs), are better positioned than the Department of Transportation to communicate with the general public regarding highway maintenance services.

The origin of the MPO extends back to the early stages of the interstate highway system. In 1962, an amendment to the Federal Aid Highway Act established that, to qualify for federal funds for local projects, every metropolitan area with a population of more than 50,000 had to be represented in matters related to transportation planning. In 1973, federal statutes coined the term "metropolitan planning organization" to describe the institution responsible for these responsibilities.

In 1978, the federal government ruled that MPOs were to be designated by mutual agreement between local government and the state's governor. In 1991, the Intermodal Surface Transportation Efficient Act empowered MPOs to allocate a significant share of available federal funds to urbanized areas. In 1998, the Transportation Equity Act for the 21st Century reaffirmed the role of the MPO and extended its functions in planning and funding allocation (MPOAC 2000).

Most MPOs are structured around three groups: the policy board (voting members), the technical advisory committee (non-voting members), and the citizens' advisory committee. The first group is formed by elected officials of general-purpose governments. The second group consists of planners, engineers, and representatives of affected local governments. The last group is comprised of concerned local residents.

The primary purpose of the MPO is to elaborate two documents related to metropolitan planning: the Long-Range Transportation Plan (LRTP) and the Transportation Improvement Program (TIP). The LRTP has a minimum planning horizon of 20 years and must be consistent with elements already approved by local governments. The TIP should include projects that can be executed within the fiscal year. The Department of Transportation must inspect these documents when updating the annual management strategy for the highway network.

Figure 8 shows the main player for the development of the LRTP and the TIP. The double arrow in the center indicates that these two documents result from cooperation between the MPO and the Department of Transportation. Note that the MPO does not run the transportation system. Although the opinion of the general public is collected by the MPO and used for planning purposes, the Department of Transportation remains accountable to politicians, taxpayers, and users for the results of those plans.

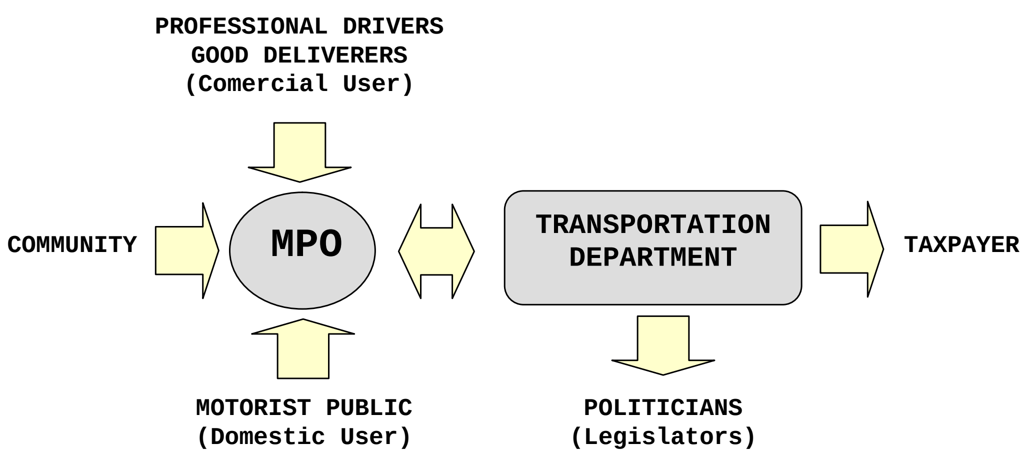

Figure 8 Metropolitan Planning Organization (MPO) Stakeholders

Participation of the general public in the preparation of planning documents is very important for implementation success, as was mentioned earlier in relation to the development of the Mississippi Costal Improvement Plan. Several techniques can be used for promoting and encouraging public involvement. In a recent survey, Florida's MPOs reported more than 30 techniques that can be combined for different purposes (Hopes et al. 2006). The following are the most commonly used techniques:

- Newsletters [4, 5]
- Public meetings [4, 5]
- Brochure [4]
- Newspaper advertisement [4, 5]
- Press release [4]
- Web page [4, 5, 6]

The most successful technique identified by Florida's MOP is individual and small group briefings at community events or neighborhood meetings. "Going to the people instead of asking them to come to you is much more effective and keeps them in their comfort zone" (Hopes et al., 2006, p.105).

2.4. Managing Customer Input in Highway Maintenance

Transportation agencies and other related authorities have spent considerable resources to bring the customer voice into the decision making process for highway maintenance services. Few agencies have succeeded in such endeavors. The next section reviews recently published papers on customer-oriented measures and highway maintenance.

2.4.1. Problems and Solutions for Data Collection

The Pennsylvania Department of Transportation (PennDOT) appears to be the most active agency in customer involvement in highway maintenance services. Poister (1999) summarized the steps taken by the agency to understand customers and their thinking in relation to services provided by the agency. The primary purpose of the study was establishing the *voice of the customer* regarding Pennsylvania highways using data collected by PennDOT.

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[4] Used for Education and Outreach efforts.
[5] Used for the development of Long-Range Transportation Plan.
[6] Used for the development of Transportation Improvement Program.

Poister reviewed several sources, including PennDOT mailed and telephone surveys, personnel interviews, his own experience, and several other sources such as the results of the 1996 National Highway User Survey and specialized magazine surveys. In addition, several highway stakeholders, such PennDOT personnel, contractors and vendors, and industry representatives, were interviewed during the study by Poister's research team. The researcher synthesized the opinions of the public regarding PennDOT's performance, determined relative importance of several attributes of the services, and analyzed customer satisfaction trends. The main problems to overcome were the utilization of different methodologies for surveying the public opinion and some contradictions among the responses (Poister 1999).

Dull and Lebwohl (2003) focused on ways to improve data collection from customers in the transportation sector. The researchers reviewed techniques such as random surveys, focus groups, regional and national studies of driver preferences, and customer comments and complaints. These techniques can be utilized independently or in combination, depending on resource availability and the type of information needed by the manager.

The main flaw identified in current practices was the use of directly stated importance for determining the relative importance of maintenance service attributes. This approach is widely criticized among market researchers. Regression and correlation techniques are better choices for deriving the importance of attributes selected by the customer. Another issue in data collection is the subjective nature of the answers provided by customers. In many cases, customers lack necessary information to articulate preferable outcomes. In these cases, the literature suggests the use of conjoint analysis, a market research technique widely used in the private sector for product design and development. However, the recommendation of producing meaningful data with the existing tools before adopting more sophisticated techniques always prevailed.

2.4.2. Highway Performance Assessment

For the past decade, road managers have used performance measures to evaluate highway maintenance programs. Meyer (2001) emphasized the need for incorporating customer perspectives in planning and decision-making and explored the relevance of performance measures for managing and operating transportation facilities and the need to consider customer preferences when selecting those measures. At present, performance measures have a strong presence in highway maintenance management systems and road managers allocate resources based on maintenance operation performance assessment.

A systematic approach for managing pavement assets using customer-oriented performance measures was developed by Haas and Hudson (1996). It starts by defining users of road pavements, followed by the major factors or measures that relate the service level to customer satisfaction and the manner in which these measures can be used in the development of maintenance strategies. Some factors must be measured by the transportation agency and linked to customer satisfaction. For example, pavement roughness and structural adequacy are measures that are intangible for the customer, but relate to ride quality.

In 2001, PennDOT and the U.S. Department of Transportation sponsored research on developing an instrument for capturing public opinion regarding maintenance service. The objective was providing county managers with adequate information to identify problems, target priorities, and improve service delivery. The instrument was structured around the three major priorities of the maintenance service that were identified by the 1996 National Highway User Survey: pavement condition, safety, and traffic flow (National Quality Initiative Steering Committee 1996). The questionnaires were mailed statewide to 67,000 motorists. The survey generated 17,500 completed answers (26.1 percent), a response rate commonly obtained by mail surveys (30 percent). The new instrument proved effective and demonstrated that it is possible to administer sophisticated surveys to obtain feedback from the highway user (Poister et al. 2002).

More recently, the National Cooperative Highway Research Program funded Project 14-13 whose goal was to illustrate the advantages of customer-driven benchmarking techniques for improving efficiency and effectiveness of maintenance product and services. Hyman and Heffner (2003) conducted a survey to determine the extent to which transportation agencies had used customer-oriented measures and benchmarking techniques to improve their maintenance operations. The results indicated that nearly 40 percent were using customer surveys to assess customer satisfaction, preferences, or expectations related to maintenance services. About 30 percent were applying benchmarking techniques to improve maintenance operation performance. Although the survey indicated a significant number of applications of benchmarking techniques, the overall discrepancy in the measures used by different agencies was identified as the main obstacle to national benchmarks.

Project 14-13 was followed by the preparation of a comprehensive guide to conducting benchmarking in the road sector. Hyman (2004) presented Customer-Driven Benchmarking as a continuous process of improvement to enhance customer satisfaction. The primary goal was to develop a maintenance program that incorporates attributes of customer satisfaction and thereby gains supporters of the maintenance program by providing a service that meets customer needs.

2.4.3. Customer Involvement in Service Development

A general approach for involving customers in the definition and refinement of transportation products and services is described in the literature as *customer-based quality* - a continuous process that utilizes customer-oriented measures for improving existing approaches, developing new ones, defining performance targets, or improving customer service. The process can be synthesized in four sequential activities: identify customers, identify customer needs, develop ways to respond to customer needs, and assess customer satisfaction (Stein-Hudson et al. 1995).

Customer-based quality was applied in highway maintenance to define performance targets – specifically the threshold at which asset performance shifts from unsatisfactory to satisfactory. Poister, Garvey, Zineddin, Pietrucha and Smith (2005) compared PennDOT's standards for ride quality with Pennsylvania motorist perceptions to "find thresholds on PennDOT's ride quality standard scale at which ride quality shifts from being unsatisfactory to satisfactory from the motorist's point of view" (Poister, et al. 2005, p.44).

Giese, Griffin, and Kuemmel (2001) also linked ride-quality standards to customer satisfaction but with a more comprehensive approach. The objective was to produce "a robust and concise psychological model that explains how drivers evaluate the quality of the pavement" (Giese et al. 2001, p.69). The researchers wanted to analyze not only the relationship between the measure of ride quality and driver satisfaction but also the psychological model that explains the satisfaction of the customer. They concluded that a cognitive structure, composed by drivers' most salient beliefs about driving on the pavement, mediates the relationship between physical pavement characteristics and customer satisfaction.

Another attempt to link service conditions with customer satisfaction was carried out by the Transit New Zealand Agency. Owen, Cenek, and Jamieson (2003) presented a procedure based on standard measures of road conditions and road geometry to identify highway areas that exhibit unfavorable conditions and determined the threshold value for a comfortable ride based on the rotational response of the cabin. An on-road experiment tested the reliability of the procedure using trucks instrumented to measure in-cab body acceleration and rotation. Truck drivers' opinions were used to determine the threshold value for a comfortable ride. The procedure, fully supported by the outcome of the road test, was adopted by Transit New Zealand as part of its state highway maintenance management system.

In Finland, road managers have experimented with a client-oriented approach to winter maintenance since 1998. The initiative originated from a gap between current winter standards and customer needs. Users of low-traffic roads in the region of Savo-Karjala complained that at certain times of the year, safety and ride quality were unsatisfactory, despite maintenance activities that complied with national standards. The transportation agency responded with a winter maintenance program incorporating local adjustments based on customer needs. In 1999, the incremental cost of these adjustments was around 3 percent of the total maintenance program. In most cases, complying with customer needs only required better timing in the implementation of maintenance activities already planned by the administration (Karjalainen 2001).

In Japan, Tokunaga, Takahashi, and Asano (2004) applied the widely used marketing research conjoint approach to solve a problem with sidewalk maintenance in Sapporo. The objective was to "identify residents' preferences among a wide variety of walkway features in order to suggest an evaluation method for winter pedestrian mobility in Sapporo" (Tokunaga et al. 2004, p.237). Road-heating systems on sidewalks and crosswalks were adopted for winter pedestrian mobility. However, financial constraints made citywide deployment unfeasible. The conjoint approach was adopted to determine which attributes of winter walkways the pedestrians were willing to sacrifice in favor of other attributes. The results demonstrate the advantages of the conjoint approach over a simple survey for determining customer preferences and satisfaction related to maintenance services.

2.4.4. Service Quality Measurement

An attempt at using customer satisfaction to measure service quality and justify maintenance funding allocation was conducted by the Maryland State Highway Administration (Jha, 2004). The agency developed a model for assessing the performance of rest areas based on customer satisfaction. However, the results of the model confirmed conditions that were already known by the agency without adding significant value to the assessment.

2.5. Competing Approaches for Measuring Service Quality

Customer satisfaction is the measure most frequent selected by state DOT for collecting input from customers (Ray 2006, McKenzie 2004, Deseran et al. 2001, Cantalupo and Quinn 1999). However, customer satisfaction is not the only way to measure customer opinions of service quality.

An alternative measure is the "Performance *minus* Expectation" specification (P-E) suggested by Parasuraman et al. (1985). P-E provides a superior diagnostic evaluation of the customer opinion related to maintenance. This advantage comes at the expense of a more complex survey questionnaire. Measuring expectations in addition to service performance increases the complexity of the instrument.

Both can measure the quality of highway maintenance. Adopting one measurement approach over the other involves choosing either better diagnostic powers of the measure and a more simple survey instrument. The road manager must "assess the practical usefulness of measuring expectations and the trade-offs involved in not doing so" (Parasuraman et al., 1994, p.120).

2.5.1. Customer Satisfaction as a Performance Measure

Encouraged by the retailing industry, customer satisfaction has been the subject of an impressive number of studies. During the last 40 years, several models have been suggested and expanded to uncover the mechanism associated with customer satisfaction.

At first, customer satisfaction was considered the result of a cognitive process – a perceived discrepancy between an initial standard and the actual performance of the service/product. This mechanism was thought to be an additive process in which new positive or negative experiences change the initial reference point or standard.

Figure 9 shows a model for measuring customer satisfaction that includes four distinctive constructs:

- Expectation or the consumer's beliefs about a product that constitute a reference point against which actual performance is assessed.
- Performance or the consumer's perception of what the product delivers during or after consumption.
- Disconfirmation or the discrepancy between actual performance and previous expectations that ultimately generates satisfaction or dissatisfaction.
- Satisfaction or the consumer's post-purchase evaluation.

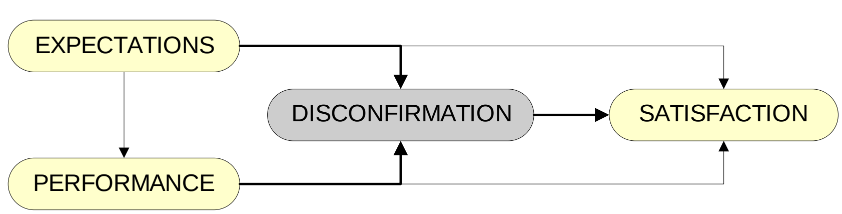

Figure 9 A Cognitive Model of Customer Satisfaction

(Churchill and Surprenant, 1982, p.498)

Several studies have concluded that disconfirmation directly affects satisfaction and mediates between performance and expectations and satisfaction (Churchill and Surprenant 1982, Oliver and Bearden 1985). Other conclusions support the direct relationship among performance, expectation, and satisfaction (Bolton and Drew 1991, Churchill and Surprenant 1982). Although the cognitive model in **Figure 9** predicts customer satisfaction fairly well, the underlying phenomenon of satisfaction was proved to be more complex than its original conception.

An important element - missing to some extent in the cognitive model presented in **Figure 9** - is consumer affect. Affect is the consumer's feelings or emotional states that derive from specific events or actions, such as product consumption (Oliver, 1993). **Figure 10** shows customer satisfaction as a function of cognition, affect, and direct experience. The model is based on the cognitive model presented in **Figure 9,** expanded to include the effect of positive and negative affects. **Figure 10** introduces a new perspective in customer satisfaction that is added to the cognitive mechanism in **Figure 9**. Satisfaction is the result of multifaceted product features, all allowing for multiple experiences with the product, some negative, some positive, and both negative and positive coexisting simultaneously. Satisfaction is the sum of multiple product-attribute experiences.

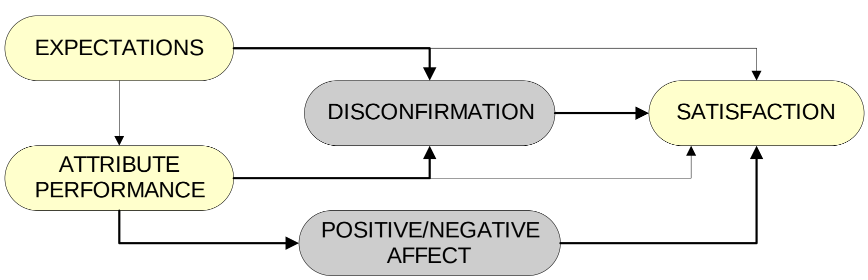

Figure 10 Combined Cognitive and Affect-Augmented CS/D Model

(Oliver, 1993, p.419, Used with permission of Journal of Consumer Research, 2008.)

2.5.1.1. Measuring Customer Satisfaction in Transportation

An attribute is a characteristic of a service or a product that satisfies a specific need of the consumer, such as the absence of offensive odors in the rest area or smoothness of ride. Highway maintenance services can include between 15 to 30 attributes, such as ride comfort, road condition (e.g. level of deterioration), visibility and usefulness of pavement markings, presence of guardrails, and plantings (Hamilton 2003).

Transportation agencies and maintenance units have been using customer satisfaction assessments since late 1990s. Road managers have adopted survey instruments as market research tools to identify service deficiencies. The scale in the questionnaire is important and requires careful design consideration. Several studies provide guidelines for the wording that should be used to measure expectations, performance, disconfirmation, and satisfaction (Hyman 2004, MORI 2002, Poister 2003).

The following are examples of customer satisfaction measurement performed by DOTs:

- The *Pennsylvania Department of Transportation* developed a systematic method to measure customer satisfaction. Road managers used customer input to identify deficient processes and areas showing poor performance from the perspective of the customer (Bilotto 2003).
- The *Louisiana Department of Transportation* used customer satisfaction as a performance measure. The department used this input to assess satisfaction with particular components of the state-maintained highway system and determine where resources were needed most (McKenzie 2004).
- The *Florida Department of Transportation* used surveys to measure the satisfaction of older Floridians. The surveys addressed several topics such as sign and road marking visibility,

construction areas, and mobility within the community using the state highway system. Road managers used the results to plan and optimally serve this particular segment of users (Deseran et al., 2001).

- The *Wyoming Department of Transportation* used customer surveys to observe general trends in customer satisfaction and determined the effectiveness of its policies and resource allocations (Taylor et al., 2004).

- The Kentucky Department of Transportation collected customer input to establish a baseline of customer satisfaction and determine needs as perceived by users. Road managers used this input to determine priorities and develop guidelines for investments and strategic planning (Anderson and Hockensmith 1997).

2.5.2. Performance minus Expectation Specification

In 1985, Parasuraman, Zeithaml, and Berry (PZB) developed a conceptual model of service quality as a theoretical background for future research. The model, shown in **Figure 11**, is based on interpretation of qualitative data from interviews and focus groups with business practitioners and consumers from the retailing industry.

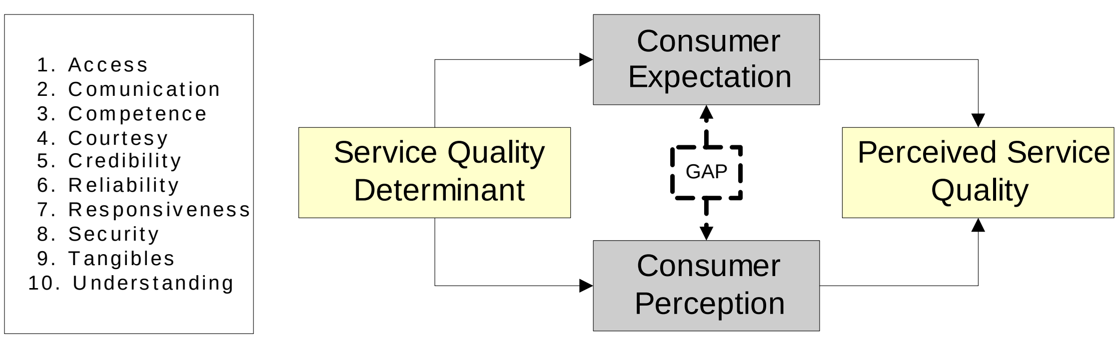

Figure 11 Perceived Service Quality

(Parasuraman et al., 1985, p.48)

After analyzing the interviewees and focus groups, PZB (1985) concluded that, regardless the type of service, consumers evaluate quality using similar criteria or *service quality determinants.* These determinants are shown on the left-most side of **Figure 11**. PZB (1985) proposed that perceived service quality is a function of the expected service (ES) or consumer expectation and the perceived service (PS) or consumer perception. When ES is greater than the PS, the quality of the service is less than satisfactory and perceived service quality is low. When the PS is greater than the ES, the quality of the service is more than satisfactory and perceived service quality is high.

PZB (1988) selected five services from the retailing industry to construct a scale for measuring service quality based on the service quality determinants in **Figure 11**. These services were appliance repair and maintenance, retail banking, long-distance telephone, security brokerage, and credit cards. These services represent the retailing industry in key dimensions such as high-contact services and tangible service results.

A two-statement questionnaire was developed to gather data from consumers. The first statement measured service expectations without making any references to a particular firm. The second statement measured the perception of the quality of service provided by a specific firm. The sample size was 200 adult respondents per service. Only consumers with recent (three months) experience with the selected services were selected.

The scale was tested and refined twice. After the first refinement, the number of service attributes decreased from 97 to 34. After the second test, the result was a 22-item five-dimension scale. According to PZB (1988), the scale presents good reliability and validity and can be used to understand consumers' expectations and perceptions. The scale can also be used to track service-quality trends, provide an overall average of service quality, assess relative importance of quality dimensions, categorize customers into perceived-quality segments, and benchmark service performance among different units/competitors.

Carman (1990) conducted a replication-and-testing study for the multiple-item scale developed by Parasuraman et al. (1988). One objective was to test the scale's five dimensions and judge whether they should be considered generic dimensions. Carman selected four different services than those used by PZB (1988). These services were a dental school clinic, a business school placement center, a tire store, and an acute care hospital. The sample size differed from that used by PZB (1988). For two services, the sample size was between 74-82 and for the other two services, the sample size exceeded 600. The data was analyzed using the same procedures followed by PZB (1988). The analysis involved three aspects of the scale: construct validation, factor analysis, and discriminat validation. Construct validation determines whether items remained in the same factor indicated by PZB or not. Factor analysis helps determine whether items grouped in the same way as indicated by PZB. Discriminant validation determines whether factors were truly different from one another. The replicated data did a fair job for the construct validity and factor analysis but the discriminant validation was somewhat in doubt.

Carman (1990) concluded that the scale can be effective for measuring service quality after incorporating particular features of the service. This outcome was expected since PZB (1988) indicated that necessary adjustments will occur when using the scale in different settings. In fact, none of the four questionnaires developed by Carman (1990) retained the original 22-item scale.

Carman also found that the dimensions suggested by PZB (1988) are not generic and factors or items should be added if the user believes they play an important role in the service-quality equation. "If one of the dimensions of quality is particularly important to customers, they are likely to break that dimension in sub-dimensions" (Carman, 1990, p.37).

2.5.2.1. Measuring Service Quality in the Public Sector

The scale from Parasuraman et al. (1988) is known as SERVQUAL Multiple-Item Scale. Several pilot programs were developed to assess the applicability of the SERVQUAL scale for measuring service quality in the public sector. The following services were selected for these programs: catering, building warrants control, building development control, grounds maintenance, housing repairs, leisure, and library services. A questionnaire was custom-developed for each program to account for the unique aspects of each service. The five dimensions proposed by Parasuraman et al. (1988) remained constant and sample sizes ranged from 100 to more than 500.

Despite limitations related to the complexity of the questionnaire, public service managers found SERVQUAL "conceptually attractive and operational useful" (Wisniewski, 2001, p.387). A recommendation to provide participants with detailed instructions for completing the questionnaire was included in the final report.

Several applications of SERVQUAL were identified from the analysis of the seven pilots. These applications did not vary significantly from those proposed by Parasuraman et al. (1988) except for: "Understanding the internal customer - In order to deliver service quality to the external customer it is well recognized that internal customer service must also be of the right quality" (Wisniewski, 2001, p. 384).

2.5.2.2. Measuring Service Quality in the Construction Industry

Kim Wan Siu et al. (2001) adopted the disconfirmation-based approach suggested by Parasuraman et al. (1988) for assessing service quality in building maintenance. The SERVQUAL scale developed by PZB (1988) was selected for measuring service quality of mechanical and engineering services. The researchers adopted the 22-item five-dimension scale and the items of the scale were adjusted to suit the building maintenance field as recommended by PZB. The beginning of the questionnaire included a new section to collect data on the relative importance of service dimensions and the customer satisfaction.

The questionnaires were mailed to clients and service providers. Fifty questionnaires were sent to each group and a 42 percent and 26 percent response were obtained from clients and service providers, respectively. The SERVQUAL values for the five dimensions were obtained by averaging the respondents' scores and then weighting them according to relative importance. The analysis concluded that perceived quality is an important antecedent of customer satisfaction in building maintenance. Knowing consumers' expectations gives the contractor the opportunity to deliver a more competent service and provides the impetus to achieve a higher level of quality – and higher levels of satisfaction (Kim Wan Siu et al., 2001).

2.6. Conclusions of Literature Review

The concept of involving the public in the development of transportation solutions was incorporated into the Federal-Aid Highway Act of 1956, the legislation that authorized the construction of the Interstate Highway System. Better plans, transparent processes, and public support are some of the benefits that road managers can achieve by educating and involving the general public. In 1991, the Intermodal Surface Transportation Efficient Act revitalized the concept of public involvement by empowering metropolitan planning organizations to participate in the planning and funding allocation of transportation projects located in metropolitan areas.

Almost concurrently, the Road Sector adopted customer satisfaction as a performance measure for identifying deficiencies in highway service and used customer input to assess user satisfaction with agency policies and strategies. During the last 20 years, research on customer-driven highway maintenance suggests increasing levels of interest supported by both public service agencies and academia. Highway performance assessment has gathered the most attention followed by customer participation in the development of maintenance services. Little research was found related to the measurement of highway maintenance service quality.

Two main approaches have been found in the literature for measuring service quality: performance-based measurements and disconfirmation-based measurements. The first approach is based on customer satisfaction measures. The second approach adopts the "Performance *minus* Expectation" specification for measuring service quality. A tradeoff between the diagnostic value of the measure and the simplicity of the survey instrument must be evaluated before adopting one method over the other.

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3. CHAPTER THREE – RESEARCH METHOD

3.1. Service Quality vs. Customer Satisfaction

Two approaches for measuring highway maintenance services were identified previously: one is based on customer satisfaction measures; the other uses service-quality measures. Customer satisfaction/dissatisfaction (CS/D) is a post-consumption evaluation of a service affected not only by the attributes of the service but also by other factors such as customer's affect. Service quality is a global evaluation of the levels of service attributes and is a cognitive judgment that persists in the absence of new information. Customer satisfaction and service quality measures are not entirely independent concepts and sometimes customers find it difficult to differentiate between the two constructs. In fact, the overall customer satisfaction involves many factors including service quality. Some of these factors are under the control of the service provider while others are not (Bitner and Hubbert 1994).

Variables that define service quality are under the control of the service provider since the outcome of the measurement depends only on the presence or absence – and levels - of attributes of the service. Adopting a service quality approach is more appropriate than a customer satisfaction approach for measuring a contractor's performance because the contractor is fully accountable for the outcome of the measurement.

3.2. Research Methodology Overview

The methodology developed for the study was divided into seven steps as indicated in **Figure 12**. The first four steps correspond to the planning phase of the data collection effort. Step 5 and Step 6 correspond to the execution phase of the study and the last step corresponds to the data analysis module.

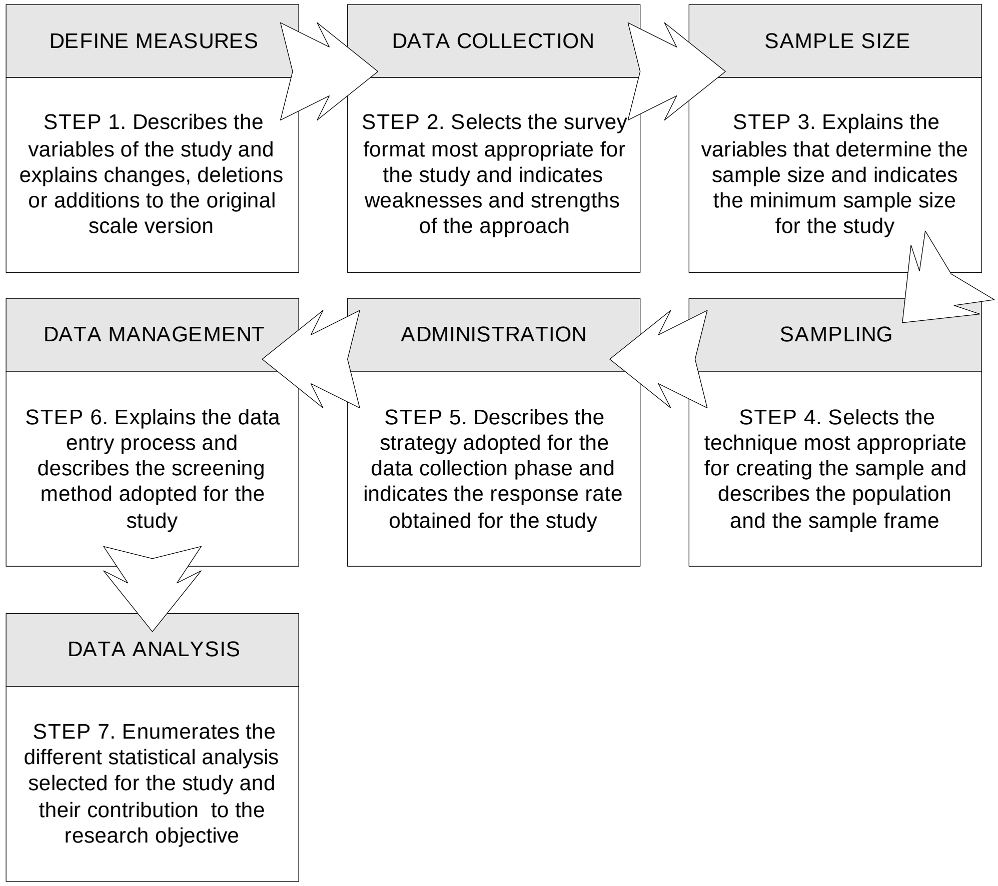

Figure 12 Seven Steps of the Research Methodology

The methodology described above was run twice: a pilot study followed by the final study. The pilot study was conducted for testing the practicability of the research methodology before spending valuable resources. The main goals or objectives of the pilot initiative were: getting familiar with the survey research methodology, gathering preliminary data related to highway maintenance service quality, and obtaining feedback on the various documents developed for the survey. The remaining of the chapter focuses on describing the strategy and elements selected for the final study; however, some references to the pilot study were needed for completeness' sake and were included in the narrative. A more detail description of the strategy adopted for the pilot study can be found in **Appendix F**.

3.3. Dimensions and Measures

The variables for measuring perceived quality of highway maintenance service delivery were adopted from the SERVQUAL multiple-item scale developed by Parasuraman et al. (1988). As discussed earlier, the scale was developed for measuring service quality in the private service sector (i.e. retailing, banks, telecommunication, etc.).

The original SERVQUAL scale was structured around five dimensions of the service:

- **Tangible**: physical facilities, equipment, and appearance of personnel
- **Responsiveness**: willingness to help customers and provide prompt service
- **Reliability**: ability to perform the promised service dependably and accurately
- **Assurance**: knowledge and courtesy of employees and their ability to inspire trust and confidence
- **Empathy**: caring, individualized attention the firm provides its customers

According to the authors of the scale, these five dimensions were considered generic service quality dimensions, applicable to any type of service. However, the variables included in some of these dimensions were inappropriate for measuring highway maintenance service quality for the following reasons.

The Responsiveness dimension measures perceived quality of service outcomes through the willingness to help customers and provide prompt service. The scale items in SERVQUAL are: (1) readiness to respond to customers' requests, (2) prompt services to customers, and (3) willingness to help customers. To measure responsiveness in service delivery, it is assumed that the employee has direct contact with the customer during the delivery of the service. In highway maintenance, the customer is the road user and a direct contact between the service employee and the customer never occurs. Consequently the scale items corresponding to the measurement of responsiveness cannot be evaluated by the road users.

The same reasoning applies to the Empathy dimension. Empathy measures the perceived quality of attention provided by the organization to its customers. The scale items included in SERVQUAL for measuring empathy are: (1) giving the customers individual attention, (2) employees who deal with customers in a caring fashion, (3) having the customer's best interest at heart, and (4) employees who understand the needs of customers. To measure these items, direct contact between the employee and road user must exist during service delivery.

For the remaining dimensions, it was assumed that road users were able to perceive service quality dimensions represented by the variables of each dimension without requiring a direct contact with service employees. Users observed the service tangibles while driving through a maintenance area. They perceived, from the manner in which the service was delivered, the quality of the service outcomes related to employees' ability to perform the service and inspire trust and confidence. **Table 1** shows the three dimensions and scale items selected for measuring the perceived quality of highway maintenance service delivery during the pilot study.

The Tangible dimension was measured with three variables: A_1, A_2, and A_3. Tangible variables are presented in the top section of **Table 1**. The wordings of these variables were similar to the wordings adopted in the original SERVQUAL scale. However, some changes were made to account for highway maintenance service settings. The Reliability dimension was measured with four variables (A_4, A_5, A_6, and A_7) that are presented in the middle section of **Table 1**. The changes performed to the wording of these variables were significant. In fact, none of the four variables remained in its original form. In all cases the changes reflected some particular characteristics of the highway maintenance service delivery process.

Table 1 Measures and Scale Items Selected for the Pilot Study

MEASURE	SCALE ITEMS	
TANGIBLE: "Physical facilities, equipment, and appearance of personnel."	A_1	Modern Equipment
	A_2	Employees wearing proper attire (e.g. hardhat, reflective vest, etc)
	A_3	Adopting Convenient working hours
RELIABILITY: "Ability to perform the service dependably."	A_4	Minimizing travel delay through maintenance areas
	A_5	Performing maintenance when required
	A_6	Keeping customers inform about maintenance activities
	A_7	Performing maintenance in a reasonable period of time
ASSURANCE: "Knowledge of employees and their ability to inspire trust and confidence."	A_8	Employees instilling confidence in you
	A_9	Making road users feel safe while driving through maintenance areas
	A_{10}	Isolating Maintenance areas effectively
GLOBAL	SQL	Overall perception of the quality of the highway maintenance service

The Assurance dimension was measured with three variables: A_8, A_9, and A_{10}. Assurance variables are presented in the bottom section of **Table 1**. The first two variables remained unchanged from their original counterparts. However some minor changes were made on variable A_9. The wording A_{10} was changed to address the manner in which maintenance areas were isolated. The last variable at the bottom of **Table 1** is a global measure. Perceived service quality (SQL) measured the overall feelings of road users toward the quality of highway maintenance services.

The same three dimensions selected for the pilot study were adopted in the final study. However, some variables changed in wording and interpretation as indicated in **Table 2**. For example, the prompt "Keeping road user informed of maintenance activities," variable A_6 from the pilot study, was originally selected as a measure of perception of VDOT's ability to provide the maintenance service (i.e. Reliability group). But it can also be interpreted as a measure of the level of confidence and safety perceived by the users while driving through a maintenance area (i.e. Assurance group). In the original SERVQUAL scale, variable A_6 was associated with notifying customers about the time and date of service delivery. In highway maintenance, variable A_6 can also be associated with notifying road users about the proximity of a maintenance area. Therefore, in highway maintenance services, variable A_6 can be labeled as a safety attribute of the service and grouped with other variables of the Assurance group. In the final study, both interpretations of variable A_6 were considered and two scale items were included in the questionnaire. One item was worded following the original interpretation and the second item was worded according to the new interpretation. The prompts for these two items are shown in **Table 2** as variables B_{12} and B_8, respectively.

The original SERVQUAL scale included an item related to the installed material (e.g. telephone equipment, installation cables, etc). The item, associated with the variable Tangible, was initially excluded from the pilot study because the quality of the material installed by the highway maintenance service provider is included in the overall evaluation of the quality of the highway and has no bearing on the assessment of the quality of the highway maintenance service delivery; hence, the exclusion of the item from the scale. However, highway maintenance service providers use materials and elements, such as reflective cones and concrete barriers, for delivering service. These elements have a visual impact on the road user and, ultimately, their appearance will affect the road user's judgment of the quality of highway maintenance services. The new scale item is shown in **Table 2** as variable B_4.

Table 2 Changes in the Scale from the Pilot Study to the Final Study

MEASURE	PILOT STUDY		FINAL STUDY	
TANGIBLE: "Physical facilities, equipment, and appearance of personnel."	A_1	Modern Equipment	B_1	Using equipment that looks well-maintained and in good working condition
	A_2	Employees wearing proper attire (e.g. hardhat, reflective vest, etc)	B_2	Employees wearing proper attire (e.g. hardhat, reflective vest, etc)
	A_3	Adopting Convenient working hours	B_3	Performing maintenance during low traffic time periods.
			B_4	Using clear indicators of maintenance activities (e.g. cones, barriers, signs, etc)
RELIABILITY: "Ability to perform the service dependably."	A_4	Minimizing travel delay through maintenance areas	B_5	Minimizing travel delay through maintenance areas
	A_5	Performing maintenance when required	B_6	Performing maintenance work when it appears to be needed
	A_7	Performing maintenance in a reasonable period of time	B_7	Completing maintenance work within a reasonable time duration
	A_6	Keeping customers inform about maintenance activities	B_8	Keeping road users informed about locations and durations of maintenance work
ASSURANCE: "Knowledge of employees and their ability to inspire trust and confidence."	A_8	Employees instilling confidence in you	B_9	Operating heavy equipment without frightening road users
	A_9	Making road users feel safe while driving through maintenance areas	B_{10}	Making road users feel safe while driving through maintenance areas
	A_{10}	Isolating Maintenance areas effectively	B_{11}	Guiding road users through well-defined maintenance areas
			B_{12}	Alerting road users when approaching maintenance areas
GLOBAL	SQL	Overall perception of the quality of the highway maintenance service	SQL	Overall perception of the quality of the highway maintenance service

3.3.1. Response Scale and Background Variables

The response scale adopted for the pilot study was one of three response scales tested by Parasuraman et al (1994) using SERVQUAL scale. The other two response scales were the P-E (Perception *minus* Expectation) specification, originally prescribed for SERVQUAL scale, and a variation of the response scale adopted for the pilot study. A comparison of the three scales showed that the response scale adopted in the final study reported the highest overall predictive power in explaining the variance of the overall perceived service quality.

The range of the response scale for the final study was different from the range of the response scale for the pilot study. One participant of the pilot study indicated that the nine-point scale was too large. Quote: "*My feelings about these questions are not well enough defined to make a nine-*

point scale meaningful. I am able to rank my answers meaningfully on a five-point scale.” In previous service quality studies, a nine-point response scale was commonly adopted for measuring service quality. However, such a scale is excessive for recording participants’ feelings about the attributes of highway maintenance services. A five-point response scale, as indicated below, proved to be more adequate than the nine-point response scale for measuring the service quality.

```
Much Lower        Same         Much Higher
    ①        ②        ③        ④        ⑤
```

The response scale adopted for measuring the global variable, SQL, was also changed from a ten-point scale to a five-point scale as indicated below.

```
Poor            Adequate       Excellent
 ①         ②         ③         ④         ⑤
```

In addition to the scale items in **Table 2**, the final study collected demographic information. The selected demographic variables were: location, age, gender, and primary trip type. **Table 3** shows the categories for each demographic variable. Information about the location of the participant was not directly obtained from the participant but derived from his or her mailing address.

Table 3 Demographic Variables

Location	Age	Gender	Primary Trip Type
Montgomery County	18 to 34	Male	Commuting to/from work/school
Giles County	35 to 54	Female	For Business
Pulaski County	55 and over		Shopping/Errands
			Recreation
			Other

3.4. Data Collection Format

Four types of data collection are commonly used in sample survey research: in-person interview, telephone survey, mail-out survey, and on-line survey. All four formats present advantages and disadvantages associated with time, resources, and other considerations. For example, administering in-person interviews and telephone surveys usually requires in-house trained personnel or the assistance of professional organizations. Conversely, the skills required for administering on-line or mail-out surveys are minimal.

The main disadvantage of the mail-out approach selected for the study is the typically low response rate (between 20-30 percent). Much research has indicated that a minimal financial token consistently improves the response rate and increasing the number of stimuli increases the likelihood of obtaining a response from the participant (Dillman 2007). Consequently, a four-contact mail-out strategy was adopted for administering the surveys and, as indicated earlier, multiple contacts and a prize/incentive were important features of the approach. Copies of the pre-notice letter, the cover letter and the questionnaire, the thank-you postcard, and the reminder letter with a replacement questionnaire are in **Appendix B**.

The pre-notice letter played a very important role by alerting participants to the upcoming questionnaire making the survey an expected item instead of an unpleasant surprise. The cover letter and first questionnaire were mailed two days after the pre-notice letter was mailed.

The main objectives for the thank-you letter were stimulating participants to complete the survey and acknowledging those who have already completed the survey. The thank-you postcards were mailed 10 days after the initial questionnaire was sent (when the number of daily responses started to decline).

The last contact - the reminder letter - was sent only to participants who did not complete the survey during the first round. Too often participants loose the initial questionnaire so a replacement questionnaire was mailed along with the reminder letter. The content of the reminder letter was different from the initial cover letter to increase response rate.

3.5. Minimum Sample Size

The study sample size was determined by the rules-of-thumb associated with the statistical analyses selected for the data analysis phase. For multiple regression analysis, the minimum sample size had to be at least 15 times the number of independent variables in the analysis (Hair et al., 1995, p.105). There were three independent variables originally selected for regression analysis, making the minimum sample size 45 responses (15 x 3). For factor analyses, the consensus for a minimum sample size is 10 times the number of variables in the analysis (Hair et al., 1995, p.373). **Table 2** shows 12 scale items, making the minimum sample size 120 responses (10 x 12). The largest number obtained using both rules-of-thumb was 120 responses, making the minimum sample size 120 responses.

3.6. Sampling Technique

Sampling techniques can be divided in two broad categories: non-probability and probability. The objective of probability sampling is to make a valid inference about a population using information from a subset of the population. In probability sampling, every participant has an equal probability of being selected for the study. On the contrary, in a non-probability sampling, participants are selected according to distinct characteristics. The subjectivity built into the selection process also prevents the researcher from making statistical inferences about the study population. A non-probability approach is useful when the researcher wants to establish the existence of a problem or when participants are difficult to contact (Henry 1990).

The most common non-probability samples are convenience samples, typical and critical case samples, snowball samples, and quota samples. A convenience sampling approach is used when a list of participants is already available for the study. The convenience sampling approach was adopted for the pilot study. Typical and critical case samplings are used when the researcher makes assumptions about the types of behavior that are present in the participants. Snowball sampling is used when participants are difficult to reach. The snowball approach requires a selected participant to identify the next participant. A quota sampling approach requires that a few easily identified characteristics of the population are known to the researcher in advance.

A quota sampling approach was adopted for the final study. Participants were selected from a contact list in quantities according to the proportions indicated by the sample quotas. The list for the study was the most current Verizon phone book for Montgomery, Giles, and Pulaski Counties. The phone book contained mailing addresses for the majority of households living in the selected area. One drawback of the phone book was that the information available in the book did not provide age nor gender. The issue was partially solved by indicating in the cover letter the gender of the person who was selected for completing the survey. The age range was not specified in the letter.

3.6.1. Population and Sample Frame

The survey population was defined as adult users of state-maintained roads. To tie the results to a physical maintenance unit, participants were selected from those who were living in the jurisdiction of the VDOT Christiansburg residency at the time the survey was released. The area included Montgomery, Giles, and Pulaski counties.

The distributions of age and gender for Montgomery, Giles and Pulaski Counties were known variables. The information was retrieved from the U.S. Census Bureau Web site. In addition to information related to the location of the participant, these two distributions were used to establish quotas for the sampling process. **Table 4** shows the figures corresponding to population, age, and gender for the three counties.

Table 4 Population, Age, and Gender for Montgomery, Pulaski and Giles Counties

Variable		Montgomery		Pulaski		Giles	
Population		70,789	63%	27,888	25%	12,989	12%
Gender	Male	37,966	45%	13,600	39%	6,231	37%
	Female	32,823	39%	14,288	41%	6,758	41%
Age	18 to 34	38,294	54%	7,517	27%	3,332	26%
	35 to 54	17,929	25%	10,877	39%	4,954	38%
	55 and over	14,566	21%	9,494	34%	4,703	36%

For a quota sampling approach, participants are selected from a contact list in quantities according to the proportions indicated by the sample quotas. The expected response rate was around 30 percent. To comply with the minimum sample size the total sample size was set at 750 participants. **Table 5** shows the quotas in the sampling process for selecting the 750 participants from the phone book. The participants were randomly selected from each page of the book. The entire phone book from A to Z was used in the selection. The reverse number-lookup feature available on the Verizon's Web Site was used to verify that users were still residing in the addresses provided by the phone book. The same feature was also used to obtain the complete ZIP code (i.e. ZIP+4 code).

Table 5 Quota Sample for the Final study Sampling Process

Population		Gender		Age	
Montgomery	63%	Male	52%	18 to 34	44%
Pulaski	25%	Female	48%	35 to 54	30%
Giles	12%			55 and over	26%

3.7. Survey Administration Process

During the administration phase, all the efforts were concentrated on reaching the participants of the survey. Earning participants' thrust, maintaining an open communication channel, and answering questions and concerns in a timely and professional manner were some of the activities performed during the administration process. Careful preparation of documentation, detailed planning and persistence were important attributes of the administration process. The instructions and documentation associated with the questionnaire were revised several times by different stakeholders, including graduate students and professors.

One reviewer indicated that the instructions provided with the survey were insufficient. "*I found the instructions for the rating system to be confusing*" she wrote. The person suggested changes to improve the instructions. "*Instead of giving an example where the personal and VDOT expectations are the same ("5"), use an example where the expectations are not the same*." The instructions were changed to include examples of different rating scenarios. Another observation in the pre-testing phase related to the use of the imperative form in the instructions for the completion of the survey. The term "you should" adopted for the instructions was changed to "you would" and the word "please" was added to every request in the instructions.

Once the pre-testing phase closed, three activities started concurrently. The first focused on the initial application for review. The application was sent to the IRB for approval. The second activity was creating a Web page whose main purpose was to provide an alternative channel for communications. The Web page included a brief description of the research and a link to the research team's main Web site page at Virginia Tech. The third activity was preparing the pre-notice letter and the first bulk mailing.

A thorough plan was developed for survey administration. **Figure 13** shows a bar chart depicting the duration of each mailing activity. The first row in **Figure 13** corresponds to the pre-notice letter and the second, third and fourth row correspond to the cover letter, the thank-you postcard, and reminder letter, respectively. The bar with diagonal strips indicates the letter was mailed from the researcher to the participant. The bar in grey indicates the letter was mailed from the participant to the researcher. The bar in black indicates that the letter is at the household. The total duration of the administration process was calculates as 34 days.

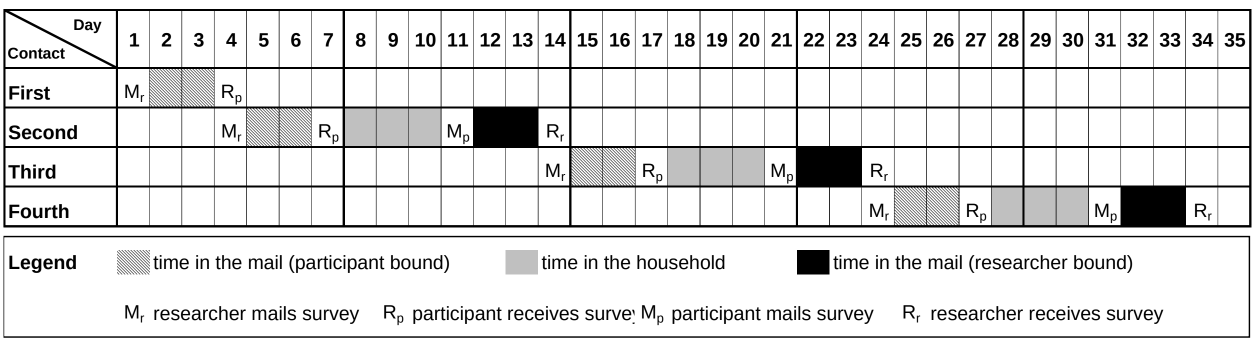

Figure 13 Surveys Administration Process Bar Chart for the Final Study

Once the permit was received from the IRB, pre-notice letters were sent to participants via the centralized mailing office at Virginia Tech. The second mailing - the cover letter and questionnaire - mailed as soon as the approval of the first amendment to the initial review was received. The printing and stuffing was completed by a one-person crew. The time required to print 750 envelopes, questionnaires, and cover letters was approximately four hours. The stuffing operation was completed in approximately six hours. The whole operation was completed in less than two days. The cover letter provided instructions for the survey and a description of the incentive included in the study. The cover letter also described the “request for removal” process and included a confidentiality disclaimer.

To maintain participant confidentiality, each survey was identified with a five-digit number on the top-right corner of the questionnaire. There was no other information about the participant on the questionnaire. The only way to link the questionnaire to the participant was through the contact list. The contact list linked each survey identification number (SIN) with the corresponding participant's full name and mailing addresses. The list was secured at the primary investigator's office. Only the primary investigator and the co-investigator had access to the drawer containing the contact list.

After mailing the questionnaire, four activities began concurrently. The first activity was answering questions and concerns from participants. Two options were included in the cover letter for communication purposes: telephone access and an email address. There were few questions during the administration phase. One participant called with a change of address. A questionnaire was immediately sent to the new address and the contact list was updated. The second activity was managing the inbound mailings. The main task involved ensuring that the identification number of each returned survey corresponded to the participant who was returning the survey. The check was justified by the possibility of misplacing the questionnaire during the stuffing process. Other tasks included scanning and filing questionnaires. The third activity was updating the contacting list. Each respondent was marked in the contact list and the date on which the completed questionnaire was received was recorded along with any comments or observations provided by the participant. The last activity was addressing withdrawals. Each participant was asked to return a blank questionnaire if he wanted to withdraw from the contact list and the study. Nine participants returned a blank questionnaire and were deleted from the contact list. A postcard confirming the withdrawals was sent to each of the nine participants.

As shown in **Figure 13**, the fourth contact mailing was sent 10 days after the thank-you postcard. The reminder was sent to 504 non-responding participants. The mailing took place immediately after the researcher received the approval of the second amendment from the IRB board. In the reminder letter, participants were urged to return a completed survey before April 15, 2008.

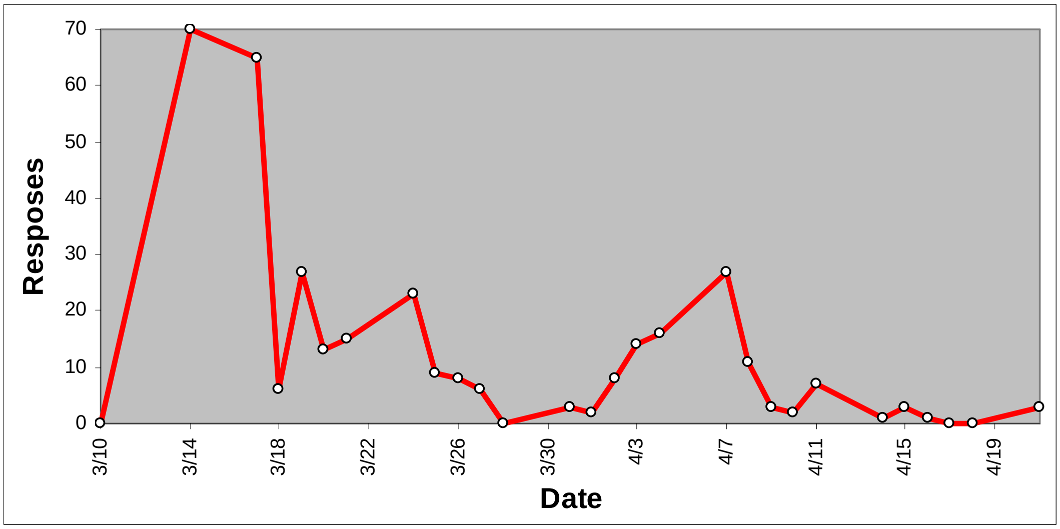

Figure 14 Final study Survey Response Time Series

Figure 14 plots the number of responses received each day during the research. The first and second peak from the left correspond to the initial questionnaire mailed on March 10, 2008. The third peak was due to the thank-you postcard mailed on March 24, 2008. The last peak was registered on April 7, 2008, a week after the reminder letter was sent.

Although, April 15, 2008, was listed as the last day of the survey, completed surveys were received until April 20, 2008. Ultimately, 343 participants sent responses. Of those responses, nine participants requested removal from the study and four surveys were returned due to deficient addresses. The total number of completed surveys was 334, a response rate of 44.6 percent.

The last activity of the administration process was the sweepstakes on April 30, 2008. The sweepstakes was designed to encourage participants to submit completed surveys. Each participant who submitted a complete survey was entered in a drawing for one of three iPod shuffles. The sweepstakes was filmed and posted on the Web site developed for the study. The three prizes were mailed to winners immediately after the drawing.

3.8. Data Management and Screening Process

Data management included data entry and screening. Data entry refers to the transfer of data from paper to electronic format. Data screening refers to the identification and processing of duplicate and missing data. The data was initially collected on paper and converted into electronic format. Scale item scores, overall rates, and demographic data were manually entered into a Microsoft Excel spreadsheet. **Table 6** shows a portion of the spreadsheet.

Table 6 Scale Item Scores, Overall Grades, and Demographic Data

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540271	3	3	3	3	3	1	3	1	1	1	1	3	.	2	2	1
540274	3	3	4	3	3	3	4	3	4	3	2	2	4	2	2	3
540276	3	2	4	4	3	2	3	1	3	3	2	2	2	1	2	..
540278	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	2
540279	3	3	2	4	3	3	2	3	3	3	3	3	4	2	2	1
540284	4	4	4	4	4	3	3	2	4	2	2	2	4	3	1	..
540286	3	3	3	3	3	3	3	3	3	2	2	2	3	1	1	1
540287	3	4	4	3	4	4	4	4	4	3	4	4	3	2	2	1
540288	4	4	4	3	3	3	3	2	3	2	2	3	.	2	1	1

The first column in **Table 6**, under the heading SIN#, is the identification number of the survey. The next 12 columns are the 12 scale items of the questionnaire. The heading SQL is for overall rating of the service quality. AGE, GEN, and TRP are the three demographic variables age, gender, and primary trip type, respectively.

Each datum was converted into a discrete value. To minimize data-entry errors, variables were recorded in the order they appeared in the questionnaire. The letter Q was used for identifying each scale item as indicated in the second row of **Table 6**. The order in which the scale items were presented in the questionnaire was different from the order in which the variables of the final study were presented in **Table 2**. The variables were re-labeled once the data entry process was completed and the data was checked for typing errors.

The scores were entered for each item according to the point selected in the response scale. For example, **Table 6** shows that participant 540271 selected "Much lower" for item Q_6 (B_5) which corresponds to point 1 of the response scale. Therefore, "1" was entered in the spreadsheet under the heading Q_6 (B_5) for survey 540271. The same participant selected "Same" for item Q_1 (B_{12}) which corresponds to point 3 of the response scale. Therefore, "3" was entered in the spreadsheet under the heading Q_1 (B_{12}). The same procedure was used to enter the scores for the global measure, SQL. Participant 540271 failed to provide an overall response for the quality of the service. Missing scores were recorded using the symbol "." (dot). Therefore, a single dot was entered for survey 540271 under the heading SQL as indicated in **Table 6**. For demographics data, each variable was coded as follows:

- Age 18 to 34: code 1
- Age 35 to 54: code 2
- Age 55 and over: code 3
- Gender Male: code 1
- Gender Female: code 2
- Primary Trip Type: Commuting to/from work/school: code 1
- Primary Trip Type: Business: code 2
- Primary Trip Type: Shopping/Errands: code 3
- Primary Trip Type: Recreation: code 4
- Primary Trip Type: Other: code 5

Although the instructions explicitly asked for only one answer to the Primary Trip Type question, several participants provided multiple answers to this item. Multiple answers were entered using the symbol ".." (double dots). In **Table 6**, participants 540276 and 540284 provided multiple answers to the Primary Trip Type item and double dots were entered into the corresponding cells of the spreadsheet. **Appendix C** shows the whole data set collected for the final study.

The transferring of data from paper to electronic format can be error-prone. The integrity and accuracy of the final data was verified by comparing tabulated data against the survey data. Two values were used for verifying data entry. The first was calculated using the original survey. The scale item scores, overall grade, and demographic data were manually summed using a calculator and the result was written at the bottom of the page. The second value was obtained from the spreadsheet.

The values in **Table 6** were summed horizontally. For each survey, the value written at the bottom of the survey was compared. Identical values indicated that the tabulated data and the survey data were the same. Divergent values indicated that an error occurred while transferring data from the paper to the electronic format. In most cases, the two values were the same but in a few cases, the values differed. The errors were always easy to spot and corrected.

3.8.1. Missing Data and Duplicated Data

The data collection process highlighted some missing data scattered among the 334 completed surveys. Both independent and dependent variables showed some missing scores. The pattern of the missing data was classified using the following three categories: missing completely at random (MCAR), missing at random (MAR), and nonignorable.

The data on a variable is said to be MCAR if "the probability of missing data on the variable is unrelated to the value of the variable or the value of any other variable in the data set" (Allison, 2002, p.3). The data on a variable is said to be MAR if "the probability of missing data on the variable is unrelated to the value of the variable, after controlling for other variables in the data set" (Allison, 2002, p.4). Probing the assumptions presented above is difficult because the value of the variable is always unknown. The data on a variable is said to be nonignorable if the data are not MAR (Allison 2002).

The following 10 surveys were missing data on independent variables: SIN# 540021, 540180, 540242, 540335, 540368, 540605, 540618, 540671, 540679, and 540728. The percentage of missing data for independent variables was calculated as 3.3 percent (10 surveys out of 334 surveys). There were no missing data recorded on variables Q_1, Q_7, Q_9, and Q_{12} (B_{12}, Q_{10}, B_1, and B_8). Variables Q_2, Q_3, Q_5, Q_6, Q_{10}, and Q_{11} (B_2, B_9, B_{11}, B_5, B_7, and B_3) showed only one missing score out of 334 surveys. In all cases the missing data was completely at random (MCAR). Variable Q_4 (B_4) had two missing scores. The dependent scores, SQL, for the two surveys with missing data on variable Q_4 (B_4) are 2 and 3. The missing scores could not possible be related to the dependent variable because the scores for the dependent variables are different. Variable Q_8 (B_6) exhibited three missing scores also unrelated to the dependent variable, SQL. It was assumed that the missing data on variable Q_4 (B_4) and Q_8 (B_6) was MAR.

The missing scores on variables Q_2, Q_3, Q_5, Q_6, Q_{10}, and Q_{11} (B_2, B_9, B_{11}, B_5, B_7, and B_3) could have been deleted from the data set without introducing any bias to the results of the statistical analyses because they were MCAR, but a different approach was adopted for the study. A score was imputed to each variable to avoid deletions and benefit from the rest of the information collected from the participant. Common imputation techniques introduce a bias to the data set.

However, the bias from imputation was negligible because the number of missing scores was very small; one out of 334 scores (0.3 percent). *Listwise* or *pairwise* deletions were not a good solution for variables Q_4 (B_4) and Q_8 (B_6). There are better but more complex methods for minimizing the bias introduced by common imputation techniques but the cost of running these methods was high compared to the benefit of doing so since the ratio of missing scores for each variable was very small. For each independent variable with missing data, the variable mode was used for imputing the missing score.

The percentage of missing data for the dependent variable was calculated as 3.8 percent (12 surveys out of 334 surveys). The following 12 surveys exhibited missing data on the dependent variable SQL: SIN# 540193, 540271, 540288, 540378, 540396, 540397, 540414, 540486, 540547, 540602, 540610, and 540611. There was no common pattern relating the missing scores in the dependent variable to any of the independent variables. It was assumed that the data on the dependent variable was MAR. The 12 surveys with missing data on the dependent variable were not used in the regression analysis.

A group of participants received two surveys during the process. The original survey was included with the cover letter. The replacement survey was included with the reminder letter. For a given participant, these two surveys had the same serial number, representing a potential source of duplicated data. After sending the reminder letter, special attention was placed on checking for duplicate numbers on incoming surveys. In two cases, the survey was found to be duplicated. The cases were named using the corresponding Survey Identification Number.

- **Case 540137**: The first completed survey was sent by the participant between the thank you postcard and the reminder letter. The survey was received at Virginia Tech after the reminder letter was sent. A completed survey with the same number was received few days letter, but the demographic information showed that the person who had completed the second survey was different from the person who had completed the first survey. The new completed survey was accepted. A new number was added at the end of the list and the answers were recorded using a new number (i.e. 540751).

- **Case 540724**: Both surveys were received the same day. The same answers were given in both surveys. The first survey was accepted and the second survey was deleted.

3.9. Institutional Review Board Research Permits

The study related to the measurement of perceived quality of highway maintenance service was conducted by a Virginia Tech (VT) faculty and a graduate student to contribute to the general body of knowledge in highway maintenance. Participation of human subjects in the data collection phase was necessary. The protocol of the research was reviewed by the Virginia Tech Institutional Review Board (IRB) to ensure that the methodology was ethical and that the rights of the participants were protected.

Before submitting the IRB application, both investigators completed the human-subjects protections training provided online by the VT IRB office. The training covered the development of codes and principles of research ethics, selection and recruitment of research participants, protection of confidentiality, basics of submitting VT IRB protocols, and the responsibilities of a VT researcher.

The notice of approval for the pilot study was received on Oct. 29, 2007. The notice of approval for the final study was received on Feb. 25, 2008. Due to changes in the documentation submitted to the IRB, the initial application was amended twice. The first amendment changed the wording of scale items. The amendment was approved on March 7, 2008, before the questionnaire was released to participants. The second amendment changed the fourth contact, the reminder letter. This change was identified during the planning phase of the survey. It was determined that the reminder letter was going to be adjusted at the moment of its release to convey the right message to the participants. The second amendment was approved on March 26, 2008. Copies of the human training certificate, the initial applications and the approvals of the initial review application and amendments are in **Appendix A**.

3.10. References

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4. CHAPTER FOUR – DATA ANALYSIS and RESULTS

4.1. Introduction

Chapter four presents the results obtained from the analysis of the collected data. The data analysis is the last step in the research methodology. **Figure 15** shows the four techniques selected and their relationship with the research objective.

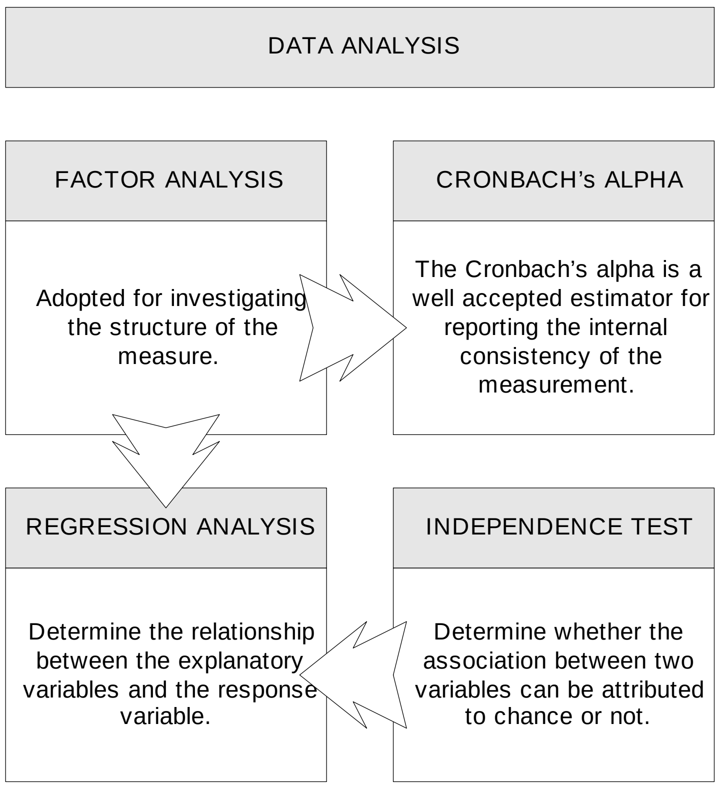


Figure 15 Data Analysis Technique Selected for the Final Study

The analysis focuses first on investigating the reliability and validity of the constructs and measures selected for the study. Reliability and validity are two psychometric properties that are crucial for supporting the results of the study. The evaluation of the psychometric properties of the measures is followed by the examination of the relationships between the dependent and independent variables of the study.

The response rate of the pilot study was low and the minimum sample size was not achieved. Nevertheless, some data analysis was performed. Details on the results obtained for the pilot study can be found in **Appendix F**. On the other hand, the response rate of the final study was higher than expected and the minimum sample size was achieved. The remaining of the chapter focuses on the data analysis corresponding to the final study.

4.2. Reliability and Validity of a Measurement

Users of tests and consumers of test information are very much concerned about the measurement reliability. "In the language of psychometrics *reliability* refers to consistency in measurement … not necessarily consistently good or bad, but simply consistent" (Cohen and Swerdlik, 2005, p.129).

The following concepts are associated with the reliability of a measurement or procedure.

- **Equivalence** refers to the degree to which the score obtained by the questionnaire can be generalized beyond selected variables to the universe of all possible variables. A test must show that variables in the questionnaire are representative of all possible variables.

- **Internal consistency** is related to the degree to which selected variables measure the same thing. A test must provide evidence of internal consistency by indicating how interrelated the variables are.

A regular procedure for testing the equivalence of a group of variables is the parallel form. Participants receive two questionnaires, each containing a subset of variables of the same domain. Each participant completes both questionnaires and then a correlation test determines whether the two questionnaires measure the same concept or not. If the test indicates a high correlation between the scores, the variables can be generalized to the same domain. On the other hand, if the result indicates a low correlation between scores, the variables cannot be generalized to the same domain. The present study did not test the equivalence of the selected variables. The questionnaire was presented to highway maintenance experts to obtain their opinion regarding whether the items were meaningful and representative of the highway maintenance service delivery. Staff members of the local MPO reviewed the questionnaire and supported the use of the items to measure the quality of highway maintenance service delivery.

The second bullet above relates to the internal consistency of the measurement and the Cronbach's alpha estimate. The Cronbach's alpha estimates the internal consistency of the measurement for a group of variables by indicating how interrelated the variables are. The closer the estimate is to the unit, the higher the internal consistency.

In the language of psychometrics "*validity* is a judgment or estimate of how well a test or measurement procedure measures what it purports to measure in a particular context" (Cohen and Swerdlik, 2005, p.156). The following concepts are associated with the validity of a measurement procedure.

- **Content validity** refers to the variables of the measurement and how representative these variables are of each service domain of the service. Many attributes define a service but not every attribute represents the same domain.

- **Construct validity** refers to the measures and whether they conform to the underlying theory adopted for the study. "Construct validity must be investigated whenever no criterion or universe of content is accepted as entirely adequate to define the quality of the measure" (Cronbach and Meehl, 1955, p.282).

The aspect of the measurement that should be subjected to validity verification depends entirely on the researcher's judgment and his or her experience. For example, in the present study, it seems appropriate to investigate the configuration of the selected measures due to the novelty of the measurement. Several quantitative analytical techniques are available for determining which variables best represent the domains of the service. This study used factor analysis to investigate the structure of the measurement

4.3. Factor Analysis

The factor analysis was adopted for investigating the structure of the measurement. In factor analysis, the main concern is to identify internal relationships between a set of variables x_i (i=1,…, p) and explain those relationships using as few factors as possible. These interrelationships can be modeled using the following equation:

$$x = \mu + Lf + \varepsilon \qquad \textbf{(Equation 1)}$$

where, $\boldsymbol{\mu}$ is a vector of constants, $\boldsymbol{f}$ is a random vector with elements $f_1,..., f_k$ ($k < p$) called the common factors, $\boldsymbol{L}$ is a p by k matrix of unknown constants called factor loadings, and $\boldsymbol{\varepsilon}$ is a vector called specific factors (Khattree and Naik 2000).

Equation 1 indicates that the measurement of a certain characteristic, represented by the variable $\boldsymbol{x}$, can be viewed as a linear combination of one or more common factors and one specific factor. In other words, the variance of variable $\boldsymbol{x}$ can be represented as the sum of two variance components: one corresponding to the common factors and the other corresponding to the specific factor. The contribution of the specific factor is called the uniqueness or specific variance and the contribution of all common factors is called the communality of common variance. The factor loadings can be interpreted as the correlation between the original variables and the common factors.

"Different [factor analysis] methods yield different solutions. However, when the sample size and the number of variables are large all the methods appear to yield similar solutions" (Khattree and Naik 2000 p.156).

Factor analysis methods can be divided in two categories: non-iteratives and iteratives. The most common non-iterative methods are the principal component method (PRINCIPAL) and the principal factor method with three choices of estimates of communalities (PF-SMC, PF-MAX, and PF-ASMC). The most common iterative methods are the maximum likelihood method (ML), unweighted least squares (ULS), iterative principal factor method (PRINIT), and the alpha factor analysis (ALPHA). **Table 7** and **Table 8** compare non-iterative methods and iterative methods, respectively.

Table 7 Non-iterative Factor Analysis Methods Comparative

METHOD	NFACT	CRITERION	TOTCOM (for nfact=2*)	RMS (for nfact=2*)
PRINCIPAL	2	MINEIGEN	7.4858 (7.4858)	0.0595 (0.0595)
PF-SMC	2	PROPORTION	6.5192 (6.5192)	0.0321 (0.0321)
PF-MAX	5	PROPORTION	7.3495 (6.6995)	0.0156 (0.0328)
PF-ASMC	5	PROPORTION	7.3452 (6.7031)	0.0141 (0.0322)

* The values in parenthesis are for the indicated option, NFACT=2

Table 8 Iterative Factor Analysis Methods Comparative

METHOD	NFACT	CRITERION	TOTCOM	RMS
ML	2	PROPORTION	6.6095	0.0317
ULS	2	PROPORTION	6.6105	0.0315
PRINIT	2	MINEIGEN	6.6110	0.0315
ALPHA	2	PROPORTION	6.6138	0.0317

The first column in each table indicates the method followed by the number of factors selected by the default options of the method. The fourth column presents the total variance explained by the number of common factors selected, TOTCOM, and the last column is the overall root mean square, RMS. The RMS can be viewed as a measure of goodness of fit for the factor model. The objective of the comparison is to find which method provides the highest TOTCOM with the lowest RMS. Also, TOTCOM and RMS were calculated for a two-factor solution. The number of factors was specified (NFACT=2). The results are shown in parentheses in **Table 7**.

In **Table 8**, there is no discrepancy among the iterative methods regarding the number of factors. All four methods selected a two-factor solution for analysis. The number of factors selected was in accordance with the number of components selected with the principal component technique. For the non-iterative method, in **Table 7**, the last two methods extracted five common factors for the analysis. When a two-factor solution was imposed, the three options of the principal factor method provided similar results.

The principal component method was selected for the analysis based on the total variance explained by the method (7.4858) which was the highest value among the eight two-factor solutions. The overall RMS of the principal component method was also the highest error among the eight two-factor solutions. However, the error (0.0595) was close to 0.05 which is the cutoff value recommended by Khattree and Naik (2000).

The outcome or solution of the factor analysis is the factor loading matrix, ***L***. The factor loading matrix can be rotated without changing the results of the analysis which means that the contribution of the common factors or communalities to the solution of the factor analysis remains constant after each rotation. Sometimes initial loading factors are hard to interpret in terms of their contribution to the explanation of the total variance. Usually, a rotation procedure changes the factor loading patterns offering a better interpretation.

When interpreting the factor loading matrix, a variable will be labeled relevant to the factor analysis when its contribution to the explanation of the total variance is significant. The absolute values of the loading factors indicate how significant the variable is in explaining the total variance. If the loading factors are low, the contribution of the variable is marginal and can be disregarded from the factor analysis. Conversely, if the loading factors are high, its contribution to the explanation of the variance is significant and the variable can be regarded as part of the factor analysis solution. However, when all the factor loadings of a variable are high, it becomes difficult to identify a single factor responsible for the explanation of the variable variance. The ideal situation is presented when one loading factor of the variable is high and the other loading factors are low because the explanation of the variance of the variable can be associated with the loading factor that shows the highest value. The loading factor of a variable that shows the highest value is called the principal factor of the variable and the remaining factors are called cross-loading factors. A variable that shows a principal factor loading greater than or equal to 0.60 and cross-loading factor(s) less than or equal to 0.30 will be retained in the solution of the factor analysis.

The first factor analysis was performed for the three dimensions hypothesized (three-factor model). **Table 9** shows the solution obtained for a NFACT=3 using an orthogonal rotation. The first four variables from the top correspond to the Reliability group, the next four variables correspond to the Assurance group, and the last four variables correspond to the Tangible variable. The total variance accounted by the three-factor solution was calculated as 8.170 and the overall error RMS was 0.0607. The number of observations used in the factor analysis was 334. For the solution presented in **Table 9**, few variables showed principal factors greater than

0.60 and only 4 variables (B_1, B_3, B_4 and B_{12}) with principal factors greater than 0.60 showed cross-loading factors less than 0.30. The three-factor solution was considered inadequate.

Table 9 Loading Factors for NFACT=3 and Orthogonal Rotation

Factor 1	Factor 2	Factor 3	Scale Item	Description
0.41	**0.62**	0.18	B5	Minimizing travel delay through maintenance areas
0.07	**0.69**	**0.38**	B6	Performing maintenance work when it appears to be needed
0.14	**0.76**	**0.32**	B7	Completing maintenance work within a reasonable time duration
0.40	**0.74**	0.01	B8	Keeping road users informed about the location and duration of maintenance work
0.78	0.21	0.10	B12	Alerting road users when approaching maintenance areas
0.59	0.16	**0.51**	B9	Operating heavy equipment without frightening road users
0.67	**0.40**	0.23	B11	Guiding road users through well-defined maintenance areas
0.58	**0.33**	**0.48**	B10	Making road users feel safe while driving through maintenance areas
0.60	0.12	**0.55**	B2	Employees wearing proper attire
0.79	0.24	0.25	B4	Using clear indicators of maintenance activities
0.26	0.27	**0.80**	B1	Using equipment that looks well-maintained and in good working condition
0.24	**0.81**	0.07	B3	Performing maintenance during low traffic time periods.

The next factor analysis considered a two-factor model. **Table 10** shows the outcome of the factor analysis using the principal component method. The factor loading matrix was rotated for better interpretation using the orthogonal method. The number of observations used in the factor analysis was 334.

Table 10 Loading Factors for NFACT=2 and Orthogonal Rotation

Factor 1	Factor 2	Scale Item	Description
0.41	**0.64**	B5	Minimizing travel delay through maintenance areas
0.23	**0.71**	B6	Performing maintenance work when it appears to be needed
0.25	**0.78**	B7	Completing maintenance work within a reasonable time duration
0.31	**0.74**	B8	Keeping road users informed about the location and duration of maintenance work
0.70	0.23	B12	Alerting road users when approaching maintenance areas
0.76	0.20	B9	Operating heavy equipment without frightening road users
0.67	**0.42**	B11	Guiding road users through well-defined maintenance areas
0.73	**0.37**	B10	Making road users feel safe while driving through maintenance areas
0.80	0.16	B2	Employees wearing proper attire
0.78	0.27	B4	Using clear indicators of maintenance activities
0.63	**0.33**	B1	Using equipment that looks well-maintained and in good working condition
0.20	**0.82**	B3	Performing maintenance during low traffic time periods.

The two-factor solution accounted for 7.4858 of the total variance (62.5 percent) with a RMS equals to 0.0595. Variables B_5, B_{10}, and B_{11} show cross-loading factors greater than 0.30 and were excluded from the factor analysis solution. Also, variable B_1 and B_8 shows a cross-loading factor slightly greater than 0.30. A second factor analysis was performed without the three variables indicated above to decide whether variable B_1 and/or B_8 should be retained in the solution or not.

Table 11 Loading Factors for NFACT=2 and Orthogonal Rotation (2nd cycle)

Factor 1	Factor 2	Scale Item	Description
0.73	0.24	B12	Alerting road users when approaching maintenance areas
0.82	0.18	B2	Employees wearing proper attire
0.77	0.20	B9	Operating heavy equipment without frightening road users
0.79	0.28	B4	Using clear indicators of maintenance activities
0.64	**0.36**	B1	Using equipment that looks well-maintained and in good working condition
0.22	**0.72**	B6	Performing maintenance work when it appears to be needed
0.25	**0.81**	B7	Completing maintenance work within a reasonable time duration
0.20	**0.81**	B3	Performing maintenance during low traffic time periods.
0.29	**0.77**	B8	Keeping road users informed about the location and duration of maintenance work

In **Table 11**, the principal loading factors for all variables were greater than 0.60. The cross loading factor for all variables, but for variable B_1, were less than 0.30. The cross loading factor of variable B_1 was calculated as 0.36. The cross loading factor for variable B_8 was 0.29. Variable B_1 was excluded from the two-factor solution because the cross loading factor was greater than 0.30. Variables B_2, B_4, B_9, and B_{12} remained associated with Factor 1 and variables B_3, B_6, B_7, and B_8 remained associated with Factor 2.

4.3.1. Interpretation of the Results of the Factor Analysis

The results of the data analysis suggests that the measurement of Highway Maintenance perceived service quality is better defined by a multiple item scale structured around two rather than three service dimensions. The three-factor multiple item scale suggested at the beginning of the study was not supported by the answers provided by the road users.

From the list of variables indicated in **Table 2** of Chapter 3, four out of 12 variables were excluded from the scale based on the results of the factor analysis. These four variables showed cross-loading factors greater than the minimum value set for the analysis. The remaining eight variables were equally distributed between the two factors of the factor analysis solution. The description of each variable is indicated in **Tables 12** and **Table 13**.

Table 12 Variables in Scale Factor 1

Variable	Description
B2	Employees wearing proper attire
B4	Using clear indicators of maintenance activities
B9	Operating heavy equipment without frightening road users
B12	Alerting road users when approaching maintenance areas

Table 13 Variables in Scale Factor 2

Variable	Description
B3	Performing maintenance during low traffic time periods.
B6	Performing maintenance work when it appears to be needed
B7	Completing maintenance work within a reasonable time duration
B8	Keeping road users informed about the location and duration of maintenance work

The variables in **Table 12** correspond to the first factor of the scale, Factor 1. These variables were initially assigned to two different service dimensions. Later, these two dimensions assembled into a single dimension with four variables: two variables, B_2 and B_4, from the Tangible dimension and variables B_9 and B_{12} from the Assurance dimension. After examining the descriptions of the variables included in Factor 1, the new combined dimension can be interpreted as "*the ability to manage obstructions and/or abnormal riding conditions within the right of way*." The new dimension was named SAFETY, since the service attributes measured by the variables of the new dimension can possibly be related to users' perceptions of the safety conditions at maintenance areas.

Most variables in **Table 13** were originally selected for measuring the Reliability dimension of the highway maintenance service. This is "*the ability to perform the service dependably.*" After examining the descriptions of the variables included in Factor 2, it was determined that the measurement remains as originally intended. Hence, the Factor 2 of the solution was named RELIABILITY.

Variable B_3 in **Table 13** was originally included in the Tangible group of variables. The allocation of the measure was based on several studies in the retailing industry. The original wording of the variable was "*convenient business hours.*" The wording adopted for the present study was "*performing the work when there is less traffic.*" The changed in the wording was driven by the assumption that convenient time for performing maintenance work is when there is less traffic. The factor analysis reallocated the variable within the Reliability group. Indeed, variable B_3 is more likely to be related with variables that measure service reliability than with variables that measure service tangibles.

4.4. Cronbach's Alpha Estimates

The reliability coefficient of a measurement is the squared correlation between the observed score Y and the true score T. These two parameters are related as follows: $Y = T + E$, where E is the error of the prediction. The error E and the true score T are independent with covariance zero, Cov $(T,E) = 0$.

The square correlation of Y and T is the coefficient of determination, $r^2(Y,T)$, a measure of the predictive value of the observed score. If the coefficient of determination is high, the observed score Y is a good predictor of the true score T. The true score T is unknown but it is possible to estimate a lower bound for the variance of T_0, $V(T_0)$, where T_0 is the total true score (Cronbach 1984). The lower bound for $V(T_0)$ is given by **Equation 4**. Assuming Cov (T_i,T_j) equal to Cov (Y_i,Y_j) for $i \neq j$, a lower bound for the reliability coefficient is given by **Equation 5**.

$$\frac{p}{p-1}\sum_{i \neq j} Cov\left(T_i, T_j\right) \quad \textbf{(Equation 4)} \qquad Cronbach's\, alpha = \frac{p}{p-1}\left(1 - \frac{\sum_j V\left(Y_j\right)}{V\left(Y_0\right)}\right) \quad \textbf{(Equation 5)}$$

Equation 5 is known as Cronbach's alpha, a well-accepted estimator for reporting internal consistency of a measurement. Cronbach's alpha indicates how interrelated the variables of the same group are. The closer the alpha value is to 1.0, the higher the interrelation is. Most statistical software packages calculate the Cronbach's alpha of a group of interrelated variables. **Table 14** and **Table 15** show the Cronbach's alpha for Safety and Reliability, respectively.

Table 14 Cronbach's Alpha for the variable in the Safety Group

Scale	**Raw variables**		**Standarized variable**	
Item	Correlation	Alpha	Correlation	Alpha
B12	0.63	0.806	0.63	0.807
B2	0.68	0.785	0.68	0.784
B9	0.63	0.804	0.63	0.805
B4	0.72	0.764	0.72	0.764
NONE	**--**	**0.834**	**--**	**0.834**

Table 15 Cronbach's Alpha for the variable in the Reliability Group

Scale	**Raw variables**		**Standarized variable**	
Item	Correlation	Alpha	Correlation	Alpha
B6	0.58	0.820	0.58	0.820
B7	0.70	0.768	0.70	0.768
B3	0.68	0.778	0.68	0.779
B8	0.68	0.779	0.68	0.779
NONE	**--**	**0.831**	**--**	**0.831**

Nunnally and Bernstein (1994) suggest a value of 0.70 as an acceptable Cronbach's alpha. The overall alpha value indicated in **Table 14** for Safety was calculated as 0.834 and the overall alpha value indicated in **Table 15** for Reliability was 0.831. The number of observations used for calculating the Cronbach's alpha was 334.

It is important to analyze the meaning of the Cronbach's alpha and avoid the temptation to accept the estimate at face value. For example, a Cronbach's alpha greater than 0.80 may mask the fact that one variable does not belong to the selected domain and an estimate close to the unit may indicate overlapping with the variable of the domain. The SAS software calculated two Cronbach's alphas, the raw alpha and the standardized alpha. The standardized alpha is obtained after standardizing scores to a standard deviation of 1. This alpha will differ from the raw alpha only if the scores varied widely. The results obtained using raw variables were similar to the results obtained using standardized variables. Other values in each table represent the impact that each variable has on the overall alpha value. The impact of a particular variable is determined by the new alpha value calculated without the contribution of the variable. A decrease in the alpha indicates a high correlation between the excluded variable and the other variables of the group. Conversely, an increase in the new alpha value indicates a low correlation between the excluded variable and the other variables of the group. The alpha value obtained after deleting one variable of the group was lower than the overall alpha value in all cases.

4.5. Demographic Variables and the Chi-Square Test of Independence

The demographic variables in the final study were added for two reasons. First, the demography of study population was adopted as the basis for sampling quotas. The three demographic variables used in the sampling process were: location, gender, and age. Second, the demographic variables were collected for use in regression analysis as background variables of the dependent variable, the overall perception of highway maintenance service quality.

The demographic variables were fixed or free, known or unknown, and quota or non-quota. **Table 16** summarizes the attributes of demographic variables selected for the study.

Table 16 Attributes of Demographic Variables

LOCATION	GENDER	AGE	PRIMARY TRIP TYPE
Fixed Known Quota	Semi-fixed Known Quota	Free Known Quota	Unfixed Unknown Non-Quota

Location was a known and fixed variable. Participants were randomly selected from the phone book according to their location. The location of the participant did not change during the data collection. Gender and age were two known demographic variables. Both are routinely reported by the U.S. Census Bureau for the three locations selected for the study, Montgomery, Giles, and Pulaski counties. Both variables were used to determine the sampling quotas. Gender was partially fixed during the survey administration. The fourth demographic variable was the primary trip type. This variable was not considered during sampling. The demography of the fourth variable was unknown at the beginning of the survey.

The main challenge in quota sampling is fulfilling the quotas once the survey is complete. To guarantee meeting established quotas, the researcher can recruit participants with particular characteristics or the researcher can persuade participants from different demographic segments to complete the survey. The second option was adopted in the study. The instructions included the gender of the participant and, although the final decision regarding the gender of the respondent was left to the participants, the approach proved to be effective. The approach could have extended to include the third variable, age. However, the need to fix a third variable was deemed unnecessary. The degree of freedom of the sampling was 2, the number of quotas minus 1. With location and gender fixed, the two degrees of freedom of the sampling were covered. **Table 17** shows the final quotas obtained for location, gender, and age.

Table 17 Comparison between Quota Target and Quota Actual

	LOCATION			GENDER		AGE		
	Montgomery	Pulaski	Giles	Male	Female	18 to 34	35 to 54	55 and over
Target	63.4%	25.0%	11.6%	52.0%	48.0%	44.0%	30.0%	26.0%
Actual	63.2%	24.0%	12.8%	47.4%	52.6%	11.4%	38.6%	50.0%
Difference	-0.2%	-1.0%	1.2%	-4.6%	4.6%	-32.6%	8.6%	24.0%

The results for the fixed variable location indicate that the responses were random and not biased toward a specific location of study. The differences between target and actual quotas for the variable location were all less than 1.5 percent. Regarding the variable gender, responses were somewhat skewed toward a female representation while target quotas indicated quite the opposite. The differences between target and actual quotas for the variable gender were less than 5 percent. For both location and gender quotas, the differences were quite small, giving the impression that sampling quotas were achieved.

The outcome for age quotas was quite the opposite. Based on age target quotas, the actual age demography shifted from the first category, 18 to 34, to the third category, 55 and over. The explanation for the shift is as follows. The source of the information for establishing age targets was the U.S. Census Bureau. The local telephone book was used to create the survey sample. It is possible to argue that most people in the first category own a cellular phone and may not be listed in a landline directory. Since the phone book was used to create the sample, age quotas represent the distribution of the people listed in the phone book and it is not surprising to find that the first group was unrepresented.

The fourth demographic variable was users' primary trip type. **Table 18** shows the percentages recorded for each category of the variable. Commuting was the most frequent answer (47.6 percent) followed by shopping and errands (26.9 percent). The instructions asked for one choice.

However, 36 surveys presented multiple choices (10.5 percent) and in two surveys the answer was missing (0.6 percent).

Table 18 Primary Trip Type Distribution among Participant Responses

PRIMARY TRIP TYPE	QUOTA
Commuting	47.6%
Business	8.1%
Shopping/Errands	26.9%
Recreation	2.1%
Other	4.2%
Multiple answers	10.5%
Missing data	0.6%

As indicated in **Table 18**, more than half of the participants, 186 respondents, use highways for commuting and business purposes. The answers provided by these two demographic groups are particularly valuable because they use the facilities on a daily basis, increasing the likelihood of experiencing traffic anomalies characteristic of maintenance operations.

The extent to which the four background variables predict the overall perception of the quality of the service was analyzed using a chi-square test of independence. The main objective of a chi-square test of independence is to determine whether there is a statistically significant association among the categories of the variables - but it cannot tell whether the association is strong or weak. Also, the test cannot determine whether the association will remain significant after a regression analysis.

The test of independence was performed on every possible combination of the overall perception of the quality of the service delivery, namely SQL, with the background variables. A two-way table is required for testing the independence between the categorical variables Y and X. The number of categories of variable Y determines the number of rows and the number of categories of variable X determines the number of columns. Each cell of the table contains the number of cases observed for the corresponding categories. **Equation 6** provides the test statistic of the chi-square test for variables Y and X

$$\chi^2 = \sum_{i,j} \left(n_{ij} - \hat{E}_{ij}\right)^2 / \hat{E}_{ij} \qquad \textbf{(Equation 6)}$$

where, n_{ij} is the observed value for the i^{th} category of variable Y and the j^{th} category of variable X, and $\hat{E}_{ij}$ is the expected value for the i^{th} category of variable Y and the j^{th} category of variable X. The expected value is calculated from the proportion of each cell of the two-way table. The proportion is calculated as the number of observed values divided by the total number of observation. The total sum of the proportions is 1.

The expected values are calculated with **Equation 7.**

$$\hat{E}_{ij} = \frac{(n_{i.})(n_{.j})}{n} \qquad \textbf{(Equation 7)}$$

where, $n_{i.}$ is the total values for row *i* and $n_{.j}$ is the total values for column *j*. As a rule-of-thumb, no expected value should be less than 5 (Otto and Longnecker 2001). When some expected values are less than 5, some categories must be combined to comply with the above mentioned rule. The new combined category must remain meaningful. Otherwise, the test loses its value.

The chi-square value calculated with **Equation 6** must be compared to a reference, the chi-square [sub] alpha, to determine whether the two variables are independent. If the chi-square value is greater than the reference value, the variables are dependent. Conversely, if the chi-square value is less than the reference value, the variables are independent.

The chi-square [sub] alpha is a function of the degree of freedom of the test and the probability of committing a type I error in the rejection of the null hypothesis of the test. The degree of freedom is equal to (r-1) times (c-1), where r is the number of rows of the two-way table and c is the number of columns of the two-way table. Several statistics reference books provide tables for determining the chi-square [sub] alpha.

The first two categories of variable SQL measured overall service quality below the adequate performance level and were combined into one single category, "1+2". Similarly, the last two categories of SQL measured overall service quality above the adequate performance level and were combined into one single category, "4+5". The combination was done to comply with the rule-of-thumb associated with expected values.

From 334 surveys, 12 surveys were removed due to missing scores in the variable SQL. **Table 19** shows the data and results of the test of independence for the variable Age.

Table 19 Chi-Square Test of Independence for Variable AGE

	AGE									
SQL	**1**	**2**	**3**	**Total**	**Expected Value**			**chi-square test of independence**		
1+2	7	21	20	48	5.7	18.5	23.9	chi-square=	**5.623**	
3	22	73	83	178	21.1	68.4	88.4	df=	4	
4+5	9	29	56	94	11.2	36.1	46.7	chi-square$_{0.05}$=	9.488	*Independent*
Total	38	123	159	320	Legend for AGE: 1=18 to 34, 2=35 to 54, 3=55 and over					

Category one represents participants 18-34 years old, category two represents participants 35-54 years old, and category three represents participants 55 years and over. The count of observation corresponding to the pair of variables Age and SQL is on the left side of **Table 19**. The expected values calculated with **Equation 7** are in the middle part of **Table 19**. The result of the chi-square test of independence for the variable Age is on the right side of **Table 19**. All expected values comply with the rule-of-thumb indicated above (i.e. $\acute{E}_{ij} \geq 5$). The chi-square statistic test was 5.623 using **Equation 6**.

The degree of freedom of the test is 4 = (3columns-1)*(3rows-1). The chi-square [sub] alpha for a 4 degree of freedom and a type I error equal to 0.05 is 9.488 (Otto and Longnecker, 2001, p.1101). Since the chi-square value is less than the chi-square [sub] alpha, the test indicates that the overall perception of the quality of service is independent of Age. Two missing values were recorded for the variable Age. Consequently, 320 surveys were used for the analysis, as indicated in **Table 19**.

Table 20 presents the observed values, expected values, test statistic, degree of freedom, and chi-square [sub] alpha for the variable Gender. Category one represents male participants and category two represents female participants. The total observations for each case are indicated on the left side of the table, the expected values are presented in the middle, and the result of the test is shown on the right side of **Table 20**. All expected values were greater than 5, as suggested by the rule-of-thumb.

Table 20 Chi-Square Test of Independence for Variable Gender

	GENDER							
SQL	1	2	Total	Expected Value		chi-square test of independence		
1+2	23	24	47	22.3	24.7	chi-square=	**0.667**	
3	81	97	178	84.5	93.5	df=	2	
4+5	47	46	93	44.2	48.8	chi-square$_{0.05}$=	5.991	*Independent*
Total	151	167	318	Legend for GENDER: 1=Male, 2=Female				

The degree of freedom of the test is equal to 2 = (2columns-1) * (3rows-1). The chi-square was 0.667 using **Equation 6**. For a type I error equal to 0.05, the chi-square [sub] alpha is 5.991. Since the chi-square is less than the chi-square [sub] alpha, the test indicates the overall perception of the quality of service is gender-independent. Five missing values were recorded for the variable gender. One missing value was recorded in one survey already deleted due to the variable SQL. Consequently, 318 surveys were used for the analysis, as shown in **Table 20**.

The next analysis corresponds to the variable primary Trip Type, which has five categories. Two categories were combined into a single category representing participants who normally use the highways for business or commuting purposes. The remaining three categories - shopping, recreational, and other - were also combined into a single category. **Table 21** presents the observed values, expected values, test statistic, degree of freedom, and chi-square [sub] alpha for the variable primary trip type.

Table 21 Chi-Square Test of Independence for Variable Primary Trip Type

	TRIP TYPE							
SQL	1	2	Total	Expected Value		chi-square test of independence		
1+2	38	10	48	30.6	17.4	chi-square=	**5.817**	
3	109	69	178	113.5	64.5	df=	2	
4+5	57	37	94	59.9	34.1	chi-square$_{0.05}$=	5.991	*Independent*
Total	204	116	320	Legend for TRIP TYPE: 1=Commuting+Business, 2=Others				

The degree of freedom is equal to 2 = (2columns-1) * (3rows-1). The chi-square was 5.817 using **Equation 6**. For a type I error equal to 0.05, the chi-square [sub] alpha is 5.991. Since the chi-square is less than the chi-square [sub] alpha, the test indicates that overall perception of service quality is independent of Trip Type. Two missing values were recorded for the variable. Consequently, 320 surveys were used for the analysis, as shown in **Table 21**.

Table 22 presents observed values, expected values, test statistic, degree of freedom, and chi-square [sub] alpha for the variable Location. The first category represents participants living in Montgomery County. The second category represents participants living in Giles County. The last category represents participants living in Pulaski County.

Table 22 Chi-Square Test of Independence for Variable Location

	LOCATION									
SQL	1	2	3		Expected Value			chi-square test of independence		
1+2	29	9	10	48	30.4	5.8	11.8	chi-square=	**3.349**	
3	112	22	45	179	113.4	21.7	43.9	df=	4	
4+5	63	8	24	95	60.2	11.5	23.3	chi-square$_{0.05}$=	9.488	*Independent*
Total	204	39	79	322	Legend for LOCATION: 1=Montgomery, 2=Giles, 3=Pulaski					

The two-way table in **Table 22** has three columns and three rows. The degree of freedom is equal to 4 = (3columns-1) * (3rows-1). The chi-square was 3.349 using **Equation 6**. For a type I error equal to 0.05, the chi-square [sub] alpha is 9.488. Since the chi-square is greater than the chi-square [sub] alpha, the test indicates that overall perception of service quality is independent of Location. No missing values were recorded. Consequently, 322 surveys were used in the analysis, as shown in **Table 22**.

4.6. Regression Analysis

The primary objective of the following regression analysis is to determine the relationship between explanatory variables and the response variable (the overall perception of service quality). None of the background variables were included in the analysis because there were all independent of the response variable as determined in previous section.

An ordinary least square (OLS) model was adopted for the first regression analysis. The model provides the parameters of the equation that minimize the squared residuals. The independent variables of the equation were the average scores of the variables in the Safety and Reliability groups. The dependent variable of the equation was the overall service quality score reported by the participants.

Figure 16 shows the results of the analysis. An F-test was used to test the statistical significance of the regression equation. The regression was statistically significant ($F=186.54$, $p <.0001$), and the two variables accounted for 53 percent of the variance in the dependent variable, the overall service quality, as shown in **Figure 16**. The number of observations used in the regression analysis was 322.

Dependent Variable: SQL

Number of Observations Read 322

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	113.45844	56.72922	186.54	<.0001
Error	319	97.01361	0.30412		
Corrected Total	321	210.47205			

Root MSE	0.55147	R-Square	0.5391
Dependent Mean	3.20497	Adj R-Sq	0.5362
Coeff Var	17.20668		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation	95% Confidence Limits	
Intercept	1	0.18383	0.17406	1.06	0.2917	0	-0.15861	0.52628
SAFETY	1	0.47275	0.05971	7.92	<.0001	1.42301	0.35527	0.59022
RELIABILITY	1	0.50552	0.04836	10.45	<.0001	1.42301	0.41037	0.60068

Figure 16 Regression Analysis using Ordinary Least Squares Model

One of the assumptions underlying the use of regression analysis is the normality of residuals. This assumption was tested with a normal q-q plot of the residuals. **Figure 17** shows the cumulative distribution for the residuals on the vertical axis and the theoretical cumulative distribution on the horizontal axis. Significant departure from the diagonal indicates departure from a normal distribution. The linear pattern, observed in **Figure 17,** follows the diagonal indicating that the underlying assumption of normality is valid.

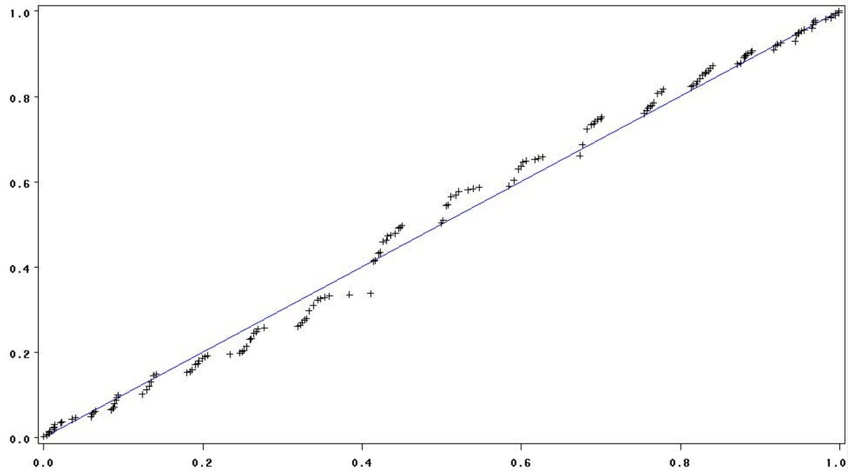


Figure 17 Q-Q Plot of the Residuals

A 95% confidence interval was built for the regression coefficients. The results are presented in **Figure 16**. For the two independent variables, the interval did not contain zero, which is equivalent to say that the two parameters are statistically significant ($p<.0001$). The interval built for the interceptor did include zero ($p=0.2917$). The estimated interceptor is not statistically significance.

$$SQL = 0.18383 + 0.47275 \times SAFETY + 0.50552 \times RELIABILITY \qquad \textbf{(Equation 8)}$$

Equation 8 shows the regression equation. **Table 23** shows the overall service quality predicted value obtained with **Equation 8**. A 95% confidence interval was calculated for the predicted value. The interval contains the actual predictive value for overall service quality with a probability of 95%. The confidence limits reflect not only the variation in the error but also the variation in the regression coefficients.

Table 23 Overall Service Quality Actual and Predicted Value using OLS

SIN#	*Actual*	*Predicted*	*Error*	*-95%CI*	*+95%CI*	*Residual*
540007	3	2.75	0.04	1.66	3.84	0.25
540031	3	2.49	0.05	1.41	3.58	0.51
540033	3	2.38	0.05	1.29	3.47	0.62

A practical problem arises from the interpretation of the 95% confidence interval. For example, the 95% confidence interval built around the predicted value 2.75 corresponding to the survey 540007 ranges from 1.66 and 3.84. The 95% confidence interval includes points 2 and 3 of the response scale. The interpretations of these two points are different. Point 2 indicates that the overall service quality is below adequate performance levels and point 3 indicates that the overall service quality is adequate. A practitioner who picks point 3 as the predicted overall service quality, simply because the average is closer to point 3 than to point 2, will report that the overall quality of the service is adequate and no corrective actions are needed. If the practitioner picks point 2 of the scale then the report will be different.

Using the proximity of the average to the point scale as the selecting criterion is not always a good approach. The predicted value indicated in **Table 23** for survey 540031 is 2.49. The 95% confidence interval ranges from 1.41 to 3.58. The interval includes points 2 and 3 of the response scale. The criterion used in previous example for picking the scale point is somewhat ambiguous in this case. The mean value is as close to point 2 as it is to point 3.

An alternative criterion for choosing the predicted overall service quality can be derived from a different regression analysis based on a multicategory response model for ordinal response variables. The following section introduces the generalized linear model (GLM) theory and briefly explains the specific models selected for the analysis. The most basic model in generalized linear model theory is the binomial response model. For this model, the response variable is divided in two subgroups. The goal is to describe the proportion of success in each subgroup in terms of the explanatory variables as indicated by **Equation 9.**

$$g(\pi_i) = \mathrm{X}\beta \quad \textbf{(Equation 9)}$$

where, **X** is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters and **g** is a link function. The logistic tolerance distribution has a link function of the form indicated in **Equation 10**.

$$g(\pi) = Ln\left[\frac{\pi(x_i)}{1-\pi(x_i)}\right] = \lambda_i \quad \textbf{(Equation 10)}$$

where, $\lambda_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \Lambda + \beta_k X_{ki}$ with k=1,2,…,n is the linear logistic regression model for ***n*** quantitative explanatory variables (Lawal 2003). The proportion of success in each subgroup can be obtained from **Equation 11**.

$$\pi(x_i) = \frac{e^{(\lambda_i)}}{1+e^{(\lambda_i)}} \quad (\textbf{Equation 11})$$

The above solution applies to binary models. When the response variable is ordinal with a J number of categories greater than 2 (i.e. J>2), several models are available for calculating the corresponding proportions of success. The two most popular models are the cumulative logit model and the proportional odds model. Since both models provide similar results, the cumulative logit model was selected for its simplicity. **Equation 12** is the cumulative logit equations of the ith logit. For J=5 there are four logit equations.

$$Ln\left[\frac{\sum_i \pi_i}{1-\sum_i \pi_i}\right] = \lambda_i \quad (\textbf{Equation 12})$$

Figure 18 shows the main results of the second analysis. The response variable of the regression model is the overall perception of the quality of highway maintenance service delivery (SQL) and the independent variables are the average scores of the variables in the Safety and Reliability group. The number of observations used in the second regression analysis was 322.

Model Information

Number of Observations Read	322

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Scaled Deviance	422	220.9269	0.5235
Log Likelihood		-257.4499	

Analysis Of Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept1	1	4.9776	0.9079	3.1982	6.7570	30.06	<.0001
Intercept2	1	8.8601	0.8781	7.1390	10.5812	101.80	<.0001
Intercept3	1	12.9240	1.0236	10.9178	14.9301	159.42	<.0001
Intercept4	1	16.0561	1.2218	13.6613	18.4508	172.69	<.0001
SAFETY	1	-1.8107	0.2593	-2.3189	-1.3025	48.77	<.0001
RELIABILITY	1	-1.9619	0.2272	-2.4073	-1.5165	74.54	<.0001
Scale	0	1.0000	0.0000	1.0000	1.0000		

Pearson Correlation Coefficients, N = 322
Prob > |r| under H0: Rho=0

	SAFETY	RELIABILITY
SAFETY	1.00000	0.54522 <.0001

Figure 18 Regression Analysis Result using Cumulative Logit Model

In **Figure 18**, all the parameters estimates are statistically significant (p<.0001). The scaled deviance was 0.5235. The value is a measure of goodness of fit of the model. The closer to the unit the value is, the better the goodness of fit is. A value above the unit is an indicator of poor fit between the observed data and the values predicted by the model. The likelihood ratio test statistic, indicated in **Figure 18** as the log likelihood, is another indicator of goodness of fit and is normally used for comparing different models.

It is important to examine the correlation between the explanatory variables in order to verify the potential problem of multicollinearity. “Multicollinearity occurs when several independent variables correlate at an excessively high level with one another” (Keith, 2006, p.199). The correlation between the two explanatory variables of the model was calculated as 0.5452 (p<.001), as shown at the bottom of **Figure 18**. The correlation coefficient indicates a moderate level of correlation between the variables. Excessively high level of correlation may indicate problems of multicollinearity. However, the opposite is untrue. “Multicollinearity can occur even when the correlation among the variables are not excessive” (Keith, 2006, p.200). To test for the presence of multicollinearity, the interaction between the variables was calculated. Interaction occurs when one variable depends on the value of another variable. In other words, there is interaction when the two measures overlap. To calculate the interaction, the cross-product between the variable must be created and included in the regression model. If the cross-product term results are statistically significant when added to the regression equation, there is evidence that the two variables overlap. Before calculating the cross-product term, one variables must be centered in order to reduce multicollinearity between the cross-product term and the uncentered variable. Centering the variable can be achieved by subtracting the mean score of the variable from the variable. The new variable has a mean equal to zero and a standard deviation equal to the original standard deviation. **Figure 19** shows the main results of the third analysis which includes the cross-product term.

Model Information

Number of Observations Read	322

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Scaled Deviance	421	220.2289	0.5231
Log Likelihood		-257.1009	

Analysis Of Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept1	1	-1.3194	0.8218	-2.9302	0.2913	2.58	0.1084
Intercept2	1	2.8057	0.5952	1.6391	3.9722	22.22	<.0001
Intercept3	1	6.9119	0.7025	5.5350	8.2888	96.81	<.0001
Intercept4	1	9.9431	0.8449	8.2870	11.5991	138.48	<.0001
SAFETYc	1	-2.3642	0.7209	-3.7771	-0.9512	10.75	0.0010
RELIABILITY	1	-1.9985	0.2323	-2.4538	-1.5431	74.00	<.0001
SAFETYc*RELIABILITY	1	0.1965	0.2355	-0.2651	0.6581	0.70	0.4041
Scale	0	1.0000	0.0000	1.0000	1.0000		

Figure 19 Cross-Product Term Analysis

The cross-product was presented **Figure 19** with the label "SAFETYc*RELIABILITY". The lowercase c indicates that variable SAFETY was centered for the analysis. The effect size of the cross-product term was calculated as 0.1965 (p=0.4041). The number of observations used in the cross-product term analysis was 322. The 95% confidence interval for the cross-product includes zero indicating that the cross-product term was not statistically significant. The analysis provides evidence of absence of multicollinearity. The result is consistent with the variance inflation factor calculated for the OLS model (VIF=1.423), as indicated in **Figure 16**. The VIF is an index which measures how much the variance of a coefficient is increased because of collinearity. Values of 6 or 7 may indicate excessive multicollinearity (Cohen 2003).

The following example explains how to calculate the probabilities using the results in **Figure 18**. The scores from survey 540007 were used in the example. The values for the two independent variables Safety and Reliability are 2.75 and 2.50, respectively. **Equation 12** is used first to calculate the 1st, 2nd, 3rd, and 4th logits of the model.

1st Logit: $Ln\left[\frac{\pi_1}{1-\pi_1}\right] = 4.9776 - 1.8107*(2.75) - 1.9619*(2.50) = -4.9065$

2nd Logit: $Ln\left[\frac{\pi_1+\pi_2}{1-(\pi_1+\pi_2)}\right] = 8.8601 - 1.8107*(2.75) - 1.9619*(2.50) = -1.0240$

3rd Logit: $Ln\left[\frac{\pi_1+\pi_2+\pi_3}{1-(\pi_1+\pi_2+\pi_3)}\right] = 12.9240 - 1.8107*(2.75) - 1.9619*(2.50) = 3.0398$

4th Logit: $Ln\left[\frac{\pi_1+\pi_2+\pi_3+\pi_4}{1-(\pi_1+\pi_2+\pi_3+\pi_4)}\right] = 16.0561 - 1.8107*(2.75) - 1.9619*(2.50) = 6.1719$

Equation 11 is used for calculating the probabilities for each category.

Probabilities Category 1: $\pi_1 = \frac{e^{(-4.9065)}}{1+e^{(-4.9065)}} = 0.0073$

Probabilities Category 2: $\pi_2 = \frac{e^{(-1.0240)}}{1+e^{(-1.0240)}} - \pi_1 = 0.2569$

Probabilities Category 3: $\pi_3 = \dfrac{e^{(3.0398)}}{1+e^{(3.0398)}} - (\pi_1 + \pi_2) = 0.6900$

Probabilities Category 4: $\pi_4 = \dfrac{e^{(6.1719)}}{1+e^{(6.1719)}} - (\pi_1 + \pi_2 + \pi_3) = 0.0435$

Probabilities Category 5: $\pi_5 = 1 - (\pi_1 + \pi_2 + \pi_3 + \pi_4) = 0.0020$

The probabilities obtained in the above example are shown in first row of **Table 24**, survey 540007. In addition, **Table 24** shows the results of the model for surveys 540031 and 540033. The category with the highest probability was selected as the predicted category of the model. For example, the probability for category 3 in survey 540007 was 69.0 percent. This value is the maximum probability obtained among the five categories of the response variable. According to the criterion of maximum probability indicated above, the predicted overall service quality for survey 540007 is point 3 which concurs with the predicted value indicated by the previous OLS model.

Table 24 Overall Service Quality Actual and Predicted Value using Cumulative Logit Model

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540007	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540031	3	3	1.9%	47.0%	**49.3%**	1.7%	0.1%
540033	3	2	3.0%	**57.1%**	38.8%	1.1%	0.0%

In **Table 23**, the predicted overall service quality for survey 540031 was calculated as 2.49. It was mentioned that the almost equal proximity of the predicted value to two points of the response scale presented a problem to the practitioner. With the criterion of maximum probability, a straight forward decision can be made. The probability for category 3 is the maximum probability among the categories of the response scale; therefore, the predicted overall service quality for survey 540031 is point 3.

In the two examples indicated above the predicted value matches the actual score provided by the participant. However, that is not the case for survey 540033. The predicted overall service quality using both criteria, proximity and maximum probability, is point 2 of the response scale as indicated in **Table 23** and **Table 24**. The actual score provided by the participant was point 3. The mismatch is attributable to the error of the model. **Appendix D** shows the complete list of probabilities and predicted levels calculated with the ordinary least squares model and the cumulative logit model.

Table 25 shows the classification of predicted values produced with the regression model using the variables in the Safety and Reliability group. The classification table indicates the extent to which the model predicted the observed data. The model correctly predicted 222 cases out of 322 (68.9 percent. In 47 cases (14.6 percent), the model predicted a lower level of quality than the actual level reported by the participants. In 53 cases (16.5 percent), the model predicted a higher level of quality than the actual level reported by the participants.

Table 25 Classification Table for Predicted vs. Actual SQL

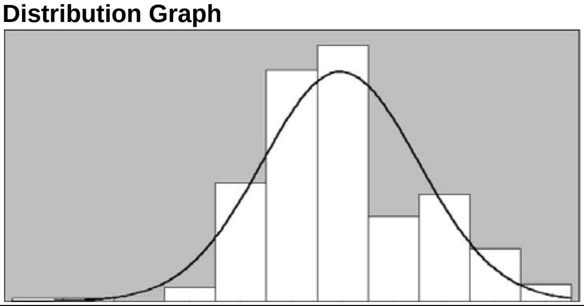
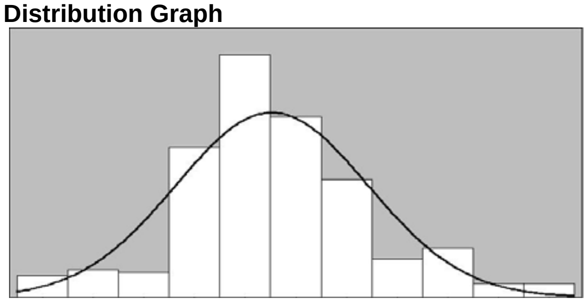
		Predicted SQL					
		1	2	3	4	5	
Actual SQL	1	2	2				4
	2		14	29	1		44
	3		3	158	18		179
	4			36	33	3	72
	5			2	6	15	23
		2	19	225	58	18	322

Finally, the error in the prediction of overall service quality level is not constant across the three levels indicated in **Table 25**. The error in the prediction of category 2 was 26.3 percent which is equal to the vertical sum of non-diagonal cells of the first column divided by the total indicated at the bottom of the column (5/19*100=26.3 percent). The errors in the prediction for category 3, 4, and 5 were 29.8 percent, 43.1 percent and 16.7 percent, respectively.

4.7. Interpreting Highway Maintenance Perceived Service Quality Scores

Safety and Reliability average scores were used as explanatory variables for the regression model adopted to predict overall perception of the highway maintenance service quality. **Table 26** shows the properties of these two variables.

Table 26 Properties of the Explanatory Variables Safety and Reliability

SAFETY		RELIABILITY	
Moments		**Moments**	
# observations	322	# observations	322
Mean	3.384	Mean	2.812
Median	3.250	Median	2.750
Mode	3.000	Mode	3.000
Standard Deviation	0.615	Standard Deviation	0.759
Variance	0.378	Variance	0.576
Skewness	0.440	Skewness	0.239
Kurtosis	0.818	Kurtosis	0.779
Tests for Location μ_0=3.0		**Tests for Location μ_0=3.0**	
Student's t statistic	11.19	Student's t statistic	-4.44
Pr > |t|	<.0001	Pr > |t|	<.0001
Tests for Normality		**Tests for Normality**	
Shapiro-Wilk W	0.943	Shapiro-Wilk W	0.968
Pr<W	0.000	Pr<W	0.000
Kolmogorov-Smirnov D	0.150	Kolmogorov-Smirnov D	0.138
Pr>D	<0.010	Pr>D	<0.010
Distribution Graph		**Distribution Graph**	
			

The mean score for the Safety group was calculated as **3.384**. A value of 3 indicates that, on average, the perceived performance of a service attribute is at the adequate level of performance. The Location test, on the left side of **Table 26,** suggests that the mean score for the Safety group is significantly different from the value of 3 (p <.0001). The Location test reveals that the mean for the Safety group is, indeed, above the value of 3. In other words, users' opinions collected indicated that, on average, the Safety attributes of the VDOT service included in the study were above the adequate level.

The mean score for variables in the Reliability group was **2.812**. The Location test, on the right side of **Table 26,** suggests that the average score is significantly different from a value of 3 (p <.0001). The mean score for the Reliability group is, indeed, below the value of 3. This means that, in the opinion of road users, the Reliability attributes of the VDOT service included in the study were, on average, below the adequate level.

Figure 19, in Chapter 4, shows the parameters obtained from the cumulative logits model. The regression coefficients were -1.8107 and -1.9619 for Safety and Reliability, respectively. These two parameters represent the weight of the independent variables of the regression model. These two values do not differ significantly. In fact, the weight for variable Safety is calculated as 48.0 percent and for variable Reliability, is calculated as 52.0 percent as indicated below. So, it is possible to assert that the Safety attributes of the highway maintenance service, on average, have the same importance as the Reliability attributes in predicting overall quality. A performance-importance analysis can be found in **Appendix G**.

$$Safety\ weight = \frac{1.8107}{(1.8107 + 1.9619)} = 0.4799 \quad \mathrm{Re}liability\ weight = \frac{1.9619}{(1.8107 + 1.9619)} = 0.5200$$

Variable SQL represents the overall perception of service quality and was the dependent variable in the regression analysis. The properties of variable SQL are presented in **Table 27**. The scores use a five-point scale with each point of the scale representing a different level of service quality (e.g. 1 for poor, 3 for adequate, and 5 for excellent).

Table 27 Properties of the Response Variable SQL

SQL: OVERALL PERCEPTION OF QUALITY		
Moments		
# observations		322
Mean		3.205
Median		3.000
Mode		3.000
Standard Deviation		0.810
Variance		0.656
Skewness		0.282
Kurtosis		0.332
Tests for Location μ_0=3.0		
Student's t statistic		4.542
Pr > |t|		<.0001
Tests for Normality		
Shapiro-Wilk W		0.851
	Pr<W	0.000
Kolmogorov-Smirnov D		0.305
	Pr>D	<0.010
Distribution Graph		

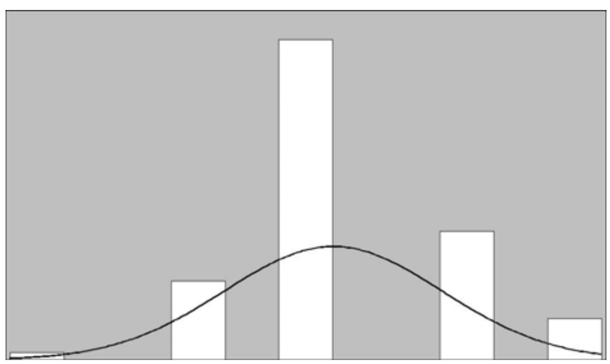


Table 27 shows the mean, median and mode for variable SQL. The mean was **3.205**. Both median and mode measures were equal to 3, indicating that "*adequate performance level*" was the most frequent response in the study. The results of the Location test suggest that the mean for SQL is significantly different from the value 3 (p-value <.0001). The results reveal that the mean for SQL is indeed above 3, meaning that, on average, road users perceive the overall performance of VDOT service to be above the adequate level.

4.8. Individual Scores and Level of Service Quality

The response variable of the regression model is the overall perception of highway maintenance service quality (SQL). Variable SQL has five categories: poor, somewhat poor (not labeled in the response scale), adequate, somewhat excellent (not labeled in the response scale), and excellent. These categories have been collapsed into 3 categories, A, B, and C, for analyzing the individual scores of the service attributes. Category A includes the first two categories of SQL: poor and somewhat poor. There were 48 answers from the 322 responses that were grouped into category A. Category B includes only the third category of SQL: adequate. There were 179 answers from the 322 responses that were placed into category B. Category C includes the last two categories of SQL: somewhat excellent and excellent. There were 95 answers from the 322 responses that were grouped into category C. There were 12 answers out of 334 responses that were missing for variable SQL. All the scores related to these 12 surveys were removed from the analysis.

Table 28 shows the properties and values for each variable of the Safety group. The first three rows show the results classified by the overall service quality level indicated by participants. The last row shows the properties and values when considering all participants' answers.

Level A in **Table 28** corresponds to perceived overall service quality that is below the adequate level. Forty-eight participants indicated that the overall level of the quality was at level A. According to the p-values in the first row of **Table 28**, these participants' scores for the four variables of the Safety group failed to reject the null hypothesis of the Location test, $\mu_0=3$. The results of the Location test reveals that the four mean scores are not statistically different from a value of 3. For these 48 participants, the perception of the overall quality of the service is in disagreement with the individual perception of the Safety attributes of the service.

Table 28 Properties of the Individual Variables of the Safety Group

		B_2	B_4	B_9	B_{12}
Level A	Mean	3.021	3.000	2.813	2.813
	Median	3.000	3.000	3.000	3.000
48 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.729	0.744	0.842	0.734
	Location Test	0.198	0.000	-1.543	-1.770
	p-value	0.844	1.000	0.130	0.083
Level B	Mean	3.291	3.291	3.134	3.268
	Median	3.000	3.000	3.000	3.000
179 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.545	0.631	0.565	0.567
	Location Test	7.130	6.159	3.176	6.333
	p-value	<.0001	<.0001	0.002	<.0001
Level C	Mean	3.958	4.063	3.705	3.800
	Median	4.000	4.000	4.000	4.000
95 obs	Mode	4.000	4.000	4.000	4.000
	Std Deviation	0.771	0.783	0.824	0.752
	Location Test	12.114	13.235	8.347	10.365
	p-value	<.0001	<.0001	<.0001	<.0001
All Levels	Mean	3.447	3.475	3.255	3.357
	Median	3.000	3.000	3.000	3.000
322 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.73115	0.798	0.759	0.728
	Location Test	10.976	10.688	6.017	8.808
	p-value	<.0001	<.0001	<.0001	<.0001

Level B in **Table 28** corresponds to perceived service quality that is adequate. There were 179 participants indicating that the overall level of highway maintenance service quality was at level B. According to the low p-values shown in the second row of **Table 28**, the individual scores for the four variables of the Safety group rejected the null hypothesis of the Location test, μ_0=3. Therefore, the mean scores for the four variables of the Safety group are, indeed, above the value of 3. For these 179 participants, the overall perception of the quality of the service is in disagreement with the individual perceptions of the Safety attributes of the service.

Level C in **Table 28** corresponds to service quality that is above adequate. There were 95 participants who indicated that the overall quality of highway maintenance service was at level C. According to the low p-values shown in the third row of **Table 28**, the individual scores for the four variables of the Safety group rejected the null hypothesis of the Location test, μ_0=3.

Therefore, the mean scores for the four variables of the Safety group are, indeed, above the value of 3. For these 95 participants, the overall perception of service quality and perceptions of the Safety attributes have the same interpretation - performance is above the adequate level.

When considering the responses of all 322 participants, the last row in **Table 28** shows that the means for each variable of the Safety group were above 3, indicating that the performances of the Safety attributes were above the adequate level. Scores provided by all participants in the four variables of the Safety group rejected the null hypothesis of the Location test, $\mu_0=3$, as indicated by the low p-values shown in the last row of **Table 28**. The Location test reveals that the mean scores are, indeed, above the value of 3. This means that, in the opinion of these participants, the performances of the Safety attributes were above adequate.

The mean score for the overall perceived service quality level, SQL, was determined to be above the adequate level, as shown in **Table 27**. According to the results in **Table 28**, the overall perception of service quality and individual perceptions of the Safety attributes carry the same interpretation - performance is above adequate.

Table 29 shows the properties and values for each variable in the Reliability group. The first three rows show the results by overall service quality level as indicated by the participants. The last row shows the properties and values obtained when considering all participants' answers together.

In **Table 29**, 48 participants indicated that the overall quality of highway maintenance service was at level A. These are the same 48 participants who are responsible for results in the first row of **Table 28**. The mean scores for each variable of the Reliability group were below 3, indicating that, on average, these participants perceived that the Reliability attributes were below the adequate level. According to the low p-values in the first row of **Table 29**, the individual scores from these participants in the four variables of the Reliability group rejected the null hypothesis of the location test, $\mu_0=3$. The Location test reveals that the mean scores are, indeed, below the value of 3. For these 48 participants, the perception of overall service quality and the perceptions of the Reliability attributes of the service have the same interpretation - performance is below adequate.

Table 29 Properties of the Individual Variables of the Reliability Group

		B_3	B_6	B_7	B_8
Level A	Mean	2.292	1.625	2.042	2.167
	Median	2.000	1.000	2.000	2.000
48 obs	Mode	1.000	1.000	2.000	3.000
	Std Deviation	1.166	0.841	0.898	0.883
	Location Test	-4.208	-11.326	-7.392	-6.537
	p-value	0.000	<.0001	<.0001	<.0001
Level B	Mean	2.726	2.547	2.726	2.832
	Median	3.000	3.000	3.000	3.000
179 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.740	0.712	0.755	0.730
	Location Test	-4.946	-8.498	-4.848	-3.070
	p-value	<.0001	<.0001	<.0001	0.003
Level C	Mean	3.453	3.147	3.421	3.589
	Median	3.000	3.000	3.000	3.000
95 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.920	0.911	0.820	0.928
	Location Test	4.796	1.577	5.007	6.190
	p-value	<.0001	0.118	<.0001	<.0001
All Levels	Mean	2.876	2.587	2.829	2.957
	Median	3.000	3.000	3.000	3.000
322 obs	Mode	3.000	3.000	3.000	3.000
	Std Deviation	0.955	0.927	0.913	0.940
	Location Test	-2.333	-7.992	-3.357	-0.830
	p-value	0.020	<.0001	0.009	0.407

In **Table 29**, 179 participants indicated that the level of service quality for highway maintenance was at level B. These are the same 179 participants responsible for the results in the second row of **Table 28**. The mean scores for each variable of the Reliability group were below 3, indicating that, on average, participants perceived the Reliability attributes were below adequate. According to the low p-values in the second row of **Table 29**, the individual scores from these participants in the four variables of the Reliability group rejected the null hypothesis of the Location test,

μ_0=3. The Location test reveals that the mean scores are, indeed, below adequate. For these 179 participants, the perception of overall service quality was in disagreement with the perceptions of the Reliability attributes.

In **Table 29**, 95 participants indicated that the overall service quality of highway maintenance was at level C. These are the same 95 participants responsible for the results in the third row of **Table 28**. The mean scores for each variable were above 3, indicating that, on average, participants perceived that the Reliability attributes of the service were above adequate. The individual scores from these participants in variables B_3, B_7, and B_8 of the Reliability group rejected the null hypothesis of the Location test, μ_0=3, as indicated by the low p-values indicated in the third row of **Table 29**. The Location test reveals that the perception of the Reliability attributes represented by variables B_3, B_7, and B_8 and the overall perception of service quality have the same interpretation - performance is above adequate.

The Location test for variable B_6 failed to reject the null hypothesis of the location test (p =0.118) indicating that the mean score for variable B_6 is not statistically different from the value of 3. The Location test for variable B_6 reveals that the service attribute represented by variable B_6 is adequate, even though the overall service performance exceeds the adequate level.

When considering the responses of all 322 participants, the last row of **Table 29** shows mean scores calculated for each variable are below 3, indicating these participants perceived the Reliability attributes of the service were below adequate. According to the low p-values shown in the last row of **Table 29**, the individual scores for variables B_3, B_6, and B_7 of the Reliability group rejected the null hypothesis of the Location test, μ_0=3. The Location test for these three variables indicates that the mean scores are, indeed, below the adequate level. The p-value for variable B_8, in the last row of **Table 29,** is greater than 0.05. The Location test for variable B_8

failed to reject the null hypothesis, $\mu_0=3$, indicating that the mean for variable B_8 of the Reliability group is not statistically different from the value of 3.

The mean score for the overall perceived service quality level, SQL, was determined to be above the adequate level, as shown in **Table 27**. According to the results in **Table 29**, the overall perception of service quality and individual perceptions of the Reliability attributes are in disagreement.

4.9. Other Analyses Performed

Other analyses were performed using the data collected during the final study. The results of these analyses are presented in **Appendix G**. Also, the formulas and SAS procedures used in the study can be found in **Appendix E**.

4.10. Limitations of the research

The results presented in this study cannot be extrapolated beyond the limits of the sample population because of several reasons. First, the sample was created using a contact list that underrepresented an important group of the study population: adults 18-34 years old. It was unforeseen that telephone directories did not contain members of the above-mentioned group in the proportion indicated by the census reports. Second, all participants were selected from rural areas that differ from urban areas in traffic conditions and maintenance complexity. Third, only one service provider was responsible for delivering maintenance services. All three issues limit the extent to which the study results can be generalized. The results of the research are specific to a certain group of road users within certain environmental conditions, and under the influence of a specific service provider. Variation in all three variables must be studied to be able to generalize and validate the research.

Another limitation of the research relates to resource availability and the format of the research. The measurement of maintenance service quality relies on users' experiences and perceptions. User opinions could have been collected using several formats, such as interviews or surveys. The latter approach was selected due to resource constraints, as explained in Chapter 3. Survey research using mail-out questionnaires (such as the one in the present research) is both self-reported and unsupervised. The survey instrument, common to every participant, was completed without the assistance of researchers. This means that there was no interviewer available to answer participant's questions or provide additional information to eliminate confusion. When confusion arises then responses may not reflect user's true opinion. Adopting in-person interviewing, as the survey format, could have produced better quality information but this type of format is usually more expensive than the mail-out survey. Due to resource constraints the mail-out format was selected over the interview format.

Finally, a limitation of the research was the lack of prior research in highway maintenance service quality. The variables selected for measurement were taken from previous studies in the retailing industry. The prompts for these variables were customized and adjusted to the context of highway maintenance. There can be no assurance that the variables selected and the wordings chosen for the study fully represent the attributes of the service. In fact, the model for regression analysis predicted the overall perception of the quality of the maintenance service with an accuracy of 69 percent, indicating that in 31 percent of the cases, the prediction was wrong. Future research may concentrate on improving the predictive power of the model by adding variables to what was studied in the present research.

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5. CHAPTER FIVE – CONCLUSIONS

5.1. Major Findings of the Research

The most significant finding of the research was the combination of two service dimensions, Assurance and Tangible, into one single service dimension, Safety. The combination of two service dimensions into one dimension was opposite of the results reported in another study in which one service dimension was divided into sub-dimensions. Carman measured service quality at a placement center and a dental clinic and concluded that "when one of the dimensions of quality is particular important to customers, they are likely to break that dimension into sub-dimensions" (Carman, 1990, p. 37). The measurement of perceived service quality for highway maintenance was reduced from a three-factor scale to a two-factor scale: Safety and Reliability. The service dimensions described by Parasuraman et al. (1985) were presented as generic dimensions of the service quality measurement, independent of service type. However, in the present study, the dimensions did not remain the same. The three-factor multiple-item scale suggested at the beginning of the study was not supported by the data collected.

The variables in the Safety group were originally assumed to be variables of two different service dimensions. **Table 61** shows the descriptions and origins of the four variables that measure the users' safety perceptions during maintenance service delivery.

Table 30 Variables in the Safety Group

Scale item	Description	Origin
B_2	Employees wearing proper attire	Tangible
B_4	Using clear indicators of maintenance activities	Tangible
B_9	Operating heavy equipment without frightening road users	Assurance
B_{12}	Alerting road users when approaching maintenance areas	Assurance

The first two variables in **Table 30** were selected to measure the Tangible dimension of the service. These two variables were combined with two other variables from the Assurance group to measure users' perceptions of Safety. The first two descriptions in **Table 30** measure users' capability of clearly seeing the people performing the work and properly identifying the boundaries of the working area. The last two descriptions in **Table 30** measure the ability of maintenance personnel to protect the public while performing their work. The internal structure of the Safety dimension has interesting implications for the design of maintenance safety protocols. The effect on public opinion of changes to these protocols can be assessed by measuring service quality using the variables indicated in **Table 30**.

The variables for measuring the Reliability dimension behaved as intended. Three out of four variables initially selected for measuring users' perceptions of the reliability of the service delivery remained in the Reliability group after the data analysis, as indicated in **Table 31**.

Table 31 Variables in the Reliability Group

Scale item	Description	Origin
B_6	Performing maintenance work when it appears to be needed	Reliability
B_7	Completing maintenance work within a reasonable time duration	Reliability
B_8	Keeping road users informed about the location and duration of work	Reliability
B_3	Performing maintenance during low traffic time periods.	Tangible

The fourth variable, "*Performing maintenance during low traffic time periods,*" moved from the Tangible group to the Reliability group. However, in the original version of the SERVQUAL scale (Parasuraman, 1985), the fourth variable was a measure of Empathy. A reassessment of the scale placed this variable in the Tangible group. Section 3.2.1, in Chapter 3, describes the reasons for ignoring the measurement of Empathy in the context of highway maintenance. This is mainly due to the lack of direct contact between the service provider and road users that prevents the measurement of empathy in highway maintenance. However, scheduling the maintenance work in periods of less traffic is a way of showing care and consideration of the public road user. The participants perceived this demonstration of caring as part of the ability of the service provider to deliver the service dependably.

The average scores of the two groups of variables indicated above, Safety and Reliability, were used as regressors in the regression analysis. These two indepent variables explain about half of the variance in the overall perception of highway maintenance service quality (R^2=0.5391 F=186.54 p<.0001). The predictive power of the variables of the measurement is of the same order of magnitude as the predicted power reported for other studies in service quality as indicated in **Table 32**.

Table 32 Predictive Power of the Measurement for Different Type of Services

Service Type Description	Number of Scale Items	Service Dimensions	R^2
Computer Manufacturer	22	5	**0.60**
Retail Chain	22	5	**0.64**
Auto Insurance	22	5	**0.63**
Life Insurance	22	5	**0.58**
Highway Maintenance	8	2	**0.54**

(Parasuraman et al. 1994)

The results provided by the Ordinary Least Squares regression-type model proved to be insufficient for predicting overall service quality when the predicted value was half way between two categories of the variable, as indicated in **Chapter 4 section 4.6**. A second regression model based on a multi-category response model for ordinal response variables was needed to generate the additional information needed for making a wise choice. The main goal of the second model, a cumulative logic model, was to describe the probability of success in each category of overall service quality in terms of Safety and Reliability scores. Based on the additional information provided by the cumulative logic model a choice of the predicted overall service quality was always possible to obtain.

In relation to the data collection format, the mail-out survey proved to be adequate for collecting road users' perceptions. The response rate was higher than the 30 percent average rate commonly found in mailed survey. Actually, the response rate of 45 percent in the present study was greater than the overall 26 percent response rate obtained by Poister et al. (2002) using a similar type of questionnaire for the PennDOT's 2001 annual motorist survey.

5.2. Contribution to the body of knowledge

The present study contributes to the field of highway maintenance in the area of customer-oriented measures for maintenance management systems. Highway maintenance management systems have few reliable tools to measure and understand road user opinion regarding the quality of highway maintenance products and services. Few of these tools have been developed in the past decade from which the PennDOT annual survey is probably the most significant (Poister, et al., 2002). However, none of these tools focus on the quality of service delivery. The data in the present research constitutes the first attempt to measure the quality of highway maintenance services. The service attributes and service dimensions identified in the present research and used for measuring highway maintenance service provide a foundation for future studies. The predictive power of the scale, comparable to those scale produced by other studies in service quality, indicates that the items of the scale are critical attributes of the service delivery. Moreover, the scale adopted in the research can be used not only to assess how users perceive the quality of the service but also to obtain additional information about which service attributes present most opportunities for improvement – to identify where changes are more needed from the users' perspective. The scale is an operational tool that can be used for planning maintenance operation and tracking service delivery performance over time.

Another contribution of the study to the body of knowledge relates to the data collection paradigm. Most transportation agencies adopt the customer satisfaction measure to collect and interpret public opinion about their products and/or services. The satisfaction/dissatisfaction approach, very popular in marketing research, collects user judgments related to the quality of the services and products delivered by the organization, but *quality* is not the only factor in satisfaction/dissatisfaction judgment. Other factors such as *affect* contribute to the evaluation. The present research adopted a different approach for measuring service quality. The approach was based on the service quality paradigm, in which the quality of the service delivered by the transportation agency is measured on the basis of attributes levels only, eliminating the undesirable subjectivity introduced by *affects* and/or other factors included in the customer satisfaction measurement.

5.3. Areas for Future Research

An area for future research that was impetus for the present research is the evaluation of the efficiency of highway maintenance service providers. It was mentioned in **Chapter 1** that service quality was one out of five distinctive components of a framework for evaluating the overall performance of highway maintenance service providers operating under the umbrella of performance-based contracts. Since the quality of service is an important component of the activities performed by the maintenance service provider, it should be included in the evaluation of the overall performance. Classic data envelopment analysis (DEA) techniques can be extended to model both production and consumption activities. The technique has the capability of incorporating multiple inputs and outputs in a performance analysis in order to provide an overall index of efficiency. Basically, the target under analysis is divided into units of analysis, called decision-making units (DMU). An efficiency index is calculated for each unit of analysis (efficient score) and then compared one against others to determine which units represent the most efficient combination of inputs and outputs. DEA network offers the possibility of integrating customer opinion (i.e. consumption function) into an efficiency and productivity measurement framework. The network model incorporate both production and consumption activities in one single model. Each function is modeled as a separate node of the network and available resources can move from one node to the other. The solution of the linear programming problem identifies the allocation of production resources that produce the optimal consumptions levels (Löthgren and Tambour, 1999).

Another area for future research relates to the validation process of the scale and consists of verifying the extent to which the variance of the measurement is due to the method of assessment rather than to the construct. The method in the present study was the self-report assessment of perceived quality of highway maintenance. The results indicated that participants assess the quality of service on the basis of two dimensions, Safety and Reliability. A classic method for determining the extent to which participants' responses actually measure the Safety and Reliability constructs is the Multitrait-Multimethod approach (MTMM). In MTMM, safety and reliability are studied using two different methods and the results are compared. For example, a measure of safety can be created using the number of accidents (fatal and non-fatal) registered in the area selected for the study. It can be assumed that if the number of accidents increases then users' perceptions of safety decreases. A measure of timeliness of response can be used as an alternative measure of reliability. It can be assumed that if timeliness of response decreases then users' perception of reliability increases. Different methods should converge in their measurement of the same trait. This means that, in the example presented above, users' perception of safety attributes should correlate at a high level with the number of accidents reported in the area and timeliness of response should correlate at a high level with users' perceptions of reliability attributes (i.e. both correlations are inverse correlation). Different methods should diverge in their measurement of different traits. This means that users' perception of safety attributes should correlate at a low level with timeliness of response and the number of accidents reported in the area should correlate at a low level with users' perceptions of reliability attributes. This convergence and divergence between different traits and different methods is the basis of the MTMM approach. The MTMM is an important methodology for investigating the fit between hypothesis and observations (Smith, 2005).

An important area for future research concerns the predictive power of the scale. The variables in the model for regression analysis predicted the overall perception of service quality with an accuracy of 69 percent. In 31 percent of the cases, the prediction was wrong. Future research may concentrate on improving the predictive power of the model by adding new variables. A good approach for adding variables is asking participants what was omitted from the measurement instrument. The best technique for obtaining this kind of information from participants is through focus groups. A focus group consists of a small number of participants who respond to open-ended questions from an experienced facilitator. The technique is an inexpensive way to gather valuable answers to specific questions. The best time for these group sessions is right after data collection processes are completed and the experience is still fresh in the minds of participants (Stein-Hudson et al. 1995).

Finally, future research can focus on the reliability of the scale. Classical reliability theory evaluates the reliability of the measurement by testing and retesting the measure and by calculating internal consistency. The former considers the source of error to be the variation in performance of the scale. The latter considers the source of error to be in the variation of items in the scale. The scale in the present study must be tested under the same and different environmental conditions such as locations, traffic conditions, service providers, etc., to increase the reliability of the measurements. A scale's usefulness largely depends on the extent to which the scale predicts the measure in some wider set of situations (Shavelson et al. 1898). The classical approach described above can be replaced with generalizability theory (GT) to examine multiple sources of error for multiple situations. That is, "instead of asking how accurately observed scores reflect their corresponding true scores, GT asks how accurately observed scores permit us to generalize about persons' behavior in a defined universe of situations" (Shavelson et al., 1998, p. 922).

5.4. References

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APPENDIX A – Institutional Review Board: Survey Permits and Protocols

Whenever, human subjects participate in a study conducted by Virginia Tech faculty and student with the purpose of contributing to the general body of knowledge, the protocol of the research is subjected to the review of the Virginia Tech Institutional Review Board (IRB) to ensure that the methodology was ethical and that the rights of the participants were protected.

In addition, each investigator has to complete the Human Subjects Protections training. The training is about the development of codes and principles of research ethics, selection and recruitment of research participants, protection of confidentiality of subjects, basics of submitting protocols and the responsibilities of a researcher. **Figure A.1** shows an example of the training certificate.

Figure A. 1 Human Subjects Protections Training Certificate

Pilot Study

The protocol of the pilot study was approved on October 29th, 2007. **Figure A.2** shows the letter of approval. Point 1 in **Figure A.2** indicates that the researchers have to report the IRB any change in the original protocol for further approval. There were no changes in the protocol for the pilot study.

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Office of Research Compliance
Carmen T. Green, IRB Administrator
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4358 Fax 540/231-0959
e-mail ctgreen@vt.edu
www.irb.vt.edu
FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: October 29, 2007

MEMORANDUM

TO: Jesus M. de la Garza
Adrian Burde

FROM: Carmen Green

SUBJECT: **IRB Exempt Approval:** "Multiple-Item Scale for Measuring Highway Maintenance Service Perceived Quality: A Pilot Study", OSP #437838, IRB # 07-528

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of October 29, 2007.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.

2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

cc: File
OSP

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Figure A. 2 Letter of Approval

There was "minimal risk to participants" involved in the study which means that the protocol was "exempted" from a full board review. **Figure A.3** shows the main page of the application which shows the request for exempt review.

VirginiaTech — Institutional Review Board

Request for Exempt Review

Directions

This form must be typed and submitted (as a Word document) to the IRB office electronically along with the other required documents (e.g., Initial Review Application, all study forms relating to human subjects, and bio-sketches of investigators) to irb@vt.edu. In addition to submitting electronically, this form, signed by all appropriate parties, must be received by the IRB office before the submission is processed. Mail or deliver the original signed copy of this form to: IRB, Virginia Tech, Office of Research Compliance, 2000 Kraft Drive, Suite 2000 (0497), Blacksburg, VA 24060. To speed up the approval process, signed Review Forms may be scanned or faxed [(540) 231-0959] to the IRB office; however, the original signatures must also be mailed or delivered to the IRB office for documentation.

Section 1: Contact Information

Principal Investigator [Faculty or Faculty Advisor] (all fields required) — **HST = Human Subjects Training**

Name: **Dr. Jesus M. de la Garza** PID: chema HST completed through: VT blackboard course

Department: **CEE** Email: **chema@vt.edu** Mail Code: **0105**

Signature of Principal Investigator — Date 10/18/2007

Co-Investigator(s) [Faculty or Student] (all fields required for each Co-Investigator)

Co-Investigator #1
Name: **Adrian Burde** PID: burde HST completed through: VT blackboard course
Organization Name: **Virginia Tech** Email: **burde@vt.edu**

Signature of Co-Investigator #1 — Date 10/18/07

Figure A. 3 Request for Exempt Review

Along with the request for review, an initial review application is submitted to the IRB. **Figure A.4** shows the first page of the application. The application includes all study forms relating to human subjects and a bio-sketch for each investigator.

VirginiaTech — **Institutional Review Board**
Initial Review Application

Directions

- **Type responses to all questions / requests below. It is recommended that you read through this document before completing.**
- **Do not leave a question blank unless directed. If a required question is not applicable to your study, explain why.**
- **Do not restrict your responses to the space provided. Provide a thorough response to each question. Be as specific as possible, keeping in mind that you are introducing the study to the IRB. Incomplete applications will result in requests for clarification from researchers and will cause delays in review and final approval.**
- **Type responses in the designated shaded boxes or check the designated check boxes.**
- **Use non-technical language throughout your application. Federal regulations require IRB applications to be written in lay language at an 8th grade reading level. Do not use jargon or scientific terms in your explanations/descriptions.**
- **Check for grammatical or typographical errors before submitting. Protocols with substantial errors will be returned for corrections.**
- **This form must be completed and submitted (as a Word document) electronically. Submit all required documents (e.g., Review Form, Initial Review Application, all study forms requested within this application, and bio-sketches) to irb@vt.edu. For questions, contact Carmen Green, IRB Administrator, at ctgreen@vt.edu or (540) 231-4358.**

Section 1: General Information

What is the Study Title: Mulitple-Item Scale for Measuring Highway Maintenance Serviced Perceive Quality: A Pilot Study

[Note: If this protocol has been submitted to a federal agency for funding, the title of that application **must** match the title of this submission.]

Figure A. 4 Initial Review Application (extract from page 1)

Final Study

The same procedure described above was followed to get the approval for second part of the study, the final study. There was no need to repeat the human subject training. The protocol of the final study was approved on February 25th, 2008. **Figure A.5** shows the letter of approval.

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
www.irb.vt.edu
FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: February 25, 2008

MEMORANDUM

TO: Jesus M. de la Garza
Adrian Burde

FROM: David M. Moore

SUBJECT: **IRB Exempt Approval:** "Adopting a Multiple Item Scale for Measuring Highway Maintenance Perceived Service Quality", OSP #437838, IRB # 08-097

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of February 25, 2008.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.

2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

cc: File
OSP

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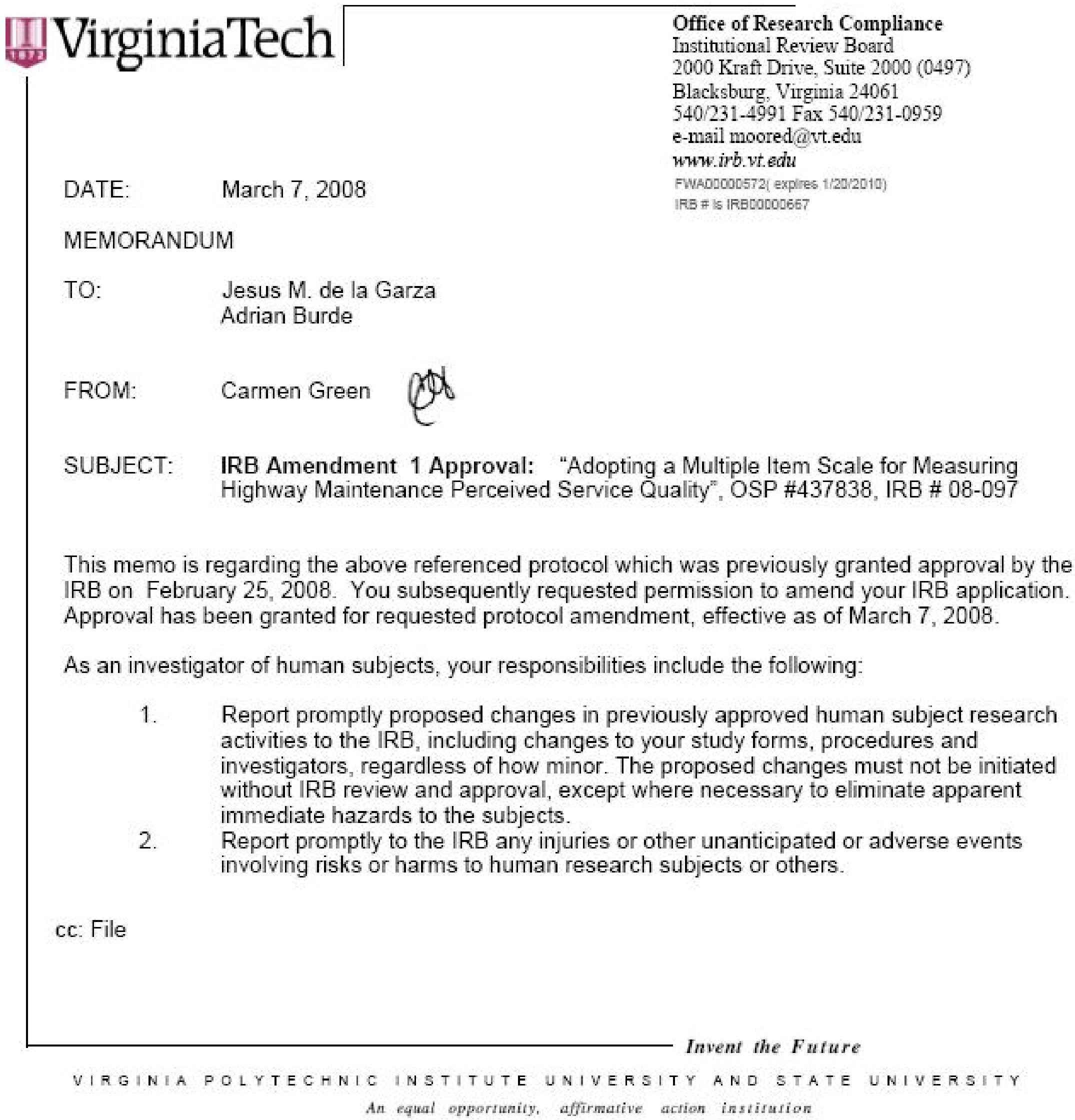
Figure A. 5 Letter of Approval

There were two amendments to the original protocol that were submitted to the IRB for approval. The first amendment was submitted before starting the data collection and consisted on several changes in the main questionnaire. The approval of the first amendment was received on March 7th, 2008, as indicated in **Figure A.6**.



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DATE: March 7, 2008

MEMORANDUM

TO: Jesus M. de la Garza
Adrian Burde

FROM: Carmen Green

SUBJECT: **IRB Amendment 1 Approval:** "Adopting a Multiple Item Scale for Measuring Highway Maintenance Perceived Service Quality", OSP #437838, IRB # 08-097

This memo is regarding the above referenced protocol which was previously granted approval by the IRB on February 25, 2008. You subsequently requested permission to amend your IRB application. Approval has been granted for requested protocol amendment, effective as of March 7, 2008.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

cc: File

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Figure A. 6 First Amendment to the Original Protocol Approval

The second amendment was due to changes in the content of the reminder letter. This change was anticipated from the beginning of the final study. The content of the reminder letter was going to be adjusted at the moment of its release in order to convey the right message to the participants. The second amendment was approved on March 26th, 2008, as indicated in **Figure A.7**.

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FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: March 26, 2008

MEMORANDUM

TO: Jesus M. de la Garza
Adrian Burde

FROM: Carmen Green

SUBJECT: **IRB Amendment 2 Approval:** "Adopting a Multiple Item Scale for Measuring Highway Maintenance Perceived Service Quality", OSP #437838, IRB # 08-097

This memo is regarding the above referenced protocol which was previously granted approval by the IRB on February 25, 2008. You subsequently requested permission to amend your IRB application. Approval has been granted for requested protocol amendment, effective as of March 26, 2008.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

cc: File

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Figure A. 7 Second Amendment to the Original Protocol Approval

APPENDIX B – Mail and Internet Survey Documents

The following appendix describes the two strategies adopted for the data collection process. The first strategy contemplated the use of the internet as the communication channel for contacting the participants and collects their opinion. The second strategy was structured as a mail-out survey. Both approaches were grounded in social exchange theory and the main objective was encouraging participants to contribute to the data collection process.

Pilot Study

A three-contact strategy was selected for the pilot study. These contacts were: the pre-notice letter, the cover letter and questionnaire, and the thank you/reminder letter with a replacement questionnaire. The pre-notice, shown in **Figure B.1**, played an important role. The main goal of the pre-notice is to discourage participants from promptly deleting any subsequent related email.

Dear Sir/Ma'am,

I'm writing to ask your help in a study related to highway maintenance service quality.

The study is being conducted by the Civil and Environmental Engineering Department at Virginia Tech as part of an effort to understand how road users perceive the quality of highway maintenance services provided by transportation agencies.

Within the next couple of days you will be receiving a brief survey at this same e-mail address. We would greatly appreciate it if you could take a few moments to complete it. If you don't want to participate in this study please let me know by replying this email and I will remove you e-mail address from the mailing list.

If you have any questions, feel free to contact me (Dan Brugh) at (540) 394-2145 or Adrian Burde from the Virginia Tech research team at (540) 231-5565, or by email at burde@vt.edu.

Thank you in advance for your cooperation.

Sincerely,

Dan Brugh
Executive Director
Blacksburg/Christiansburg/Montgomery Area Metropolitan Planning Organization

Figure B. 1. Pre_notice Letter

The main purpose of the cover letter, shown in **Figure B.2**, is to convey the three elements of exchange theory (i.e. reward, cost, and thrust) to the participants in a simple manner. For example, third paragraph indicates the amount of time required for completing the survey and last paragraph indicates that answers are confidential and will be released only as summaries.

Dear Sir/Ma'am,

A few days ago we sent you an invitation to participate in a study being conducted by the Civil and Environmental Engineering Department at Virginia Tech. The purpose of the study is to understand how road users perceive the quality of highway maintenance services provided by transportation agencies (e.g. closing a traffic lane, operating heavy equipment in maintenance area, or removing snow/debris from the pavement surface).

I would like to ask you to complete a brief survey. The intention of the survey is to capture your opinion related to the manner in which the Virginia Department of Transportation conducts highway maintenance services in Montgomery County.

The survey is voluntary. However, you can help us very much by taking a few minutes to share your experiences and opinion. Completing the survey will take no more than 5 minutes and we request that you complete the survey by November 14th.

When you feel ready please click on the following link to start the survey and follow the instructions located at the top: https://survey.vt.edu/survey/entry.jsp?id=1192630868894.

Your answers are confidential and will be released only as summaries in which no individual's answers can be identified. If you have any questions, feel free to contact me (Adrian Burde) at (540) 231-5565. My email is burde@vt.edu.

Thank you very much for helping with this study.

Sincerely,

Adrian Burde
Department of Civil and Environmental Engineering
Virginia Tech

Figure B. 2 Cover Letter

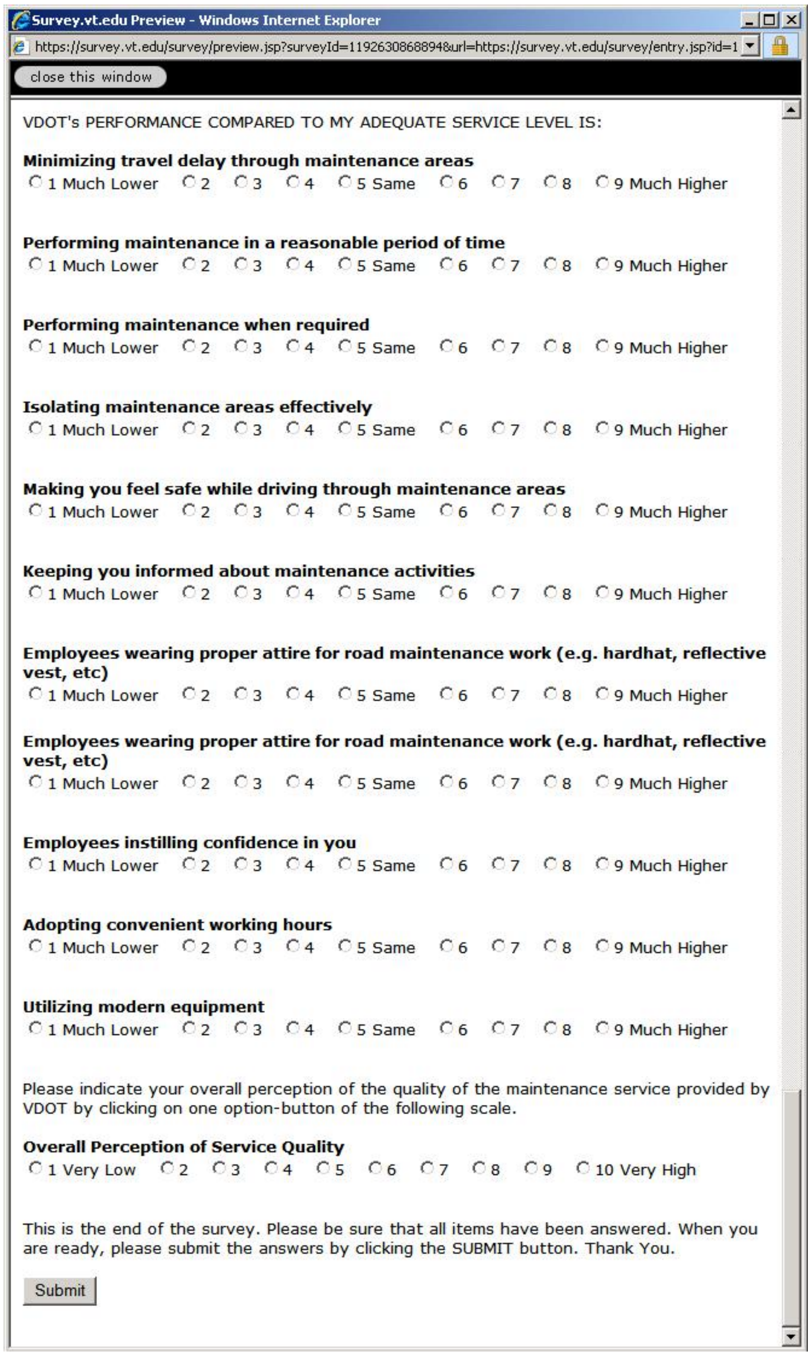
The instructions for completing the survey, shown in **Figure B.3**, must be clear and easy to follow. Any reference as how to complete the survey or what information should be included in the answers has to be specified in the instructions.

DIRECTIONS: Based on your experience, think about the quality of highway maintenance services provided by the Virginia Department of Transportation (VDOT). Please limit your answers to state maintained roads located in Montgomery County. Examples of these roads are I81 (Interstate), Route 8 (Primary), and Route 685, Prices Fork Rd (Secondary).

For each of the following attributes, please indicate how VDOT's performance compares with your adequate service level. Adequate service level is the minimum level of service performance you would consider acceptable. If VDOT's performance is much lower than your adequate service level then click option-button 1. If VDOT's performance is much higher than your adequate service level then click option-button 9. If VDOT's performance matches your adequate service level then click option-button 5.

Figure B. 3 Instructions for the Completion of the Questionnaire

The questionnaire was administered on-line by e-mail using web survey tools available at survey.vt.edu. **Figure B.4** shows a screen shot of the web tool. The benefits from using on-line survey include the nearly complete elimination of paper, postage, and mail-out cost, and a considerably reduction in administration time.


Survey.vt.edu Preview - Windows Internet Explorer

https://survey.vt.edu/survey/preview.jsp?surveyId=1192630868894&url=https://survey.vt.edu/survey/entry.jsp?id=1

close this window

VDOT's PERFORMANCE COMPARED TO MY ADEQUATE SERVICE LEVEL IS:

Minimizing travel delay through maintenance areas
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Performing maintenance in a reasonable period of time
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Performing maintenance when required
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Isolating maintenance areas effectively
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Making you feel safe while driving through maintenance areas
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Keeping you informed about maintenance activities
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Employees wearing proper attire for road maintenance work (e.g. hardhat, reflective vest, etc)
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Employees wearing proper attire for road maintenance work (e.g. hardhat, reflective vest, etc)
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Employees instilling confidence in you
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Adopting convenient working hours
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Utilizing modern equipment
1 Much Lower 2 3 4 5 Same 6 7 8 9 Much Higher

Please indicate your overall perception of the quality of the maintenance service provided by VDOT by clicking on one option-button of the following scale.

Overall Perception of Service Quality
1 Very Low 2 3 4 5 6 7 8 9 10 Very High

This is the end of the survey. Please be sure that all items have been answered. When you are ready, please submit the answers by clicking the SUBMIT button. Thank You.

Submit

Figure B. 4 On-line Questionnaire

The thank-you/reminder letter, shown in **Figure B.5**, was the last contact of the data collection process for the pilot study. The main goal of the letter is to recognize those participants who completed the survey and encourage the other to compete it.

Dear Sir/Ma'am,

Last week a survey seeking your opinion about the quality of the maintenance service provided by the Virginia Department of Transportation was e-mailed to you.

If you have already completed and submitted the questionnaire to us, please accept our sincere thanks. If not, please do so today.

In case the link to the survey has been deleted from your e-mail account, we have included it again: https://survey.vt.edu/survey/entry.jsp?id=1192630868894. Please click on the link to start the survey and follow the instructions located at the top.

We are especially grateful for your help because it is only by asking people like you to share your experiences and opinion that we can understand how road users perceive the quality of highway maintenance services. Should you have any questions or concerns, feel free to contact me (Adrian Burde) at 540-2315565, or by email at burde@vt.edu.

Thank you for your cooperation.

Sincerely,

Adrian Burde
Department of Civil and Environmental Engineering
Virginia Tech

Figure B. 5 Thank-you/Reminder Letter

Final Study

A four-contact strategy was adopted for the final study. Multiple contacts and a prize/incentive were the important features of this approach. The multiple contacts were: the pre-notice letter, the cover letter and the questionnaire, the thank-you postcard, and the reminder letter with a replacement questionnaire.

The pre-notice letter, shown in **Figure B.6**, played a very important role by alerting participants of the forthcoming questionnaire making the survey an expected item instead of an unpleasant surprise.

Dear Sir/Madam,

I'm writing to ask your help in a study related to highway maintenance service quality. The study is being conducted by the Civil and Environmental Engineering Department at Virginia Tech, as part of an effort to understand how road users perceive the quality of the highway maintenance services provided by transportation agencies.

Within the next couple of days you will be receiving a brief survey. The purpose of the survey is to capture your opinion as a road user related to the quality of the highway maintenance services, delivered by VDOT, in your area. We would greatly appreciate it if you could take a few moments to complete it.

If you have any questions, feel free to contact me (Adrian Burde) at (540) 231-5565, or by email at burde@vt.edu.

Thank you in advance for your cooperation.

Sincerely,

Adrian Burde
Graduate Research Assistant
Virginia Tech

Figure B. 6 Pre-notice Letter

The cover letter, shown in **Figure B.7**, includes all three elements of exchange theory. The first paragraph introduce the research team and the subject of research. On the second paragraph the time for completion is indicated. This time gives the participant an idea of the cost of completing the survey. The cost of completing the survey is then compared to the reward of completing the survey which is indicated at the end of the same paragraph. Cost and rewards are important elements of the exchange theory. If the cost is greater than the reward is very likely that the participant will ignore the survey.

The third paragraph was included to induce responses towards the quota samples selected for the sample, in particular the gender of the participant. The last paragraph reassures the confidentiality of the answers and also provides participant with a mechanism for withdrawing from the study. The last two component of the letter were included in order to augment thrust between the researcher and the participants. In addition, a website was created to provide an alternative channel of communication. The URL to the website was indicated at the end of the letter.

Dear Sir/Madam,

A few days ago we sent you an invitation to participate in a study being conducted by the Department of Civil and Environmental Engineering at Virginia Tech. The purpose of the study is to capture road users' opinion related to the quality of the highway maintenance services delivered by VDOT[1].

We would like to ask you to complete a brief survey. The survey is voluntary; however, you can help us very much by taking a few minutes to share your experiences and opinion. Completing the survey will take no more than 10 minutes. In appreciation for your time, your returned and complete survey will be entered into a sweepstakes to win one of three Apple iPod shuffle[2].

Any adult resident (18 years old or over) can complete the survey. If possible, we would like to have a **female** completing the survey. The reason for this request is to fulfill specific sample quotas required to make the response sample representative of the study population.

Your answers will remain confidential and will be released only as summaries, in which no individual's answers can be identified. If you do not wish to participate in the study, please return the survey empty and I will remove your address from the mailing list.

If you have any questions, feel free to contact me (Adrian Burde) at (540) 231-5565, or by email at burde@vt.edu.

Thank you very much for helping with this study.

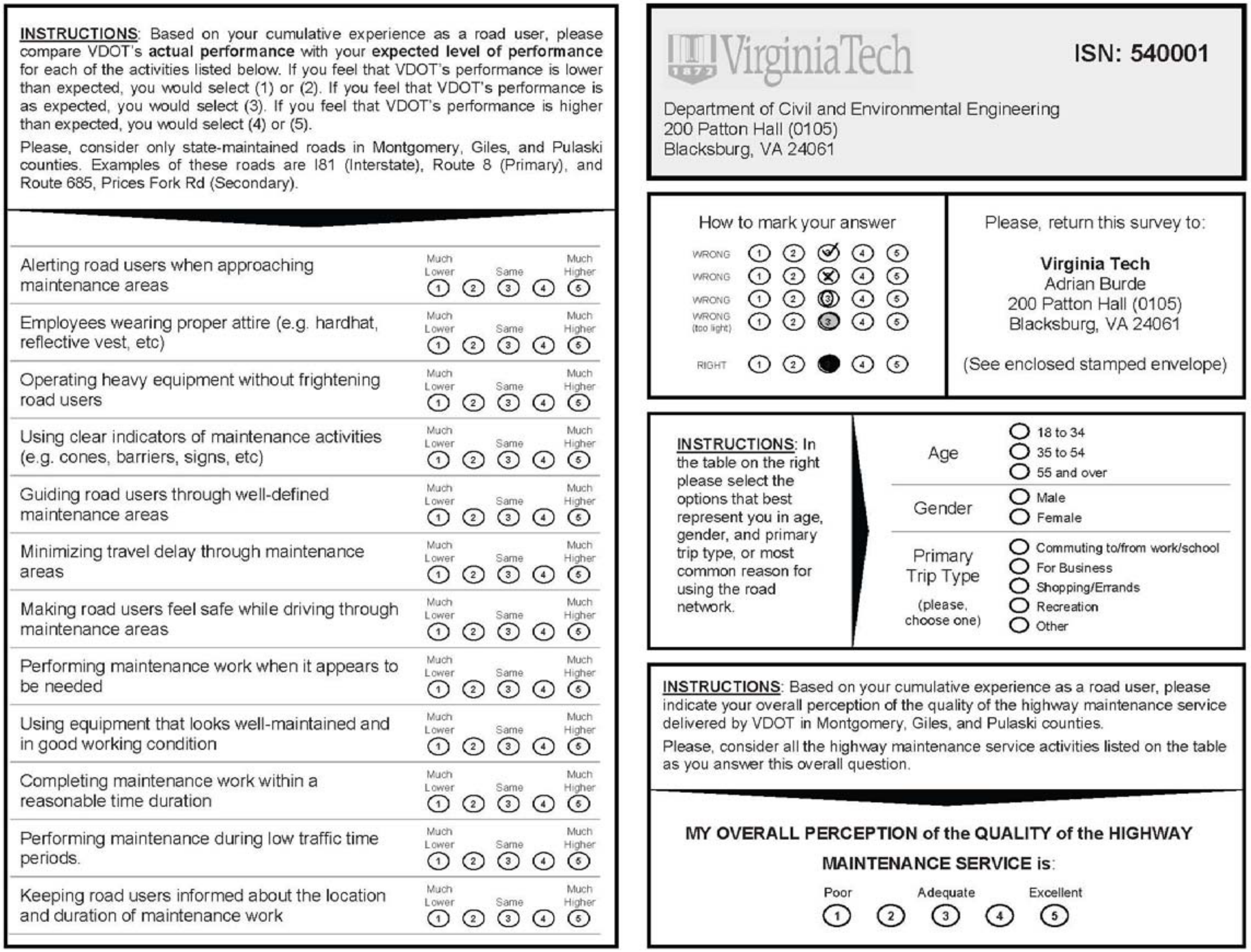
Sincerely,

Adrian Burde
Graduate Research Assistant
Virginia Tech

[1] Virginia Department of Transportation
[2] Drawing will be held on April 30, 2008 (odds 1 in 250). For results visit www.filebox.vt.edu/users/burde/HMSQSurvey/

Figure B. 7 Cover Letter

The questionnaire, shown in **Figure B.8**, was personalized with the name and address of each participant. The instructions for completion were embedded in the format. Careful attention was paid to the layout of the different component of the questionnaire in order to locate them in the right sequence, left to right and top to bottom.



INSTRUCTIONS: Based on your cumulative experience as a road user, please compare VDOT's **actual performance** with your **expected level of performance** for each of the activities listed below. If you feel that VDOT's performance is lower than expected, you would select (1) or (2). If you feel that VDOT's performance is as expected, you would select (3). If you feel that VDOT's performance is higher than expected, you would select (4) or (5).

Please, consider only state-maintained roads in Montgomery, Giles, and Pulaski counties. Examples of these roads are I81 (Interstate), Route 8 (Primary), and Route 685, Prices Fork Rd (Secondary).

Activity	Much Lower		Same		Much Higher
Alerting road users when approaching maintenance areas	1	2	3	4	5
Employees wearing proper attire (e.g. hardhat, reflective vest, etc)	1	2	3	4	5
Operating heavy equipment without frightening road users	1	2	3	4	5
Using clear indicators of maintenance activities (e.g. cones, barriers, signs, etc)	1	2	3	4	5
Guiding road users through well-defined maintenance areas	1	2	3	4	5
Minimizing travel delay through maintenance areas	1	2	3	4	5
Making road users feel safe while driving through maintenance areas	1	2	3	4	5
Performing maintenance work when it appears to be needed	1	2	3	4	5
Using equipment that looks well-maintained and in good working condition	1	2	3	4	5
Completing maintenance work within a reasonable time duration	1	2	3	4	5
Performing maintenance during low traffic time periods.	1	2	3	4	5
Keeping road users informed about the location and duration of maintenance work	1	2	3	4	5

VirginiaTech

ISN: 540001

Department of Civil and Environmental Engineering
200 Patton Hall (0105)
Blacksburg, VA 24061

How to mark your answer

WRONG	1	2	3	4	5
WRONG	1	2	3	4	5
WRONG	1	2	3	4	5
WRONG (too light)	1	2	3	4	5
RIGHT	1	2	3	4	5

Please, return this survey to:

Virginia Tech
Adrian Burde
200 Patton Hall (0105)
Blacksburg, VA 24061

(See enclosed stamped envelope)

INSTRUCTIONS: In the table on the right please select the options that best represent you in age, gender, and primary trip type, or most common reason for using the road network.

Age	18 to 34 35 to 54 55 and over
Gender	Male Female
Primary Trip Type (please, choose one)	Commuting to/from work/school For Business Shopping/Errands Recreation Other

INSTRUCTIONS: Based on your cumulative experience as a road user, please indicate your overall perception of the quality of the highway maintenance service delivered by VDOT in Montgomery, Giles, and Pulaski counties.

Please, consider all the highway maintenance service activities listed on the table as you answer this overall question.

MY OVERALL PERCEPTION of the QUALITY of the HIGHWAY MAINTENANCE SERVICE is:

Poor		Adequate		Excellent
1	2	3	4	5

Figure B. 8 Questionnaire

The main objectives for the thank-you letter, shown in **Figure B.9**, were stimulating participants to complete the survey and acknowledging those who have already completed the survey. The format of the thank-you letter was different from the format of the cover letter. The change in the format was made intentional to produce a different impact in the participant.

VirginiaTech

March 19, 2008

Dear Sir/Madam,

Earlier this month a survey seeking your opinion about the quality of the maintenance service provided by VDOT was mailed to you. If you have already completed and submitted the questionnaire to us, please accept our sincere thanks. If not, please do so today.

We are especially grateful for your help, because it is only by asking people like you to share your experiences and opinion that we can understand how road users perceive the quality of highway maintenance services.

Thank you for your cooperation.

Sincerely,

Adrian Burde

The drawing to win one of three Apple iPod shuffles will be held on April 30.
For results visit
www.filebox.vt.edu/users/burde/HMSQSurvey/

Figure B. 9 Thank You Postcard

The reminder letter, shown in **Figure B.10**, was sent only to participants who did not completed the survey during the first round. Too often participants loose the questionnaire that was initially sent with the cover letter so a replacement questionnaire was mailed alone with the reminder letter. The content of the reminder letter was different from the content of the initial cover letter in order to increase the chances of obtaining a response from the participant.

The reminder letter clearly indicated the end date for submitting the answers and also the closing date of the whole data collection effort. The same notice included in the thank-you postcard regarding the sweepstakes was repeated in the reminder letter.

Dear Sir/Madam,

We are pleased to announce that the survey on highway maintenance service quality that we started three weeks ago is going well. So far, we have received more than 200 responses. We are very excited with this number because the more answers we get from you the better we can support our conclusions.

What is more, the current number of responses allows us to run statistical analyses for determining how road users perceive the quality of the highway maintenance services. We believe that the results of these analyses and the study overall will contribute to improving the manner in which maintenance services are being delivered by transportation agencies and their maintenance operators.

As of today, we have not received a completed survey from you and we would like to have your opinion. Your answer is very important to us. We have enclosed a replacement questionnaire to this letter. This questionnaire is the same as the one that was mailed to you three weeks ago. Please return your answer to us no later than April 11th. The survey will end on April 15th.

If you have any questions, feel free to contact me (Adrian Burde) at (540) 231-5565, or by email at burde@vt.edu.

Once more, thank you very much for your cooperation.

Sincerely,

Adrian Burde
Graduate Research Assistant
Virginia Tech

The drawing to win one of three Apple iPod shuffles will be held on April 30.
For results please visit:
www.filebox.vt.edu/users/burde/HMSQSurvey/

Reminder: Any adult resident (18 years old or over) can complete the survey. If possible, we would like to have a **male** completing the survey. The reason for this request is to fulfill specific sample quotas required to make the response sample representative of the study population.

Figure B. 10 Reminder Letter

An additional letter was included to the communication process during the data collection. The letter was a notification that the participant was removed from the study as per her or his request. **Figure B.11** shows an example of the letter.

VirginiaTech

Dear Sir/Madam,

As per your request, we have removed your information from the mailing list of the study on highway maintenance service delivery conducted by the Department of Civil and Environmental Engineering at Virginia Tech.

Sincerely,

Adrian Burde

Figure B. 11 Notification of Removal

Finally, **Figure B.12** shows a screen shoot of the website created for notifying the winners of the sweepstakes.

VirginiaTech *Invent the Future*

CHAMPS *Center for Highway Asset Management ProgramS*

Adopting a Multiple-Item Scale for Measuring Highway Maintenance Perceived Service Quality

Highway Maintenance Perceived Service Quality Survey

April 30th 2008

Numbers Drawn*		Name	Address Line 1	Address Line 2
First Number=	289	Cole	4535 Thaxton Rd, Apt 1	Pulaski, VA 24301-3036
Second Number=	15	Frahm	201 Spickard St	Blacksburg, VA 24060-1329
Third Number=	194	Atkins	6463 Virginia Ave	Pembroke, VA 24136-3012

*The total number of participants that submitted a completed survey is 333. The winning numbers have been randomly selected between 1 and 333 using the following excel formula: **ROUNDUP(ROUND(RAND(),3)*333,0)**.

The sweepstakes took place at 5:00 pm April 30th during Dr. de la Garza's class (Virginia Tech /Blacksburg). For a short video clip of the drawing click here (realplayer media software is required to watch the video). The three winners will receive the prizes within a week to ten days after the drawing. For any questions about the survey or if you want to know more about the results of the survey please contact me Adrian Burde.

Thank you for your participation.

Adrian Burde - Graduate Research Assistant - Virginia Tech

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Figure B. 12 Website

APPENDIX C – Data Collection Results

The data was collected in two different formats. For the pilot study, the data was collected on-line through a web tool. For the final study, the data was collected by the mail-out approach. In both cases, the data collected was stored in Excel format for further analysis.

Pilot Study

The total number of complete questionnaires received at the end of the survey was 47, representing a 15.6 percent response rate (47 / 300 = .156). The data was converted from text format into Excel spreadsheet format as presented in **Table C.1**.

Table C. 1 Data Collected for the Pilot Study

TANGIBLE			RELIABILITY				ASSURANCE			SQL
A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	
5	7	4	6	3	6	3	6	4	5	5
5	5	5	5	3	5	3	5	5	3	5
8	8	8	5	1	5	1	8	8	5	3
5	5	5	4	5	5	5	5	5	5	6
5	5	4	5	5	4	5	5	5	5	3
5	6	4	4	4	5	5	4	5	5	5
6	6	6	6	6	5	6	3	3	6	6
7	4	3	5	4	4	6	6	6	5	8
5	6	6	6	5	5	6	5	6	4	8
8	8	4	5	5	6	3	6	6	5	6
6	7	6	6	4	3	4	6	6	6	6
5	5	5	6	4	6	5	5	5	5	8
6	5	5	5	4	5	5	5	5	5	6
8	8	6	8	6	8	8	8	8	8	8
7	6	7	8	6	5	8	6	6	6	7
5	5	5	5	5	5	6	5	6	5	6
5	5	5	5	1	5	1	5	4	5	1
5	5	5	5	5	5	5	5	5	5	5
6	7	5	6	4	6	3	5	5	5	4
5	5	7	8	**4**	2	7	5	7	2	7
5	7	5	5	2	4	5	5	4	5	5
5	5	4	5	4	5	4	5	5	5	5
5	9	5	1	1	5	1	9	5	5	5
5	5	5	4	3	4	3	4	4	5	5
5	5	5	5	5	5	5	5	5	5	6
5	5	5	5	4	5	5	5	5	4	7
5	2	2	5	2	2	2	2	4	4	3
6	7	4	4	2	6	3	**5**	6	3	6
5	7	5	5	4	6	4	7	**5**	5	4

Table C.1 Data Collected for the Pilot Study (continue)

TANGIBLE			RELIABILITY				ASSURANCE			SQL
A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	
5	7	3	4	3	5	4	5	6	6	5
7	7	4	4	3	5	4	5	5	5	4
5	5	6	6	5	6	7	5	6	6	7
5	5	2	5	3	6	3	5	5	5	4
7	8	5	2	2	5	2	2	2	5	3
6	6	6	6	6	6	6	6	5	5	6
5	5	5	5	5	5	5	5	5	5	10
5	5	1	5	5	5	5	5	5	5	6
5	8	8	8	4	4	5	8	8	8	7
9	9	9	8	4	9	8	6	9	9	8
5	5	5	5	5	9	5	5	7	7	6
5	5	5	5	3	3	**5**	5	5	**5**	4
5	5	5	5	4	5	5	5	6	5	7
7	7	6	7	7	8	7	7	8	7	8
5	5	4	5	5	5	3	5	5	5	6
5	5	3	3	1	3	1	5	5	3	4
5	5	3	**5**	4	4	6	5	5	5	5
8	6	4	7	8	8	9	8	2	8	8

The variables indicated in **Table C.1** correspond to the three groups or dimensions of the highway maintenance service (i.e. tangible, reliability, and assurance). The description for each variable is presented next in **Table C.2**.

Table C. 2 Description for the Variables Adopted in the Pilot Study

Variable	Description
A_1	Modern Equipment
A_2	Employees wearing proper attire (e.g. hardhat, reflective vest, etc)
A_3	Adopting Convenient working hours
A_4	Minimizing travel delay through maintenance areas
A_5	Performing maintenance when required
A_6	Keeping customers inform about maintenance activities
A_7	Performing maintenance in a reasonable period of time
A_8	Employees instilling confidence in you
A_9	Making road users feel safe while driving through maintenance areas
A_{10}	Isolating Maintenance areas effectively
SQL	Overall perception of the quality of the highway maintenance service

Final Study

A total of 343 participants sent their responses for the final surveys. From the 343 responses, 9 were removed from the study and 4 surveys came back due to wrong address. The total number of completed surveys was 334 representing a response rate of 44.6 percent. The data was manually entered into the Excel spreadsheet presented in **Table C.3**.

Table C. 3 Data Collected for the Final Study

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540002	3	3	4	4	3	3	3	1	3	2	2	3	2	3	1	..
540004	3	4	3	3	2	3	3	2	3	3	4	2	3	1	2	1
540005	4	4	3	3	3	2	4	3	3	4	4	3	3	2	2	2
540006	4	4	4	4	3	5	4	3	4	4	5	3	5	2	2	1
540007	3	2	3	3	3	3	3	2	3	2	3	3	3	1	2	..
540011	3	3	4	3	4	3	3	4	3	5	1	4	3	1	1	1
540013	3	3	3	3	4	3	3	3	4	3	2	3	3	2	2	1
540014	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1
540016	1	3	3	3	3	3	3	1	3	1	2	1	2	2	1	1
540017	3	3	3	3	3	3	3	3	3	2	2	3	3	2	2	1
540018	4	4	4	4	4	4	4	4	4	4	4	4	4	3	2	1
540019	3	3	3	2	3	3	3	2	3	2	3	3	3	2	1	3
540021	4	4	**3**	4	4	3	3	3	3	4	2	4	3	2	2	..
540023	2	3	3	2	3	2	3	2	3	2	1	2	2	1	2	3
540024	3	3	3	3	2	2	3	2	3	2	2	2	2	3	1	3
540026	2	3	2	3	3	2	2	2	2	1	1	2	2	2	2	3
540028	4	3	4	4	3	3	3	4	4	3	3	3	5	2	2	1
540029	4	4	3	3	3	2	3	2	4	3	2	3	3	2	2	4
540030	3	2	3	3	2	3	2	3	3	2	4	3	4	2	1	3
540031	2	3	3	3	3	2	3	2	3	2	2	2	3	3	2	1
540033	2	3	2	3	3	3	3	2	3	2	2	2	3	3	1	3
540034	4	4	4	4	3	3	3	2	3	3	3	3	3	3	1	3
540043	4	4	4	4	3	3	4	5	5	5	4	5	4	1	2	3
540046	4	4	4	3	3	4	4	3	3	2	2	3	3	1	1	4
540048	3	3	3	4	3	2	3	2	3	2	2	2	3	.	2	3
540049	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	..
540052	2	3	3	2	2	3	2	2	4	2	2	1	2	1	2	1
540054	4	3	4	5	4	3	4	5	3	4	4	3	3	3	1	5
540058	4	5	5	5	5	4	5	4	5	4	4	3	5	3	1	3
540063	3	4	4	4	3	1	3	3	4	2	2	3	3	2	2	1
540067	5	5	5	5	5	5	5	5	5	5	5	5	5	3	2	3
540068	3	3	3	4	4	4	4	3	4	3	4	3	3	3	1	1
540070	4	5	5	5	4	5	5	5	5	5	4	5	5	3	2	3
540071	3	3	2	3	2	3	3	2	4	3	2	3	3	3	1	..
540072	4	4	4	4	4	4	4	3	4	3	3	3	4	3	2	2
540073	3	3	3	3	3	3	3	3	3	3	3	3	3	1	2	1
540074	3	3	4	3	3	3	3	3	3	3	3	3	3	1	2	4
540075	4	4	3	3	3	4	2	3	4	3	2	2	3	2	1	2
540076	3	3	3	3	2	2	3	3	3	2	3	2	3	2	1	1
540078	4	3	3	4	3	1	3	2	3	1	3	3	3	3	1	3
540079	4	4	4	3	3	2	3	3	3	3	3	2	3	3	2	3

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540080	3	3	3	4	3	3	4	3	3	3	3	3	4	3	1	5
540081	5	3	3	4	3	3	3	3	3	4	2	5	3	2	2	3
540082	4	4	2	4	4	1	2	1	4	4	5	3	2	2	1	1
540084	3	3	3	3	3	3	3	3	3	3	3	3	4	2	2	3
540086	3	4	3	4	4	4	4	3	4	4	5	4	4	2	1	2
540087	3	3	3	2	2	3	3	2	3	4	3	3	3	2	2	2
540089	4	3	3	4	3	1	3	1	4	1	2	1	3	1	1	1
540090	4	4	4	4	4	3	4	4	4	4	3	4	4	3	1	1
540091	3	3	3	3	3	2	3	2	3	3	1	3	3	3	2	3
540092	4	4	4	3	3	3	3	2	3	3	2	2	3	2	1	3
540095	3	3	2	3	3	2	3	1	3	2	3	2	2	2	1	1
540096	3	3	4	4	3	3	4	2	3	3	4	4	3	3	1	3
540103	3	3	3	2	3	3	3	4	3	4	4	4	4	3	2	..
540104	5	5	2	2	5	2	5	5	5	5	5	5	5	1	1	1
540105	3	4	3	4	4	3	3	2	4	3	3	4	4	1	2	4
540106	4	5	5	5	5	5	5	3	5	4	4	4	4	3	2	3
540110	3	3	3	3	3	4	3	4	3	4	4	3	4	2	2	1
540113	3	3	2	3	3	3	3	4	3	3	4	3	5	1	1	1
540114	3	4	3	4	3	1	3	3	3	3	3	3	3	2	1	1
540117	3	3	3	3	3	3	3	2	3	3	3	3	3	2	2	1
540118	2	3	3	3	3	2	3	2	3	3	3	3	3	2	2	1
540119	3	3	2	3	3	2	2	3	3	3	3	3	3	2	2	1
540120	3	4	3	3	3	3	2	3	4	2	2	3	3	2	2	..
540124	4	3	3	4	3	3	3	2	3	2	3	3	3	1	2	1
540125	3	4	4	5	5	4	5	2	3	4	3	3	4	3	2	3
540127	3	3	3	4	4	3	3	3	3	3	2	3	3	3	1	1
540129	3	3	3	3	2	2	3	3	3	2	3	3	3	3	2	3
540130	3	4	3	4	3	3	4	2	3	3	3	4	4	3	1	3
540134	4	4	4	4	4	3	3	3	3	2	2	3	3	3	2	3
540135	5	3	4	4	4	3	3	2	3	3	3	4	4	2	1	1
540136	3	4	3	4	4	4	4	3	4	3	3	4	4	3	1	1
540137	3	3	2	3	2	3	3	1	2	2	1	2	2	2	1	1
540139	3	4	4	5	4	4	5	3	4	4	3	5	4	3	1	3
540140	4	5	4	5	4	4	3	4	4	5	5	5	5	3	1	..
540141	4	4	3	4	3	3	3	3	4	4	4	3	4	3	1	3
540142	4	5	3	5	4	3	4	3	5	4	5	5	5	3	2	3
540143	3	3	3	3	2	3	2	3	3	2	2	2	3	3	1	3
540144	4	5	3	4	4	4	4	3	4	2	4	3	4	2	1	1
540145	3	3	2	3	2	2	2	3	3	2	2	2	2	2	2	1
540146	5	5	4	5	4	4	5	5	4	3	4	4	5	1	2	1
540149	3	3	3	3	3	3	3	2	3	3	3	2	3	2	1	1
540150	3	4	4	4	3	3	3	3	4	4	3	3	4	2	2	1
540151	3	3	3	4	4	3	4	3	3	5	4	4	3	3	1	5
540153	4	4	2	4	3	2	4	4	4	4	3	2	4	2	2	1
540156	3	3	4	4	4	3	3	3	4	2	2	4	3	1	1	1
540164	3	4	3	3	3	4	3	3	3	4	4	4	4	1	2	1
540165	4	4	3	5	3	3	3	3	4	2	2	3	3	1	2	..
540168	5	5	5	4	1	2	3	1	5	1	1	1	3	3	2	5
540169	4	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1
540173	3	3	3	3	3	2	3	3	3	3	2	3	4	2	2	2
540174	3	3	4	3	3	3	3	3	3	3	3	2	4	1	1	2
540176	4	4	4	5	3	3	3	2	3	3	2	2	4	2	1	1
540177	4	3	3	3	3	2	3	2	3	2	2	2	2	3	2	1
540180	3	3	3	3	3	2	2	**3**	3	2	2	3	3	2	2	3
540183	5	5	4	5	5	3	4	3	4	3	2	5	4	2	1	2

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540187	3	4	3	4	4	3	4	4	4	3	3	3	3	3	1	3
540189	3	3	3	4	4	3	3	2	2	2	4	4	2	2	1	1
540190	3	3	3	2	2	3	3	1	3	3	2	2	3	2	2	1
540191	3	4	4	4	3	3	3	2	3	3	3	3	3	3	1	2
540192	3	3	2	2	2	3	2	1	3	1	3	3	2	1	2	1
540193	3	3	3	3	3	2	3	3	3	3	2	3	.	2	2	1
540198	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	3
540203	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1
540204	3	3	4	4	3	3	3	3	4	2	3	3	4	3	1	1
540207	3	3	3	3	2	2	3	2	3	2	2	3	3	2	2	1
540209	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	5
540210	3	3	3	3	3	1	3	2	3	2	1	2	3	2	1	1
540219	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	..
540220	5	5	5	5	5	5	5	5	5	5	5	5	5	3	1	1
540228	5	4	3	5	3	3	4	2	3	3	4	5	3	3	2	1
540231	3	3	3	4	3	3	3	2	4	3	3	2	4	3	2	2
540232	3	3	3	3	3	4	3	1	3	1	3	3	2	2	1	1
540233	3	3	3	3	3	2	3	2	3	3	3	3	3	2	2	1
540239	3	3	2	3	3	3	3	3	3	4	4	3	3	3	2	..
540240	3	3	3	3	3	2	3	3	3	3	2	3	3	3	1	3
540241	3	4	3	3	2	3	3	2	3	3	3	2	3	3	1	..
540242	3	3	3	**3**	3	2	3	3	3	2	2	3	3	2	2	3
540243	4	4	4	4	4	4	4	2	4	4	4	4	3	3	1	1
540245	3	3	3	3	3	2	3	1	3	3	2	3	2	2	2	1
540246	3	4	4	4	3	3	4	3	4	3	4	3	3	3	1	3
540252	4	3	2	4	3	3	4	2	3	2	4	2	3	3	1	1
540253	3	4	3	4	3	3	3	3	4	2	2	4	4	2	2	1
540258	3	3	4	4	4	4	3	4	3	4	4	4	4	3	1	1
540261	4	4	3	3	3	3	3	2	3	2	3	3	3	2	1	1
540262	4	4	3	3	4	3	3	3	3	3	3	3	3	2	2	3
540266	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	1
540270	3	3	3	3	3	2	3	2	3	2	2	3	3	3	1	3
540271	3	3	3	3	3	1	3	1	1	1	1	3	.	2	2	1
540272	3	3	3	3	3	3	3	1	3	3	2	3	2	3	1	1
540274	3	3	4	3	3	3	4	3	4	3	2	2	4	2	2	3
540276	3	2	4	4	3	2	3	1	3	3	2	2	2	1	2	..
540278	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	2
540279	3	3	2	4	3	3	2	3	3	3	3	3	4	2	2	1
540281	3	4	4	3	3	3	3	2	3	2	2	2	2	3	1	1
540282	4	4	4	4	4	3	4	3	3	2	3	3	4	1	2	1
540284	4	4	4	4	4	3	3	2	4	2	2	2	4	3	1	..
540286	3	3	3	3	3	3	3	3	3	2	2	2	3	1	1	1
540287	3	4	4	3	4	4	4	4	4	3	4	4	3	2	2	1
540288	4	4	4	3	3	3	3	2	3	2	2	3	.	2	1	1
540289	3	3	3	3	3	3	3	2	3	2	3	2	3	3	1	3
540291	3	4	3	3	3	3	3	2	3	4	2	3	3	3	1	1
540293	4	4	3	4	3	3	3	3	3	3	3	2	3	1	1	1
540297	3	4	3	3	3	4	4	2	3	2	2	2	3	2	2	1
540298	4	5	5	5	5	4	4	4	4	4	4	5	5	3	1	2
540305	4	3	3	3	3	2	3	3	3	1	2	2	3	3	1	1
540308	4	4	4	3	4	4	4	3	3	3	3	3	4	3	1	..
540309	1	3	1	1	1	1	1	1	1	1	1	1	1	2	2	3
540310	3	3	2	3	2	2	2	2	3	3	3	3	3	3	2	5
540311	4	3	3	3	3	4	3	3	3	3	3	3	3	3	1	1
540313	4	3	3	4	3	3	4	3	3	2	2	3	3	2	2	1

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540317	2	3	3	3	2	1	3	1	4	3	2	3	2	3	1	3
540321	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3
540323	3	3	2	3	2	2	2	3	3	3	2	2	2	3	2	..
540329	3	4	3	3	3	2	3	1	3	2	3	3	2	3	1	..
540331	4	3	3	4	4	2	3	2	3	4	4	4	3	2	1	1
540332	4	3	2	3	3	2	3	3	3	3	3	3	3	3	1	5
540333	4	3	3	3	4	3	3	3	3	3	3	3	3	3	2	3
540334	4	5	5	5	5	4	4	4	4	4	4	4	5	3	2	3
540335	4	3	4	3	3	3	3	**3**	3	2	**3**	3	3	3	2	.
540336	3	3	3	2	3	4	4	2	4	2	3	3	3	2	1	1
540338	3	3	1	2	2	2	3	1	3	1	1	1	2	2	1	1
540340	3	4	3	5	3	2	3	3	4	2	4	4	3	1	1	1
540343	3	5	4	4	3	3	3	1	4	3	2	3	2	2	2	2
540347	3	3	3	3	3	3	3	2	3	2	3	3	3	3	2	..
540348	4	4	4	5	5	3	4	3	3	2	3	3	4	2	2	1
540351	2	5	4	3	2	1	2	3	3	3	2	3	4	2	2	1
540352	3	3	2	3	2	2	2	3	3	2	3	2	3	2	2	1
540356	3	4	4	4	4	4	3	2	3	3	3	3	3	2	2	1
540358	3	3	3	2	2	3	3	3	3	2	2	3	3	2	2	2
540363	3	4	4	4	2	4	4	1	4	3	3	3	4	2	2	1
540364	4	5	5	5	4	5	4	3	4	3	4	4	4	3	1	3
540368	3	3	3	3	**3**	3	3	3	3	3	3	4	5	3	2	..
540373	4	4	4	4	4	4	4	3	4	3	3	3	4	2	1	1
540374	3	3	3	3	3	2	3	1	3	3	3	2	4	3	2	1
540375	3	3	3	3	3	2	3	2	5	3	2	2	3	2	2	..
540378	3	3	3	3	3	4	3	4	3	4	4	3	.	3	1	..
540380	4	4	3	4	3	3	3	3	3	4	3	3	3	2	2	1
540382	3	4	4	4	4	3	4	4	4	2	2	2	3	2	2	1
540383	3	1	3	3	3	3	2	2	3	2	4	3	2	2	2	1
540384	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	1
540386	4	4	4	4	4	3	4	1	3	2	3	3	2	3	1	3
540387	3	2	3	3	3	3	3	3	3	3	2	3	3	1	2	1
540390	4	3	3	3	3	3	3	2	3	3	2	3	3	3	1	1
540393	4	4	3	4	4	4	3	2	3	3	4	2	2	2	1	1
540394	3	3	3	3	3	3	3	2	3	3	3	3	4	3	1	1
540396	3	4	3	3	3	3	3	2	3	3	2	3	.	3	.	5
540397	4	4	4	4	4	4	4	3	3	3	3	3	.	3	1	3
540398	4	4	4	4	4	4	4	3	4	4	4	4	4	3	1	1
540400	3	3	3	3	3	1	3	2	3	3	2	3	3	1	2	1
540401	3	3	3	4	4	3	3	2	3	3	4	4	2	3	2	3
540403	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	..
540411	4	4	3	4	2	4	3	3	3	2	3	3	4	2	1	1
540412	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	..
540413	4	3	2	4	4	4	4	1	4	3	3	4	3	2	2	1
540414	5	5	5	5	5	5	5	5	5	5	5	5	.	3	2	1
540422	3	3	3	3	2	3	2	2	3	3	4	2	3	3	1	1
540423	2	4	3	3	2	1	3	1	3	1	1	1	2	1	2	3
540425	3	3	2	3	2	1	2	1	3	2	1	1	2	3	1	2
540426	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3
540428	3	3	3	3	3	3	3	2	3	3	2	3	3	3	1	3
540432	3	2	3	3	2	3	2	4	3	2	2	2	3	3	1	1
540433	3	3	3	3	4	3	3	3	4	2	2	1	3	2	2	3
540434	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
540437	5	5	4	5	4	4	4	4	5	4	4	4	4	3	2	1
540439	3	3	4	4	3	2	3	3	4	2	4	2	3	2	2	4

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540440	3	3	3	3	3	2	3	2	3	3	2	2	3	2	2	1
540441	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	2
540442	3	3	3	3	3	2	3	2	3	2	3	2	2	2	2	1
540445	3	3	2	3	3	3	3	3	2	2	3	3	3	2	2	1
540447	4	4	4	4	4	4	4	2	3	3	3	3	3	3	1	3
540450	2	3	2	2	4	3	4	2	4	4	2	2	3	2	2	1
540451	3	4	4	3	4	1	3	1	3	1	1	1	1	3	1	..
540452	4	4	3	5	3	3	3	3	3	3	3	3	4	3	1	..
540460	3	3	3	3	3	3	3	2	3	2	2	3	3	3	1	..
540461	3	3	3	3	3	3	3	4	4	4	3	3	3	2	2	1
540462	3	4	3	4	4	3	3	2	4	3	4	3	4	2	2	1
540463	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3
540467	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
540469	5	5	5	5	5	5	5	5	5	5	5	5	5	3	1	1
540470	3	3	3	3	3	3	3	3	4	3	2	2	3	2	1	2
540471	4	3	3	3	3	3	3	2	3	3	2	3	3	3	2	1
540479	5	5	4	5	4	4	4	3	4	3	3	3	4	3	2	3
540480	3	3	4	4	3	3	3	3	3	4	3	4	4	3	1	3
540486	4	2	2	4	3	4	3	1	3	2	2	4	.	2	2	3
540487	5	3	3	4	4	4	3	4	3	4	4	5	5	1	1	1
540488	5	5	4	4	4	4	4	3	3	3	4	4	4	3	1	3
540489	3	3	3	3	3	3	2	3	3	3	3	4	3	2	2	3
540490	4	4	4	3	3	2	4	3	3	2	2	2	3	1	2	3
540491	3	4	3	4	3	2	3	2	3	3	2	3	3	3	1	5
540494	3	2	3	3	3	2	3	3	3	2	1	1	2	2	.	1
540495	5	5	5	5	5	5	5	5	5	5	5	5	5	3	2	5
540498	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1
540501	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	1
540505	3	4	5	4	4	4	4	2	4	2	1	1	2	3	1	2
540506	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1
540513	3	3	3	3	2	3	2	2	3	3	3	3	2	3	2	..
540515	3	3	2	3	3	3	3	3	3	2	2	2	3	1	1	1
540516	3	3	3	3	3	2	3	2	3	2	3	2	3	3	2	3
540530	3	3	3	2	2	2	2	2	3	3	2	3	3	3	2	1
540531	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
540533	3	2	3	4	2	3	3	2	4	2	4	3	2	2	2	1
540534	4	4	4	4	4	2	4	1	4	3	4	4	3	2	2	1
540535	3	3	3	2	3	2	3	2	3	2	2	3	3	2	2	1
540538	5	4	4	4	4	3	4	3	4	3	3	3	4	2	2	1
540539	4	4	4	4	4	3	5	4	4	3	3	3	4	3	2	3
540541	4	5	4	4	4	4	4	3	4	4	3	3	4	3	2	1
540542	3	2	3	4	3	3	2	2	3	3	3	3	3	3	1	3
540543	4	3	3	3	3	2	3	2	3	1	1	1	2	3	2	1
540547	4	4	4	4	4	4	4	3	4	4	4	4	.	3	1	4
540551	3	4	4	3	3	4	4	3	5	4	3	3	4	2	2	1
540552	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	..
540553	2	3	2	2	3	2	3	2	3	2	3	3	3	2	2	1
540557	3	4	4	4	3	3	3	3	5	1	3	2	3	3	1	..
540558	4	4	4	4	3	3	3	3	3	3	3	3	4	3	1	2
540559	3	3	5	3	2	3	3	2	3	3	3	2	3	3	1	3
540560	4	3	3	4	3	3	3	3	3	3	3	4	3	3	1	1
540570	3	3	3	3	3	3	3	3	3	2	1	1	3	3	2	3
540571	3	3	4	3	4	2	3	2	3	2	3	2	3	2	1	1
540572	3	3	3	4	4	3	3	3	3	3	4	3	3	2	2	2
540573	4	4	3	3	4	3	3	1	3	3	2	1	3	3	2	2

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540578	3	3	4	4	3	3	4	3	4	2	3	4	3	3	1	3
540581	3	3	3	3	1	1	3	1	3	4	1	2	3	2	2	1
540583	3	3	3	3	3	3	3	2	3	3	3	3	3	2	2	1
540585	4	3	3	3	3	2	3	2	3	3	2	2	3	2	2	1
540587	3	3	3	3	3	3	3	2	3	3	3	3	3	3	1	3
540588	3	3	3	3	3	2	3	2	3	2	3	2	3	2	1	1
540592	4	3	2	4	3	1	3	1	4	3	1	3	4	3	1	1
540593	3	3	2	3	4	3	3	3	4	3	4	3	4	2	2	1
540597	3	3	4	3	3	5	3	5	3	5	5	3	2	3	1	..
540598	3	4	3	4	4	3	3	2	3	3	2	3	3	2	2	1
540600	3	3	3	3	4	3	3	4	3	3	3	3	3	3	2	3
540601	4	4	4	5	4	3	3	2	3	3	3	2	3	3	2	3
540602	3	3	3	3	3	2	3	2	4	3	2	4	.	3	2	3
540605	3	**3**	2	4	2	2	4	2	3	3	3	4	3	2	2	3
540607	2	5	5	5	5	4	4	4	4	4	4	4	3	3	2	..
540609	2	3	2	3	3	1	3	1	3	1	1	2	2	1	2	1
540610	4	4	4	4	3	2	4	2	4	3	2	3	.	3	1	..
540611	3	3	3	3	3	3	3	2	3	3	3	2	.	2	2	1
540618	2	2	3	**3**	4	2	3	3	1	1	3	2	2	3	2	1
540621	4	3	3	4	3	4	3	1	4	3	4	3	2	1	1	1
540622	3	4	3	4	3	3	3	3	3	3	3	3	3	2	2	3
540625	4	4	3	4	4	3	3	2	4	3	1	1	4	3	2	1
540639	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1
540644	3	3	3	4	2	3	4	4	4	3	4	2	3	3	1	3
540645	3	4	4	4	4	3	4	3	3	3	3	3	3	2	.	3
540647	3	3	3	3	2	3	1	1	1	2	3	3	3	2	2	5
540649	5	3	4	5	4	1	5	2	3	2	1	3	4	2	1	2
540650	3	3	3	3	3	3	3	2	3	3	3	3	4	3	1	1
540652	4	4	5	5	5	4	5	2	3	3	3	5	4	2	2	1
540653	5	5	5	5	5	3	3	3	3	3	3	3	5	3	.	3
540655	4	3	3	3	3	2	3	1	3	1	2	1	3	1	2	2
540659	4	4	3	4	4	3	4	4	3	3	4	4	4	3	1	3
540661	4	4	4	4	4	4	4	2	4	3	3	4	5	3	1	3
540664	4	4	4	5	5	5	4	3	3	4	4	5	4	3	2	3
540668	3	4	3	4	4	3	4	3	4	3	4	4	3	3	1	3
540669	4	4	3	4	3	4	3	3	3	3	4	3	4	3	2	5
540671	4	4	3	4	3	**3**	3	3	3	4	3	2	3	2	1	1
540674	4	3	3	4	3	4	3	3	3	2	4	3	3	2	2	1
540679	3	4	3	3	3	3	3	**3**	4	4	4	4	4	3	1	3
540682	5	5	4	4	5	5	4	3	4	5	5	4	5	3	2	3
540684	3	4	4	4	3	3	3	3	3	3	2	2	3	1	2	3
540687	4	4	5	5	5	5	5	3	5	4	5	5	5	3	1	2
540690	3	4	4	3	3	2	3	2	4	3	3	3	3	3	1	1
540696	5	5	5	5	5	5	5	3	5	5	5	5	5	3	1	3
540697	4	3	3	4	3	3	3	3	4	3	3	3	4	3	1	1
540699	4	4	3	3	3	2	3	1	3	2	2	2	3	3	1	..
540701	4	4	5	5	4	3	5	3	5	4	4	4	4	2	1	1
540702	4	3	3	3	4	4	3	3	3	2	3	3	3	3	1	1
540708	3	4	3	3	2	2	3	1	3	1	2	3	3	2	1	2
540715	3	4	3	3	3	2	3	2	4	4	3	3	3	3	1	1
540716	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	..
540718	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	2
540720	4	3	4	3	3	4	4	3	3	2	4	4	3	3	2	1
540722	3	3	3	3	3	3	3	2	3	2	4	4	4	2	1	3
540723	3	3	3	3	3	3	3	1	3	2	3	2	2	3	2	3

Table C.3 Data Collected for the Final Study (continue)

SIN #	B12	B2	B9	B4	B11	B5	B10	B6	B1	B7	B3	B8	SQL	AGE	GEN	TRP
SIN #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	SQL	AGE	GEN	TRP
540724	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	5
540727	3	3	4	3	3	3	4	2	4	2	3	2	3	2	2	1
540728	3	3	3	3	3	3	3	3	3	**3**	3	3	3	1	2	3
540729	4	4	5	4	5	4	4	3	4	3	4	5	4	.	.	.
540730	2	4	3	2	3	1	3	2	3	2	2	3	3	2	1	1
540732	4	4	4	5	4	4	4	5	5	4	4	4	4	3	1	1
540733	3	2	2	3	2	2	2	2	3	3	3	4	3	2	1	2
540735	3	3	2	3	3	2	2	1	2	1	1	1	2	2	1	1
540736	4	4	4	3	4	3	3	3	3	4	3	4	3	3	1	..
540739	2	2	2	2	1	1	2	1	2	1	1	1	1	2	2	1
540741	3	3	3	3	3	3	3	2	3	3	3	3	3	3	1	3
540742	4	3	3	4	4	4	4	3	4	4	3	5	3	3	1	3
540744	3	3	4	3	4	2	3	3	3	2	2	3	3	2	2	1
540745	4	4	3	4	4	3	3	3	4	4	3	3	3	1	2	1
540746	3	3	3	2	2	2	2	1	3	2	3	3	2	2	1	1
540748	5	5	3	5	3	3	2	2	3	1	1	2	3	2	2	4
540749	5	5	4	5	5	4	5	4	5	4	4	5	5	3	1	5
540751	3	4	3	3	3	3	2	2	3	3	4	3	3	3	2	1

Whenever there was a missing, data the variable was entered with the symbol ".". For variable Primary Trip Type (TRP), indicated in **Table C.3**, the symbol ".." means that the participant responded the item with multiple choices. The description for each variable indicated in **Table C.3** is presented in **Table C.4**.

Table C. 4 Description of the Variables Adopted in the Final Study

Variable		Description
B_{12}	Q_1	Alerting road users when approaching maintenance areas
B_2	Q_2	Employees wearing proper attire
B_9	Q_3	Operating heavy equipment without frightening road users
B_4	Q_4	Using clear indicators of maintenance activities
B_{11}	Q_5	Guiding road users through well-defined maintenance areas
B_5	Q_6	Minimizing travel delay through maintenance areas
B_{10}	Q_7	Making road users feel safe while driving through maintenance areas
B_6	Q_8	Performing maintenance work when it appears to be needed
B_1	Q_9	Using equipment that looks well-maintained and in good working condition
B_7	Q_{10}	Completing maintenance work in reasonable time duration

Table C.4 Description of the Variables Adopted in the Final Study (Continue)

Variable		Description
B_3	Q_{11}	Performing maintenance during low traffic time periods
B_8	Q_{12}	Keeping users informed about the location and duration of maintenance work
SQL		Overall perception of the quality of the highway maintenance services
AGE		Age (1=18 to 34, 2=35 to 54, 3=55 and over)
GEN		Gender (1=male, 2=female)
TRP		Primary Trip Type (1=commuting, 2=business, 3=shopping, 4=recreational, 5=others)
LOC		Location (1=Montgomery Co., 2=Giles Co., 3=Pulaski Co.)

Regression Analysis Input

Table C.5 shows the observations used for the regression analyses. Both average scores and centering term were included in the table as well as the overall level of service quality.

Table C. 5 Explanatory and Response Variables for the Regression Analysis

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540002	3.50	2.00	0.13	2
540004	3.25	2.75	-0.12	3
540005	3.50	3.50	0.13	3
540006	4.00	3.75	0.63	5
540007	2.75	2.50	-0.62	3
540011	3.25	3.50	-0.12	3
540013	3.00	2.75	-0.37	3
540014	3.00	3.00	-0.37	3
540016	2.50	1.25	-0.87	2
540017	3.00	2.50	-0.37	3
540018	4.00	4.00	0.63	4
540019	2.75	2.50	-0.62	3
540021	3.75	3.25	0.38	3
540023	2.50	1.75	-0.87	2
540024	3.00	2.00	-0.37	2
540026	2.50	1.50	-0.87	2
540028	3.75	3.25	0.38	5
540029	3.50	2.50	0.13	3
540030	2.75	3.00	-0.62	4
540031	2.75	2.00	-0.62	3
540033	2.50	2.00	-0.87	3
540034	4.00	2.75	0.63	3
540043	4.00	4.75	0.63	4
540046	3.75	2.50	0.38	3
540048	3.25	2.00	-0.12	3
540049	3.00	3.00	-0.37	4
540052	2.50	1.75	-0.87	2
540054	4.00	4.00	0.63	3
540058	4.75	3.75	1.38	5

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540063	3.75	2.50	0.38	3
540067	5.00	5.00	1.63	5
540068	3.25	3.25	-0.12	3
540070	4.75	4.75	1.38	5
540071	2.75	2.50	-0.62	3
540072	4.00	3.00	0.63	4
540073	3.00	3.00	-0.37	3
540074	3.25	3.00	-0.12	3
540075	3.50	2.50	0.13	3
540076	3.00	2.50	-0.37	3
540078	3.50	2.25	0.13	3
540079	3.75	2.75	0.38	3
540080	3.25	3.00	-0.12	4
540081	3.75	3.50	0.38	3
540082	3.50	3.25	0.13	2
540084	3.00	3.00	-0.37	4
540086	3.50	4.00	0.13	4
540087	2.75	3.00	-0.62	3
540089	3.50	1.25	0.13	3
540090	4.00	3.75	0.63	4
540091	3.00	2.25	-0.37	3
540092	3.75	2.25	0.38	3
540095	2.75	2.00	-0.62	2
540096	3.50	3.25	0.13	3
540103	2.75	4.00	-0.62	4
540104	3.50	5.00	0.13	5
540105	3.50	3.00	0.13	4
540106	4.75	3.75	1.38	4
540110	3.00	3.75	-0.37	4
540113	2.75	3.50	-0.62	5
540114	3.50	3.00	0.13	3
540117	3.00	2.75	-0.37	3
540118	2.75	2.75	-0.62	3
540119	2.75	3.00	-0.62	3
540120	3.25	2.50	-0.12	3
540124	3.50	2.50	0.13	3
540125	4.00	3.00	0.63	4
540127	3.25	2.75	-0.12	3
540129	3.00	2.75	-0.37	3
540130	3.50	3.00	0.13	4
540134	4.00	2.50	0.63	3
540135	4.00	3.00	0.63	4
540136	3.50	3.25	0.13	4
540137	2.75	1.50	-0.62	2
540139	4.00	3.75	0.63	4
540140	4.50	4.75	1.13	5
540141	3.75	3.50	0.38	4
540142	4.25	4.25	0.88	5
540143	3.00	2.25	-0.37	3
540144	4.00	3.00	0.63	4
540145	2.75	2.25	-0.62	2
540146	4.75	4.00	1.38	5
540149	3.00	2.50	-0.37	3
540150	3.75	3.25	0.38	4
540151	3.25	4.00	-0.12	3
540153	3.50	3.25	0.13	4

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540156	3.50	2.75	0.13	3
540164	3.25	3.75	-0.12	4
540165	4.00	2.50	0.63	3
540168	4.75	1.00	1.38	3
540169	3.25	3.00	-0.12	3
540173	3.00	2.75	-0.37	4
540174	3.25	2.75	-0.12	4
540176	4.25	2.25	0.88	4
540177	3.25	2.00	-0.12	2
540180	3.00	2.50	-0.37	3
540183	4.75	3.25	1.38	4
540187	3.50	3.25	0.13	3
540189	3.25	3.00	-0.12	2
540190	2.75	2.00	-0.62	3
540191	3.75	2.75	0.38	3
540192	2.50	2.00	-0.87	2
540198	3.00	3.00	-0.37	4
540203	3.00	3.00	-0.37	3
540204	3.50	2.75	0.13	4
540207	3.00	2.25	-0.37	3
540209	3.00	3.00	-0.37	3
540210	3.00	1.75	-0.37	3
540219	3.00	3.00	-0.37	3
540220	5.00	5.00	1.63	5
540228	4.25	3.50	0.88	3
540231	3.25	2.50	-0.12	4
540232	3.00	2.00	-0.37	2
540233	3.00	2.75	-0.37	3
540239	2.75	3.50	-0.62	3
540240	3.00	2.75	-0.37	3
540241	3.25	2.50	-0.12	3
540242	3.00	2.50	-0.37	3
540243	4.00	3.50	0.63	3
540245	3.00	2.25	-0.37	2
540246	3.75	3.25	0.38	3
540252	3.25	2.50	-0.12	3
540253	3.50	2.75	0.13	4
540258	3.50	4.00	0.13	4
540261	3.50	2.50	0.13	3
540262	3.50	3.00	0.13	3
540266	3.00	3.00	-0.37	3
540270	3.00	2.25	-0.37	3
540272	3.00	2.25	-0.37	2
540274	3.25	2.50	-0.12	4
540276	3.25	2.00	-0.12	2
540278	3.00	3.00	-0.37	3
540279	3.00	3.00	-0.37	4
540281	3.50	2.00	0.13	2
540282	4.00	2.75	0.63	4
540284	4.00	2.00	0.63	4
540286	3.00	2.25	-0.37	3
540287	3.50	3.75	0.13	3
540289	3.00	2.25	-0.37	3
540291	3.25	2.75	-0.12	3
540293	3.75	2.75	0.38	3
540297	3.25	2.00	-0.12	3

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540298	4.75	4.25	1.38	5
540305	3.25	2.00	-0.12	3
540308	3.75	3.00	0.38	4
540309	1.50	1.00	-1.87	1
540310	2.75	2.75	-0.62	3
540311	3.25	3.00	-0.12	3
540313	3.50	2.50	0.13	3
540317	2.75	2.25	-0.62	2
540321	3.00	2.75	-0.37	3
540323	2.75	2.50	-0.62	2
540329	3.25	2.25	-0.12	2
540331	3.50	3.50	0.13	3
540332	3.00	3.00	-0.37	3
540333	3.25	3.00	-0.12	3
540334	4.75	4.00	1.38	5
540335	3.50	2.75	0.13	3
540336	2.75	2.50	-0.62	3
540338	2.25	1.00	-1.12	2
540340	3.75	3.25	0.38	3
540343	4.00	2.25	0.63	2
540347	3.00	2.50	-0.37	3
540348	4.25	2.75	0.88	4
540351	3.50	2.75	0.13	4
540352	2.75	2.50	-0.62	3
540356	3.75	2.75	0.38	3
540358	2.75	2.50	-0.62	3
540363	3.75	2.50	0.38	4
540364	4.75	3.50	1.38	4
540368	3.00	3.25	-0.37	5
540373	4.00	3.00	0.63	4
540374	3.00	2.25	-0.37	4
540375	3.00	2.25	-0.37	3
540380	3.75	3.25	0.38	3
540382	3.75	2.50	0.38	3
540383	2.50	2.75	-0.87	2
540384	3.00	3.00	-0.37	3
540386	4.00	2.25	0.63	2
540387	2.75	2.75	-0.62	3
540390	3.25	2.50	-0.12	3
540393	3.75	2.75	0.38	2
540394	3.00	2.75	-0.37	4
540398	4.00	3.75	0.63	4
540400	3.00	2.50	-0.37	3
540401	3.25	3.25	-0.12	2
540403	3.00	3.00	-0.37	3
540411	3.75	2.75	0.38	4
540412	3.00	3.00	-0.37	3
540413	3.25	2.75	-0.12	3
540422	3.00	2.75	-0.37	3
540423	3.00	1.00	-0.37	2
540425	2.75	1.25	-0.62	2
540426	3.00	3.00	-0.37	3
540428	3.00	2.50	-0.37	3
540432	2.75	2.50	-0.62	3
540433	3.00	2.00	-0.37	3
540434	3.00	3.00	-0.37	3

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540437	4.75	4.00	1.38	4
540439	3.50	2.75	0.13	3
540440	3.00	2.25	-0.37	3
540441	3.00	3.00	-0.37	2
540442	3.00	2.25	-0.37	2
540445	2.75	2.75	-0.62	3
540447	4.00	2.75	0.63	3
540450	2.25	2.50	-1.12	3
540451	3.50	1.00	0.13	1
540452	4.00	3.00	0.63	4
540460	3.00	2.25	-0.37	3
540461	3.00	3.50	-0.37	3
540462	3.50	3.00	0.13	4
540463	3.00	3.00	-0.37	3
540467	3.00	3.00	-0.37	3
540469	5.00	5.00	1.63	5
540470	3.00	2.50	-0.37	3
540471	3.25	2.50	-0.12	3
540479	4.75	3.00	1.38	4
540480	3.50	3.50	0.13	4
540487	3.75	4.25	0.38	5
540488	4.50	3.50	1.13	4
540489	3.00	3.25	-0.37	3
540490	3.75	2.25	0.38	3
540491	3.50	2.50	0.13	3
540494	2.75	1.75	-0.62	2
540495	5.00	5.00	1.63	5
540498	3.00	3.00	-0.37	3
540501	2.25	2.00	-1.12	2
540505	4.00	1.50	0.63	2
540506	3.00	3.00	-0.37	3
540513	3.00	2.75	-0.37	2
540515	2.75	2.25	-0.62	3
540516	3.00	2.25	-0.37	3
540530	2.75	2.50	-0.62	3
540531	3.00	3.00	-0.37	3
540533	3.00	2.75	-0.37	2
540534	4.00	3.00	0.63	3
540535	2.75	2.25	-0.62	3
540538	4.25	3.00	0.88	4
540539	4.00	3.25	0.63	4
540541	4.25	3.25	0.88	4
540542	3.00	2.75	-0.37	3
540543	3.25	1.25	-0.12	2
540551	3.50	3.25	0.13	4
540552	1.00	1.00	-2.37	1
540553	2.25	2.50	-1.12	3
540557	3.75	2.25	0.38	3
540558	4.00	3.00	0.63	4
540559	3.50	2.50	0.13	3
540560	3.50	3.25	0.13	3
540570	3.00	1.75	-0.37	3
540571	3.25	2.25	-0.12	3
540572	3.25	3.25	-0.12	3
540573	3.50	1.75	0.13	3
540578	3.50	3.00	0.13	3

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540581	3.00	2.00	-0.37	3
540583	3.00	2.75	-0.37	3
540585	3.25	2.25	-0.12	3
540587	3.00	2.75	-0.37	3
540588	3.00	2.25	-0.37	3
540592	3.25	2.00	-0.12	4
540593	2.75	3.25	-0.62	4
540597	3.25	4.50	-0.12	2
540598	3.50	2.50	0.13	3
540600	3.00	3.25	-0.37	3
540601	4.25	2.50	0.88	3
540605	3.00	3.00	-0.37	3
540607	4.25	4.00	0.88	3
540609	2.50	1.25	-0.87	2
540618	2.50	2.25	-0.87	2
540621	3.50	2.75	0.13	2
540622	3.50	3.00	0.13	3
540625	3.75	1.75	0.38	4
540639	3.00	3.00	-0.37	3
540644	3.25	3.25	-0.12	3
540645	3.75	3.00	0.38	3
540647	3.00	2.25	-0.37	3
540649	4.25	2.00	0.88	4
540650	3.00	2.75	-0.37	4
540652	4.50	3.25	1.13	4
540653	5.00	3.00	1.63	5
540655	3.25	1.25	-0.12	3
540659	3.75	3.75	0.38	4
540661	4.00	3.00	0.63	5
540664	4.25	4.00	0.88	4
540668	3.50	3.50	0.13	3
540669	3.75	3.25	0.38	4
540671	3.75	3.00	0.38	3
540674	3.50	3.00	0.13	3
540679	3.25	3.75	-0.12	4
540682	4.50	4.25	1.13	5
540684	3.75	2.50	0.38	3
540687	4.50	4.25	1.13	5
540690	3.50	2.75	0.13	3
540696	5.00	4.50	1.63	5
540697	3.50	3.00	0.13	4
540699	3.50	1.75	0.13	3
540701	4.50	3.75	1.13	4
540702	3.25	2.75	-0.12	3
540708	3.25	1.75	-0.12	3
540715	3.25	3.00	-0.12	3
540716	3.00	3.00	-0.37	3
540718	3.00	3.00	-0.37	3
540720	3.50	3.25	0.13	3
540722	3.00	3.00	-0.37	4
540723	3.00	2.00	-0.37	2
540724	3.00	3.00	-0.37	3
540727	3.25	2.25	-0.12	3
540728	3.00	3.00	-0.37	3
540729	4.25	3.75	0.88	4
540730	2.75	2.25	-0.62	3

Table C.5 Explanatory and Response Variables for the Regression Analysis (continue)

SIN #	SAFETY	RELIABILITY	SAFETYc	SQL
540732	4.25	4.25	0.88	4
540733	2.50	3.00	-0.87	3
540735	2.75	1.00	-0.62	2
540736	3.75	3.50	0.38	3
540739	2.00	1.00	-1.37	1
540741	3.00	2.75	-0.37	3
540742	3.50	3.75	0.13	3
540744	3.25	2.50	-0.12	3
540745	3.75	3.25	0.38	3
540746	2.75	2.25	-0.62	2
540748	4.50	1.50	1.13	3
540749	4.75	4.25	1.38	5
540751	3.25	3.00	-0.12	3

APPENDIX D – Predicted Level of Overall Service Quality

Chapter 4 describes two regression analyses. The first analysis adopted an Ordinary Least Squares model. The second analysis adopted a Cumulative Logit model. The following are the predicted levels of overall service quality produced by each model.

Ordinary Least Squares Model

The response variable of the regression model is the overall perception of the quality of highway maintenance service delivery (SQL). **Table D.1** shows the actual overall service quality and the predicted overall service quality obtained with the model.

Table D. 1 Ordinary Least Squares Model Results

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540002	2	2.85	0.05	1.76	3.94	-0.85
540004	3	3.11	0.03	2.02	4.20	-0.11
540005	3	3.61	0.04	2.52	4.70	-0.61
540006	5	3.97	0.05	2.88	5.06	1.03
540007	3	2.75	0.04	1.66	3.84	0.25
540011	3	3.49	0.05	2.40	4.58	-0.49
540013	3	2.99	0.04	1.90	4.08	0.01
540014	3	3.12	0.04	2.03	4.21	-0.12
540016	2	2.00	0.07	0.90	3.09	0.00
540017	3	2.87	0.04	1.78	3.95	0.13
540018	4	4.10	0.06	3.01	5.19	-0.10
540019	3	2.75	0.04	1.66	3.84	0.25
540021	3	3.60	0.04	2.51	4.69	-0.60
540023	2	2.25	0.06	1.16	3.34	-0.25
540024	2	2.61	0.05	1.52	3.70	-0.61
540026	2	2.12	0.06	1.03	3.22	-0.12
540028	5	3.60	0.04	2.51	4.69	1.40
540029	3	3.10	0.04	2.01	4.19	-0.10
540030	4	3.00	0.05	1.91	4.09	1.00
540031	3	2.49	0.05	1.41	3.58	0.51
540033	3	2.38	0.05	1.29	3.47	0.62
540034	3	3.47	0.05	2.38	4.55	-0.47
540043	4	4.48	0.09	3.38	5.57	-0.48
540046	3	3.22	0.04	2.13	4.31	-0.22
540048	3	2.73	0.05	1.64	3.82	0.27
540049	4	3.12	0.04	2.03	4.21	0.88

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540052	2	2.25	0.06	1.16	3.34	-0.25
540054	3	4.10	0.06	3.01	5.19	-1.10
540058	5	4.33	0.08	3.23	5.42	0.67
540063	3	3.22	0.04	2.13	4.31	-0.22
540067	5	5.08	0.10	3.97	6.18	-0.08
540068	3	3.36	0.04	2.28	4.45	-0.36
540070	5	4.83	0.09	3.73	5.93	0.17
540071	3	2.75	0.04	1.66	3.84	0.25
540072	4	3.59	0.04	2.50	4.68	0.41
540073	3	3.12	0.04	2.03	4.21	-0.12
540074	3	3.24	0.03	2.15	4.32	-0.24
540075	3	3.10	0.04	2.01	4.19	-0.10
540076	3	2.87	0.04	1.78	3.95	0.13
540078	3	2.98	0.04	1.89	4.06	0.02
540079	3	3.35	0.04	2.26	4.43	-0.35
540080	4	3.24	0.03	2.15	4.32	0.76
540081	3	3.73	0.04	2.64	4.81	-0.73
540082	2	3.48	0.04	2.39	4.57	-1.48
540084	4	3.12	0.04	2.03	4.21	0.88
540086	4	3.86	0.06	2.77	4.95	0.14
540087	3	3.00	0.05	1.91	4.09	0.00
540089	3	2.47	0.09	1.37	3.57	0.53
540090	4	3.97	0.05	2.88	5.06	0.03
540091	3	2.74	0.04	1.65	3.83	0.26
540092	3	3.09	0.05	2.00	4.18	-0.09
540095	2	2.49	0.05	1.41	3.58	-0.49
540096	3	3.48	0.04	2.39	4.57	-0.48
540103	4	3.51	0.09	2.41	4.61	0.49
540104	5	4.37	0.11	3.26	5.47	0.63
540105	4	3.36	0.03	2.27	4.44	0.65
540106	4	4.33	0.08	3.23	5.42	-0.33
540110	4	3.50	0.07	2.40	4.59	0.50
540113	5	3.25	0.07	2.16	4.35	1.75
540114	3	3.36	0.03	2.27	4.44	-0.36
540117	3	2.99	0.04	1.90	4.08	0.01
540118	3	2.87	0.05	1.79	3.96	0.13
540119	3	3.00	0.05	1.91	4.09	0.00
540120	3	2.98	0.03	1.90	4.07	0.02
540124	3	3.10	0.04	2.01	4.19	-0.10
540125	4	3.59	0.04	2.50	4.68	0.41
540127	3	3.11	0.03	2.02	4.20	-0.11
540129	3	2.99	0.04	1.90	4.08	0.01
540130	4	3.36	0.03	2.27	4.44	0.65
540134	3	3.34	0.06	2.25	4.43	-0.34
540135	4	3.59	0.04	2.50	4.68	0.41
540136	4	3.48	0.04	2.39	4.57	0.52
540137	2	2.24	0.06	1.15	3.33	-0.24
540139	4	3.97	0.05	2.88	5.06	0.03

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540140	5	4.71	0.09	3.61	5.81	0.29
540141	4	3.73	0.04	2.64	4.81	0.27
540142	5	4.34	0.07	3.25	5.43	0.66
540143	3	2.74	0.04	1.65	3.83	0.26
540144	4	3.59	0.04	2.50	4.68	0.41
540145	2	2.62	0.04	1.53	3.71	-0.62
540146	5	4.45	0.08	3.36	5.55	0.55
540149	3	2.87	0.04	1.78	3.95	0.13
540150	4	3.60	0.04	2.51	4.69	0.40
540151	3	3.74	0.07	2.65	4.84	-0.74
540153	4	3.48	0.04	2.39	4.57	0.52
540156	3	3.23	0.03	2.14	4.32	-0.23
540164	4	3.62	0.06	2.52	4.71	0.38
540165	3	3.34	0.06	2.25	4.43	-0.34
540168	3	2.93	0.15	1.81	4.06	0.07
540169	3	3.24	0.03	2.15	4.32	-0.24
540173	4	2.99	0.04	1.90	4.08	1.01
540174	4	3.11	0.03	2.02	4.20	0.89
540176	4	3.33	0.08	2.24	4.43	0.67
540177	2	2.73	0.05	1.64	3.82	-0.73
540180	3	2.87	0.04	1.78	3.95	0.13
540183	4	4.07	0.08	2.98	5.17	-0.07
540187	3	3.48	0.04	2.39	4.57	-0.48
540189	2	3.24	0.03	2.15	4.32	-1.24
540190	3	2.49	0.05	1.41	3.58	0.51
540191	3	3.35	0.04	2.26	4.43	-0.35
540192	2	2.38	0.05	1.29	3.47	-0.38
540198	4	3.12	0.04	2.03	4.21	0.88
540203	3	3.12	0.04	2.03	4.21	-0.12
540204	4	3.23	0.03	2.14	4.32	0.77
540207	3	2.74	0.04	1.65	3.83	0.26
540209	3	3.12	0.04	2.03	4.21	-0.12
540210	3	2.49	0.05	1.40	3.58	0.51
540219	3	3.12	0.04	2.03	4.21	-0.12
540220	5	5.08	0.10	3.97	6.18	-0.08
540228	3	3.96	0.05	2.87	5.05	-0.96
540231	4	2.98	0.03	1.90	4.07	1.02
540232	2	2.61	0.05	1.52	3.70	-0.61
540233	3	2.99	0.04	1.90	4.08	0.01
540239	3	3.25	0.07	2.16	4.35	-0.25
540240	3	2.99	0.04	1.90	4.08	0.01
540241	3	2.98	0.03	1.90	4.07	0.02
540242	3	2.87	0.04	1.78	3.95	0.13
540243	3	3.84	0.05	2.76	4.93	-0.84
540245	2	2.74	0.04	1.65	3.83	-0.74
540246	3	3.60	0.04	2.51	4.69	-0.60
540252	3	2.98	0.03	1.90	4.07	0.02
540253	4	3.23	0.03	2.14	4.32	0.77

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540258	4	3.86	0.06	2.77	4.95	0.14
540261	3	3.10	0.04	2.01	4.19	-0.10
540262	3	3.36	0.03	2.27	4.44	-0.36
540266	3	3.12	0.04	2.03	4.21	-0.12
540270	3	2.74	0.04	1.65	3.83	0.26
540272	2	2.74	0.04	1.65	3.83	-0.74
540274	4	2.98	0.03	1.90	4.07	1.02
540276	2	2.73	0.05	1.64	3.82	-0.73
540278	3	3.12	0.04	2.03	4.21	-0.12
540279	4	3.12	0.04	2.03	4.21	0.88
540281	2	2.85	0.05	1.76	3.94	-0.85
540282	4	3.47	0.05	2.38	4.55	0.54
540284	4	3.09	0.07	1.99	4.18	0.91
540286	3	2.74	0.04	1.65	3.83	0.26
540287	3	3.73	0.05	2.64	4.82	-0.73
540289	3	2.74	0.04	1.65	3.83	0.26
540291	3	3.11	0.03	2.02	4.20	-0.11
540293	3	3.35	0.04	2.26	4.43	-0.35
540297	3	2.73	0.05	1.64	3.82	0.27
540298	5	4.58	0.08	3.48	5.67	0.42
540305	3	2.73	0.05	1.64	3.82	0.27
540308	4	3.47	0.04	2.39	4.56	0.53
540309	1	1.40	0.10	0.29	2.50	-0.40
540310	3	2.87	0.05	1.79	3.96	0.13
540311	3	3.24	0.03	2.15	4.32	-0.24
540313	3	3.10	0.04	2.01	4.19	-0.10
540317	2	2.62	0.04	1.53	3.71	-0.62
540321	3	2.99	0.04	1.90	4.08	0.01
540323	2	2.75	0.04	1.66	3.84	-0.75
540329	2	2.86	0.04	1.77	3.95	-0.86
540331	3	3.61	0.04	2.52	4.70	-0.61
540332	3	3.12	0.04	2.03	4.21	-0.12
540333	3	3.24	0.03	2.15	4.32	-0.24
540334	5	4.45	0.08	3.36	5.55	0.55
540335	3	3.23	0.03	2.14	4.32	-0.23
540336	3	2.75	0.04	1.66	3.84	0.25
540338	2	1.75	0.08	0.66	2.85	0.25
540340	3	3.60	0.04	2.51	4.69	-0.60
540343	2	3.21	0.06	2.12	4.30	-1.21
540347	3	2.87	0.04	1.78	3.95	0.13
540348	4	3.58	0.06	2.49	4.67	0.42
540351	4	3.23	0.03	2.14	4.32	0.77
540352	3	2.75	0.04	1.66	3.84	0.25
540356	3	3.35	0.04	2.26	4.43	-0.35
540358	3	2.75	0.04	1.66	3.84	0.25
540363	4	3.22	0.04	2.13	4.31	0.78
540364	4	4.20	0.08	3.10	5.29	-0.20
540368	5	3.25	0.05	2.16	4.33	1.76

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540373	4	3.59	0.04	2.50	4.68	0.41
540374	4	2.74	0.04	1.65	3.83	1.26
540375	3	2.74	0.04	1.65	3.83	0.26
540380	3	3.60	0.04	2.51	4.69	-0.60
540382	3	3.22	0.04	2.13	4.31	-0.22
540383	2	2.76	0.06	1.66	3.85	-0.76
540384	3	3.12	0.04	2.03	4.21	-0.12
540386	2	3.21	0.06	2.12	4.30	-1.21
540387	3	2.87	0.05	1.79	3.96	0.13
540390	3	2.98	0.03	1.90	4.07	0.02
540393	2	3.35	0.04	2.26	4.43	-1.35
540394	4	2.99	0.04	1.90	4.08	1.01
540398	4	3.97	0.05	2.88	5.06	0.03
540400	3	2.87	0.04	1.78	3.95	0.13
540401	2	3.36	0.04	2.28	4.45	-1.36
540403	3	3.12	0.04	2.03	4.21	-0.12
540411	4	3.35	0.04	2.26	4.43	0.65
540412	3	3.12	0.04	2.03	4.21	-0.12
540413	3	3.11	0.03	2.02	4.20	-0.11
540422	3	2.99	0.04	1.90	4.08	0.01
540423	2	2.11	0.08	1.01	3.20	-0.11
540425	2	2.12	0.07	1.02	3.21	-0.12
540426	3	3.12	0.04	2.03	4.21	-0.12
540428	3	2.87	0.04	1.78	3.95	0.13
540432	3	2.75	0.04	1.66	3.84	0.25
540433	3	2.61	0.05	1.52	3.70	0.39
540434	3	3.12	0.04	2.03	4.21	-0.12
540437	4	4.45	0.08	3.36	5.55	-0.45
540439	3	3.23	0.03	2.14	4.32	-0.23
540440	3	2.74	0.04	1.65	3.83	0.26
540441	2	3.12	0.04	2.03	4.21	-1.12
540442	2	2.74	0.04	1.65	3.83	-0.74
540445	3	2.87	0.05	1.79	3.96	0.13
540447	3	3.47	0.05	2.38	4.55	-0.47
540450	3	2.51	0.07	1.42	3.60	0.49
540451	1	2.34	0.10	1.24	3.45	-1.34
540452	4	3.59	0.04	2.50	4.68	0.41
540460	3	2.74	0.04	1.65	3.83	0.26
540461	3	3.37	0.06	2.28	4.46	-0.37
540462	4	3.36	0.03	2.27	4.44	0.65
540463	3	3.12	0.04	2.03	4.21	-0.12
540467	3	3.12	0.04	2.03	4.21	-0.12
540469	5	5.08	0.10	3.97	6.18	-0.08
540470	3	2.87	0.04	1.78	3.95	0.13
540471	3	2.98	0.03	1.90	4.07	0.02
540479	4	3.95	0.08	2.85	5.04	0.05
540480	4	3.61	0.04	2.52	4.70	0.39
540487	5	4.11	0.07	3.01	5.20	0.89

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540488	4	4.08	0.06	2.99	5.17	-0.08
540489	3	3.25	0.05	2.16	4.33	-0.25
540490	3	3.09	0.05	2.00	4.18	-0.09
540491	3	3.10	0.04	2.01	4.19	-0.10
540494	2	2.37	0.05	1.28	3.46	-0.37
540495	5	5.08	0.10	3.97	6.18	-0.08
540498	3	3.12	0.04	2.03	4.21	-0.12
540501	2	2.26	0.06	1.17	3.35	-0.26
540505	2	2.83	0.09	1.73	3.93	-0.83
540506	3	3.12	0.04	2.03	4.21	-0.12
540513	2	2.99	0.04	1.90	4.08	-0.99
540515	3	2.62	0.04	1.53	3.71	0.38
540516	3	2.74	0.04	1.65	3.83	0.26
540530	3	2.75	0.04	1.66	3.84	0.25
540531	3	3.12	0.04	2.03	4.21	-0.12
540533	2	2.99	0.04	1.90	4.08	-0.99
540534	3	3.59	0.04	2.50	4.68	-0.59
540535	3	2.62	0.04	1.53	3.71	0.38
540538	4	3.71	0.06	2.62	4.80	0.29
540539	4	3.72	0.04	2.63	4.81	0.28
540541	4	3.84	0.05	2.75	4.93	0.16
540542	3	2.99	0.04	1.90	4.08	0.01
540543	2	2.35	0.08	1.26	3.45	-0.35
540551	4	3.48	0.04	2.39	4.57	0.52
540552	1	1.16	0.12	0.05	2.27	-0.16
540553	3	2.51	0.07	1.42	3.60	0.49
540557	3	3.09	0.05	2.00	4.18	-0.09
540558	4	3.59	0.04	2.50	4.68	0.41
540559	3	3.10	0.04	2.01	4.19	-0.10
540560	3	3.48	0.04	2.39	4.57	-0.48
540570	3	2.49	0.05	1.40	3.58	0.51
540571	3	2.86	0.04	1.77	3.95	0.14
540572	3	3.36	0.04	2.28	4.45	-0.36
540573	3	2.72	0.06	1.63	3.82	0.28
540578	3	3.36	0.03	2.27	4.44	-0.36
540581	3	2.61	0.05	1.52	3.70	0.39
540583	3	2.99	0.04	1.90	4.08	0.01
540585	3	2.86	0.04	1.77	3.95	0.14
540587	3	2.99	0.04	1.90	4.08	0.01
540588	3	2.74	0.04	1.65	3.83	0.26
540592	4	2.73	0.05	1.64	3.82	1.27
540593	4	3.13	0.06	2.04	4.22	0.87
540597	2	4.00	0.09	2.90	5.09	-2.00
540598	3	3.10	0.04	2.01	4.19	-0.10
540600	3	3.25	0.05	2.16	4.33	-0.25
540601	3	3.46	0.07	2.36	4.55	-0.46
540605	3	3.12	0.04	2.03	4.21	-0.12
540607	3	4.22	0.06	3.12	5.31	-1.22

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540609	2	2.00	0.07	0.90	3.09	0.00
540618	2	2.50	0.05	1.41	3.59	-0.50
540621	2	3.23	0.03	2.14	4.32	-1.23
540622	3	3.36	0.03	2.27	4.44	-0.36
540625	4	2.84	0.07	1.75	3.94	1.16
540639	3	3.12	0.04	2.03	4.21	-0.12
540644	3	3.36	0.04	2.28	4.45	-0.36
540645	3	3.47	0.04	2.39	4.56	-0.47
540647	3	2.74	0.04	1.65	3.83	0.26
540649	4	3.20	0.09	2.11	4.30	0.80
540650	4	2.99	0.04	1.90	4.08	1.01
540652	4	3.95	0.07	2.86	5.05	0.05
540653	5	4.06	0.10	2.96	5.17	0.94
540655	3	2.35	0.08	1.26	3.45	0.65
540659	4	3.85	0.05	2.76	4.94	0.15
540661	5	3.59	0.04	2.50	4.68	1.41
540664	4	4.22	0.06	3.12	5.31	-0.22
540668	3	3.61	0.04	2.52	4.70	-0.61
540669	4	3.60	0.04	2.51	4.69	0.40
540671	3	3.47	0.04	2.39	4.56	-0.47
540674	3	3.36	0.03	2.27	4.44	-0.36
540679	4	3.62	0.06	2.52	4.71	0.38
540682	5	4.46	0.07	3.37	5.55	0.54
540684	3	3.22	0.04	2.13	4.31	-0.22
540687	5	4.46	0.07	3.37	5.55	0.54
540690	3	3.23	0.03	2.14	4.32	-0.23
540696	5	4.82	0.09	3.72	5.92	0.18
540697	4	3.36	0.03	2.27	4.44	0.65
540699	3	2.72	0.06	1.63	3.82	0.28
540701	4	4.21	0.06	3.11	5.30	-0.21
540702	3	3.11	0.03	2.02	4.20	-0.11
540708	3	2.60	0.06	1.51	3.70	0.40
540715	3	3.24	0.03	2.15	4.32	-0.24
540716	3	3.12	0.04	2.03	4.21	-0.12
540718	3	3.12	0.04	2.03	4.21	-0.12
540720	3	3.48	0.04	2.39	4.57	-0.48
540722	4	3.12	0.04	2.03	4.21	0.88
540723	2	2.61	0.05	1.52	3.70	-0.61
540724	3	3.12	0.04	2.03	4.21	-0.12
540727	3	2.86	0.04	1.77	3.95	0.14
540728	3	3.12	0.04	2.03	4.21	-0.12
540729	4	4.09	0.06	3.00	5.18	-0.09
540730	3	2.62	0.04	1.53	3.71	0.38
540732	4	4.34	0.07	3.25	5.43	-0.34
540733	3	2.88	0.07	1.79	3.97	0.12
540735	2	1.99	0.08	0.89	3.09	0.01
540736	3	3.73	0.04	2.64	4.81	-0.73
540739	1	1.63	0.09	0.54	2.73	-0.63

Table D.1 Ordinary Least Squares Model Results (Continue)

SIN#	Actual	Predicted	Error	-95%CI	+95%CI	Residual
540741	3	2.99	0.04	1.90	4.08	0.01
540742	3	3.73	0.05	2.64	4.82	-0.73
540744	3	2.98	0.03	1.90	4.07	0.02
540745	3	3.60	0.04	2.51	4.69	-0.60
540746	2	2.62	0.04	1.53	3.71	-0.62
540748	3	3.07	0.12	1.96	4.18	-0.07
540749	5	4.58	0.08	3.48	5.67	0.42
540751	3	3.24	0.03	2.15	4.32	-0.24

Cumulative Logit Model

Table D.2 shows the actual overall service quality and the predicted overall service quality obtained with the model.

Table D. 2 Cumulative Logit Model Results

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540002	2	3	0.5%	19.3%	**73.7%**	6.2%	0.3%
540004	3	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540005	3	4	0.0%	1.3%	41.8%	**51.5%**	5.5%
540006	5	4	0.0%	0.3%	15.4%	**65.3%**	18.9%
540007	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540011	3	3	0.0%	2.0%	**52.3%**	42.2%	3.5%
540013	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540014	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540016	2	2	11.9%	**74.9%**	13.0%	0.2%	0.0%
540017	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540018	4	4	0.0%	0.2%	10.1%	**62.1%**	27.6%
540019	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540021	3	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540023	2	2	4.8%	**66.3%**	28.2%	0.7%	0.0%
540024	2	3	1.2%	36.6%	**59.4%**	2.6%	0.1%
540026	2	2	7.6%	**72.4%**	19.5%	0.4%	0.0%
540028	5	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540029	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540030	4	3	0.3%	11.6%	**76.8%**	10.8%	0.6%
540031	3	3	1.9%	47.0%	**49.3%**	1.7%	0.1%
540033	3	2	3.0%	**57.1%**	38.8%	1.1%	0.0%
540034	3	3	0.0%	2.2%	**54.9%**	39.7%	3.2%
540043	4	5	0.0%	0.0%	2.5%	35.1%	**62.4%**
540046	3	3	0.1%	5.4%	**71.8%**	21.4%	1.3%
540048	3	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540049	4	3	0.2%	7.7%	**75.4%**	15.8%	0.9%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540052	2	2	4.8%	**66.3%**	28.2%	0.7%	0.0%
540054	3	4	0.0%	0.2%	10.1%	**62.1%**	27.6%
540058	5	4	0.0%	0.1%	4.5%	**47.9%**	47.5%
540063	3	3	0.1%	5.4%	**71.8%**	21.4%	1.3%
540067	5	5	0.0%	0.0%	0.3%	5.4%	**94.3%**
540068	3	3	0.1%	3.2%	**62.8%**	31.8%	2.2%
540070	5	5	0.0%	0.0%	0.7%	12.8%	**86.6%**
540071	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540072	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540073	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540074	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540075	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540076	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540078	3	3	0.3%	12.8%	**76.7%**	9.7%	0.5%
540079	3	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540080	4	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540081	3	4	0.0%	0.8%	31.6%	**59.2%**	8.3%
540082	2	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540084	4	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540086	4	4	0.0%	0.5%	21.6%	**64.6%**	13.3%
540087	3	3	0.3%	11.6%	**76.8%**	10.8%	0.6%
540089	3	2	2.2%	**49.6%**	46.7%	1.5%	0.1%
540090	4	4	0.0%	0.3%	15.4%	**65.3%**	18.9%
540091	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540092	3	3	0.2%	8.6%	**76.1%**	14.4%	0.8%
540095	2	3	1.9%	47.0%	**49.3%**	1.7%	0.1%
540096	3	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540103	4	3	0.0%	1.8%	**50.6%**	43.8%	3.8%
540104	5	5	0.0%	0.1%	3.8%	43.9%	**52.3%**
540105	4	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540106	4	4	0.0%	0.1%	4.5%	**47.9%**	47.5%
540110	4	3	0.0%	1.9%	**51.4%**	43.0%	3.7%
540113	5	3	0.1%	4.7%	**69.8%**	23.9%	1.5%
540114	3	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540117	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540118	3	3	0.5%	17.6%	**74.7%**	6.9%	0.3%
540119	3	3	0.3%	11.6%	**76.8%**	10.8%	0.6%
540120	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540124	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540125	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540127	3	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540129	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540130	4	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540134	3	3	0.1%	3.5%	**64.9%**	29.5%	2.0%
540135	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540136	4	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540137	2	2	5.0%	**66.9%**	27.5%	0.6%	0.0%
540139	4	4	0.0%	0.3%	15.4%	**65.3%**	18.9%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540140	5	5	0.0%	0.0%	1.0%	18.6%	**80.4%**
540141	4	4	0.0%	0.8%	31.6%	**59.2%**	8.3%
540142	5	5	0.0%	0.1%	4.2%	46.3%	**49.4%**
540143	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540144	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540145	2	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540146	5	5	0.0%	0.0%	2.8%	37.5%	**59.7%**
540149	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540150	4	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540151	3	4	0.0%	0.7%	30.1%	**60.3%**	8.9%
540153	4	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540156	3	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540164	4	4	0.0%	1.2%	40.9%	**52.2%**	5.7%
540165	3	3	0.1%	3.5%	**64.9%**	29.5%	2.0%
540168	3	3	0.4%	15.0%	**76.0%**	8.2%	0.4%
540169	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540173	4	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540174	4	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540176	4	3	0.1%	3.7%	**65.6%**	28.8%	1.9%
540177	2	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540180	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540183	4	4	0.0%	0.2%	11.2%	**63.3%**	25.4%
540187	3	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540189	2	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540190	3	3	1.9%	47.0%	**49.3%**	1.7%	0.1%
540191	3	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540192	2	2	3.0%	**57.1%**	38.8%	1.1%	0.0%
540198	4	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540203	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540204	4	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540207	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540209	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540210	3	3	2.0%	47.9%	**48.4%**	1.6%	0.1%
540219	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540220	5	5	0.0%	0.0%	0.3%	5.4%	**94.3%**
540228	3	4	0.0%	0.3%	15.9%	**65.4%**	18.3%
540231	4	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540232	2	3	1.2%	36.6%	**59.4%**	2.6%	0.1%
540233	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540239	3	3	0.1%	4.7%	**69.8%**	23.9%	1.5%
540240	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540241	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540242	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540243	3	4	0.0%	0.5%	22.9%	**64.1%**	12.5%
540245	2	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540246	3	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540252	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540253	4	3	0.1%	5.2%	**71.3%**	22.0%	1.3%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540258	4	4	0.0%	0.5%	21.6%	**64.6%**	13.3%
540261	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540262	3	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540266	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540270	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540272	2	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540274	4	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540276	2	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540278	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540279	4	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540281	2	3	0.5%	19.3%	**73.7%**	6.2%	0.3%
540282	4	3	0.0%	2.2%	**54.9%**	39.7%	3.2%
540284	4	3	0.2%	8.9%	**76.2%**	14.0%	0.7%
540286	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540287	3	4	0.0%	0.8%	30.8%	**59.7%**	8.6%
540289	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540291	3	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540293	3	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540297	3	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540298	5	5	0.0%	0.0%	1.7%	27.5%	**70.7%**
540305	3	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540308	4	3	0.0%	2.1%	**54.0%**	40.5%	3.3%
540309	1	1	**57.4%**	41.1%	1.5%	0.0%	0.0%
540310	3	3	0.5%	17.6%	**74.7%**	6.9%	0.3%
540311	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540313	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540317	2	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540321	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540323	2	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540329	2	3	0.5%	18.7%	**74.1%**	6.4%	0.3%
540331	3	4	0.0%	1.3%	41.8%	**51.5%**	5.5%
540332	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540333	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540334	5	5	0.0%	0.0%	2.8%	37.5%	**59.7%**
540335	3	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540336	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540338	2	2	25.8%	**68.6%**	5.5%	0.1%	0.0%
540340	3	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540343	2	3	0.1%	5.6%	**72.3%**	20.8%	1.2%
540347	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540348	4	4	0.0%	1.4%	44.4%	**49.3%**	4.9%
540351	4	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540352	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540356	3	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540358	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540363	4	3	0.1%	5.4%	**71.8%**	21.4%	1.3%
540364	4	4	0.0%	0.1%	7.2%	**57.0%**	35.7%
540368	5	3	0.1%	4.9%	**70.3%**	23.3%	1.4%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540373	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540374	4	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540375	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540380	3	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540382	3	3	0.1%	5.4%	**71.8%**	21.4%	1.3%
540383	2	3	0.7%	25.0%	**69.6%**	4.5%	0.2%
540384	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540386	2	3	0.1%	5.6%	**72.3%**	20.8%	1.2%
540387	3	3	0.5%	17.6%	**74.7%**	6.9%	0.3%
540390	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540393	2	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540394	4	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540398	4	4	0.0%	0.3%	15.4%	**65.3%**	18.9%
540400	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540401	2	3	0.1%	3.2%	**62.8%**	31.8%	2.2%
540403	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540411	4	3	0.1%	3.4%	**64.2%**	30.3%	2.0%
540412	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540413	3	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540422	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540423	2	2	8.2%	**73.1%**	18.4%	0.4%	0.0%
540425	2	2	7.9%	**72.8%**	18.9%	0.4%	0.0%
540426	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540428	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540432	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540433	3	3	1.2%	36.6%	**59.4%**	2.6%	0.1%
540434	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540437	4	5	0.0%	0.0%	2.8%	37.5%	**59.7%**
540439	3	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540440	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540441	2	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540442	2	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540445	3	3	0.5%	17.6%	**74.7%**	6.9%	0.3%
540447	3	3	0.0%	2.2%	**54.9%**	39.7%	3.2%
540450	3	3	1.8%	45.2%	**51.1%**	1.8%	0.1%
540451	1	2	3.5%	**60.2%**	35.4%	0.9%	0.0%
540452	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540460	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540461	3	3	0.1%	3.0%	**62.0%**	32.6%	2.3%
540462	4	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540463	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540467	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540469	5	5	0.0%	0.0%	0.3%	5.4%	**94.3%**
540470	3	3	0.5%	18.1%	**74.4%**	6.7%	0.3%
540471	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540479	4	4	0.0%	0.4%	17.0%	**65.4%**	17.2%
540480	4	4	0.0%	1.3%	41.8%	**51.5%**	5.5%
540487	5	4	0.0%	0.2%	9.7%	**61.7%**	28.3%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540488	4	4	0.0%	0.2%	10.8%	**62.9%**	26.1%
540489	3	3	0.1%	4.9%	**70.3%**	23.3%	1.4%
540490	3	3	0.2%	8.6%	**76.1%**	14.4%	0.8%
540491	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540494	2	2	3.1%	**57.9%**	37.9%	1.0%	0.0%
540495	5	5	0.0%	0.0%	0.3%	5.4%	**94.3%**
540498	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540501	2	2	4.7%	**65.7%**	29.0%	0.7%	0.0%
540505	2	3	0.5%	20.4%	**72.9%**	5.8%	0.3%
540506	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540513	2	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540515	3	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540516	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540530	3	3	0.7%	25.7%	**69.0%**	4.4%	0.2%
540531	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540533	2	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540534	3	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540535	3	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540538	4	4	0.0%	0.9%	33.3%	**58.1%**	7.8%
540539	4	4	0.0%	0.8%	32.4%	**58.7%**	8.0%
540541	4	4	0.0%	0.5%	23.6%	**63.8%**	12.1%
540542	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540543	2	2	3.4%	**59.4%**	36.2%	1.0%	0.0%
540551	4	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540552	1	1	**76.9%**	22.4%	0.6%	0.0%	0.0%
540553	3	3	1.8%	45.2%	**51.1%**	1.8%	0.1%
540557	3	3	0.2%	8.6%	**76.1%**	14.4%	0.8%
540558	4	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540559	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540560	3	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540570	3	3	2.0%	47.9%	**48.4%**	1.6%	0.1%
540571	3	3	0.5%	18.7%	**74.1%**	6.4%	0.3%
540572	3	3	0.1%	3.2%	**62.8%**	31.8%	2.2%
540573	3	3	0.8%	27.9%	**67.2%**	3.9%	0.2%
540578	3	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540581	3	3	1.2%	36.6%	**59.4%**	2.6%	0.1%
540583	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540585	3	3	0.5%	18.7%	**74.1%**	6.4%	0.3%
540587	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540588	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540592	4	3	0.8%	27.1%	**67.8%**	4.1%	0.2%
540593	4	3	0.2%	7.4%	**75.1%**	16.3%	0.9%
540597	2	4	0.0%	0.3%	14.0%	**65.0%**	20.7%
540598	3	3	0.2%	8.3%	**75.9%**	14.9%	0.8%
540600	3	3	0.1%	4.9%	**70.3%**	23.3%	1.4%
540601	3	3	0.0%	2.3%	**55.7%**	38.9%	3.1%
540605	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540607	3	4	0.0%	0.1%	6.7%	**55.8%**	37.4%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540609	2	2	11.9%	**74.9%**	13.0%	0.2%	0.0%
540618	2	3	1.9%	46.1%	**50.2%**	1.7%	0.1%
540621	2	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540622	3	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540625	4	3	0.5%	19.8%	**73.3%**	6.0%	0.3%
540639	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540644	3	3	0.1%	3.2%	**62.8%**	31.8%	2.2%
540645	3	3	0.0%	2.1%	**54.0%**	40.5%	3.3%
540647	3	3	0.8%	26.4%	**68.4%**	4.2%	0.2%
540649	4	3	0.1%	5.8%	**72.7%**	20.2%	1.2%
540650	4	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540652	4	4	0.0%	0.3%	16.4%	**65.4%**	17.8%
540653	5	4	0.0%	0.2%	11.5%	**63.6%**	24.7%
540655	3	2	3.4%	**59.4%**	36.2%	1.0%	0.0%
540659	4	4	0.0%	0.5%	22.2%	**64.4%**	12.9%
540661	5	4	0.0%	1.4%	43.5%	**50.0%**	5.1%
540664	4	4	0.0%	0.1%	6.7%	**55.8%**	37.4%
540668	3	4	0.0%	1.3%	41.8%	**51.5%**	5.5%
540669	4	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540671	3	3	0.0%	2.1%	**54.0%**	40.5%	3.3%
540674	3	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540679	4	4	0.0%	1.2%	40.9%	**52.2%**	5.7%
540682	5	5	0.0%	0.0%	2.7%	36.7%	**60.6%**
540684	3	3	0.1%	5.4%	**71.8%**	21.4%	1.3%
540687	5	5	0.0%	0.0%	2.7%	36.7%	**60.6%**
540690	3	3	0.1%	5.2%	**71.3%**	22.0%	1.3%
540696	5	5	0.0%	0.0%	0.7%	13.2%	**86.1%**
540697	4	3	0.1%	3.3%	**63.5%**	31.0%	2.1%
540699	3	3	0.8%	27.9%	**67.2%**	3.9%	0.2%
540701	4	4	0.0%	0.1%	6.9%	**56.4%**	36.6%
540702	3	3	0.2%	8.0%	**75.6%**	15.4%	0.8%
540708	3	3	1.3%	37.5%	**58.6%**	2.5%	0.1%
540715	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%
540716	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540718	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540720	3	3	0.0%	2.0%	**53.2%**	41.3%	3.4%
540722	4	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540723	2	3	1.2%	36.6%	**59.4%**	2.6%	0.1%
540724	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540727	3	3	0.5%	18.7%	**74.1%**	6.4%	0.3%
540728	3	3	0.2%	7.7%	**75.4%**	15.8%	0.9%
540729	4	4	0.0%	0.2%	10.4%	**62.5%**	26.8%
540730	3	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540732	4	5	0.0%	0.1%	4.2%	46.3%	**49.4%**
540733	3	3	0.4%	17.0%	**75.0%**	7.2%	0.4%
540735	2	2	12.3%	**74.9%**	12.5%	0.2%	0.0%
540736	3	4	0.0%	0.8%	31.6%	**59.2%**	8.3%
540739	1	2	35.3%	**61.1%**	3.6%	0.1%	0.0%

Table D.2 Cumulative Logit Model Results (Continue)

SIN#	Actual	Predicted	Prob C1	Prob C2	Prob C3	Prob C4	Prob C5
540741	3	3	0.3%	12.0%	**76.8%**	10.4%	0.5%
540742	3	4	0.0%	0.8%	30.8%	**59.7%**	8.6%
540744	3	3	0.3%	12.4%	**76.7%**	10.1%	0.5%
540745	3	4	0.0%	1.3%	42.6%	**50.8%**	5.3%
540746	2	3	1.2%	35.8%	**60.2%**	2.7%	0.1%
540748	3	3	0.2%	9.5%	**76.5%**	13.1%	0.7%
540749	5	5	0.0%	0.0%	1.7%	27.5%	**70.7%**
540751	3	3	0.1%	5.1%	**70.9%**	22.6%	1.4%

APPENDIX E – SAS Procedures and Formulas Used

Most of the analyses presented in Chapter 4 have been run using SAS 9.1.3 Service Pack 4, 2007. The next sections present the SAS coding and main datasets used for the analyses. The procedures are grouped according to the main type of analysis.

Factor Analysis

The dataset used in the factor analysis was presented in **Table C.3** of Appendix C. Below is the SAS code for loading the data into the memory of the computer. All 12 variables were loaded. The variables utilized in each analysis were specified on each procedure.

```
DATA SerQual;
INPUT Q6 Q8 Q10 Q12 Q1 Q3 Q5 Q7 Q2 Q4 Q9 Q11;
DATALINES;
3      1      2      3      3      4      3      3      3      4      3      2
3      2      3      3      3      3      3      2      4      3      3      4
;
RUN;
```

The following are the main procedures executed in the factor analysis. The first two procedures are similar but for the number of factors selected for the analysis. The first procedure adopted the eigenvalue criterion for selected the number of factors while for the second procedure the number of factors is specified. The third procedure is similar to the first procedure but for the rotation technique.

In the first procedure an orthogonal rotation (Variamx) was applied to the loading matrix while in the third procedure an oblique rotation was selected (Promax).

```
Procedure 1: PROC Factor DATA=SerQual METHOD=principal RES ROTATE=Varimax;
VAR Q6 Q8 Q10 Q12 Q1 Q3 Q5 Q7 Q2 Q4 Q9 Q11;
RUN;
```

```
Procedure 2: PROC Factor DATA=SerQual METHOD=principal RES NFACT=3
ROTATE=Varimax;
VAR Q6 Q8 Q10 Q12 Q1 Q3 Q5 Q7 Q2 Q4 Q9 Q11;
RUN;
```

```
Procedure 3: PROC Factor DATA=SerQual METHOD=principal RES ROTATE=Promax;
VAR Q6 Q8 Q10 Q12 Q1 Q3 Q5 Q7 Q2 Q4 Q9 Q11;
RUN;
```

The following procedures were used for creating **Table 7** and **Table 8**, in Chapter 4. The first two groups correspond to the non-iterative methods and the third group corresponds to the iterative methods. The number of factor was specified in the second group (NFACT=2) in order to normalize the results and be able to compare with the iterative methods.

```
Non-Iterative Method
PROC Factor DATA=SerQual METHOD=principal RES;
PROC Factor DATA=SerQual METHOD=principal priors=smc RES;
PROC Factor DATA=SerQual METHOD=principal priors=max RES;
PROC Factor DATA=SerQual METHOD=principal priors=asmc  RES;
RUN;

PROC Factor DATA=SerQual METHOD=principal NFACT=2 RES;
PROC Factor DATA=SerQual METHOD=principal priors=smc NFACT=2 RES;
PROC Factor DATA=SerQual METHOD=principal priors=max NFACT=2 RES;
PROC Factor DATA=SerQual METHOD=principal priors=asmc NFACT=2 RES;
RUN;


Iterative Method
PROC Factor DATA=SerQual METHOD=ml hey RES;
PROC Factor DATA=SerQual METHOD=uls hey RES;
PROC Factor DATA=SerQual METHOD=prinit hey RES;
PROC Factor DATA=SerQual METHOD=alpha hey RES;
RUN;
```

The results of the factor analysis indicated in **Appendix G** were obtained using the same procedures indicated above; however, the dataset used in the analysis changed. The new dataset contains only the participants who indicated that their primary used of the highway was either for commuting or for business purposes.

Correlation and Alpha Values

The following are the procedures used in the data analysis of the pilot study for creating **Table F-4** in Appendix F. The dataset utilized for the correlation analysis is indicated first followed by the procedure that provides the Pearson's correlation and the p-value of the correlation test. The last procedure provides the Fisher's z for combining the correlations.

```
DATA SerQual;
INPUT A1 A2 A3 A4 A5 A6 A7 A8 A9 A10;
DATALINES;
5	7	4	6	3	6	3	6	4	5
5	5	5	5	3	5	3	5	5	3
8	6	4	7	8	8	9	8	2	8
;
RUN;
```

```
Pearson's correlation: PROC CORR DATA=SerQual PEARSON NOSIMPLE;
VAR A1 A2 A3 A4 A5 A6 A7 A8 A9 A10;
RUN;
```

```
Fisher transformation: PROC CORR DATA=SerQual FISHER PEARSON NOCORR NOSIMPLE;
VAR A1 A2 A3 A4 A5 A6 A7 A8 A9 A10;
RUN;
```

The Cronbach's alpha values reported in **Table 14**, **Table 15** were obtained using the same procedure adopted for the correlation analysis but with different options, as indicated below. The dataset used for calculating the alpha values was the same dataset used for the factor analysis.

```
PROC CORR DATA=SerQual ALPHA NOCORR NOSIMPLE;
VAR Q8 Q10 Q11 Q12;
RUN;
```

```
PROC CORR DATA=SerQual ALPHA NOCORR NOSIMPLE;
VAR Q1 Q2 Q3 Q4;
RUN;
```

Regression Analysis

The regression analysis was done using the average scores of the variables in the Safety group and the average score of the variables in the Reliability group. The overall score was treated as a numerical variable in the first analysis and as a multicategory variable in the second analysis. The procedures for loading the data into the memory of the computer are slightly different but the scores remain the same.

First analysis using OLS model

```
DATA SerQual;
INPUT SAFETY RELIABILITY SQL;
DATALINES;
3.50  2.00  2
3.25  2.75  3
3.25  3.00  3
;
RUN;
```

The results indicated in **Figure 17** of Chapter 4 were obtained with the following SAS procedure:

```
PROC REG data=SerQual;
model SQL = SAFETY RELIABILITY / CLB CLI VIF R;
RUN;
```

The "R" option at the end of the model statement provides the residuals values of the regression. The normality of the distribution of the residuals was confirmed with a Q-Qplot obtained with the following procedure.

```
PROC CAPABILITY data=Residual NORMALTEST;
var RES;
ppplot RES ;
RUN;
```

Second analysis using Cumulative Logit Model

The procedure for loading the data is the same as the procedure indicated before but for the following line: `INPUT SAFETY RELIABILITY SQL$;` The symbol $ at the end of the SQL variable converts the scores from numerical into categorical.

The results indicated in **Figure 19** of Chapter 4 were obtained with the following SAS procedure:

```
PROC GENMOD data=SerQual;
model SQL=SAFETY RELIABILITY  / dist=multinomial
                                link=cumlogit
                                aggregate
                                Predicted
                                type1;
RUN;
```

The cross-product term analysis was performed using the same procedure indicated above. The dataset for the analysis included the result of the "centering" performed on the Safety variable of the model.

APPENDIX F – Pilot Study

Variables and Measures

Table F.1 shows the three domains and scale items or variables used during the pilot study for measuring the perceived quality of highway maintenance service delivery. All variables indicated in **Table F.1** (except for variable SQL) were measured using a nine-point Likert response scale with the following labels: “lower”, “higher”, and “The same.” The first label was for point 1 in the Likert scale and the second label was for point 9. The third label was for the middle point of the scale, point 5. The following legend was shown above the response scales: “*VDOT’s performance compared to my adequate level of service is.*” Adequate service was defined in the instructions as the minimum service performance level accepted by the road user for a particular questionnaire item. The response scale adopted for measuring the global variable, SQL, was a ten-point scale without labels.

Table F. 1 Measures and Scale Items Selected for the Pilot Study

MEASURE	SCALE ITEMS	
TANGIBLE: "Physical facilities, equipment, and appearance of personnel."	A_1	Modern Equipment
	A_2	Employees wearing proper attire (e.g. hardhat, reflective vest, etc)
	A_3	Adopting Convenient working hours
RELIABILITY: "Ability to perform the service dependably."	A_4	Minimizing travel delay through maintenance areas
	A_5	Performing maintenance when required
	A_6	Keeping customers inform about maintenance activities
	A_7	Performing maintenance in a reasonable period of time
ASSURANCE: "Knowledge of employees and their ability to inspire trust and confidence."	A_8	Employees instilling confidence in you
	A_9	Making road users feel safe while driving through maintenance areas
	A_{10}	Isolating Maintenance areas effectively
GLOBAL	SQL	Overall perception of the quality of the highway maintenance service

Data Collection Format

The availability of e-mail addresses and the short period required for its administration made the on-line survey the most convenient approach of the four formats for conducting the pilot study. The benefits of online surveys include the near-complete elimination of paper, postage, and mail-out costs, and a considerable reduction in administration time. The questionnaire was administered by e-mail using a Web survey tool available to Virginia Tech students and faculty at www.survey.vt.edu. A three-contact on-line strategy was selected for the pilot using multiple contacts and personalized e-mails. Copies of the pre-notice, the cover letter and questionnaire, and the thank-you/reminder letter with a replacement questionnaire can be found in **Appendix B**. The on-line pre-notice played a very important role by discouraging participants from promptly deleting any subsequent and related e-mail. The questionnaire was sent just a few days after the pre-notice so both e-mails could be associated. The thank-you/reminder notice with a replacement questionnaire was sent the week after the first questionnaire.

Sample Frame

The local metropolitan planning organization (MPO) within the Montgomery area provided the contact list for the pilot study. The list contained 300 e-mail addresses from people affiliated with the local MPO. The complete list was adopted as the sample frame for the pilot study without any sampling process. The estimated number of responses was 180 based on the typical response rate for an online survey. No sampling was performed for the pilot study; the whole sample frame was surveyed.

Administration Process

The pre-testing phase was the last chance to identify problems within the documentation. A main concern was addressing computer literacy to avoid respondent frustration and embarrassment when trying to answer the survey. Most people have some experience with paper surveys, but the same assumption did not necessarily apply to electronic surveys. The three contact letters and the questionnaire were sent to five graduate students and three staff members of the local MPO, including a former VDOT resident manager to solicit their feedback. The order and appearance of the questions were adjusted accordingly. None of the comments related to the wording of the questionnaire. The pre-notice email was sent Nov. 6, 2007. The cover letter e-mail was sent on Nov. 9, 2007. This second e-mail included a link to the online survey and appropriate instructions . The last communication was sent on Nov. 16, 2007. Staff members of the local MPO managed the outbound communication. Questions and concerns were addressed in a timely and professional manner by the research team. The e-mails were sent using the blind carbon copy (bcc) feature available in most e-mail software. The use of bcc addressing prevented individual participants from receiving other participants' e-mail. Additionally, the survey software provides returned responses without indicating the source. This feature prevented the researcher from linking individual results with participants. **Figure F.1** shows the distribution of responses from the beginning to the end of the survey. The total of completed questionnaires was 47, representing a 15.6 percent response rate (47 / 300 = .156).

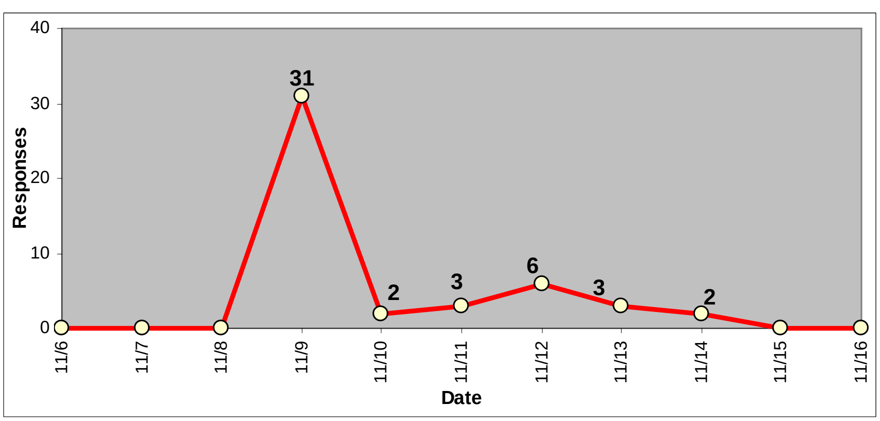

Figure F. 1 Pilot Survey Response Time Series

The thank-you letter was originally scheduled for Nov. 14, 2007. The need to send a new contact right after the questionnaire was supported by the decline in the response rate. In **Figure F.1**, the responses declined after Nov. 12; however, the thank-you letter was not sent until Nov. 16. The delay was due to miscommunication; however, two important lessons were learned . First, the administration process must be completely controlled by the research team and, second, keeping participants engaged through multiple contacts is paramount in survey research.

Data Management

The data management process included data entry and data screening. The data entry task refers to the process of transferring the data from paper to electronic format. The data screening task refers to the process of identifying and processing duplicated and missing data.

```
1;2007-11-09 09:44:54;;;;;;6;;3;;3;;5 Same;;4;;6;;7;;6;;4;;5 Same;;;5;;
7;2007-11-09 10:20:24;;;;;;6;;6;;6;;6;;3;;5 Same;;6;;3;;6;;6;;;6;;
8;2007-11-09 10:22:42;;;;;;5 Same;;6;;4;;5 Same;;6;;4;;4;;6;;3;;7;;;8;;
11;2007-11-09 10:41:27;;;;;;6;;4;;4;;6;;6;;3;;7;;6;;6;;6;;;6;;
```

Figure F. 2 Web Tool Output Data Format

For the on-line survey, data entry was limited to converting the file from one electronic format to another. Responses were stored in a text format as shown in **Figure F.2**. At the conclusion of the survey, the data was downloaded from the Web site and stored on a computer controlled by the research team. Then, the data was converted from text format into a Microsoft Excel spreadsheet.

Data Screening, Missing Data, and Duplicated Answers

Data collection produced some missing data scattered among the 47 completed surveys. Only independent variables showed missing scores. The pattern of the missing data was classified using three categories: missing completely at random (MCAR), missing at random (MAR), and non-ignorable (Allison 2002).

Table F.2 shows a summary of the missing data recorded for the pilot study. Five surveys presented missing data on several independent variables. There was no missing data for variables A_1, A_2, A_3, A_6 and the dependent variable OVE. There was one missing score on variable A_4. The sole missing data on variable A_4 was completely at random (i.e. MCAR). The same assumption applied to variables A_5, A_7, A_8, A_9, and A_{10}, all of which showed only one missing score in 47 surveys.

Table F. 2 Missing Data for Pilot Study Surveys

A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
5	5	7	8	**Miss**	2	7	5	7	2
6	7	4	4	2	6	3	**Miss**	6	3
5	7	5	5	4	6	4	7	**Miss**	5
5	5	5	5	3	3	**Miss**	5	5	**Miss**
5	5	3	**Miss**	4	4	6	5	5	5

Common imputation techniques introduce a bias to the data set. However, that bias was negligible in this case because the number of missing scores for each variable was very small (1 out of 47 scores). For each independent variable with missing data, the mode of the variable was used for imputing the missing score. The mode is the score that occurs most often. **Table F.3** shows the imputed scores calculated for each independent variable with missing data.

Table F. 3 Imputed Score on Missing Data for Pilot Study Surveys

A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
5	5	7	8	**4**	2	7	5	7	2
6	7	4	4	2	6	3	**5**	6	3
5	7	5	5	4	6	4	7	**5**	5
5	5	5	5	3	3	**5**	5	5	**5**
5	5	3	**5**	4	4	6	5	5	5

The Web survey tool returned responses without indicating the source of the information. This feature enhanced participant confidentiality but prevents verification of duplicate answers. Therefore, duplicate answers were not investigated in the pilot study because there was no available information regarding their origin. Some Web survey tools enable researchers to define a returning list. Only participants on the returning list can access the survey and once an answer is submitted, the participant can no longer access the survey. The returning list feature was not available at the time the online survey was administered. **Appendix C** shows the result of the data collection process for the pilot study.

Correlation Analysis

The primary objective of correlation analysis is finding a linear relationship between two variables, X and Y. The parameter of the analysis is the correlation coefficient, r_{xy}. A value of r_{xy} equal to zero means that there is no relation between changes in X and changes in Y. **Equation F.1** presents the mathematical expression for calculating the sample correlation r_{xy}:

$$r_{xy} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{S_{xx} S_{yy}}} \quad \textbf{(Equation F.1)}$$

where, S_{xx} is the variance of *X*, S_{yy} is the variance of *Y*, $\bar{x}$ is the mean value of *X*, and $\bar{y}$ is the mean value of *Y*. The sample correlation parameter can be interpreted as the standardized covariance of X and Y, Cov(x,y), representing the degree to which the two variable varied together. If there is absolutely no change in Y when X changes, Cov(x,y) = 0, then the two variables are independent (Otto and Longnecker 2001). **Figure F.3** shows two scatter plots corresponding to two different parameters of correlation. The left plot corresponds to a parameter r_{xy} equal to 0.3 and the right plot corresponds to a parameter r_{xy} equal to 0.6. The plot on the left shows very little trend; the dots are scattered all around the main diagonal. The plot on the right shows a defined pattern; dots are scatter around the main diagonal. The parameters, r_{xy}=0.3 and r_{xy} =0.6, were used for interpreting the correlation matrix shown next in **Table F.4**.

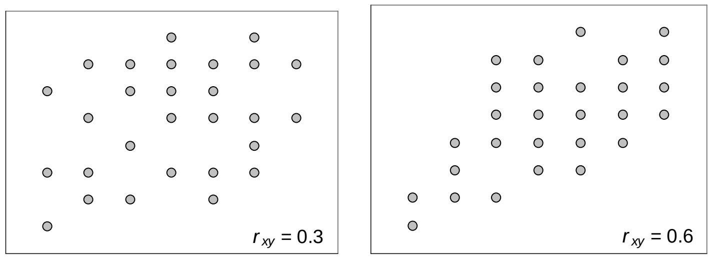

Figure F. 3 Scatter Plots for r_{xy}=0.3 and r_{xy} =0.6

Table F.4 shows sample correlation parameters calculated for all variables selected for the pilot study. The values below the diagonal correspond to the sample correlation parameter and the p-value of the correlation test. The values above the diagonal correspond to Fisher's z, a transformation of the sample correlation parameter.

Table F. 4 Pair-Wise Correlations for the Variables of the Pilot Study

		TANGIBLE			RELIABILITY				ASSURANCE		
		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
TANGIBLE	A_1		0.612	0.379	0.342	0.231	0.525	0.302	0.374	0.294	0.552
	A_2	0.545 <.0001		0.529	0.055	-0.090	0.440	-0.021	0.626	0.326	0.459
	A_3	0.362 0.013	0.484 0.001		0.558	0.147	0.223	0.331	0.364	0.560	0.382
RELIABILITY	A_4	0.330 0.024	0.055 0.713	0.506 0.000		0.660	0.272	0.867	0.282	0.503	0.487
	A_5	0.227 0.125	-0.090 0.548	0.146 0.328	0.578 <.0001		0.470	1.130	0.144	0.099	0.498
	A_6	0.481 0.001	0.414 0.004	0.219 0.138	0.266 0.071	0.438 0.002		0.387	0.393	0.266	0.741
	A_7	0.293 0.046	-0.021 0.889	0.320 0.029	0.700 <.0001	0.811 <.0001	0.369 0.011		0.177	0.277	0.537
ASSURANCE	A_8	0.358 0.014	0.556 <.0001	0.349 0.016	0.274 0.062	0.143 0.336	0.374 0.010	0.175 0.239		0.527	0.418
	A_9	0.286 0.052	0.315 0.031	0.508 0.000	0.464 0.001	0.099 0.507	0.260 0.078	0.270 0.067	0.483 0.001		0.311
	A_{10}	0.502 0.000	0.429 0.003	0.364 0.012	0.452 0.001	0.460 0.001	0.630 <.0001	0.491 0.001	0.395 0.006	0.302 0.039	

The null hypothesis of the correlation test proposes that the population correlation ρ_{xy} is equal to zero. Falling to reject the null hypothesis implies that there is absolutely no change in Y when X changes. A reasonable alpha value for rejecting the null hypothesis is 0.05. The alpha value is the error of rejecting the null hypothesis when the null hypothesis is true. The p-value corresponding to the selected alpha value is 0.05.

In most cases in **Table F.4** the null hypothesis was rejected (i.e. p-value less than 0.05). However, the p-value of the correlation test was closer to or greater than 0.05 whenever the sample correlation was less than 0.30. In these cases, the test fails to reject the null hypothesis. For example, the sample correlation between A_1 and A_5 was 0.227 and the p-value of the correlation test was 0.123 (the results for the pair A_1 and A_5 can be found in the middle-left side of **Table F.4)**. The p-value of the correlation test was greater than 0.05; therefore, the test fails to reject the null hypothesis of the correlation test, suggesting that variables A_1 and A_5 are statistically uncorrelated despite having a sample correlation r_{xy} greater than zero. More observations would be needed to confirm the effect observed between variables A_1 and A_5 and thereby reject the null hypothesis. The lack of statistical significance in some of the results in **Table F.4** was a direct consequence of the low response rate during data collection.

The third parameter in **Table F.4** is the Fisher's **z,** is a transformation of the **r** sample correlation. The statistic **z** combines different sample correlations into a weighted average - or combined sample correlation - providing a mean for describing the discriminant and convergence power of a group of variables. Discriminant power is the capacity to differentiate between different constructs and convergence power is the capacity to approach a single measure for a construct.

The sample correlation **r** must be normalized before it can be combined with other sample correlations. This is achieved with a Fisher's transformation. The new statistic **z** has an approximate normal distribution and can be combined into a weighted average. **Equation F.2** provides the mathematical expression for calculating the weighted average **z**, $\bar{z}$ (SAS 9.1.3 Service Pack 4 2007).

$$\bar{z} = \frac{\sum_i (n_i - 3) * |z_i|}{\sum_i (n_i - 3)} \quad \textbf{(Equation F.2)}$$

The weighted average **z** can be transformed back into a sample correlation or combined sample correlation, **rz**, for interpretation. When the combined sample correlation represents the scores of a group of variables within the same construct, a value of 0.6 or greater will indicate that the variables in average converge in their measurement of the construct. When the combined sample correlation represents the scores of a group of variables of two different constructs, a value close to 0.3 or less will indicate that the variables in average recognize the difference between the constructs.

Table F.5 shows the weighted average **z** and the reverse-transformation **rz** corresponding to the sample correlations in **Table F.4**. The left side of **Table F.5** shows the weighted average **z** and the combined sample correlation **rz** for variables within the same construct. The right side of **Table F.5** shows the weighted average **z** and the combined sample correlation **rz** for variables of different constructs.

Table F. 5 Combined Sample Correlations

Within construct	z	rz	Between constructs	z	rz
Reliability (Rel)	0.631	0.559	Rel + Ass	0.367	0.351
Assurance (Ass)	0.419	0.396	Ass + Tan	0.437	0.412
Tangible (Tan)	0.506	0.467	Rel + Tan	0.272	0.266

The highest combined sample correlation **rz** for variables within the same construct was 0.559, as shown in **Table F.5**. The other two combined sample correlations were 0.396 and 0.467 for the variables in the Assurance group and Tangible group, respectively. The lowest combined sample correlation **rz** for variables of different constructs was 0.266, as shown in **Table F.5**. The other two possible combinations between variables of different constructs are Reliability and Assurance groups and Tangible and Assurance groups. The combined sample correlations in these two cases were 0.351 and 0.412, respectively.

Based on the results in **Table F.5**, there is insufficient evidence to conclude that the three constructs, Tangible, Reliability and Assurance, are independent. In fact, the results in **Table F.5** suggest that these two groups of variables should be considered as one single group, as indicated by the factor analysis.

Cronbach's Alpha

The Cronbach's alpha indicates how interrelated the variables of a same group are. The closer the alpha value is to one, the higher the interrelation is. Most statistical packages calculate the Cronbach's alpha of a group of interrelated variables. Even so, the Cronbach's alpha can be easily calculated with an excel spreadsheet using **Equation F.3**.

$$Cronbach's\,alpha = \frac{p}{p-1}\left(1-\frac{\sum_j V(Y_j)}{V(Y_0)}\right) \quad \textbf{(Equation F.3)}$$

Table F.6 shows the input for calculating the Cronbach's alpha associated with the variables A_4, A_5, A_6, and A_7 of the Reliability group.

Table F. 6 Cronbach's Alpha Calculations for Variables in the Reliability Group

Variables	A_4	A_5	A_6	A_7	All
Variance	**2.020**	**2.435**	**2.231**	**3.768**	**27.108**
p	4				
$\Sigma_j V(Y_i)$	10.454				
$V(Y_0)$	27.108				
Lower bound	**0.819**				

$$\sum_j V(Y_j) = 2.020+2.435+2.231+3.768.$$

The variance of the observed scores are indicated in the second row for each variable and for the total observed scores, V(Y_0). Using **Equation F.3**, the Cronbach's alpha was calculated as 0.819, as shown in **Table F.6**. The same value was obtained using the SAS statistical package, as indicated in **Table F.7**.

Table F. 7 Cronbach's Alpha for the variables in the Reliability Group

Variable Deleted	**Raw variables** Correlation	Alpha	**Standarized variable** Correlation	Alpha
A_1	0.52	0.651	0.53	0.653
A_2	0.61	0.512	0.62	0.531
A_3	0.49	0.694	0.48	0.706
NONE	**--**	**0.712**	**--**	**0.722**

Table F.8 and **Table F.9** show the output corresponding to the Assurance and Tangible groups, respectively.

Table F. 8 Cronbach's Alpha for variables in the Assurance Group

Variable Deleted	**Raw variables** Correlation	Alpha	**Standarized variable** Correlation	Alpha
A_4	0.63	0.778	0.62	0.779
A_5	0.78	0.706	0.77	0.706
A_6	0.40	0.870	0.40	0.873
A_7	0.80	0.693	0.80	0.691
NONE	**--**	**0.819**	**--**	**0.817**

Table F. 9 Cronbach's Alpha for variables in the Tangible Group

Variable Deleted	Raw variables		Standarized variable	
	Correlation	Alpha	Correlation	Alpha
A_8	0.55	0.463	0.54	0.464
A_9	0.47	0.566	0.47	0.566
A_{10}	0.40	0.651	0.40	0.652
NONE	**--**	**0.661**	**--**	**0.660**

The results at the bottom of each table are the Cronbach's alpha for all variables considered. The SAS software calculated two Cronbach's alphas, the raw alpha and the standardized alpha. The standardized alpha is obtained after standardizing scores to a standard deviation of 1. This alpha will differ from the raw alpha only if the scores varied widely. Other values in each table represent the impact that each variable has on the overall alpha value. The impact of a particular variable is determined by the new alpha value calculated without the contribution of the variable. A decrease in the alpha indicates a high correlation between the excluded variable and the other variables of the group. Conversely, an increase in the new alpha value indicates a low correlation between the excluded variable and the other variables of the group.

For example, the alpha value calculated without factoring variable A_6 of the Reliability group was 0.870, which is considerably greater than the overall alpha (0.819). The new alpha suggests that variable A_6 does not correlate at a high level to the other variables of the group and should be excluded from the Reliability group.

Factor Analysis

It is important to note that the minimum sample size required for factor analysis (100 responses) was not achieved. The shortfall prevented use of all the selected variables in one single factor analysis. Therefore, the factor analysis was divided into three factor analyses with each analysis comparing no more than seven variables at a time.

The first analysis included variables associated with the tangibles and reliability dimensions of the highway maintenance service delivery. The first three variables in **Table F.10** correspond to the Tangible group and the remainders correspond to the Reliability group. The outcome of the factor analysis was a two-factor solution.

Table F. 10 Factor Analysis for Tangible and Reliability Group

Factor 1	Factor 2	Variable	Description
0.20	**0.78**	A1	Utilizing modern equipment
0.21	**0.89**	A2	Employees wearing proper attire for road maintenance work
0.25	**0.66**	A3	Adopting convenient working hours
0.79	0.26	A4	Minimizing travel delay through maintenance areas
0.91	0.04	A5	Performing maintenance in a reasonable period of time
0.37	**0.59**	A6	Keeping you informed about maintenance activities
0.92	0.14	A7	Performing maintenance when required

The requirement in this study for retaining a variable in a two-factor solution is: one loading factor must be greater than or equal to 0.60 (principal loading factor) and the other loading factor must be less than or equal to 0.30 (cross-loading factor).

The loading factor matrix in **Table F.10** was obtained after rotating the original loading factor matrix using an orthogonal rotation method (SAS Varimax procedure). All variables in the first factor analysis complied with the above-mentioned requirement, except for variable A_6. The principal factor of variable A_6 was 0.59 and the cross-loading factor was 0.37, as shown in **Table F.10**. For the remaining variable, the results in **Table F.10** indicates that variables A_1, A_2, and A_3 can be associated with the common Factor 1 and the variables A_4, A_5, and A_7 can be associated with the common Factor 2. Variable A_6 was excluded from the solution.

The second factor analysis included variables associated with the Tangible group and the Assurance group. The outcome of the factor analysis is in **Table F.11**. All loading factors were greater than 0.60. Therefore, all the variables were associated with the same common factor of the solution.

Table F. 11 Factor Analysis for Tangible and Assurance Group

Factor 1	Variable	Description
0.71	A1	Utilizing modern equipment
0.79	A2	Employees wearing proper attire for road maintenance work
0.71	A3	Adopting convenient working hours
0.73	A8	Employees instilling confidence in you
0.66	A9	Making you feel safe while driving through maintenance areas
0.69	A10	Isolating maintenance areas effectively

The third factor analysis includes the variables from the Assurance and Reliability groups. The outcome of the factor analysis was a two-factor solution.

Table F. 12 Factor Analysis for Assurance and Reliability Group

Factor 1	Factor 2	Variable	Description
0.73	**0.32**	A4	Minimizing travel delay through maintenance areas
0.92	0.01	A5	Performing maintenance in a reasonable period of time
0.45	**0.53**	A6	Keeping you informed about maintenance activities
0.92	0.11	A7	Performing maintenance when required
0.05	**0.85**	A8	Employees instilling confidence in you
0.11	**0.77**	A9	Making you feel safe while driving through maintenance areas
0.57	**0.53**	A10	Isolating maintenance areas effectively

The loading factor matrix presented in **Table F.12** was obtained after an orthogonal rotation of the initial loading factors. Two variables clearly did not comply with the factor loading requirement. Variable A_6, principal loading factor 0.53 and cross-loading factor 0.45, and variable A_{10}, principal factor 0.57 and cross-loading factor 0.53, were excluded from the solution. The principal loading factor of variable A_4 was 0.73 and the cross-loading factor was 0.32, as shown in **Table F.12**. Variable A_4 was retained in the solution of the third analysis despite the fact that the cross-loading factor was slightly greater than the required value.

The outcome of the third analysis, presented in **Table F.12**, indicates that variables A_4, A_5, and A_7 can be associated with common Factor 1 and variables A_8 and A_9 can be associated with common Factor 2. The groups Assurance and Reliability remained separate in the factor analysis solution.

Lessons Learned from the Pilot Study

The number of complete surveys submitted by participants of the pilot study was below expectations. The expected response rate was 0.60 while the actual response rate was 0.16. The following are possible explanations for the shortfall.

- The questionnaire was not clear enough
- The incentive for answering the survey was insufficient
- The number of contacts was not enough

The first possible cause relates to the wording of the items in the questionnaire. Before administering the survey, the questionnaire was pre-tested. As previously noted, the three contact letters and the questionnaire were sent to five graduate students and three staff members of the local MPO, including a former VDOT resident manager. Students and staff members commented on the documents. None of the comments related to the wording of the items. However, it is possible for participants to experience some difficulties in understanding the wording of the items.

The second potential cause for the low response rate relates to the incentives for completing of the survey. Under social exchange theory, a participant will evaluate the costs and benefits of answering a survey. If the benefits outweigh the costs of carrying out the task, the participant will complete the survey. For the pilot study, the researcher appealed to the affiliation of participants with the local MPO and interpreted their commitment to the organization as an incentive for completing the survey. No other incentive was offered. A different approach is needed for future surveys. Much research has indicated that a minimal financial token consistently improves response rates (Dillman, 2007).

The third potential cause for the low response rate is a low number of contacts who received the pilot study. Each point of contact should be considered a stimulus for completing the survey and each contact must be distinctive to be effective. Five contacts is the maximum number of stimuli recommended in the literature. For the pilot study, a three-contact strategy was selected. These three contacts were a pre-notice, a cover letter and a questionnaire, and a thank-you note with a replacement questionnaire. The third contact could have been divided into two contacts: a thank-you note and a reminder note with a questionnaire.

According to Dillman (2007), a greater number of stimuli increases the likelihood of obtaining a response. The thank-you note could have been printed in a small card and sent to all participants followed by a reminder letter a few days later. The new strategy increases the number of contact from three to four: a pre-notice, a cover letter and questionnaire, a thank-you letter, and a reminder letter and a replacement questionnaire.

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APPENDIX G – Other Analysis

Cost Analysis for the Mail-out Survey

Cost data was recorded for the data collection. **Table G.1** shows the unit cost and total cost of each contact submitted during the survey. The cost to submit the first three contacts was $1,234 and the number of responses generated by these three contacts was 236 completed surveys, approximately 70 percent% of the total responses. After sending the reminder letter, 98 additional surveys were received, representing the remaining 30 percent. The cost of the reminder was $385. The total cost of the data collection process was $1,618.

Table G. 1 Unit Cost and Total Cost of the Survey

Item	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Total
Unit Cost	$0.26	$0.16	$0.41	$0.01	$0.04	$0.02	$0.02	$0.11	$49.00	$5.85	-
Pre-notice letter		$123	-	$11	-	$18	-	-	-	$59	$210
Cover letter and Questionnaire		$123	$308	$11	$30	$18	$18	-	$147	$59	$713
Thank you letter	$195		-	-	-	-	-	$81	-	$35	$311
Reminder		$82	$205	$7	$20	$12	$12	-	-	$47	$385
Total Cost	$195	$328	$513	$28	$50	$48	$30	$81	$147	$199	**$1,618**

Legend:

#1 Bulk mailing (VT post office)
#2 Bulk mailing (Central mailing VT)
#3 Additional stamp
#4 Envelope #10
#5 Envelope #9
#6 Letter paper
#7 Letter paper (Survey)
#8 Postcard
#9 Incentive
#10 Labor (VA minimum wage)

The average cost of obtaining a completed survey was $4.85. The cost of obtaining a response with the first three contacts was $5.23 while the cost of obtaining a response with the last contact was $3.92. The last contact increased the response number 40 percent with an increased cost of 31 percent. The decreased cost of obtaining a completed survey after the third contact is due to two reasons. First, the cost of incentives was allocated to the second contact and, second, the number of mailings decreased after the third contact because the reminder was sent only to non-respondents. The minimum sample size for the closing study was determined to be 120 responses. Therefore, the additional cost of the reminder could have been avoided. However, the decision to send the last contact was dictated by the need to gather as much information as possible for statistical analyses. Moreover, the cost of the last contact was relatively low compared to the total cost of the data collection process.

Oblique Rotation in the Factor Analysis

To confirm the factor structure obtained with the orthogonal rotation, an oblique rotation was performed using the same data. **Table G.2** shows the outcome of the factor analysis for an oblique rotation using the same factor analysis and the same number of common factors presented in **Chapter 4 Section 4.4**.

Table G. 2 Loading Factors for NFACT=2 and Oblique Rotation

Factor 1	Factor 2	Scale Item	Description
0.24	**0.59**	B5	Minimizing travel delay through maintenance areas
0.00	**0.75**	B6	Performing maintenance work when it appears to be needed
0.01	**0.82**	B7	Completing maintenance work within a reasonable time duration
0.09	**0.75**	B8	Keeping road users informed about the location and duration of maintenance work
0.73	0.01	B12	Alerting road users when approaching maintenance areas
0.81	-0.04	B9	Operating heavy equipment without frightening road users
0.63	0.25	B11	Guiding road users through well-defined maintenance areas
0.71	0.17	B10	Making road users feel safe while driving through maintenance areas
0.87	-0.10	B2	Employees wearing proper attire
0.82	0.02	B4	Using clear indicators of maintenance activities
0.61	0.16	B1	Using equipment that looks well-maintained and in good working condition
-0.07	**0.88**	B3	Performing maintenance during low traffic time periods.

The factor structure in **Table G.2** is similar to the factor structure obtained with an orthogonal rotation. In fact, all variables were retained in the oblique rotation solution (the principal factor loading of variable B_5 was slightly below the limit). Thus, the solution obtained with an oblique rotation included the solution obtained with an orthogonal rotation. This outcome was expected since the oblique rotation allows for certain degrees of overlap between the two factors. However, it was desirable to keep the two factors as independent as possible. Therefore, preference was given to the orthogonal rotation method over the oblique method.

Commuting and Business Primary Trip Type

More than half of the participants who submitted a completed survey responded that their primary use of the highway was either for commuting or business purposes (N=186). These responses were of particular value because participants who use the highway daily are more likely to experience traffic anomalies characteristic of maintenance operations. A factor analysis was performed using the data from these participants. **Table G.3** shows the outcome of the factor analysis.

Table G. 3 Loading Factors for PRIMARY TRIP TYPE=Business and Commuting

Factor 1	Factor 2	Scale Item	Description
0.35	**0.61**	B5	Minimizing travel delay through maintenance areas
0.24	**0.68**	B6	Performing maintenance work when it appears to be needed
0.24	**0.74**	B7	Completing maintenance work within a reasonable time duration
0.36	**0.69**	B8	Keeping road users informed about the location and duration of maintenance work
0.66	0.26	B12	Alerting road users when approaching maintenance areas
0.73	0.20	B9	Operating heavy equipment without frightening road users
0.70	**0.36**	B11	Guiding road users through well-defined maintenance areas
0.77	0.29	B10	Making road users feel safe while driving through maintenance areas
0.71	0.23	B2	Employees wearing proper attire
0.78	0.22	B4	Using clear indicators of maintenance activities
0.55	**0.42**	B1	Using equipment that looks well-maintained and in good working condition
0.16	**0.81**	B3	Performing maintenance during low traffic time periods.

The solution did not differ much from the solution presented in **Chapter 4 Section 4.4**. Variables B_{11} and B_5 were excluded just as they were excluded in the previous solution. However, variable B_{10} was retained in the solution. The principal loading factor of variable B_{10} was greater than 0.60 and the corresponding cross-loading factor was less than 0.30. Variable B_1 and B_8 were excluded from the solution because both variables showed cross-loading factors greater than 0.30 and the principal loading factor of variable B_1 was less than 0.60.

Variable B_{10} measures the ability to inspire confidence while users drive through the maintenance area. The variable was excluded from the first round of factor analysis because the cross-loading factor was greater than 0.30. In **Table G.3**, the variable B_{10} not only showed a cross-loading factor of less than 0.30 but also a principal loading factor of 0.77 indicating a strong correlation with the Safety dimension of the service. Moreover, the mean score for the variable was calculated as 3.182 with a standard deviation of 0.680. The location test revealed that the mean is statistically different from 3.000 ($p<.0001$), indicating that, on average, the perception of service quality is above adequate.

Although the results presented in **Table G.3** represents the perceptions of a small portion of the sample, its implication in the evaluation of the quality of the maintenance service provided by VDOT is relevant due to the characteristics of the respondents.

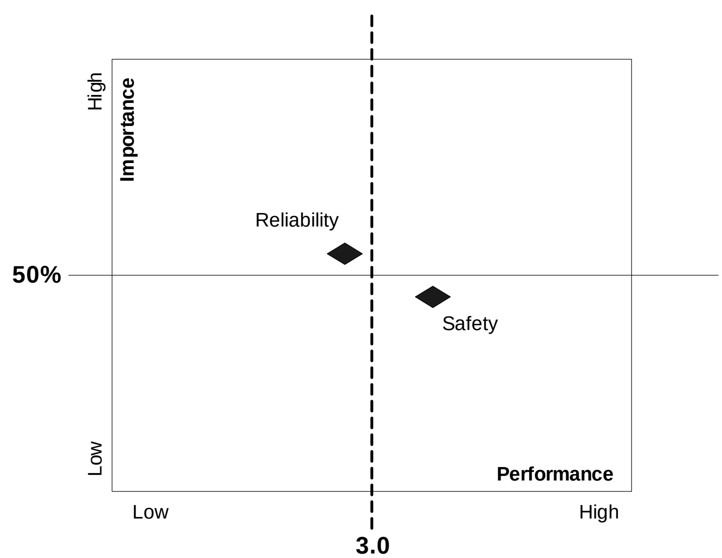
Importance-Performance Analysis

Importance-Performance analysis is a useful technique for analyzing public opinion related to service performance. A grid with four quadrants, representing the possible combinations of performance and importance, is used in the analysis. The quadrants of the grid are: low performance - low importance, high performance – low importance, low performance – high importance (critical), and high performance – high importance. The information derived from this type of analysis can be used to complement other sources of information that relates to policy and managerial decision-making.

The weights calculated in **Chapter 4 section 4.6** indicate the importance of the independent variables of the regression analysis, Safety and Reliability, related to the dependent variable, the Overall Service Quality. The measure of importance has been derived from the regression model and is known as *derived importance*. The derived importance calculated for Safety is 0.48 (or 48 percent) and for Reliability is 0.52 (or 52 percent). The performance measure is the mean score of the attributes of the group. The performance for Safety was calculated as 3.4 and for Reliability was 2.8.

Figure G.1 shows the grid for the analysis. Importance is presented on the vertical axis and performance on the horizontal axis. Only two points are shown in the grid, Safety and Reliability. A value of 0.50 was selected as the cut point for importance. The importance of the variables is high if the weight is above 0.50 and low if the weight is below 0.50. The cut point selected for performance is 3. The performance of the variable is high if the mean score is above 3 and low if the mean score is below 3.

Figure G. 1 Importance-Performance Analysis for Safety and Reliability Attributes



The graph shows Safety and Reliability in different quadrants of the grid. Safety is in the *high performance-low importance* quadrant and Reliability is in the *low performance-high importance* quadrant. From a managerial point of view, the results indicate that the emphasis should be place on the attributes of the Reliability group since the importance of these attributes related to the overall perceptions of service quality is high and the performance of the group was low.