COMPARATIVE ASSESSMENT OF

ON-BOARD TRANSIT SURVEY METHODS

By

BABAK MEMARIAN

Bachelor of Science in Civil Engineering

Tehran Azad University

Tehran, Iran

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ON-BOARD TRANSIT SURVEY METHODS

Thesis Approved:

Dr. Hyungseok (David) Jeong
Thesis Adviser

Dr. Garold D. Oberlender

Dr. Samir Ahmed

Dr. A. Gordon Emslie
Dean of the Graduate College

PREFACE

On-board Transit Survey is a specific type of surveys conducted on transit units like buses to obtain vital information regarding customer trip characteristics, travel behavior, demographic characteristics, and customers' attitude toward services. Survey results are used for current or future route planning, modeling, etc. Applying an appropriate conducting method is crucial to collect the required amount of data to fulfill transit systems' current and future needs without survey cost and time overruns.

This study performed a literature review and case studies on various methods of conducting on-board surveys used by different transit systems. In this research, the effect of: 1) length of questionnaire, 2) different incentives, and 3) surveyors on the response rate, unit cost, and duration of the survey were tested. These tests were conducted on the selected routes of Tulsa Transit system.

Using short questionnaires with six essential origin/destination (O/D) questions obtained the highest response rate with 11.4 and 11.1 percentage points differences compared to questionnaires with 14 (O/D and demographic) questions and 29 (O/D, demographic, marketing, and rating) questions. This questionnaire incurred the lowest unit cost with 25.8 and 23.4 percentage points lower than two other questionnaires. As an incentive, offering a drawing to win 31 days free pass obtained 8.2 higher percentage points response rate compared to offering a two free-ride ticket as an incentive to complete a questionnaire, while it increased the unit cost of the survey by 98.4 percentage

points. To conduct the data collection phase, female and male surveyors increased the response rate of the survey by 56.7 and 47.2 percentage points respectively, compared to using boxes. Female and male surveyors increased the unit cost of the survey by 56.2 and 80 percentage points. They also obtained 73.7 and 64.2 percentage points higher daily response rates than the method of using boxes, respectively.

Results indicate that, when a high response rate is critical a survey with six essential O/D questions offering a drawing to win 31 days free pass distributed by female surveyors can be the best combination. When the cost of survey is critical, a survey with six essential O/D questions offering a two free-ride ticket distributed by using boxes can be the best option. If the survey duration is critical and the survey has to be conducted under a limited timeframe, a survey conducted by female surveyors can be the best method while using male surveyors can be an alternative method of data collection.

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CHAPTER I

INTRODUCTION

1.1 Overview

Transit agencies use on-board surveys to collect vital data regarding customer trip characteristics, travel behavior, demographic characteristics, and customers' attitudes toward services. Survey results are used for travel modeling, long-range and area wide planning, route planning and scheduling, service design, marketing, and customers' communications (Schaller, 2005). An on-board transit survey is a type of survey which is conducted on transit units like buses, subways, light rail cars, commuter transits, and sometimes para transit vehicles.

The quality of data collected from on-board survey is a main concern of transit systems conducting on-board surveys. The amount of data expected from a planned survey is determined by targeting a specific response rate (typically 25%-30%).

The process of an on-board transit survey includes the steps at planning, designing, and conducting the survey. Failures in any step can result in a lower response rate, higher cost, or longer time than predicted. When a lower response rate than targeted is obtained, transit systems are made to go back to the field and run the survey again for a longer time to reach the targeted response rate, which can cause a cost and time overrun.

Applying appropriate conducting methods are crucial to collecting the required amount of data, at the least cost and time, to fulfill transit systems' current and future needs. A review of current methods of conducting on-board surveys shows that in most cases transit systems design and conduct their surveys by trial and error process based in several years of conducting surveys.

1.2 Research Work Plan

The main objective of this study is to assess the effectiveness of different methods of designing and conducting On-Board Transit Surveys in terms of response rate, unit cost, and duration of the survey by comparing current methods used by Tulsa Transit System. The work plan for this study is shown in Figure 1.1.

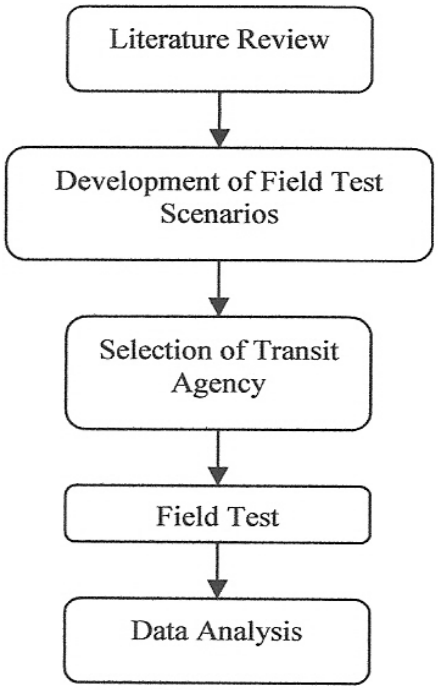

Figure 1.1: Research Work Plan

a. Literature Review: This task is to study common steps of planning, designing, and conducting an on-board survey and to investigate the methodologies and techniques used by different transit systems. This task will also identify the advantages and drawbacks of current conducting methods.

b. Development of Field Test Scenarios: This task is to develop field test scenarios for different conducting methods of on-board surveys based on problems identified in literature review and case studies. In order to collect required data to analyze the developed scenarios, a field test is conducted with a transit system.

c. Selection of Transit Agency: This task is to select a transit system to conduct the field test and collect the required data.

d. Field Test: This task is to conduct a survey to test the scenarios developed in task b. This field test is conducted by a small size transit system selected in task c.

e. Data analysis: This task is to analyze collected data and compare the output of different scenarios to evaluate the effect of each scenario on the response rate of the survey. To do so, three statistical methods will be employed to show the effect of different conducting methods on the response rate. These methods are: 1) Z test for difference in two proportions, 2) logistic regression model, and 3) odds ratio analysis. Cost and time analysis will also be performed to

show the effect of different conducting methods on the unit cost and duration of the survey.

1.3 Organization of this Report

Chapter II provides an overview of a typical procedure of developing and conducting an on-board transit survey. Chapter III presents a brief summary of previous studies of on-board transit surveys to examine and explain the possibility of either adoption or adaptation of their findings for development of field testing scenarios in this study. Chapter IV presents an overview of Tulsa Transit system and existing routes in the service area. The test scenarios to be tested on Tulsa Transit system are explained in detail. Also, this chapter provides the field test plan and implementation of the field test to be conducted in Tulsa. Chapter V presents the results of the field test and discusses the statistical analysis of collected data by employing the "Z test for difference of two proportions" method. Cost and time analyses are performed to evaluate the effect of each conducting method on the unit cost and duration of a survey. A logistic regression model is developed for each test scenario to explain the effect of different conducting methods on the response rate of the survey. Odds ratio analysis is performed to show the "effect size" of each conducting method on the response rate. Chapter VI provides conclusions based on analysis of collected data and provides some implications to facilitate the process of designing and conducting future on-board surveys. This chapter presents some recommendations based on weaknesses and shortcomings observed in this study for consideration in future studies.

CHAPTER II

BACKGROUND

This chapter provides an overview of a typical procedure involved in an on-board transit survey. The role and characteristics of each step in the procedure will be discussed in detail.

2.1 General Procedure for an On-Board Transit Survey

Figure 2.1 illustrates a typical procedure involved in an on-board survey. It starts with the need for information to accomplish the goal of the survey, such as transit system modeling or alternate study. The survey proceeds by planning to select an appropriate data collection method. Then, appropriate samples from the passengers and routes to represent the characteristics of trips and transit riders must be collected. Based on the results of sampling, a well organized survey tool (questionnaire) is developed and is pre-tested before going to the field. After pre-testing, the questionnaire can be slightly adjusted and the data collection phase then starts by hiring, training surveyors and sending them out to the field. Data collection is followed by cleaning and processing the collected data. Finally, the survey outcomes are evaluated based on some predetermined performance measures.

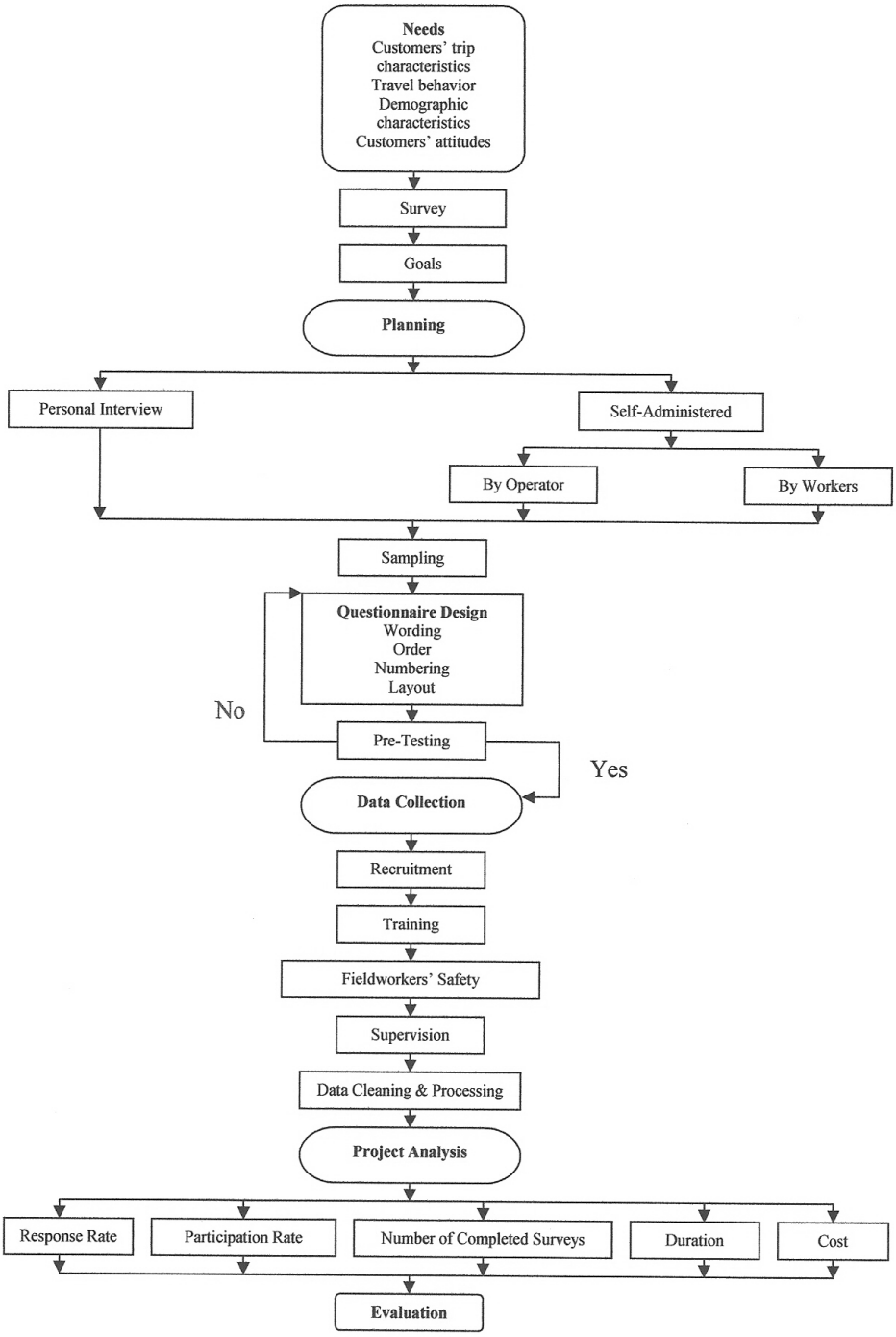

Figure 2.1: General Procedure of On-Board Transit Survey

2.2 Planning

Planning an on-board survey requires defining project goals, choosing where and how to conduct the survey, identifying the study population and sampling frame, and deciding what degree of precision is needed in the results (Schaller, 2005).

The main question asked in order to plan a survey is 'what information does the survey need to collect?' Typically, surveys ask questions in regard to some of following questions, rather than one or all of them; travel modeling, long-range and area-wide planning, route planning and scheduling, marketing, and customer communications (Schaller, 2005).

On-board surveys target two different points. First, it might be designed to collect very specific data in order to be applied for current or future system's planning. In this instance, survey methodology and questionnaire design tend to be developed in much specified framework. Second, it might seek very general purposes such as describing who benefits from transit service, or making a comparison with counterpart transit agencies and so on. It is also common that a survey may be for both specific and general purposes. In order to have a smooth survey process, a clear survey objective is a prerequisite to determining the right respondents selection, sampling size, data collection method selection, and instrument design.

The next step in planning an on-board survey is how to conduct the survey and determine which method would enable the survey to appropriately meet pre-defined goals. Typically, three different methods are applied in order to conduct an on-board survey; 1) personal interview, 2) self-administered questionnaire, and 3) in some cases a

combination of these two methods. The next subsections will describe the characteristics of these three methods.

2.2.1 Interview

Surveyors aboard the transit vehicle can conduct interviews with the boarding passengers, record the passengers' responses, and count each boarding passengers (Cambridge Systematics, 1996). Since personal interviews are conducted individually and face to face, the interviewer has an opportunity to explain the survey's goals and every single question on the survey questionnaire. The significant advantages of personal interview are; 1) higher level of respondents understanding of questions, 2) reduction of non-response items, 3) obtaining responses from people with limited literacy skills, and 4) skipping some questions according to previously answered questions. The disadvantages include; 1) time and labor intensity, 2) possibility of bias from non-random selected interviewees and 3) high cost.

Personal interviews are the most expensive method of conducting an on-board transit survey. However, this interview method can be the most efficient method when the following conditions exist; 1) having short questionnaire, 2) small sample size needed, 3) respondents' inability to complete a questionnaire due to lack of literacy, 4) language barrier, 5) physical disability, and 6) an alternative to self-administered at the choice of respondents (Schaller, 2005).

2.2.2 Self-Administered Survey

Self-administered surveys involve respondents completing survey forms themselves and then returning the forms to the agency or its representatives either when

alighting or by mailing it back from home. Questionnaires are typically distributed by survey workers (in-house staff or temporary fieldworkers) and transit operators. Other options are seat drops prior to customers boarding or placing questionnaires in convenient location for riders to pick up.

The self-administered method can be the most efficient method when the following conditions exist; 1) high demand for large number of respondents, 2) asking same questions from all respondents, and 3) relatively long questionnaires (Schaller, 2005).

Advantages of self-administered survey include; 1) need fewer surveyors to complete the given survey, 2) completion of a number of questionnaires simultaneously by respondents, and 3) capability of surveying all riders boarding the transit unit instead of selecting a sample of them. Compared with Personal Interview method the weaknesses of this approach include; 1) misinterpretation and misunderstanding of questions by respondents (measurement error), 2) partially completion of questionnaires by respondents (item non-response), 3) lower response rate than the interview method, 4) dependency upon respondents literacy and reading skill, and 5) less opportunity to use branching and skip patterns (Schaller, 2005).

2.2.3 Combined Personal Interview and Self-administered Questionnaire Method

In this method fieldworkers conduct a very short interview with the passengers passing the survey location, then hand out self-completion mail-back survey forms to interviewees. The primary advantage of this approach is that small amounts of data are collected from potential respondents before they answer the main questionnaire. This allows the survey team to perform screening of potential respondents. In addition, based

on interview data, the survey team is able to detect and possibly correct systematic non-response bias in mail returns (Cambridge Systematics, 1996). Cost and passengers' disruption may be main problems of this approach.

2.3 Sampling

The sample frame is the listing of the study population from which the sample will be drawn (Schaller, 2005). Sampling methods are usually divided into two groups; probability and non-probability. Probability sampling is any sampling method in which the probability or odds of choosing each individual (public transit customer in this case) is the same. These are also commonly referred to as random sampling methods. The major difference between the two methods is that non-probability sampling doesn't involve the random selection of individuals (Baltes, 2002).

For on-board surveys, the sample frame is customers boarding on specific listed routes. Sampling frame may include several variations such as; 1) surveying just high ridership routes, 2) surveying at centralized nodes to approach a cross section of different units' riders, 3) surveying based on time of day, 4) week days or weekends, and 5) direction of travel.

Generally, on-board transit surveys employ "two stage samples". The first stage is a selection of the transit vehicle trips from all the transit trips in the study area. The second stage is the sampling of passengers riding a particular sampled bus trip (Cambridge Systematics, 1996). An example of this approach can be found from NuStats' On-board survey for the Los Angeles Metropolitan Transportation Authority (NuStats, 2007). For selecting the sample of passengers, this survey gave a questionnaire to 100% of the passengers age 12 or older, who boarded the sampled bus trips. For

selecting the sample of bus trips, a plan was prepared to sample bus trips that were statistically significant at the route level. The sample plan design was developed to represent weekday trips by time of day and direction. Times of day periods were defined as AM peak (6:00am-9:00am), mid-day (9:01am- 2:59pm), and PM peak (3:00pm-7:00pm). Direction is defined as eastbound and westbound for the Metro Orange Line and eastbound, westbound, northbound and southbound for the Metro Rapid Bus.

For on-board surveys, in most cases, the sample may consist of the entire sample frame, and inevitably, the sample consists of just riders. In self-administered surveys, typically, the sample comprises riders of transit units working in a given sample frame and surveyors have the chance of surveying the entire transit units' riders. For personal interview surveys, due to time requirements it is almost impossible to interview the units' entire riders. Transit agencies typically attempt to maintain the randomness of the sampling procedure by selecting every n^{th} person (i.e. interview every fifth person to board the transit unit) (Schaller, 2005). Since on-board surveys rely on sampling of transit riders, not all of the riders, thus, it is subject to error and undoubtedly, the result would differ in comparison with the result of the entire riders' survey.

2.4 Questionnaire Design

The questionnaire is considered as the most critical part of a survey to extract what the survey intends to gather. Questionnaire design typically involves four stages; introduction, layout, wording, and ordering.

2.4.1 Introduction

The introduction part describes survey goals and respectfully asks recipients to participate in the survey. Conveying how important their responses are in the systems' decision making hopefully will motivate respondents to participate in survey.

Sometimes the introduction part is accompanied by some instruction to recipients. Instructions, whether read by the respondent or by the interviewer to the respondent, need to be placed where that information is needed and not at the beginning of the questionnaire or in the separate instruction booklet. At best, instruction books are used unevenly by respondents, resulting in some respondents being subjected to different stimuli than others. Respondents start answering questions and revert to instruction booklets when they run into problems. Instruction should be provided at the point respondents are ready to act on them (Zmud, 2004).

Figure 2.2 shows a format for the introduction and instruction part of a questionnaire used for 2007 transit rider survey by Charlotte Area Transit System. It briefly describes the goal of the survey, and the type of incentive offered for completing surveys. Furthermore, there is a visual and verbal instruction to recipients to help them fill out the questionnaire.

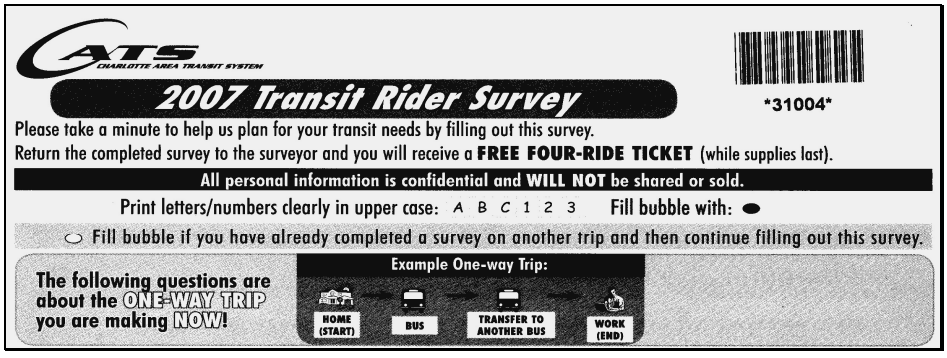

Figure 2.2: Instruction to Recipient (CATS, 2007)

2.4.2 Layout

Layout of a questionnaire plays a critical role to entice recipients to participate in the survey. The following factors are very important to persuade potential respondents to complete a survey; 1) questionnaire wording, 2) font selection, 3) number of questions and pages, 4) and layout of questionnaires. Questionnaires used in on-board surveys should be simple and consistent with logical flow of questions to convey the goals of the project in one or two pages. Typically, the most important information for respondents should be placed in the upper left-hand corner and less important information in the lower right quadrant (Zmud, 2004).

Typically questionnaires are typed in black color on light color pages (mostly white). In order to save the space when a large number of choices are involved, answer choices are arranged in multi-columns, listed horizontally on the same line, and 'Matrix format' which is often used for Origin/Destination questions. Although space is saved, these practices increase the non-response problem due to confusion of respondents (Schaller, 2005). Accordingly, it is strongly recommended to have a clearly structured questionnaire in several pages than a tightly packed one which is difficult to read.

The "Branching and Skips" term is used when a survey needs to ask following up questions regarding respondents' previous answers. In such a case verbal instruction or arrow format is used to help recipients. "Following the Instruction" is the potential challenge associated with this approach. In Figure 2.3, questions 2 and 3 show examples of "Branching & Skips".

Using a multi-language questionnaire is an approach used in areas with riders from different nations (see Figure 2.4). Even though it would facilitate the survey to reach a better response rate, it causes some challenges such as “following instruction”.

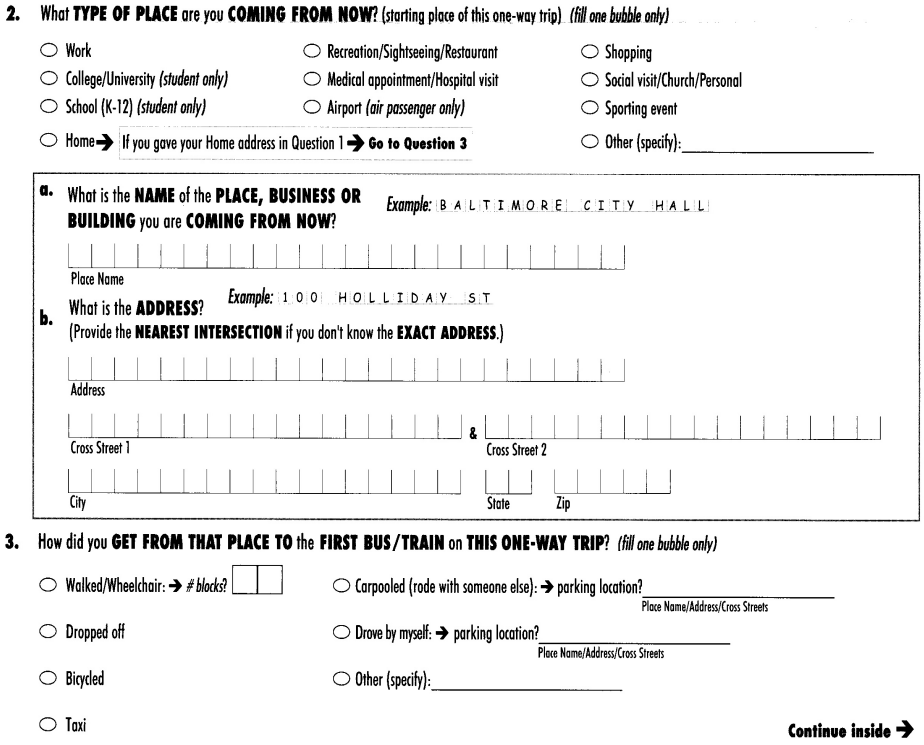

Figure 2.3: Branching & Skips (Maryland Transit Rider Survey)

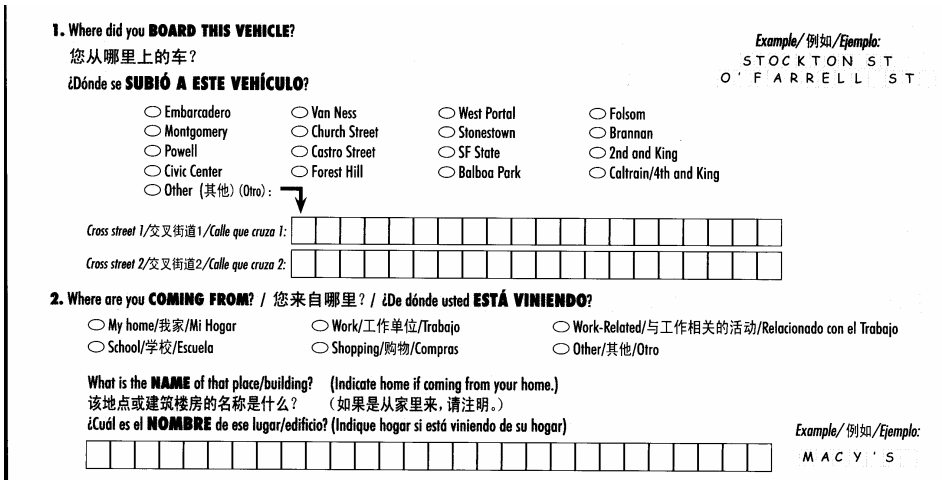

Figure 2.4: Multi-language Questionnaire (2004 Muni Metro)

2.4.3 Wording

Questions are a converted form of survey goals. Questions must be exhaustive to draw responses in the most precise and standard format. In some surveys, questions are very simple and frequently used by different agencies, while, in some instance, the art of question wording is vital to draw required data and response rate to meet the goal of the survey.

Since respondents provide requested answers, understanding of who is going to be the respondent of a particular questionnaire is very critical for the question writer. Focusing on respondents' characteristics, conceptions, and inspirations lead to the writing of well organized questionnaire, which facilitates respondents to interpret and provide appropriate answers. Wording of questions should be very carefully considered, easy to understand, straightforward, and consistent with other similar ongoing surveys. Respondents' privacy must be protected in the writing of questions, especially for personal interview in public places. Respondents' privacy must be always protected.

2.4.4 Ordering

Questions should follow a coherent and consistent sequence to achieve the most possible clarity. The purpose of the survey leads to how questions should be placed in logical order. Dillman (2000) recommends that the first question be easy to answer, apply to all of the respondents, be interesting, and be clearly connected to the purposes and topic of the survey. For instance, almost all origin/destination surveys begin with a question about the current trip. Surveyors try to ask this question from all riders to make sure the primary question is answered; even if respondents don't answer the rest of questions. Dillman (2000) suggests starting with attitudinal questions which are likely to

have salience with respondents, rather than factual questions of less interest (Schaller, 2005).

2.5 Pre-Test the Questionnaire

The last step of questionnaire design is to test the designed questionnaire with a small number of surveys before conducting the main survey. Pre-testing is essential to ensure that respondents provide answers that are valid and reliable. Generally questions should be tested for four characteristics: 1) an acceptable level of variation in the target population; 2) whether the meaning intended by the writer was shared by respondents; 3) the level of cognitive effort required to answer the question; and 4) respondents interest and attention. The first characteristic affects the statistical analyses that can be done with the data. The second affects the measurement error, and the latter two impact respondent burden and non-response (Zmud, 2004).

Ideally, the sample of pre-testing should be from the same population and from the same routes as the main survey sample is. Also the same process should be followed by surveyors and respondents as it would be in main survey. Running a pre-test reveals questionnaire's problems in wording, clarity, consistency, instruction, skip pattern, length, etc. For example, a lot of 'Don't know' responses indicate unclear or inappropriate wording. In case of facing any confusion by respondents; they would be asked to state their comments in verbal style.

Pre-testing is strongly recommended for new designed questionnaires. Changes made according to the first pre-test must be tested in the second one to see the result of reconstruction of the questionnaire. Although extending the time and cost of a survey, running pre-test surveys can tremendously decrease future re-works and double spending.

2.6 Data Collection

Once transit agencies finish pre-testing and modification of their designed questionnaire, they can move on to the data collection phase. This phase is considered as one of the most critical phases of on-board surveys. Since data collection is conducted by field workers, it can be a challenging phase to the supervision system. This phase includes 1) staff recruitment, 2) training, 3) supervision, 4) safety, and 5) data cleaning and processing which are discussed in detail in the following subsection.

2.6.1 Staffing

In order to collect data required for on-board surveys, there are three common approaches used by transit agencies; 1) in-house transit agency staff, 2) consultants, and 3) academic institutions. In most cases data collections are conducted by consultants or in-house staff and in some cases by academic institutions. In the first two cases they may use their own permanent staff or hire part-time field workers. Preferably, for small surveys including 2000 samples or less, transit agencies use their own in-house staff to conduct the survey. Since for larger surveys the number of in-house staff may not be adequate to meet the survey needs, transit agencies often ask a consulting firm to conduct the surveys with sample size of 5000 or 10,000 or more (Schaller, 2005). For instance, for Washington State's Ferries passengers' survey in 2006, Nustats Company was hired to conduct the survey and distribute 31,663 questionnaires. To do so, 125 temporary fieldworkers were hired for data collection (Cambridge Systematics, 2007).

Some agencies hire college students temporarily. Chicago Transit Authority recruited survey workers through posting on college campuses. These fieldworkers would be compensated by free fare media. Agencies would obtain their work forces and fulfill

their needs and also students can gain enough skills for future projects as well. Students might be compensated in several ways like free monthly ticket, hourly based, and so on.

Time, cost, and quality are the main variables in every data collection process. The quality of temporary hired workers can easily affect the duration and quality of data collection and consequently the cost. So, training of the field workers is one of the most important issues in data collection phase which is discussed more in detail in next section.

2.6.2 Training

Since data collection is conducted by field workers, their training is critical for achieving a higher response rate, more accurate collected data, and less time required. Training may cover a range of topics such as survey purpose, deployment and scheduling, how to approach passengers, how to aid passengers requesting assistance in completing the survey, tracking refusals, safety, dress, behavior and courtesy, and record keeping (Schaller, 2005).

Temporarily hired field workers typically need more training than experienced survey staff, to get familiar with the survey and data collection procedure. Survey workers must be punctual and able to identify and reach the correct survey location. They must give attention to detail in tracking surveys, yet also be reasonably outgoing in greeting passengers. Survey workers must be able to greet passengers with a friendly countenance. They must possess the stamina to work on a moving bus or train for hours at a time. They must also have the fortitude and good judgment to mollify the occasional disgruntled rider or bus operator (Schaller, 2005).

2.6.3 Fieldworkers' Safety

Physical safety of fieldworkers is one of the supervision system's responsibilities. Due to the nature of data collection phase, field workers are supposed to go to different locations and places during day time, night time, or early in the morning. Also they need to conduct their interviews or fill the questionnaires while transit units are in motion and they are standing. Consequently, they would be at risk of several incidences. In order to increase the safety of field workers, all safety steps must be taught properly during training courses and also field workers must be given enough instructions and safety facilities. For instance, agencies sometimes limit the hours the survey is conducted (to the 8 a.m. to 5 p.m. period) and avoid assigning female surveyors to night shifts. Agencies also issue workers identification badges, alert police officials of the survey schedule dates, and notify bus operators that survey workers would be on their buses (Schaller, 2005).

2.6.4 Supervision

Supervision is mainly responsible for giving each field workers assignment's at the beginning of each shift and also ensure that all field workers are in the right location and conducting given assignments properly. Different supervision systems apply different methods to monitor their data collection procedure. Supervisors may randomly pick and get on to the one of the buses or trains being surveyed and observe surveyors performance in that unit. In some cases transit units' drivers may be appointed and get involved to monitor surveyors' performance as a supervisor.

It is a common trend that the supervision system starts to evaluate completed questionnaires and collected data once they are submitted by the surveyors, sometimes

while survey is currently being carried out, to ensure that the surveyors are on the right track and the designed procedure is being followed as well. The supervision system is also responsible for field workers' safety which was discussed in previous section.

2.6.5 Data Cleaning

In order to ensure the survey is on the right track and each surveyor is conducting the survey properly, it is crucial to start editing completed surveys once they are returned from the field. The following steps are typically involved.

Comparing the number of completed surveys with the number of boarding passengers is one of the methods to ensure that the given numbers of collected questionnaires are correct, and not more than boarding passengers. Ideally, it is supposed that the number of distributed questionnaires be equal to the stated number of conducted surveys.

According to the purpose of each survey, the rules to identify usable completed questionnaires would be different. Just questionnaires which are approved by the editors are sorted for survey analysis and the rest will be discarded.

Recently some companies have applied newly developed devices to reduce the time and increase the accuracy of their data. They include; 1) hand-held devices, 2) bar-coded questionnaires, 3) scanning in the field and the web-based field management. In web-based field management system, all collected questionnaires are sorted and edited by survey editors in the field, and then they are scanned and data are transferred electronically to the management office for analysis process. These new devices allow completing the survey in less time and allow the delivery of the processed data in a shorter time period. For example, in Washington State Ferries 2006 Origin/Destination

survey, using new devices decreased the survey time to three months in 2006 compared with nine months in 1999 survey (Cambridge systematics, 2007).

All collected questionnaires are reviewed by survey editors. In most surveys, questionnaires which have not answered origin/destination questions are discarded. Also, questionnaires with incomplete information of respondents and mailing addresses are not entered into the process of data analysis. Once data cleaning process is completed, analysis of completed questionnaires can start.

2.7 Performance Measures

Once an on-board survey is completed, the sponsor of the survey analyzes the output of the conducted survey to evaluate whether or not the survey has met their goals. To do so, survey analysts must have some measures to assess the survey performance. According to the goals of a particular survey, different measures might be applied to analyze the survey results. These measures are: 1) survey response rate, 2) percent of potential respondents contacted (participation rate), 3) number of completed questionnaires with valid response, 4) survey duration, 5) survey cost.

2.7.1 Survey Response Rate

One of the most common performance measures of an on-board survey is the response rate. Response rate is generally used to illustrate the effectiveness of: 1) questionnaire, 2) data collection methods used, 3) incentives, 4) sampling method, and 5) surveyors' level of expertise to conduct the survey and encourage potential respondents to participate in the survey. According to the versatility of the response rate in evaluating survey results, it would be considered as one of the most important measures.

Typically, two methods are applied to calculate the response rate:

1. Ideally, the response rate is computed as the ratio of the completed returned surveys (based on definition of completeness) to the total number of passengers asked to participate in survey. For example, if 500 customers were asked to participate in a survey and 150 customers agreed and returned the completed questionnaire, the response rate for the survey would be 30%.

2. Another common approach is computed by the ratio of the number of completed questionnaires to the number of customers willing to participate in the survey.

Since the number of customers agreeing to participate in a survey is always less than the actual number of passengers, the second approach may overstate the response rate of the survey. Generally, to state which approach has been applied to compute the response rate of the survey, analysts mention whether or not refusals have been counted. If refusals have been counted, it means the first approach has been applied; otherwise the second approach has been used.

In some surveys, the analyst would target a specific response rate and the survey will be continued to reach the targeted response rate. Therefore, reaching a high response rate earlier in the survey would reduce the cost by decreasing the number of field workers and also by reducing the number of questionnaires required.

2.7.2 Percent of Potential Respondents Contacted (Participation Rate)

The participation rate enables transit agencies to specifically assess the effectiveness of the data collection method to contact the most possible number of potential respondents. It also measures the surveyors' level of expertise to encourage

passengers to participate in the survey either by offering an incentive or by verbal skills. Therefore, the participation rate is an important measure for transit agencies to assess the performance of their survey in the data collection phase.

This rate is defined as "number of returned questionnaires divided by the number of distributed questionnaires" (Cambridge Systematics, 2007). Sometimes, analyst of the survey defines a time frame which must be consistent with previously conducted surveys to make an accurate participation rate comparison.

2.7.3 Number of Completed Questionnaires with Valid Response

This measure evaluates: 1) the coherence of questions sequence in a questionnaire, 2) placement of critical questions necessary to be answered, 3) level of question difficulty to be understood by respondents, 4) instructions to navigate respondents, and 5) surveyors' level of expertise to assist respondents to find the right answer choices. According to these capabilities, "number of completed questionnaires with valid response" is another important measure to evaluate the performance of a particular survey.

The identification rules of valid-completed questionnaires differ. Only the questionnaires approved by the editors are sorted for survey analysis and the rest are discarded. Generally, a questionnaire is usable if the origin and destination of the trip are filled in and are codable (Cambridge Systematics, 1996). Cleaning the data begins with range checks once it is entered into the system. For example, if the possible answers to a question are numbered 1 to 4 and the non-response is coded as 0, then all answers greater than 4 must be erroneous. In addition, certain cross checks must be performed to verify the accuracy of the data (Cambridge Systematics, 1996).

The 1972 Urban Mass Transportation Travel Survey Manual discusses the types of errors usually encountered:

- Omissions where either the interviewer or the respondents (in a self-administered survey) failed to make an entry.

  Sometimes the editor can complete the form based on estimation according to available information. For example if the time of the survey is missing, the editor may estimate the time according to serial number of the form and before and after complete of the questionnaires. But, in some cases guessing is not allowable and may result in incorrect entry. For example, when the gender of the respondent is missing, it is impossible to guess if the respondent has been male or female.

- Impossible entries.

  An example of an impossible entry might be the recording of an address in an area that is not within a reasonable distance from the transit boarding place, when the respondent indicated that he walked to the boarding place.

- Inconsistent entries.

  These occur when two or more entries must bear a particular relationship to each other, but do not. For example, the addresses recorded for “boarding address” and “alighting address” may be reversed.

- Unreasonable magnitudes of entries which might not necessarily be wrong, but which appear unreasonable (Cambridge Systematics, 1996).

For example, if the respondent stated the number of automobiles available to use at his home as 20.

Identification of logically completed questionnaires would introduce another comparison scale. The total number of distributed questionnaires yields the total number of contacted passengers, therefore, after refining collected questionnaires and after discarding unusable ones, the percentage of completed (according to definition of completeness) questionnaire can be easily calculated.

2.7.4 Survey Duration

Since collected data from an on-board survey is used for a specific system modeling, or alternative study purposes, for a limited time frame, finishing the survey within the given time frame is very important. Furthermore, controlling survey duration enables transit agencies to control their survey cost by limiting man-hour required to finish a given survey.

Duration of surveys can be as short as a few weeks and in some cases longer than two years. The median duration for O/D surveys is 10 months from start to finish of a survey. This median duration in the case of non-O/D surveys, with 1,000 or more completed surveys, is approximately six months. For smaller surveys, it decreases to median duration of three months (Schaller, 2005).

In order to apply time as a comparison scale, the analyst may target a specific number of completed questionnaires, and once that targeted percentage is met, measuring survey duration is stopped. The duration of a particular survey can be analyzed either as time per completed questionnaire (unit time), or the time to complete the entire process.

2.7.5 Survey Cost

Since financial constraint is always a vital issue for survey sponsors, each transit company usually allots a limited amount of money to conduct a particular survey.

Therefore, controlling survey cost, which is typically calculated based on "cost per completed survey" enables transit agencies to analyze the incurred cost versus factors such as: 1) duration, 2) number of printed questionnaires, 3) number of fieldworkers hired, 4) length of questionnaires, 5) incentives, and 6) newly developed technology used. Therefore, a survey analyst considers cost as an important factor to evaluate the performance of a survey.

There are a number of factors affecting survey costs, directly or indirectly. These factors can be categorized as: a) project goals: study population, number of completed surveys needed, need for origin and destination data; b) external factors: density of riders on the route or in stations, rider income, education, literacy, and trip length; c) questionnaire design: well-defined objectives, length of survey, level of detail, clarity of questions, and lay out/ease of navigation; d) response rate: venue (on-board or in-station), interview or self-administered survey, distribution and collection method (self administered), incentives, and frequency of surveying; and e) survey implementation (fieldwork): enthusiasm and diligence of survey staff, training, and supervision (Schaller, 2005).

The cost of surveys can always be affected by the scale of the survey. Large scale surveys tend to incur less unit cost than the surveys of a smaller scale. Furthermore, due to fewer survey worker hours required to cover a given number of passengers, transit

agencies with higher number of passengers per vehicle-hour-which are likely in cities with high population density.

In order to use the cost of a survey as a measure to evaluate the performance of a survey, the common method is to calculate the cost per completed survey. Every survey is also formed by several essential steps like: designing the questionnaire, surveyors' recruitment and training, and incentives. The unit cost per completed survey, incurred in each step, can be calculated and compared with other similar surveys as well.

Due to the variability of surveyors' issues and potential cost of using different resources to carry out the survey, fieldworkers' costs per completed survey would be one of the most important elements in this stage of project analysis.

CHAPTER III

REVIEW OF PRIOR STUDIES ON ON-BOARD TRANSIT SURVEY

This chapter presents a brief summary of previous studies of on-board transit surveys to examine and explain the possibility of either adoption or adaptation of their findings for development of field test scenarios in this study.

3.1 TCRP Synthesis 63

Schaller (2005) developed an extensive transit survey synthesis which discusses all steps of on-board and intercept transit survey techniques in details. It goes through definitions, methodologies, and survey conducting steps such as introduction, questionnaire design, sampling, data collection phase, and fieldworker issues. The study developed the relationship chart between transit agencies' needs and type of questions which must be provided in a questionnaire (Figure 3.1).

In terms of evaluating survey performance, Schaller mainly focuses on cost per completed survey, response rate, and the quality of collected data. He briefly discussed other possible performance measures such as participation rate and duration. The study also discussed factors affecting the cost and quality of collected data. These factors include; 1) questionnaire design, 2) response rate, and 3) survey implementation (see Figure 3.2).

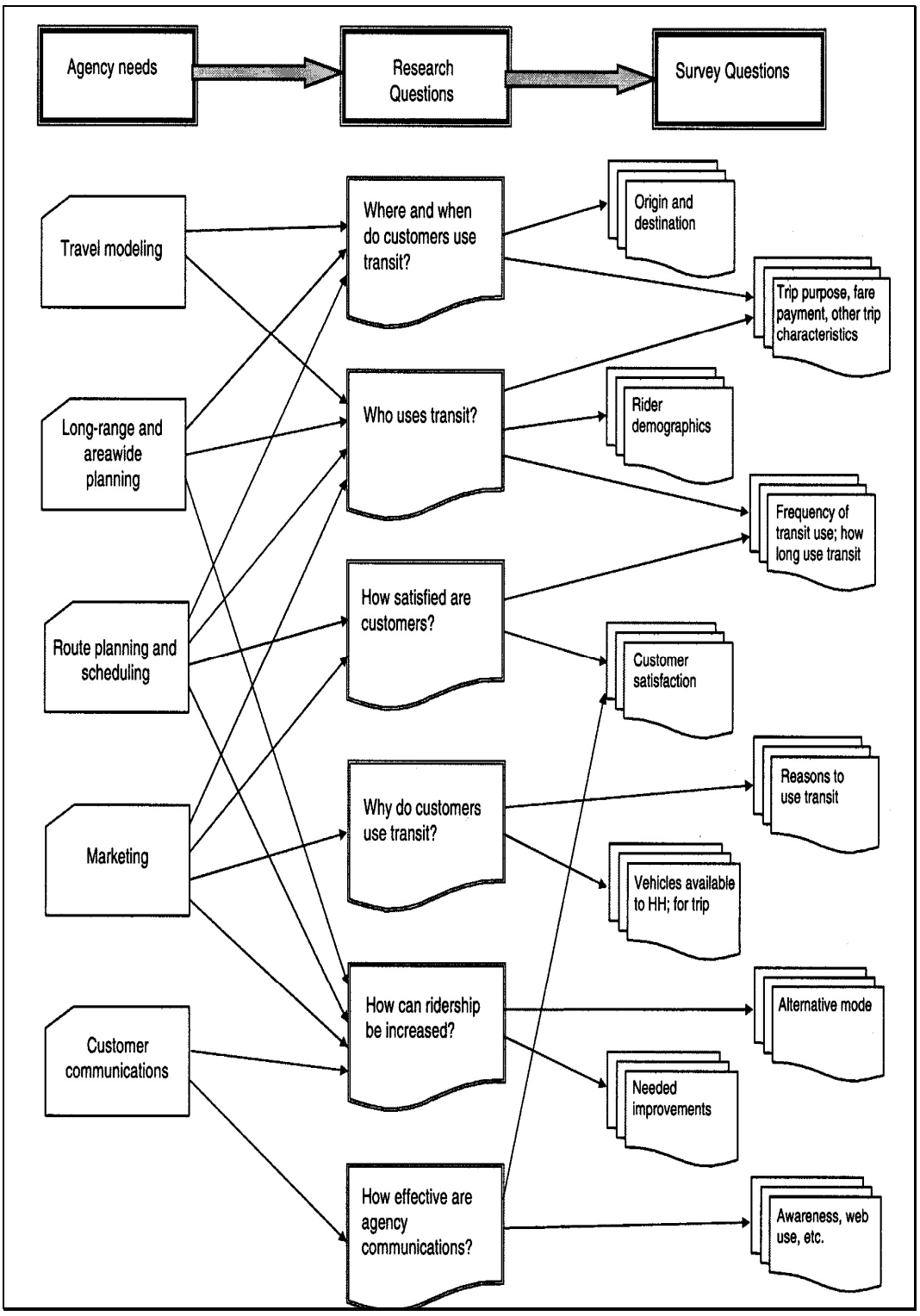

Figure 3.1: Relationship Chart between Transit Agencies' Needs and Types of Questions (Schaller 2005)

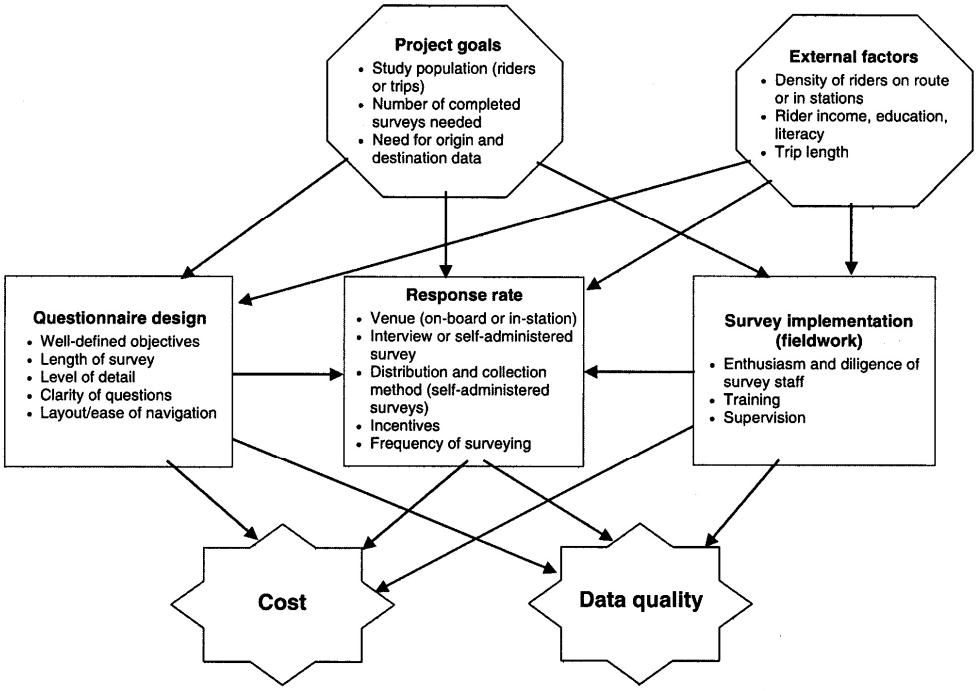

Figure 3.2: Factors Affecting Data Quality and Cost (Schaller 2005)

He recommended conducting more research to analyze the impacts of the questionnaire design, questionnaire layout, and the use of incentives on the overall survey performance. One of the main suggested research topics is placing "attitudinal questions" at the beginning of the questionnaire which may improve the overall and unit response rate. A wide range of techniques used by different companies in the data collection phase, questionnaire design, wording, fieldworkers, and incentives have been cited and in some cases meaningful comparisons have been made among them. To conduct an on-board survey Schaller has pointed to three different approaches; 1) using in-house staff for small size surveys (2000 questionnaire and less), 2) hiring consulting companies for large size surveys (more than 10,000), and 3) hiring college students for small surveys. Several examples of questionnaires with different wording, layout, length, etc which can be used as practical examples for other agencies future surveys. Schaller also provides a list of

different companies that have previously used incentives in their surveys, but there is no analysis and comparisons illustrating the effect of using incentives in a particular survey.

Overall, this synthesis is a very well organized report to assist transit agencies in taking advantages of previously conducted surveys, including 56 different surveys and methods used in those surveys. Although providing very detailed definitions, methodologies, and examples, this study does not offer any guidelines or preferred methods which can be used under a specific existing condition for a particular survey. For example, in the stage of pre-testing, there is no guideline in terms of sample size, crew size, and duration of a sample test. Newly developed devices, their applications, and the benefits are also not covered. This study did not address the appropriate combinations of fieldworker teams in terms of their gender, age, and race; or the size of data collection teams hired under different survey conditions to improve the response rate and participation rate of the survey.

3.2 Travel Survey Manual

Cambridge Systematics, Inc. (1996) conducted an in-depth study for the U.S. Department of Transportation and U.S. Environmental Protection Agency in regard to all types of travel surveys including house-hold and activity survey, vehicle intercept survey, on-board survey, and so on. This manual initially discusses the generic travel survey process (Figure 3.3) and then specifically discusses on-board transit surveys. The manual provides a very detail explanation of pre-testing, fieldworkers' recruitment, and data cleaning and processing and it covers almost all steps needed to be taken for an on-board survey as well.

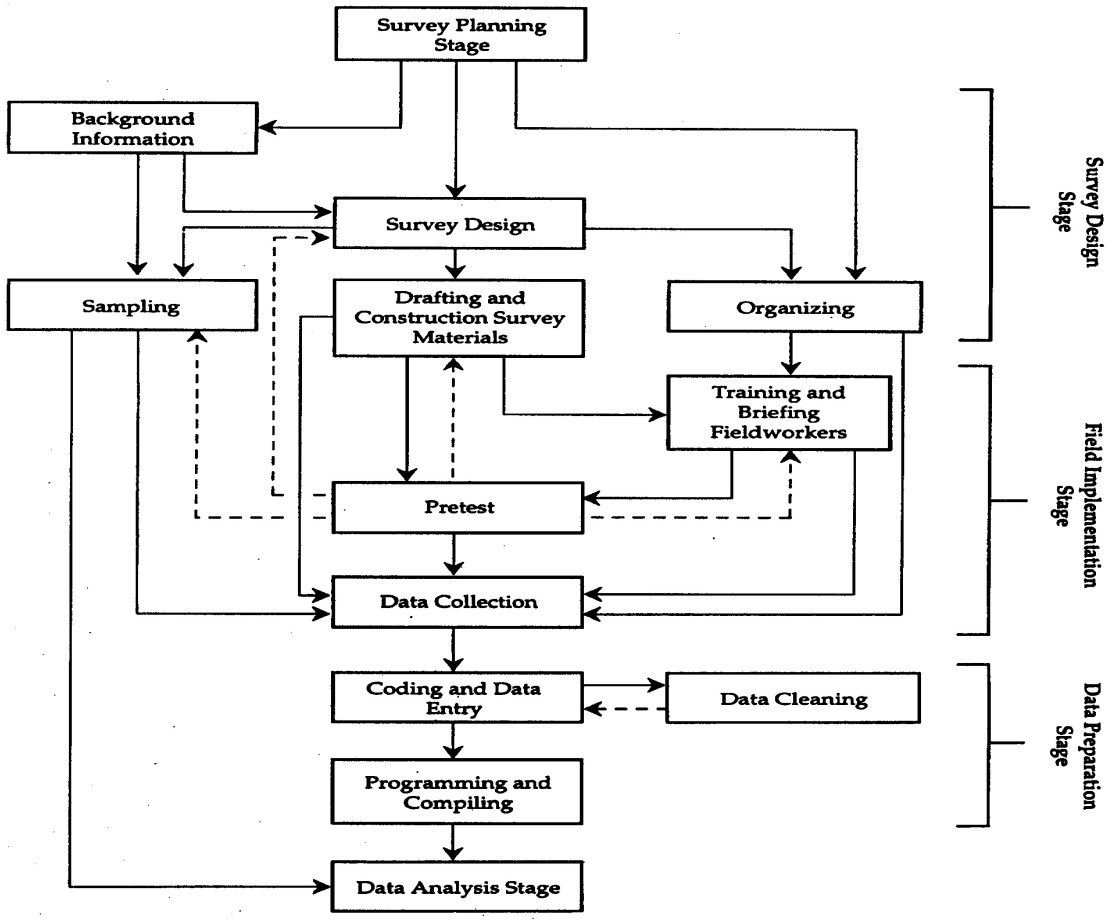

Figure 3.3: The Travel Survey Process (Cambridge Systematics, 1996)

In this manual a full chapter is allocated to discuss sampling methods and it explains statistical methods, sample sizes, sampling errors, sampling biases, etc. in very detail. However, some sections such as questionnaire design were discussed very briefly. Also, there are little comparisons made among different methods used by different agencies and no suggestions for selecting an appropriate method under particular circumstances. Another important issue which was not addressed in this manual is the size and the combination of data collection teams and the effect of age, gender, and ethnic of fieldworkers on the overall result of surveys.

3.3 A Design Manual for On-Board Surveys

Baltes (2002) developed the "how-to manual" that describes the steps to follow when conducting an on-board survey of public transit customers. This how-to manual describes the various components and steps in the on-board transit customer surveying process. It also reported on several other widely used methods for gathering information about public transit customers such as telephone assisted transit interview (CATI), computer assisted personal interviews (CAPI), and standard mail surveys.

Among all on-board survey steps, this report discusses sampling methods and biases in more details. The most interesting part of this report is "questionnaire wording" This study emphasized that on-board survey should avoid 1) ambiguous meaning, 2) biased wording, 3) doubled-barreled questions, 4) double-negatives, 5) hypothetical questions, and 6) acronyms in developing a questionnaire. In "Fieldworkers Training", the report provides some instructions for fieldworkers training material, their work schedule, etc. Some checklists which can be used by transit agencies for controlling all steps of designing and conducting of a survey are presented at the end of the report. These checklists are not seen in Schaller (2005) and Cambridge Systematics (1996). A little comparison among results of previously conducted surveys has been made, but the positive and negative aspects of their methods are missing in this report.

3.4 Instrument Design: Decisions and Procedures

Zmud (2004) developed a report which can be used as a manual to design a questionnaire for an on-board survey. It provides ideas of designing a questionnaire by referring to several surveying references. This report gives different tips to improve every single step of questionnaire design and also identify potential problems in each step.

Factors which may affect the effectiveness of a questionnaire are discussed in this study. These factors are; questionnaire instruction, questionnaire wording, physical layout, design, and ordering of questions. Zmud also discusses the importance of the pre-testing of the questionnaire and survey process before going to field to collect the data. The application of GPS technology for data collection accuracy, data validity, and avoiding under-reporting of trips by respondents is also discussed.

This report suggests several research issues for future directions. One issue is the need for improved measures of data quality to evaluate improvements achieved by different questioning strategies (Zmud, 2004). Another idea is to build in cognitive assessments in order to measure and to test the effects of factors that may influence respondents' performance of trip-related survey items (Zmud, 2004). Another research topic is to test strategies for developing comparative measures of travel behavior across countries. This relates to the ways in which questions are adopted or adapted for use in different countries.

3.5 Case Studies

3.5.1 On-Board Surveys of Los Angeles County Transit Authority (LACTA)

LACTA hired Nustats Company to conduct an on-board survey in December 2006. Due to receiving a lower response rate (20%) than the expected response rate (30%) in the first attempt, Nustats returned and by revising their procedure, started the second round of the survey in January 2007. A self-administered survey by a team of 16 surveyors was conducted. Passenger counter teams were equipped with the hand-held

GPS devices. Spanish questionnaires were also provided and registering to win $100 cash was used as the incentive for this survey.

Among all identified reasons which caused the low response rate, respondents' race was identified as the main factor. It was observed that respondents were extremely reluctant to participate in surveys distributed by surveyors from other races. This must be taken in account in the future surveys by hiring fieldworkers of different races in accordance with the demographics of the survey area. Another reason for the lower response rate could have been the closeness of this survey to the prior customer satisfaction survey conducted right before the survey. This low response rate may result in: 1) increased cost to contractor due to increased hours and more printed questionnaires 2) extension of time 3) shifting resources to routes experiencing low response rate, and 4) survey goals reduction (Nustats, 2007).

Since Nustats had planned all survey steps based on targeted response rate of 30%, at the end of the survey they figured out that assuming an overall response rate of 20% instead of 30% and planning everything based on reaching 20% response rate will help the agency in more accurate estimation of survey hours, number of surveyors, field editing personnel, survey days, and total number of questionnaires. All these factors may result in lower unit cost of the survey.

At the beginning of the survey LACTMA agreed to take the responsibility of Geo-coding, to reduce the scope of Nustats work. But, according to unfavorable result of this experience, after Geo-coding 70% of the survey, Nustats took the responsibility of Geo-coding for the rest of the survey. According to this experience, Nustats recommends in order to reduce contractor's scope of work and reduce the cost of the survey for the

contractor it would be more effective to reduce the overall number of surveys or reduce the survey length instead of taking on some tasks by the client (Nustats, 2007).

3.5.2 Washington State Ferries 2006 Origin/Destination On-Board Survey

In October 2006, Nustats conducted an Origin/Destination on-board survey for Washington State Ferries. The survey took three months in 2006 compared to nine months in the 1999 survey (Cambridge Systematics, 2007). This time saving can be attributed to improved field technologies such as hand-held devices, bar coded questionnaire, scanning in the field and the web-based management system. The use of improved field technology allowed the team to complete the survey in a less time and allowed the delivery of the processed data in a shorter time period.

CHAPTER IV

FIELD TESTS

This chapter provides an overview of Tulsa Transit system, and presents three field test scenarios developed based on the problems identified in the case studies and the literature reviews to expand previous studies. These tests are: 1) length of questionnaire, 2) different incentives, and 3) surveyors. This chapter also discusses all the steps taken to plan, implement, and conduct the survey. All the steps of data collection phase are also discussed in this chapter.

4.1 Tulsa Transit System

Tulsa Transit system, established in 1968, operates the local bus service in Tulsa, Jenks, Broken Arrow and Sand Springs. Tulsa Transit operates with 170 employees and covers 197 square miles of service area with 389,410 populations. The operational vehicles are 60 buses for “Fixed Routes” and 41 vehicles for “Lift Program” that operate on 18 routes (Figure 4.1) providing approximately 8,500 passenger trips a day. There are two main stations in the system, Denver Avenue station and Memorial Midtown station, where all the routes ordinate from and terminate.

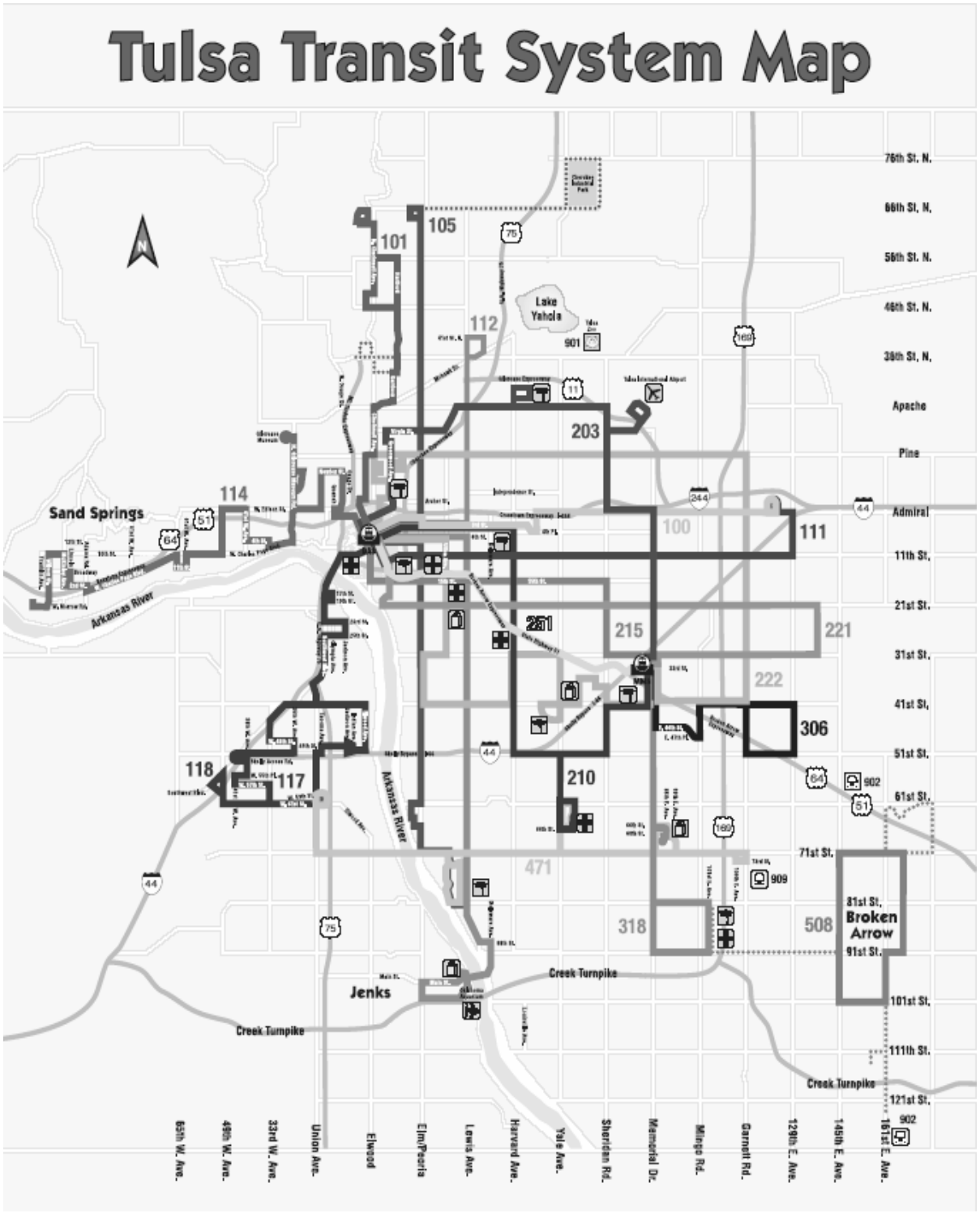

Figure 4.1: Tulsa Transit System Map

The bus service runs from 5:30 a.m. to 7:00 p.m. Monday through Friday and 7:00 a.m. to 6:00 p.m. on Saturday. There is no bus service on Sunday. Tulsa Transit offers limited late-night service on weekdays, which operates until 12:00 midnight.

According to Tulsa Transit survey in 2007 the average Tulsa Transit customer is an African-American female, between the ages of 45 and 54 with a high school education and no children living at home, with average annual income of less than $15,000. Tulsa Transit system conducts on-board surveys every two years to collect data mainly used for their system modeling, customers' satisfaction, and recently for their rail commuter model. In all surveys, Tulsa Transit uses a self-administered survey conducted by using boxes designated for data collection phase and offers a two free-ride ticket as an incentive to complete a questionnaire. Based on the number of completed questionnaires received in Tulsa Transit's survey conducted in 2007 compared to the survey in 2005, a 10.4% decrease (Figure 4.2) in number of participants is noted, which is not a satisfactory trend.

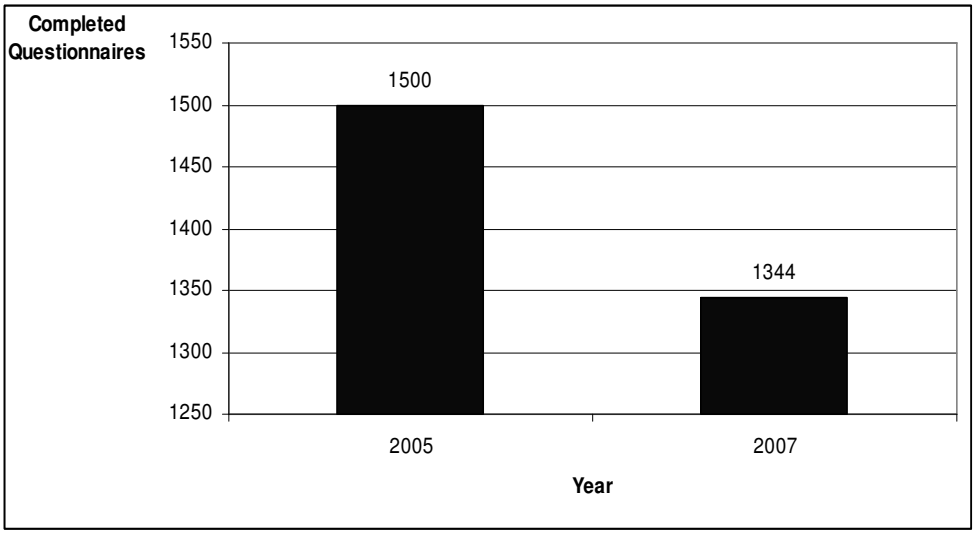

Figure 4.2: Tulsa Transit Surveys Comparison in 2007 and 2005

4.2 Testing Scenarios

Three test scenarios were developed to evaluate the effect of different conducting methods on the response rate, unit cost, and duration of the survey (Table 4.1).

Table 4.1: Testing Scenarios

Scenario	Questionnaire	Number of Questions	Incentive	Surveyor Or No Surveyor
Length of Questionnaire	**A_1**	6	2 Free Rides	No Surveyor (Boxes)
	A_2	14		
	A_3	29		
Incentives	**B_F**	14	2 Free Rides	No Surveyor (Boxes)
	B_D	14	Drawing for 31 day passes	
Surveyors	**C_M**	14	2 Free Rides	Male Surveyor
	C_F	14		Female Surveyor
	C_N	14		Boxes

4.2.1 Scenario A: Length of the questionnaire

This scenario is to test the effect of the length of questionnaire on the response rate of a survey. Tulsa Transit system surveys conducted in years 2003 and 2005 used the same questionnaire consisting of: 1) O/D and trip behavior questions and 2) demographic questions. In the survey conducted in 2007, four rating and six marketing questions were added to the questionnaire, but there was no evidence on how it might affect the response rate of the survey. In order to determine the optimum length of a questionnaire that enables transit systems to attract as many respondents as possible to participate in the survey and improve the response rate, this scenario was selected to be tested.

This scenario has three different questionnaires (see Appendix A) each with a different number of questions. To identify the questionnaires they were coded as: A_1, A_2, and A_3. Questionnaire A_1 has just six essential O/D questions, Questionnaire A_2 has 14

questions including O/D questions enhanced by eight demographic questions, and Questionnaire A_3 is a longer version of A_2 with 29 questions enhanced by 15 marketing and rating questions.

These questionnaires were placed in distribution boxes for one week (5 business days) and a two free-ride ticket was used as an incentive to complete a questionnaire. Respondents were provided with three options to return the completed questionnaire: 1) drop the completed questionnaires in the designated box on the buses, 2) mail back the completed questionnaires to the addresses provided at the end of the questionnaire, and 3) return completed questionnaires to the customer service of Tulsa Transit system.

4.2.2 Scenario B: Different Incentives

This scenario is to test the effect of using different incentives on the response rate and unit cost of a survey. Different transit systems use different incentives to attract their passengers to participate in the survey, but there is no evidence on which incentive may improve the response rate. Tulsa Transit used two incentives in previous surveys: offered a) a two free-ride ticket to complete the questionnaire and b) a drawing to win a 31-days free pass. There is no evidence on which of these two incentives is more attractive.

This test scenario used two questionnaires (see Appendix B) with the same number of questions (14 questions) similar to questionnaire A_2. To identify different questionnaires, they were coded as: B_F and B_D. Questionnaire B_F offers a two free-ride ticket and B_D offers a drawing to win a 31 days free pass. To distribute and collect the questionnaires two boxes were used for a whole week (5 business days).

4.2.3 Scenario C; Surveyors

This scenario is to test the effect of using different options to distribute and collect questionnaires on the response rate, unit cost, and duration of a survey. In all previous surveys, due to lack of human resources, Tulsa Transit Authority used boxes to conduct the data collection phase. As discussed in Chapter II, conducting the data collection phase by surveyors is the most common method used by transit systems, and using boxes for data collection is not a popular method among transit systems. In order to test the effect of using different data collection methods on the response rate, this test scenario was selected.

This scenario had three questionnaires (see Appendix C) the same as questionnaire A_2 with 14 questions. A two free-ride ticket was offered as an incentive to complete each questionnaire for all three questionnaires. To identify different questionnaires they were coded as: C_M, C_F, and C_N. C_M questionnaires were distributed by male surveyors, C_F questionnaires were distributed by female surveyors, and C_N were distributed in boxes. Questionnaires C_M and C_F were distributed within a day, but C_N questionnaires were left in the boxes for a whole week (5 business days).

4.3 Sampling

In order to take a correct sample size for the planned survey, two-stage sampling was applied including: 1) sample routes and 2) respondents' sample size.

To increase the probability of intercepting as many respondents as possible, three busiest routes (Table 4.2) were selected based on Tulsa Transit's 2007 survey. These routes were: 1) route 105, 2) route 222, and 3) route 101.

Table 4.2: Busiest Routes of Tulsa Transit System

Routes	Daily Passenger Trips	Service Area	Fleet Size	Testing Scenarios
105	1600	North Tulsa to South Tulsa	5 off-peak hours- 6 peak hours	A
222	1100	Central Tulsa	3 clock wise – 3 counter clock wise	C
101	925	North Tulsa to Central Tulsa	3 daily – 1 tripper	B

Route 105 is the busiest route in the service area with approximately 1,600 Passenger trips per day connecting north Tulsa to south Tulsa (see Appendix D). Five buses operate during off-peak hours and six buses operate during peak hours (6 a.m. - 9 a.m. and 3 p.m. - 6 p.m.). Route 222 has approximately 1,100 passenger trips per day. Six buses operate in this route, three buses in the clock-wise (CW) direction and three buses in the counter-clock wise (CCW) direction, covering central Tulsa area (see Appendix D). Route 101 has approximately 925 passenger trips per day connecting north Tulsa to central Tulsa via Denver Avenue station (see Appendix D). Three buses operate in route 101, and a tripper bus operates two times a day, the first starts at 9:20 a.m. and the second starts at 3:00 p.m.

Routes 105 and 101 serve two parallel directions and cover areas with similar demographic characteristics. Due to this similarity, and because of similar conducting methods employed for scenarios A and B, these two routes were selected for these testing scenarios. Route 222 serves an area with major schools, health centers, and shopping centers. Since the surveyors for scenario C were all students, and due to passengers' demographic characteristics, it was assumed that selecting this route might increase the probability of intercepting more students and people who might show better cooperation to participate in the survey.

This study was primarily to assess the effect of different conducting methods on the response rate of a survey. Based on the total daily passenger trips of three selected routes combined (Table 4.2), 3625 passengers are using these three routes daily. In order to take an appropriate number of samples, by considering the probability of taking more than one ride per day by some passengers, 2720 questionnaires were printed which was 75% of total daily riders of these three routes. Printed questionnaires were evenly divided for eight developed tests, and each test had 340 questionnaires for the survey.

4.4 Implementation of Field Test

All survey materials including printed questionnaires, boxes, and pens were taken to Tulsa Transits' main office a week before the test day. All the questionnaires were put into designated boxes for each bus with a sign on them instructing passengers to pick up the questionnaires and drop off the completed one in the designated boxes. The size of the boxes was 15"×11"×4" and they were all with lids and in white color. Some advertisements were installed on buses introducing the survey to passengers and inviting them to participate in the survey.

Surveyors were selected from Oklahoma State University (OSU) undergraduate students. Two male and two female surveyors were hired, and they received a short training session on March 7th explaining all steps of the survey, such as: objectives, date, time, routes, and approaching method. Surveyors were also asked to make their summaries regarding their experience and observations from the conducted survey and make suggestions to improve the quality of future surveys.

Tulsa Transit Authority was provided with a complete set of information regarding survey objectives, date, time, and conducting methods. All steps of the survey

were coordinated by the assistant manager of Tulsa Transit system, Mrs. Cynthia Staab. A meeting was set at Tulsa Transit main office with all managers, operators, and drivers from targeted routes on Thursday March 6th to inform them about the March 10th planned survey.

The field test started on Monday March 10th. For the tests which would be conducted by using boxes on routes 101, 105, and a part of 222, all boxes were put on the buses a night before starting day in order to cover early morning riders. The questionnaires were left on the buses for a whole week (5 business days) until Friday March 14th. The deadline to receive completed questionnaires was Friday March 21st.

For scenario C, there were six operational buses on route 222 to cover two directions, clock-wise (cw) and counter-clock wise (ccw). Two of those buses, one from "cw" direction and the other from "ccw" direction, were covered by boxes and the other four buses were covered by surveyors, two by male and two by female surveyors.

The surveying team arrived in Tulsa Memorial Mid Town station at 6:45 a.m. All the surveyors had badges on their shirts introducing them to passengers as surveyors. The assistant manager of Tulsa transit arrived at 6:55 a.m. for the final check up. The first surveyor started at 7:05 a.m. on clock wise bus, the second at 7:20 a.m. on counter clock wise, the third at 8:10 a.m. on clock wise bus, and the fourth one started at 8:20 a.m. on a counter clock wise bus. Before lunch break, each surveyor covered two complete rounds.

Each round took approximately two hours and 15 minutes. After an hour lunch break, surveyors started at 1:30 p.m. to cover afternoon services, and each surveyor covered another two rounds. The data collection for surveyors (plans C_F and C_M) finished at 7:25 p.m. when the last surveyor got off the last bus.

CHAPTER V

SURVEY RESULTS AND ANALYSIS

This chapter statistically analyzes the data collected from field tests and discusses the implications of the results for future on-board transit survey planners. It first presents the results of the collected data phase for all tested scenarios. Second, response rates are statistically compared two-by-two by employing the "Z test for difference in two proportions" method to show the significance of differences between response rates of each pair of tests. Then a logistic regression model will be developed to explain the impact of different scenarios on the overall response rate and statistical significance. Furthermore, based on the logistic regression models developed in this stage, an odds ratio analysis will be performed for each pair of tests to show the "effect size" of each scenario on the response rate. A unit cost comparison will be performed for each test scenario to show the effect of each conducting method on the unit cost of a survey. For scenario C a time analysis will also be performed to show the effect of using surveyors on response rate and duration of the survey compared to using boxes.

5.1 Survey Results

Table 5.1 shows the total number of distributed questionnaires and the number of completed questionnaires and response rate for each test scenario. In computing the response rate, questionnaires which have answered O/D questionnaires were considered as valid complete questionnaires. Response rate is commonly computed by the ratio of the number of completed questionnaires to the number of passengers willing to participate in the survey.

Table 5.1: Survey Results

Scenarios	Questionnaires	Test Description	Distributed Questionnaires	Completed Questionnaires	Response Rates (%)
Length of Questionnaire	A_1	Essential O/D Questions	340	63	18.5
	A_2	O/D & Demographic Questions	340	24	7.1
	A_3	O/D, Demographic, & Marketing	340	25	7.4
Different Incentives	B_F	Two Free-Ride Ticket	340	40	11.8
	B_D	Drawing to Win 31 Days Free Pass	340	68	20
Surveyors	C_M	Male Surveyors	174	119	68.4
	C_F	Female Surveyors	204	159	77.9
	C_N	Boxes	340	72	21.2

For the scenarios other than scenario C (surveyors), the number of passengers who agreed to participate in the survey for each scenario was equal to the total number of questionnaires printed (N=340), as no questionnaires were left in the pick-up boxes at the end of data collection phase.

As mentioned in chapter II, the measure to compare the costs of different surveys is cost per completed questionnaire. In order to do a cost analysis for the test scenarios, all unit costs for test scenarios have been calculated as shown in Table 5.2. Equation 5.1 yields the unit cost for each test scenario.

$$Unit\ Cost_{(i)} = \frac{T_i}{N_i} \qquad \text{(Eq.5.1)}$$

Where,

$Unit\ Cost_{(i)}$ = *Unit Cost of Scenario (i)*

T_i = *Total Cost for Scenario (i)*

N_i = *Number of Completed Questionnaires of Scenario (i)*

Table 5.2: Unit Costs for All Test Scenarios

Cost Items	A_1	A_2	A_3	B_F	B_D	C_M	C_F	C_N
Printing Cost	$18.44	$18.44	$18.44	$18.44	$18.44	$18.44	$18.44	$18.44
Female Surveyors						$300.00		
Male Surveyors							$300.00	
Pens						$5.00	$5.00	
Boxes	$10.00	$10.00	$10.00	$10.00	$10.00			$10.00
Incentives 2 free rides	$126.00	$48.00	$50.00	$80.00		$238.00	$318.00	$144.00
Incentives Drawing 31 days pass					$400.00			
Postage & Envelopes	$31.50	$12.00	$12.50	$20.00	$5.00	$59.50	$79.50	$36.00
Total Cost (T)	$185.94	$88.44	$90.94	$128.44	$433.44	$620.94	$720.94	$208.44
# of Completed Questionnaires (N)	63	24	25	68	40	119	159	72
Cost Per Completed Survey	**$2.95**	**$3.69**	**$3.64**	**$3.21**	**$6.37**	**$5.22**	**$4.53**	**$2.90**

5.2 Z Test for Difference in Two Proportions

Response rate is a proportional type data. To make a comparison of statistical significance between two proportions, the "Z Test for Difference in Two Proportions" method can be used. Z test assist to show whether or not the difference between two proportions is statistically significant. To use this method three assumptions must be met. They are: 1) random sample, 2) independent sample, and 3) large sample ($n \geq 30$). If p_1 and p_2 are proportions of populations 1 and 2, $\hat{p}_1$ and $\hat{p}_2$ are called sample of first and second proportions. By considering x_1 and x_2 as the numbers of successes in sample 1 and

sample 2, and sample sizes of n_1 and n_2, Equation 5.2 yields $\hat{p}_1$ and $\hat{p}_2$. These two values are pooled together into a better estimate of the common proportion shown by $\hat{p}$. Equation 5.3 yields $\hat{p}$. In the "Z Test for the Difference in Two Proportions" the null hypothesis is that the proportions are equal ($P_1=P_2$). The test statistic applied for this method is the Z Test that Equation 5.4 yields the Z value. If the α value (confidence level) is greater than p value ($\alpha > p$) corresponding the Z, then the null hypothesis is rejected and proportions are not equal ($P_1 \neq P_2$).

$$\hat{p}_1 = \frac{x_1}{n_1} \quad , \quad \hat{p}_2 = \frac{x_2}{n_2} \qquad \text{(Eq.5.2)}$$

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2} \qquad \text{(Eq.5.3)}$$

$$Z = \frac{(\hat{p}_1 - \hat{p}_2)}{\sqrt{\hat{p}.(1-\hat{p}).\left[\frac{1}{n_1} + \frac{1}{n_2}\right]}} \qquad \text{(Eq.5.4)}$$

In the current study the sample size is n=340 which is larger than 30, samples are passengers who independently answer the questions, and passengers are randomly selected to participate in the survey. Therefore, all necessary assumptions required to use the "Z Test for Difference in Two Proportions" are met. In order to use this method, the number of completed questionnaires is considered as the number of successes for each test and the number of distributed questionnaires is considered as the sample size for the same test. By plugging these values into the Equations 5.2 to 5.4 the Z value is computed and corresponding p value is pulled out from statistical tables.

All scenarios were analyzed with 95% confidence level ($\alpha = 0.05$) and response rates were compared two-by-two by employing the "Z Test for the Difference in Two Proportions".

5.2.1 Response Rate Comparisons for Test Scenarios

Among three tests under scenario A, the shortest questionnaire (A_1) obtained the highest response rate (18.5%) and A_2 and A_3 obtained very close response rates to each other with noticeable differences from A_1 (Figure 5.1). Overall, passengers were significantly more likely to complete and return questionnaire A_1 than A_2 and A_3. The differences are 11.4 and 11.1 percentage points lower response rates, respectively.

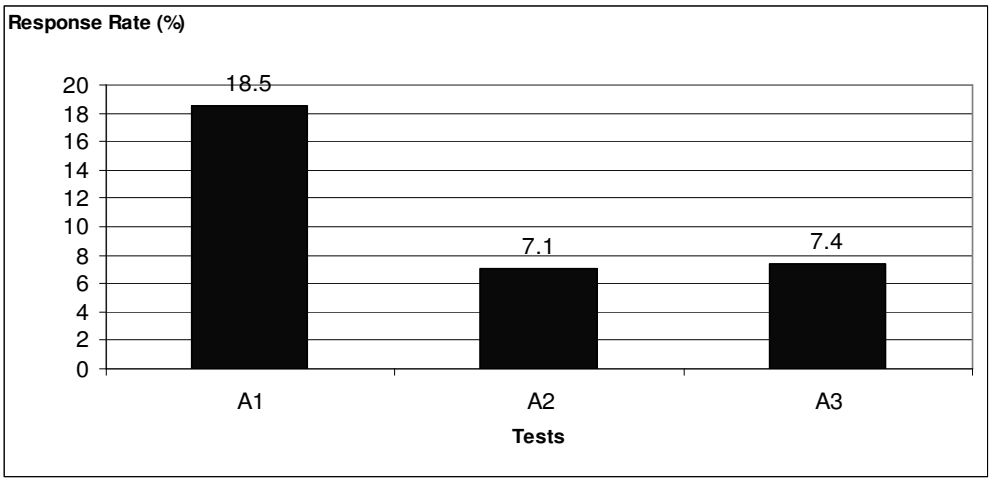

Figure 5.1: Comparison of Response Rates of Test Scenario A

Table 5.3: Z Test Results for the Test Scenario A

Compared Tests	Differences	Z	p	Confidence Interval	Results
A_1 vs. A_2	0.114	4.54	0.0000	(0.065, 0.164)	significant difference
A_1 vs. A_3	0.111	4.4	0.0000	(0.0620, 0.162)	significant difference
A_2 vs. A_3	0.003	-0.15	0.882	(-0.042, 0.036)	Non significant difference

The Z test performed for scenario A (Table 5.3) statistically indicates that there are significant differences in response rate obtained by A_1 compared to A_2 and A_3. Although there is a slight difference between response rates of A_2 and A_3, statistically there is no significant difference between them.

Between the two tests under scenario B, passengers were significantly more likely to complete and return the questionnaires offering a drawing to win a 31 days free pass than a two free-ride ticket. The difference was 8.2 percentage points (Figure 5.2).

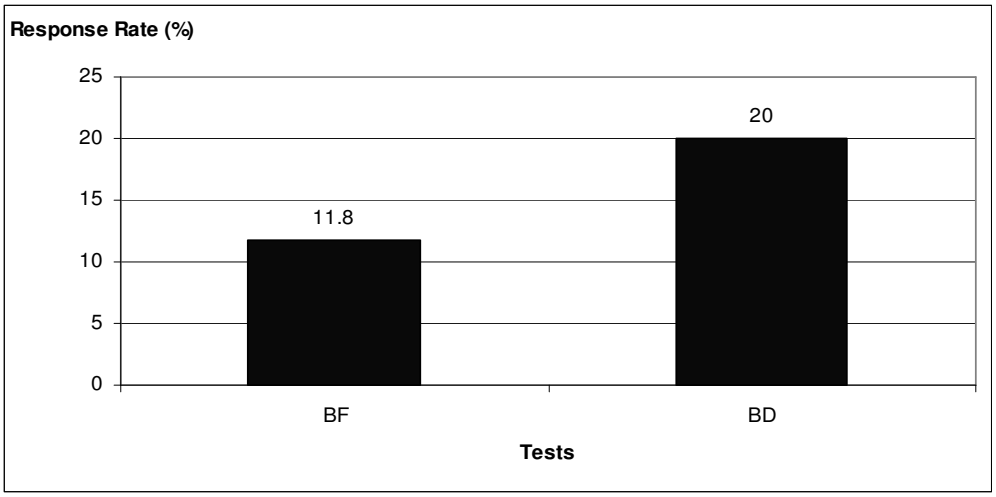

Figure 5.2: Comparison of Response Rates of Test Scenario B

The Z test performed for scenario B (Table 5.4) indicates that statistically there is a significant difference between these two response rates.

Table 5.4: Z Test Results for the Test Scenario B

Compared Tests	Differences	Z	p	Confidence Interval	Result
B_F vs. B_D	0.082	-2.96	0.003	(-0.137, -0.028)	significant difference

Among three tests under scenario C, passengers were significantly more likely to participate in the survey conducted by female surveyors (77.9%) compared to surveys

conducted by male surveyors and using boxes. The differences were 9.5 and 56.7 percentage points, respectively (Figure 5.3). Also, there was a significant difference between the response rates of surveys conducted by male surveyors compared to using boxes. The difference was 47.2 percentage points.

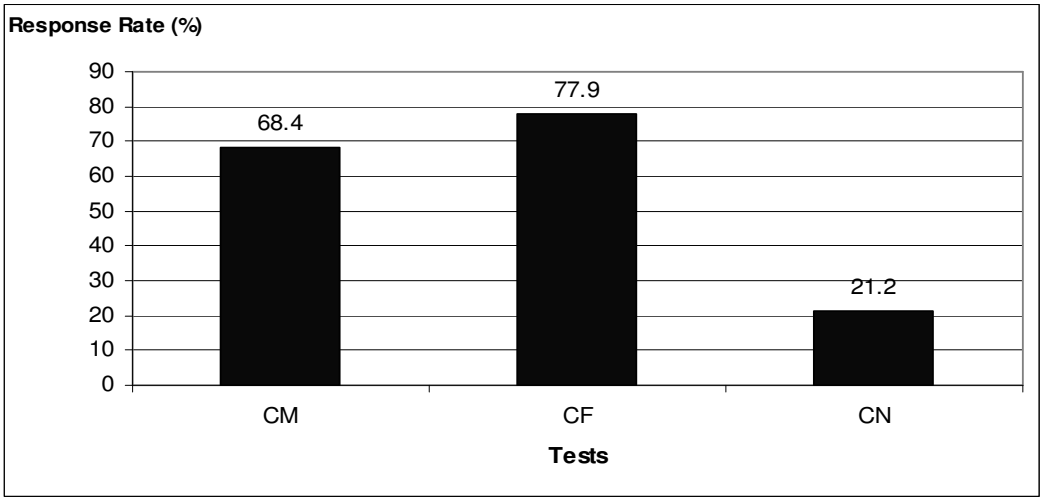

Figure 5.3: Comparison of Response Rates of Test Scenario C

The Z test performed for scenario C (Table 5.5) indicates that using surveyors, either male or female, can achieve a higher response rate than the method using boxes to distribute and collect questionnaires. Statistically, there are significant differences between all pairs of tests. Although male surveyors obtained a noticeable response rate, there is still a significant difference between response rates of female and male surveyors.

Table 5.5: Z Test Results for the Test Scenario C

Compared Tests	Differences	Z	p	Confidence Interval	Results
C_M vs. C_F	0.095	-2.09	0.036	(-0.185, -0.006)	significant difference
C_M vs. C_N	0.472	11.34	0.000	(0.390, 0.554)	significant difference
C_F vs. C_N	0.567	15.54	0.000	(0.496, 0.639)	significant difference

5.3 Cost Analysis

As shown in Table 5.2, unit costs are computed and compared to show the effect of each test scenario on the unit cost of the survey. The unit costs (cost per completed questionnaire) calculated for each test in scenario A show that A_1 is the most cost effective method compared to A_2 and A_3 with 25.8 and 23.4 percentage points lower unit cost, respectively (Figure 5.4). Questionnaires A_3 and A_2 have almost the same unit cost as they are very close in the response rate.

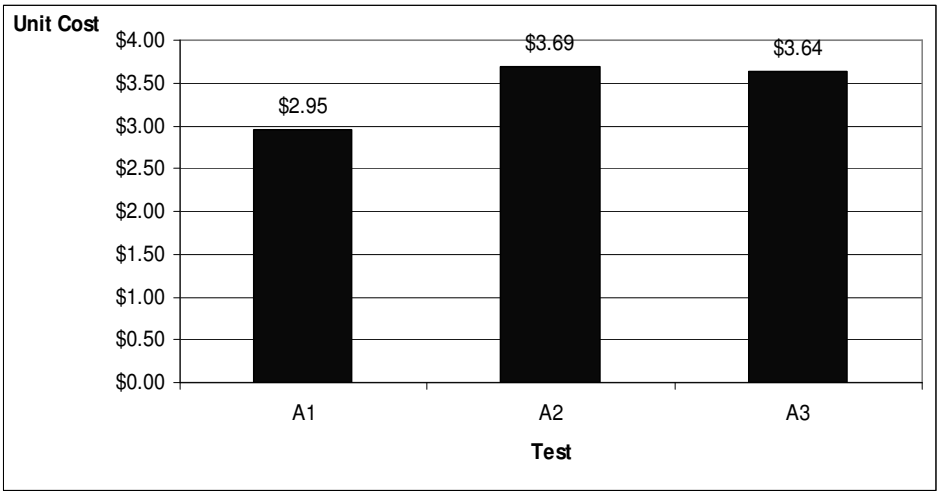

Figure 5.4: Comparison of Unit Costs of Test Scenario A

In scenario B as shown in Figure 5.5, offering a two free-ride ticket to complete a questionnaire is a more cost effective incentive than drawing to win a 31 days free pass. Although offering 31 days free pass has obtained 8.2% higher response rate compared to a two free-ride, it has increased the unit cost of the survey by 98.4 percentage points.

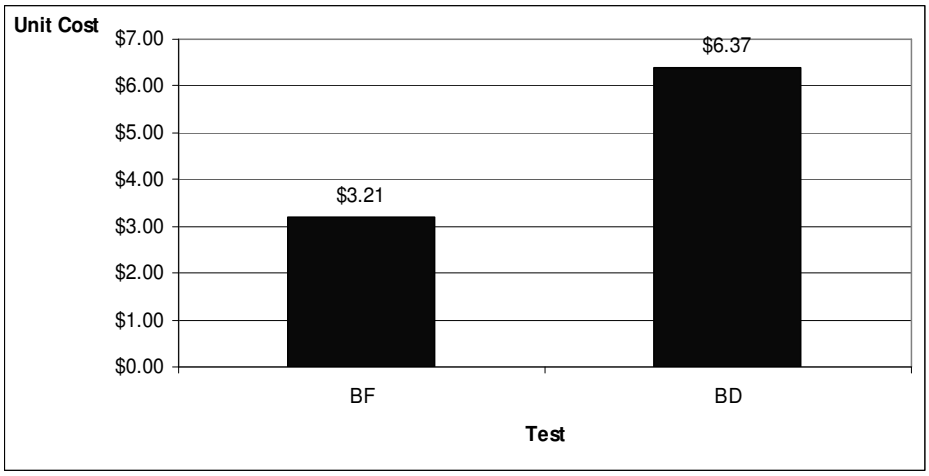

Figure 5.5: Comparison of Unit Costs of Test Scenario B

In scenario C as shown in Figure 5.6, between tests conducted by male and female surveyors, using female surveyors is more cost effective than using male surveyors. But overall, conducting data collection phase by using boxes is the most cost effective method among the three methods used in scenario C. This comparison concludes that although female and male surveyors have obtained 56.7% and 47.2% higher response rates compared to using boxes, they have increased the unit cost of the survey by 56.2% and 80%, respectively.

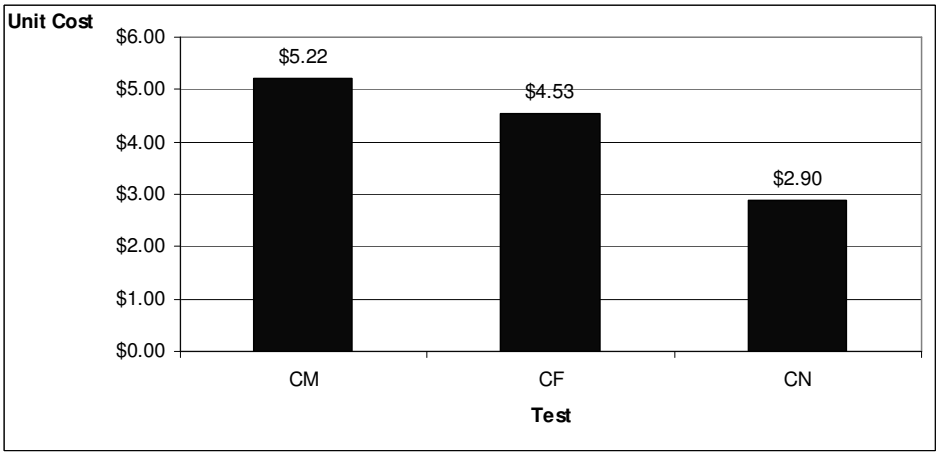

Figure 5.6: Comparison of Unit Costs of Test Scenario C

5.4 Time Analysis for Test Scenario C

As mentioned earlier, male and female surveyors conducted surveys for a whole day, but boxes were left on the buses for a whole week (5 business days) to distribute and collect the questionnaires. To compare and analyze the effect of each test on the duration of the survey the units must be the same. Therefore, the response rate obtained by using boxes is converted to an average daily rate which is 4.24% per day. As it is shown in Figure 5.7, female and male surveyors have obtained 73.7 and 64.2 higher percentage points response rate in one day of conducting the survey compared to using boxes.

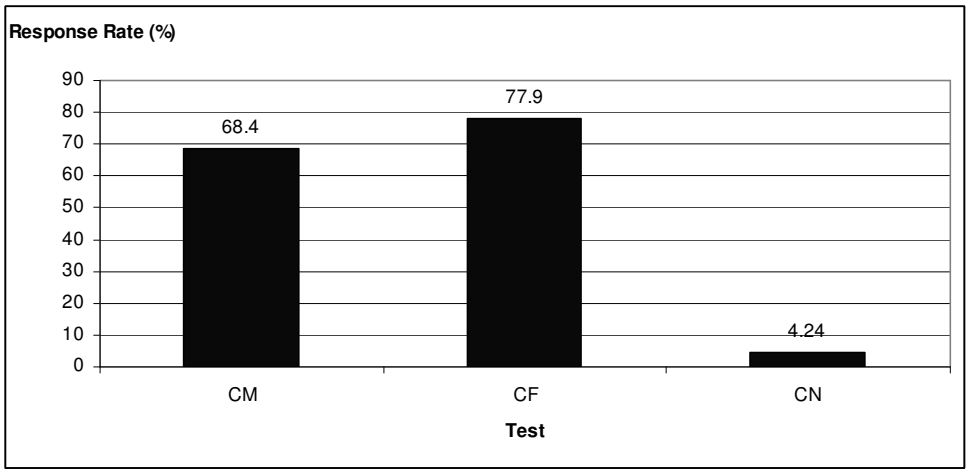

Figure 5.7: Daily Response Rate Comparison of Test Scenario C

5.5 Implications of Results Analysis

Analysis of the results obtained from test scenario A shows if O/D questions in a survey are vital, a short questionnaire by focusing on O/D questions may result in 11.4% and 11.1% higher response rate than longer versions with 14 and 29 questions, while it may decrease the unit cost of the survey by 25.1% and 23.4%, respectively. Since there is no significant differences between the response rates and unit costs of A_2 and A_3, if the

survey planner is planning to collect data for O/D and demographic characteristics, adding marketing and rating questions will not incur extra cost to the survey. This will reduce the need of transit systems to conduct further surveys to collect marketing and rating data and they will benefit from collecting all data by conducting just one survey.

In selecting an appropriate incentive for an on-board survey, this study revealed that an option of offering a drawing to win a 31 days free pass guarantees higher response rate than two free-ride tickets as an incentive by 8.2%. However, an economic feasibility of the survey must be considered to avoid cost overrun due to 98.4% higher unit cost that this incentive incurred to the survey.

Also, when a high response rate is critical, another option to collect the data could be female surveyors. This method may increase the response rate by 9.5% and 56.7% compared to male surveyors and using boxes respectively. Female surveyors may incur 15.2% lower costs than male surveyors and 56.2% higher cost than using boxes to the survey. To achieve a high response rate when survey duration is critical, male surveyors can be an alternative method for female surveyors.

Assuming that a survey planner has freedom to choose the length of questionnaire, incentive, and conducting method the optimum combination of these factors can be made in terms of response rate, survey cost, and duration. The highest response rate can be reached by using questionnaires with essential O/D questions offering a drawing to win 31 day free pass as an incentive which is conducted by female surveyors. The optimum unit cost may be met by using questionnaires with the essential O/D questions offering a two free-ride ticket as an incentive which is conducted by using

boxes. In terms of survey duration, conducting the survey by female surveyors will be the fastest method to reach the targeted response rate under the defined timeframe.

A_2, B_F, and C_N methods are exactly identical methods with the same length of questionnaire and the same incentive used, but under different settings (routes). In order to come up with the best combination of methods to conduct an on-board survey, under each scenario, the response rate obtained by each method is compared to response rate of one of these three methods under the same scenario and is given a score. For example in scenario A, if A_2 is compared to A_2 the score will be 1 ($\frac{A_2}{A_2} = 1$). Now, if A_1 is compared to A_2 the score of A_1 will be 2.6 compared to A_2 ($\frac{A_1}{A_2} = \frac{18.5\%}{7.1\%} = 2.6$). The same approach is taken for all three scenarios and all tests are given a score as shown in Figures 5.8 to 5.10. To rank combinations of methods, the scores of tests making each combination are multiplied and the product is the score of that combination. The larger the score, the higher the ranking is. Table 5.6 shows the scores and rankings of 18 possible combinations of methods. Based on the scores given to each combination, to achieve the highest response rate a survey with six essential O/D questions (A_1) offering a drawing to win 31 days free pass as an incentive conducted by female surveyors can be the best combination to conduct the survey. Alternative combinations can be selected based the ranking shown in Table 5.6.

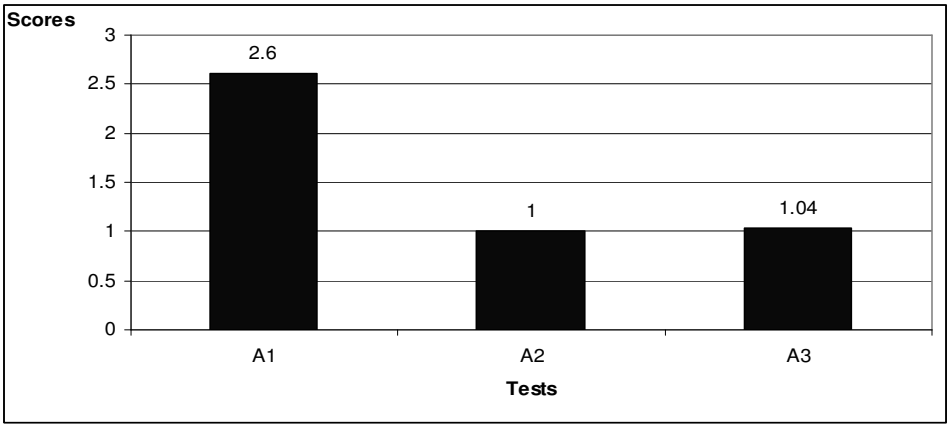

Figure 5.8: Scoring of Test Scenario A Based on Response Rates

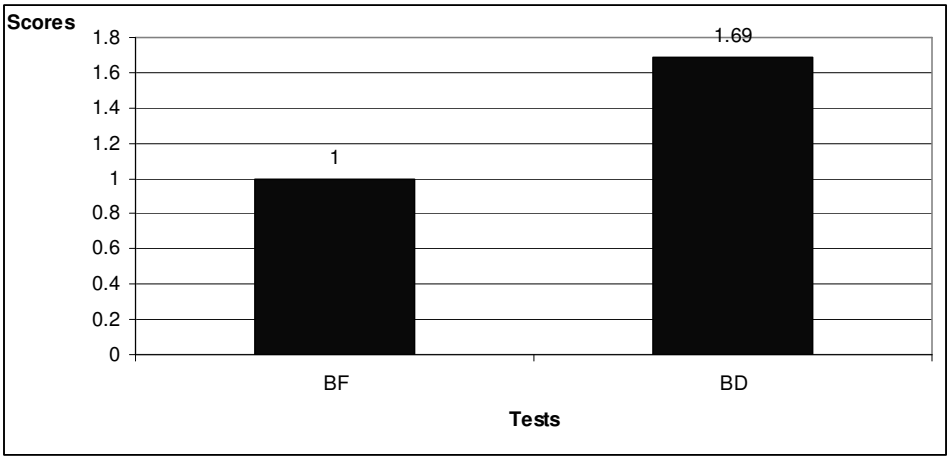

Figure 5.9: Scoring of Test Scenario B Based on Response Rates

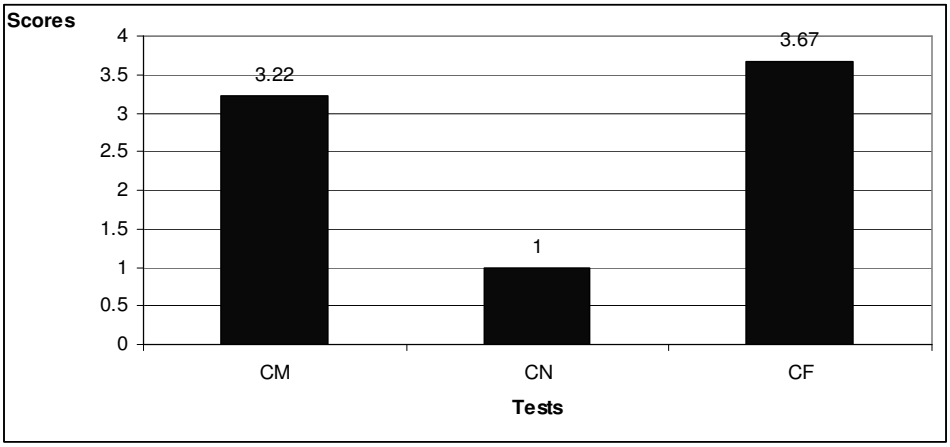

Figure 5.10: Scoring of Test Scenario C Based on Response Rates

Table 5.6: Ranking of Combinations of Methods Based on Response Rates

Ranking	Length of Questionnaire	Incentives	Surveyors	Scores
1	A_1	B_D	C_F	16.12
2	A_1	B_D	C_M	14.15
3	A_1	B_F	C_F	9.54
4	A_1	B_F	C_M	8.38
5	A_3	B_D	C_F	6.45
6	A_2	B_D	C_F	6.2
7	A_3	B_D	C_M	5.7
8	A_2	B_D	C_M	5.44
9	A_1	B_D	C_N	4.4
10	A_3	B_F	C_F	3.82
11	A_2	B_F	C_F	3.7
12	A_3	B_F	C_M	3.35
13	A_2	B_F	C_M	3.22
14	A_1	B_F	C_N	2.6
15	A_3	B_D	C_N	1.8
16	A_2	B_D	C_N	1.7
17	A_3	B_F	C_N	1.04
18	A_2	B_F	C_N	1

To come up with the best combination of methods to conduct a survey in terms of unit cost of the survey, A_2, B_F, and C_N methods are selected as the scales and the same approach is taken to score each combination as it was done for the response rats. But, in this step using unit costs are used instead of the response rates. The smaller the score is, the higher the ranking is. Figures 5.11 to 5.13 show the scores given to each test under different test scenarios.

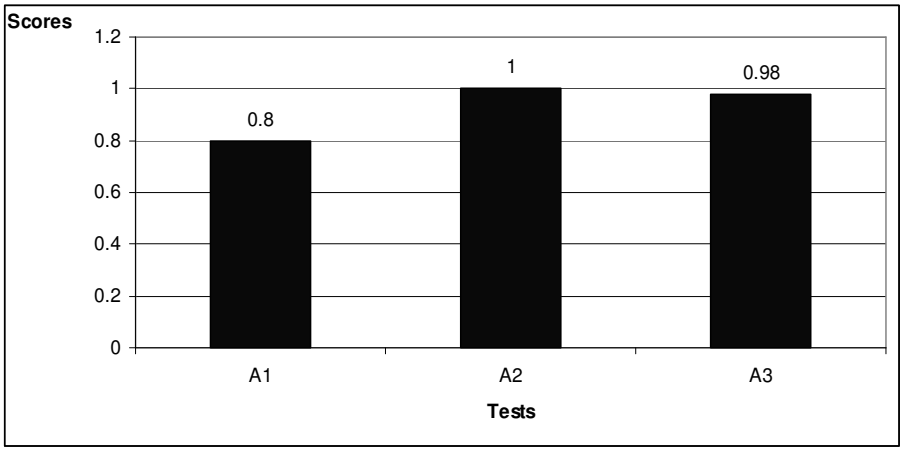

Figure 5.11: Scoring of Test Scenario A Based on Unit Costs

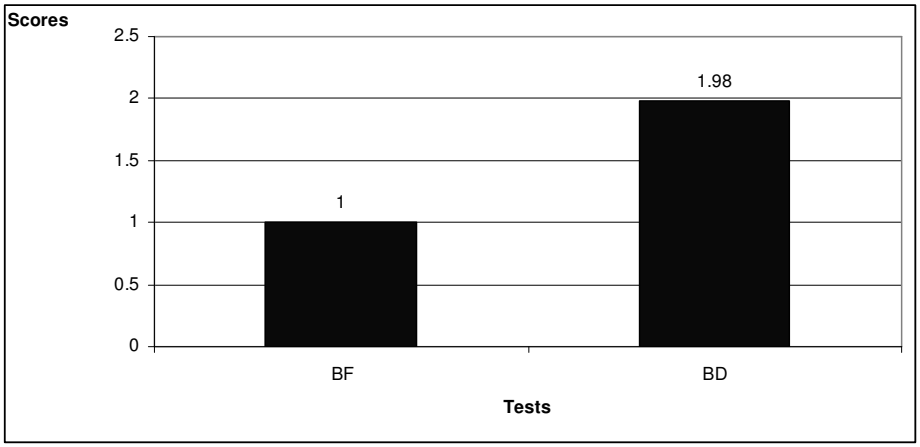

Figure 5.12: Scoring Test Scenario B Based on Unit Costs

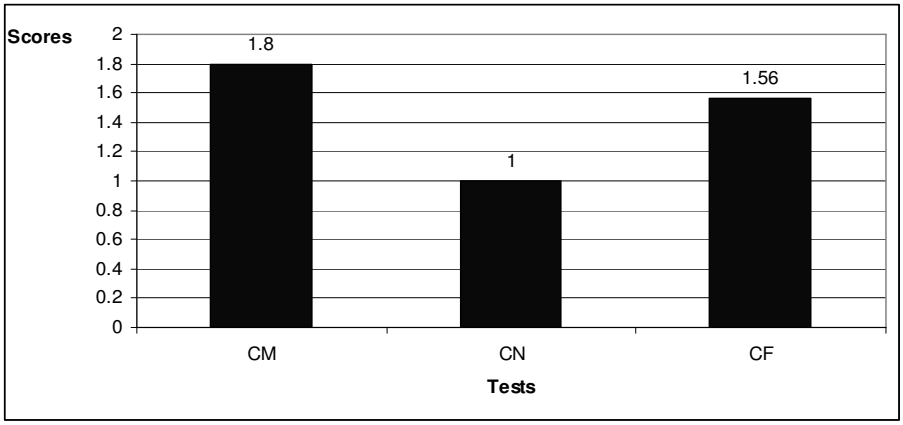

Figure 5.13: Scoring Test Scenario C Based on Unit Costs

Base on the scores given to each combination, the most cost effective combination of methods can be a survey with six essential O/D questions offering a two free-ride ticket as an incentive conducted by using boxes. Alternative combinations of the methods can be selected based on the ranking shown in Table 5.7.

Table 5.7: Ranking of Combinations of Methods Based on Unit Costs

Ranking	Length of Questionnaire	Incentives	Surveyors	Scores
1	A_1	B_F	C_N	0.8
2	A_3	B_F	C_N	0.98
3	A_2	B_F	C_N	1
4	A_1	B_F	C_F	1.25
5	A_1	B_F	C_M	1.44
6	A_3	B_F	C_F	1.53
7	A_2	B_F	C_F	1.56
8	A_1	B_D	C_N	1.58
9	A_3	B_F	C_M	1.76
10	A_2	B_F	C_M	1.8
11	A_3	B_D	C_N	1.94
12	A_2	B_D	C_N	1.98
13	A_1	B_D	C_F	2.47
14	A_1	B_D	C_M	2.85
15	A_3	B_D	C_F	3.02
16	A_2	B_D	C_F	3.1
17	A_3	B_D	C_M	3.5
18	A_2	B_D	C_M	3.56

5.6 Logistic Regression Model

Logistic regression model is a tool used for prediction of the probability of occurrence of an event. It makes use of several predictor variables that may be either numerical or categorical (Agresti, 2002). In this study data can be divided into two categories, one is complete questionnaires and the other one is incomplete or unreturned questionnaires. Therefore, logistic regression model can be applied for the current study. In a regression model the "input" is *logit (p)* (Equation 5.5) and the "output" is *f (logit*

(p)) (Equation 5.6) where *P* is the probability of occurrence of an event and $\frac{p}{1-p}$ is defined as the odds in the favor of that event.

$$Logit\ (p) = \log(\frac{p}{1-p}) = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + ... + \beta_n\chi_n \quad \text{(Eq.5.5)}$$

$$f\,(Logit\ (p)) = \frac{1}{1+e^{-\log it(p)}} \quad \text{(Eq.5.6)}$$

β_0 is called the "intercept" and $\beta_1, \beta_2, \ldots, \beta_n$ are called the "regression coefficients" of $\chi_1, \chi_2, ,\ldots,\ \chi_n$, respectively. The variable *logit (p)* represents the exposure to some set of factors, while *f* (*logit (p)*) represents the probability of a particular outcome, given that set of factors. The variable *logit (p)* is a measure of the total contribution of all the factors used in the model. Each of the regression coefficients describes the size of the contribution of that factor. A positive regression coefficient means the factor increases the probability of the outcome, while a negative regression coefficient means that the factor decreases the probability of that outcome: a large regression coefficient means that the factor strongly influences the probability of that outcome; while a near-zero regression coefficient means that factor has little influence on the probability of that outcome (Agresti, 2002).

In this study all the data are dichotomous data which have response answers of "Yes" or "No". All valid-completed qestionnaires are considered as "Yes" and are given value of 1. Incomplete or unreturned questionnaires are considered as "No" and are given value of 0. Table 5.8 shows all test scenarios with number of "Yes" or "No" answers received in each test.

Table 5.8: Dichotomus Data for Logistic Regression Models

Test Scenarios	Questionnaires	Test Description	# of Responses		Total
			Yes=1	No=0	
Length of Questionnaire	A_1	Essential O/D Questions	63	277	340
	A_2	O/D & Demographic Questions	24	316	340
	A_3	O/D, Demographic, & Marketing	25	315	340
Different Incentives	B_F	Two Free-Ride Ticket	40	300	340
	B_D	Drawing to Win 31 Days Free Pass	68	272	340
Surveyors	C_M	Male Surveyors	119	55	174
	C_F	Female Surveyors	159	45	204
	C_N	Boxes	72	268	340

Since under each test scenario there are at least two variables and data are categorical type data, all assumptions of developing a logistic regression model are met. This model will explain the impact of each test scenario on the response rate of the survey and predict the probability of answering to each questionnaire by considering existing variables. To use the model for each scenario the values of design variables (1,0) are plugged into the model and the probability of answering the questionnaire is predicted by plugging the value *logit (p)* into the Equation 5.6.

Analysis of the developed models will provide the odds ratios which show the "effect size" of different conducting methods on the response rate. The odds ratio is a measure of effect size. It is defined as the ratio of the odds of an event occurring in one group to the odds of it occurring in another group, or to a sample-based estimate of that ratio. These groups might be any other dichotomous classification. If the probabilities of the event in each of the groups are p (first group) and q (second group), then Equation 5.7 yields the odds ratio.

$$\frac{p\ /(1-p)}{q\ /(1-q)} = \frac{p(1-q)}{q(1-p)} \qquad \text{(Eq.5.7)}$$

An odds ratio of 1 indicates that the condition or event under study is equally likely in both groups. An odds ratio greater than 1 indicates that the condition or event is more likely in the first group. And an odds ratio less than 1 indicates that the condition or event is less likely in the first group. The odds ratio must be greater than or equal to zero. As the odds of the first group approaches zero, the odds ratio approaches zero. As the odds of the second group approaches zero, the odds ratio approaches positive infinity (Agresti, 2002).

5.6.1 Logistic Regression Models for Test Scenarios

The logistic regression models (Equations 5.8, 5.9, & 5.10) were developed to predict the probability of answering different questionnaires in each test scenario and show the effect of each method on the response rate of the survey. Based on SAS outputs (see Appendix E), the models were developed by plugging estimates and Intercepts values into Equation 5.2. Table 5.9 shows the value of regression coefficients used for each test to apply developed models in order to estimate the response rates.

$$Logit\ (p_A) = -2.2 + 0.72\chi_1 - 0.38\chi_2 \qquad \text{(Eq.5.8)}$$

$$Logit\ (p_B) = -1.7 + 0.31\chi_3 \qquad \text{(Eq.5.9)}$$

$$Logit\ (p_C) = 0.24 + 1.02\chi_5 + 0.53\chi_6 \qquad \text{(Eq.5.10)}$$

Table 5.9: Design Variables of Different Regression Models

Equations	Design Variables	Selected Method
Eq.5.8	x_1= 0	A_1 is not selected
	x_1= 1	A_1 is selected
	x_1= -1	A_3 is selected
	x_2= 0	A_2 is not selected
	x_2= 1	A_2 is selected
	x_2= -1	A_3 is selected
Eq.5.9	x_3= 0	B_D is not selected
	x_3= 1	B_D is selected
	x_3= -1	B_F is selected
Eq.5.10	x_5= 0	C_M is not selected
	x_5= 1	C_M is selected
	x_5= -1	C_N is selected
	x_6= 0	C_F is not selected
	x_6= 1	C_F is selected
	x_6= -1	C_N is selected

Plugging the value of design variables into the models (Equations 5.8 to 5.10) and then using Equation 5.3 yield the probability of answering each questionnaire (shown in Tables 5.10 to 5.12). For example in scenario A, if x_1=1 it means that A_1 is selected for the test and when x_1=0 it means A_1 is not selected. When x_1= -1, it means that A_3 is selected in this test. In Eq.5.9, since there are two factors to be compared, there is only one regression coefficient in the model and x_4 is not entered in the model.

Table 5.10: Probability of Answering Questionnaires of Test Scenario A

Conducting Methods	Variables		Estimated Response Rates
	x_1	x_2	
A_1	1	0	18.53
A_2	0	1	7.1
A_3	-1	-1	7.4

Table 5.11: Probability of Answering Questionnaires of Test Scenario B

Conducting Methods	Variables		Estimated Response Rates
	x_3	x_4	
$\mathbf{B_D}$	1	0	20
$\mathbf{B_F}$	-1	-1	11.8

Table 5.12: Probability of Answering Questionnaires of Test Scenario C

Conducting Methods	Variables		Estimated Response Rates
	x_5	x_6	
$\mathbf{C_F}$	1	0	77.9
$\mathbf{C_M}$	0	1	68.4
$\mathbf{C_N}$	-1	-1	21.2

5.6.2 Odds Ratio Analysis

Odds ratio analysis results (Table 5.13) indicate that the probability of answering questionnaire A_1 is 2.99 times higher than answering questionnaire A_2 and 2.86 times higher than answering questionnaire A_3. It also shows that the probability of answering questionnaire A_3 is 1.05 times higher than answering questionnaire A_2. Since this ratio is

relatively close to 1, it is be interpreted that the probabilities of answering A_2 and A_3 are almost the same.

If in a survey these three options for the length of the questionnaire are available, this analysis indicates that the shortest version including essential O/D questions (A_1) will have the highest probability to reach the highest response rate. Also, the questionnaire with O/D and demographic questions (14 questions) and the questionnaire with O/D, demographic, marketing, and rating questions (29 questions) will obtain very close response rates. According to this comparison and likelihoods of answering 14 (O/D and demographic) and 29 (O/D, demographic, marketing, and rating) questions by respondents, it can be concluded that the survey planner may conduct a survey with using the longest version of the questionnaire according to the same probability of answering 14 and 29 questions.

Table 5.13: Odds Ratio Comparisons of Scenario A

Compared Methods	**Odds Ratios**
A_1 vs. A_2	2.99
A_1 vs. A_3	2.86
A_3 vs. A_2	1.05

Odds ratio analysis result (Table 5.14) indicates that the probability of answering questionnaire offering a drawing to win a 31 days free pass as an incentive is 1.88 times higher than answering questionnaire offering a two free-ride ticket as an incentive to complete a questionnaire.

If in a survey these two options of incentive are available, offering a drawing to win a 31 days free pass may secure obtaining a higher response rate.

Table 5.14: Odds Ratio Comparisons of Scenario B

Compared Methods	Odds Ratio
B_D vs. B_F	1.88

Odds ratio analysis results (Table 5.15) indicate that the probability of answering questionnaire distributed by female surveyors is 13.15 times higher than answering questionnaire distributed by using boxes and 1.63 times higher than answering questionnaire distributed by male surveyors. It also indicates that the probability of answering questionnaire distributed by male surveyors is 8.05 times higher than answering questionnaire distributed by using boxes. This analysis indicates that if a survey planner has these three options of conducting method, using female surveyors can be the best option to conduct data collection phase.

Table 5.15: Odds Ratio Comparisons of Test Scenario C

Compared Methods	Odds Ratios
C_F vs. C_N	13.15
C_M vs. C_N	8.05
C_F vs. C_M	1.63

Odds ratio analysis indicates that the questionnaire with six essential O/D questions has the highest probability of achieving the highest response rate among three options of length of questionnaire. Questionnaires with 14 and 29 questions have very

close probabilities of achieving a high response rate. Between two incentive options, the drawing to win a 31 days free pass has higher probability of achieving higher response rate. Among three data collection methods, female surveyors have the highest probability of achieving a high response rate while male surveyors have very close probability to achieve a high response rate to female surveyors.

In order to come up with the best combination of methods based on response rates, odds ratios are used to score each combination as it was done in section 5.2. Methods A_2, B_F, and C_N are selected as the scales since they are identical methods used on different routes. Under each scenario, odds of each test are compared to one of above corresponding tests to come up with a score. For example in scenario A, if A_2 is compared with itself the score will be 1 ($\frac{A_2}{A_2} = 1$), but if A1 is compared to A_2, the score of A_1 will be 2.99 ($\frac{A_1}{A_2} = 2.99$). The approach is taken for all other tests. Figures 5.14 to 5.16 show the scores given to each test.

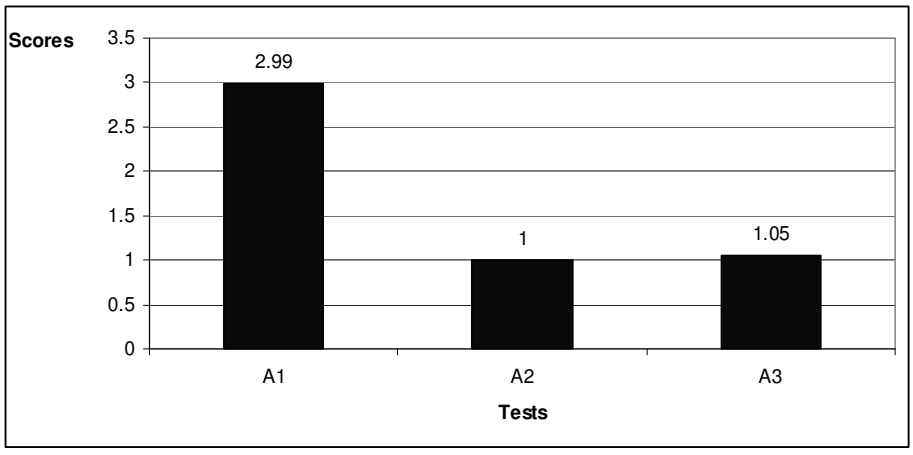

Figure 5.14: Scoring of Test Scenario A Based on Odds Ratios

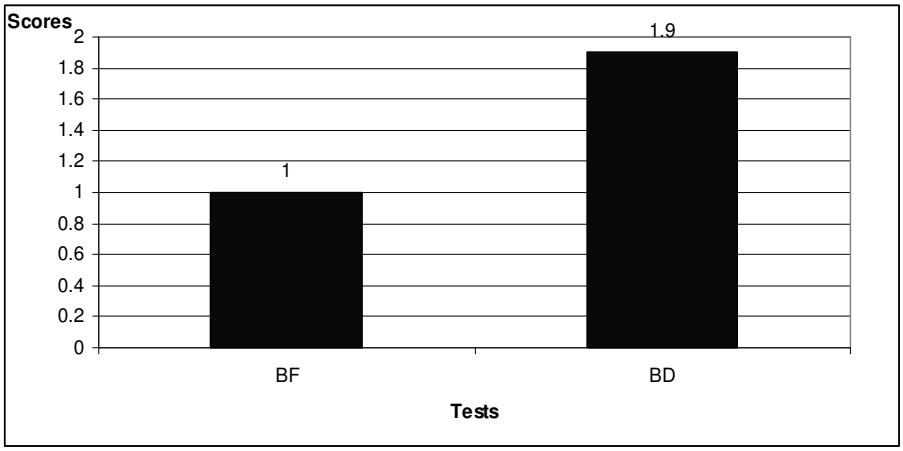

Figure 5.15: Scoring of Test Scenario B Based on Odds Ratios

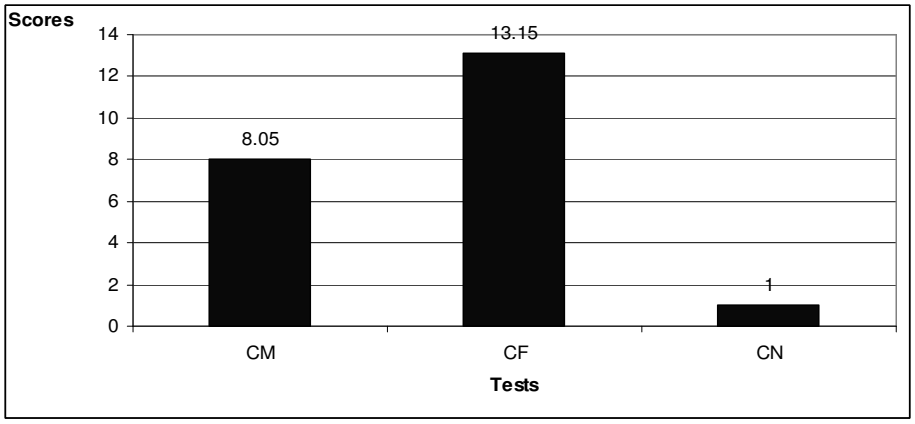

Figure 5.16: Scoring of Test Scenario C Based on Odds Ratios

Based on number of tests conducted, 18 different combinations of methods can be made. The product of multiplying the scores of tests in each combination gives the overall score for the combination. The larger the score, the higher the ranking is. Table 5.16 shows the scores of the combinations and ranking of the combinations based on given scores. According to the ranking shown in Table 5.16, to obtain a high response rate, a survey with six essential O/D questions offering a drawing to win 31 days free

pass conducted by female surveyors can be the best combination of methods. Alternative methods can be selected based on their ranking in this table.

Table 5.16: Ranking of Combinations of Methods Based on Odds Ratios

Ranking	Length of Questionnaire	Incentives	Surveyors	Scores
1	A_1	B_D	C_F	74.7
2	A_1	B_D	C_M	45.7
3	A_1	B_F	C_F	39.3
4	A_3	B_D	C_F	26.2
5	A_2	B_D	C_F	25
6	A_1	B_F	C_M	24.1
7	A_3	B_D	C_M	16.1
8	A_2	B_D	C_M	15.3
9	A_3	B_F	C_F	13.8
10	A_2	B_F	C_F	13.2
11	A_3	B_F	C_M	8.5
12	A_2	B_F	C_M	8.1
13	A_1	B_D	C_N	5.7
14	A_1	B_F	C_N	3
15	A_3	B_D	C_N	2.0
16	A_2	B_D	C_N	1.9
17	A_3	B_F	C_N	1.1
18	A_2	B_F	C_N	1.0

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This chapter first summarizes what has been accomplished in this study and results of statistical analysis of the tests. Second, it discusses the limitations of the study, lessons learned from the field tests, and recommendations to facilitate the process of designing and conducting future surveys for similar studies.

6.1 Summary

Transit systems conduct on-board surveys for current or future planning, system modeling, and customer satisfaction. But in most cases the process of designing and conducting surveys has been developed through trial and errors to come up with better methods and results. There is no comparative assessment providing enough statistical evidence whether or not the modifications in the process are effective and are economically justified.

Tulsa Transit system has been using an old-simple method by using boxes to distribute and collect questionnaires offering two free-ride tickets as an incentive to complete a questionnaire in addition to putting names in a drawing to win a 31 days free-pass. Questionnaires used for these surveys used to have 20 questions which have been increased to 30 questions since 2007. This study has made three empirical comparisons

by conducting tests on three different methods of an on-board transit survey. They are: 1) length of questionnaire, 2) different incentives, and 3) use of surveyors. The context of these tests was based on Tulsa Transit system's survey process to evaluate the effectiveness of each method on the response rate, unit cost, and duration of the survey.

First test was made to determine the optimum length of the questionnaire by considering all vital questions in the questionnaire. Designing the questionnaire based on the main goal of the survey, in most cases origin/destination, and eliminating unnecessary questions could improve the response rate of the survey by 11.4% compared to longer version of the questionnaire with additional demographic questions. It also improved the response rate by 11.1% compared to questionnaire with additional demographic, marketing, and rating questions. Shorter questionnaire allows passengers to complete and return questionnaires while they are still on-board and will reduce the need of providing mail-back service which can also reduce the cost of the survey.

Second test was made by offering two different incentives to assess the effect of these incentives on response rate and unit cost. This study found that passengers are more interested in a drawing to win a 31 days free pass than a two free-ride ticket. This incentive improved the response rate of the survey by 8.2% compared to an option of offering two free-ride tickets. Although drawing to win 31 days free pass improved the response rate, it increased the unit cost of the survey by 98.4%. If a higher response rate is required, offering 31 days free pass is desirable but budget constraints must be considered in order to avoid cost overrun.

The third test was made to assess the efficiency of using surveyors for data collection phase in terms of response rate, cost, and duration of the survey. This test

showed first, using female surveyors improved the response rate of the survey by 56.7% and male surveyors improved the response rate by 47.2% compared to a method of using boxes. Second, the unit cost of the survey by using female surveyors was $4.53 per completed questionnaire which is 56.2% increase compared to the unit cost of using boxes which was $2.90. Also, the unit cost of using male surveyors was $5.22 per completed survey which is 80% increase compared to the unit cost of using boxes. Third, surveyors (males and females) can finish the survey for one day but the method of using boxes required a whole week (5 business days). Converting the response rate obtained by boxes to "average daily response rate" showed female surveyors have obtained 73.7% and male surveyors have obtained 64.2% more response rate for one day survey compared to 4.24% response rate while boxes were used. These results show if a high response rate is critical female surveyors can be the best choice to conduct the survey. When budget constraints exist, the method using boxes still can meet the targeted response rate without cost overrun. If the planner of a survey would reach the targeted response rate under a limited timeframe the method using female surveyors is the best choice and male surveyors would also be considered as an alternative.

Outputs of this study would assist on-board survey planners in selecting an appropriate on-board survey method in terms of the length of questionnaire, incentives, and use of surveyors.

6.2 Limitations and Recommendations

This study could only test three different conducting methods of on-board transit surveys. More tests are still needed to find better methods to improve the response rate, lower the cost of survey, and reduce the duration of survey. These tests can be: wording

and ordering of questions, surveyors' issues (age, race…), and use of newly developed technologies like GPS. These tests may assist to improve the response rate, decrease the cost, and decrease the duration of a survey. The following recommendations can be made to improve the quality of future studies of on-board transit surveys.

1. Conducting a pilot test is vital to identify the weaknesses and shortcomings of a survey. This test can be done under a limited timeframe by taking small number of designed questionnaires to the field to assess the weaknesses and shortcomings of the process. Based on the feedbacks received from respondents, the planner of the survey can assess surveyors' level of expertise, questionnaire design and wording effectiveness, and incentives as well.

2. In this study to test the effect of length of questionnaire on the response rate, three different questionnaires were developed. Another test can be conducted by developing and using more questionnaires with different number of questions. Plotting a curve based on the response rates obtained from different questionnaires will assist to find out the point, where increasing the number of questions does not affect the response rate. The same approach can be taken for the cost analysis to find out where increasing the length of questionnaire doesn't affect the unit cost anymore.

3. In this study to assess the effect of using surveyors on the response rate, two male and two female surveyors were used. In order to come up with a more accurate and reliable analysis, another test may be conducted by using a larger number of

surveyors. Using surveyors from different races can be another issue to be tested in future studies.

4. To evaluate the effectiveness of different incentives in this study, incentives were offered separately on different buses, which means respondents were not aware of that another type of incentive was being offered on the other buses. In order to perform a better assessment, future studies may offer different incentives to respondents concurrently. This gives respondents the freedom of choosing their favorite incentives.

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APPENDICES

APPENDIX A

QUESTIONNAIRES FOR SCENARIO A

A1

Dear Tulsa Transit Customer: March, 2008

At Tulsa Transit, we're committed to making your transit service the best it can be. And now, we're putting you in the driver's seat. Please take a few minutes to help us plan for your transit needs by filling out this survey and we will mail ***2 free rides***. To receive the coupons, you must complete the entire survey and provide your address and name. Only one set of coupons will be mailed to any address.

BUS RIDER SURVEY

Your name and mailing address are required for us to mail you the coupons.

Name:
_____

Mailing address:
_____

_____
(Include apartment #, if applicable, and city, state, zip)

Address of where you live: (if different from above)
_____

_____

Please put an 'X' in the appropriate box for each question or write out your answer as completely and clearly as possible on the lines provided.
Thank you for your time and assistance.
For questions 1-5, please think about the most common trip you make on the bus.

1. Do you begin your most common trip from your home?
   a. ☐ yes.
   b. ☐ No. If not, where does this trip begin?
   (give address or nearest major intersection)
   _____

   _____

2. What is the address (or the nearest major intersection) of the place you tavel to most? (include North, South, East or West. Example: 31st St. & S.Harvard)
   _____

   _____

3. How often do you make this trip riding the bus?
   a. ☐ 5 or more days per week
   b. ☐ 2-4 days per week
   c. ☐ less than 2 days per week

4. How many bus routes do you normally take to reach your final destination?
   a. ☐ One bus route
   b. ☐ Two bus routes
   c. ☐ Three or more bus routes

5. What are the three bus routes (numbers) that you most often ride?
   a. _____ (most frequent)
   b. _____
   c. _____ (Less frequent)

6. How long have you been riding Tulsa Transit?
   a. ☐ Less than 6 months
   b. ☐ Between 6 months and 1 year
   c. ☐ Between 1 year and 5 years
   d. ☐ More than 5 years

Here are three ways you can submit this survey and receive Two free rides:

1. On the bus: put in the box labled "completed surveys"
2. Or mail it to; Tulsa Transit Survey, 510 S.Rockford, Tulsa, 74120
3. Give it to the customer service attendant at Denver Ave. Station or Memorial MidtownStation.

A2

Dear Tulsa Transit Customer: March, 2008

At Tulsa Transit, we're committed to making your transit service the best it can be. And now, we're putting you in the driver's seat. Please take a few minutes to help us plan for your transit needs by filling out this survey and we will mail ***2 free rides***. To receive the coupons, you must complete the entire survey and provide your address and name. Only one set of coupons will be mailed to any address.

BUS RIDER SURVEY

Your name and mailing address are required for us to mail you the coupons.

Name: _____

Mailing address: _____
_____
(Include apartment #, if applicable, and city, state, zip)

Address of where you live: (if different from above)
_____
_____

Please put an 'X' in the appropriate box for each question or write out your answer as completely and clearly as possible on the lines provided. Thank you for your time and assistance.
For questions 1-6, please think about the most common trip you make on the bus.

1. Do you begin your most common trip from your home?
   a. ☐ yes.
   b. ☐ No. If not, where does this trip begin? (give address or nearest major intersection)
   _____
   _____

2. What is the address (or nearest major intersection) of the place you tavel to most? (include North, South, East or West. Example: 31st St. & S.Harvard)
   _____
   _____

3. How often do you make this trip riding the bus?
   a. ☐ 5 or more days per week
   b. ☐ 2-4 days per week
   c. ☐ less than 2 days per week

4. What is the purpose of your most common bus trip?
   a. ☐ commuting to or from work
   b. ☐ personal business/medical appointment
   c. ☐ school/ college
   d. ☐ shopping
   e. ☐ social/recreational purposes
   f. ☐ other (please specify) _____

5. How many bus routes do you normally take to reach your final destination?
   a. ☐ One bus route
   b. ☐ Two bus routes
   c. ☐ Three or more bus routes

6. What are the three bus routes (numbers) that you most often ride?
   a. _____ (most frequent)
   b. _____
   c. _____ (Less frequent)

7. How long have you been riding Tulsa Transit?
   a. ☐ Less than 6 months
   b. ☐ Between 6 months and 1 year
   c. ☐ Between 1 year and 5 years
   d. ☐ More than 5 years

8. Which type of fare payment do you normally use?
   a. ☐ $ 1.25 Adult cash fare
   b. ☐ $ 1.00 Youth cash fare
   c. ☐ $ .60 Senior/Medicare cash fare
   d. ☐ $ .60 Disable persons cash fare
   e. ☐ $ 1.50 Express cash fare
   f. ☐ Adult 31-Day pass
   g. ☐ reduced fare 31-Day pass
   h. ☐ Local 10-ride fare card
   i. ☐ Express 10-ride fare card
   j. ☐ Reduced fare 10-ride fare card
   k. ☐ Youth 10-ride fare card
   l. ☐ $ 3 day pass
   m. ☐ $ 1.50 Reduced day pass
   n. ☐ Free-Super Senior
   o. ☐ Token or 2-ride Special ticket

9. How many motor vehicles are available to members of your household?
   a. ☐ None b. ☐ 1 c. ☐ 2
   d. ☐ 3 e. ☐ 4 or more

10. Including yourself, how many people over the age of 18 live in your household?
    a. ☐ 1 b. ☐ 2 c. ☐ 3 d. ☐ 4
    e. ☐ 5 or more

11. You are :
    a. ☐ Female b. ☐ Male

12. Your age:
    a. ☐ Under 18
    b. ☐ 18-24
    c. ☐ 25-34
    d. ☐ 35-44
    e. ☐ 45-54
    f. ☐ 55-64
    g. ☐ 65 or older

13. What is your estimated "TOTAL HOUSEHOLD INCOME" before tax?
    a. ☐ Under $15,000
    b. ☐ $15,000- $24,999
    c. ☐ $25,000- $34,999
    d. ☐ $35,000- $49,999
    e. ☐ $50,000- $74,999
    f. ☐ $75,000- $99,999
    g. ☐ $100,000 or more

14. What is your Race/Ethnicity? (only one)
    a. ☐ African American
    b. ☐ Caucasian/White
    c. ☐ Hispanic/Latino
    d. ☐ Native American
    e. ☐ Oriental/Asian
    f. ☐ Other:_____

Here are three ways you can submit this survey and receive Two free rides:

1. On the bus: put in the box labled "completed surveys"
2. mail it to; Tulsa Transit Survey, 510 S.Rockford, Tulsa, 74120
3. Or Give it to the customer service attendant at Denver Ave. Station or Memorial MidtownStation.

TULSA TRANSIT

A3

Dear Tulsa Transit Customer: March, 2008

At Tulsa Transit, we're committed to making your transit service the best it can be. And now, we're putting you in the driver's seat. Please take a few minutes to help us plan for your transit needs by filling out this survey and we will mail ***2 free rides***. To receive the coupons, you must complete the entire survey and provide your address and name. Only one set of coupons will be mailed to any address.

BUS RIDER SURVEY

Your name and mailing address are required for us to mail you the coupons.
Please print clearly so we can send the coupons to the correct address.

Name: _____

Mailing address: _____
_____
(Include apartment #, if applicable, and city, state, zip)

Address of where you live: (if different from above)
_____
_____

Please put an 'X' in the appropriate box for each question or write out your answer as completely and clearly as possible on the lines provided. Thank you for your time and assistance.
For questions 1-6, please think about the most common trip you make on the bus.

1. Do you begin your most common trip from your home?
   a. ☐ yes.
   b. ☐ No. If not, where does this trip begin? (give address or nearest major intersection)
   _____
   _____

2. What is the address (or nearest major intersection) of the place you tavel to most? (include North, South, East or West. Example: 31st St. & S.Harvard)
   _____
   _____

3. How often do you make this trip riding the bus?
   a. ☐ 5 or more days per week
   b. ☐ 2-4 days per week
   c. ☐ less than 2 days per week

4. What is the purpose of your most common bus trip?
   a. ☐ commuting to or from work
   b. ☐ personal business/medical appointment
   c. ☐ school/ college
   d. ☐ shopping
   e. ☐ social/recreational purposes
   f. ☐ other (please specify) _____

5. Which type of fare payment do you normally use?
   a. ☐ $ 1.25 Adult cash fare
   b. ☐ $ 1.00 Youth cash fare
   c. ☐ $ .60 Senior/Medicare cash fare
   d. ☐ $ .60 Disable persons cash fare
   e. ☐ $ 1.50 Express cash fare
   f. ☐ Adult 31-Day pass
   g. ☐ reduced fare 31-Day pass
   h. ☐ Local 10-ride fare card
   i. ☐ Express 10-ride fare card
   j. ☐ Reduced fare 10-ride fare card
   k. ☐ Youth 10-ride fare card
   l. ☐ $ 3 day pass
   m. ☐ $ 1.50 Reduced day pass
   n. ☐ Free-Super Senior
   o. ☐ Token or 2-ride Special ticket

6. How many bus routes do you normally take to reach your final destination?
   a. ☐ One bus route
   b. ☐ Two bus routes
   c. ☐ Three or more bus routes

7. What are the three bus routes (numbers) that you most often ride?
   a. _____ (most frequent)
   b. _____
   c. _____ (Less frequent)

8. Which ONE of the following reasons was <u>most important</u> in your decision to first start riding TulsaTransit? (please choose only one)
   a. ☐ Don't have car available
   b. ☐ Avoid traffic congestion
   c. ☐ Save money over the driving/High gas prices
   d. ☐ Avoid cost of parking
   e. ☐ My company pays for my pass
   f. ☐ Reduce air polution
   g. ☐ Avoid construction on highways/roads
   h. ☐ Relax while traveling on Tulsa Transit
   i. ☐ Being productive and working while riding

9. Which ONE of these improvements whould encourage you to ride Tulsa Transit more often? (please choose only one)
   a. ☐ More frequent service
   b. ☐ More express or limited stop service
   c. ☐ Fewer transfers to reach final destination
   d. ☐ More locations served
   e. ☐ Sunday service
   f. ☐ More evening/late night service
   g. ☐ More Saturday service
   h. ☐ More crosstown service which doesn't require traveling through downtown
   i. ☐ other _____

10. How long have you been riding Tulsa Transit?
    a. ☐ Less than 6 months
    b. ☐ Between 6 months and 1 year
    c. ☐ Between 1 year and 5 years
    d. ☐ More than 5 years

11. Are you familiar with Tulsa Transit's EZ Rider Discount Program?
    ☐ No

    ☐ Yes => Do you take advantage of the discounts at area merchants?
    ☐ Yes ☐ No

12. Please check only the following statements that apply to you:
    a. ☐ I have access to the internet at home or work
    b. ☐ I have a cell phone
    c. ☐ I have a cell phone with internet access

(Continued on back)

A3

13. Have you been on Tulsa Transit's website (www.TulsaTransit.org) to get informatio
☐ No
☐ Yes => how often do you logon to www.TulsaTransit.org for information?
a. ☐ Everyday
b. ☐ A few times a week
c. ☐ A few times a month
d. ☐ A few times a year

Think about your recent bus trips. How would you rate Tulsa Transit on the items listed below? Please rate each item on a scale of 1 to 5.
(1= poor & 5= Excellent)

14. Tulsa Transit Bus Driver performance
Bus Driver Courtesy 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Driver's safe Operation of the bus
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

15. Comfort
Cleanliness of bus interior including seats and floors
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

16. Customer Information
Accuracy of information provided Tulsa Transit Call Center staff
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
or 6 ☐ Don't know
Ease of reading schedules
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Getting information from our website- www.TulsaTransit.org
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
or 6 ☐ Don't know

17. Denver Avenue Station
Safety 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5☐
Cleanliness of facility1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

18. Which of the following do you regularly read? (Mark an 'X' by that apply)
a. ☐ Riders Digest Newsletter
b. ☐ Tulsa Transit schedule book
c. ☐ Advertising inside bus
d. ☐ Advertising om exterior of bus
e. ☐ Bus bench adevrtising

19. What category best describes your current occupation?
a. ☐ Professional/Managerial
b. ☐ Laborer/Craftsman
c. ☐ Sales/Clerical/Service
d. ☐ Student (only)
e. ☐ Student/Employed
f. ☐ Retired
g. ☐ Homemaker
h. ☐ Disabled-Unable to work
i. ☐ Unemployed
j. ☐ Other _____

20. How many motor vehicles are available to members of your household?
a. ☐ One
b. ☐ Two
c. ☐ Three
d. ☐ Four or more
e. ☐ None

21. Is a car or other motor vehicle available to you at the time your ride the bus?
a. ☐ Yes as a driver
b. ☐ Yes as a passenger
c. ☐ No

22. You are :
a. ☐ Female b. ☐ Male

23. Your age:
a. ☐ Under 18
b. ☐ 18-24
c. ☐ 25-34
d. ☐ 35-44
e. ☐ 45-54
f. ☐ 55-64
g. ☐ 65 or older

24. How many children (under 18) live in your household?_____

25. How many persons over the age of 65 live in your household?_____

26. How many persons with disabilities live in your household?_____

27. What is the highest level of formal education you have completed?
a. ☐ Less than 12 years
b. ☐ High school graduate
c. ☐ Some college
d. ☐ College graduate
e. ☐ Post graduate degree

28. What is your Race/Ethnicity? (only one)
a. ☐ African American
b. ☐ Caucasian/White
c. ☐ Hispanic/Latino
d. ☐ Native American
e. ☐ Oriental/Asian
f. ☐ Other:_____

29. What is your estimated "TOTAL HOUSEHOLD INCOME" before tax?
a. ☐ Under $15,000
b. ☐ $15,000- $24,999
c. ☐ $25,000- $34,999
d. ☐ $35,000- $49,999
e. ☐ $50,000- $74,999
f. ☐ $75,000- $99,999
g. ☐ $100,000 or more

Here are three ways you can submit this survey and receive Two free rides:

1. On the bus: put in the box labled "completed surveys"
2. Or mail it to; Tulsa Transit Survey, 510 S.Rockford, Tulsa, 74120
3. Give it to the customer service attendant at Denver Ave. Station or Memorial MidtownStation.

TULSA TRANSIT

APPENDIX B

QUESTIONNAIRES FOR SCENARIO B

BF

Dear Tulsa Transit Customer: March, 2008

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BUS RIDER SURVEY

Your name and mailing address are required for us to mail you the coupons.

Name: _____

Mailing address: _____

_____

(Include apartment #, if applicable, and city, state, zip)

Address of where you live: (if different from above)

_____

_____

Please put an 'X' in the appropriate box for each question or write out your answer as completely and clearly as possible on the lines provided. Thank you for your time and assistance.
For questions 1-6, please think about the most common trip you make on the bus.

1. Do you begin your most common trip from your home?
   a. ☐ yes.
   b. ☐ No. If not, where does this trip begin? (give address or nearest major intersection)
   _____
   _____

2. What is the address (or nearest major intersection) of the place you tavel to most? (include North, South, East or West. Example: 31st St. & S.Harvard)
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   _____

3. How often do you make this trip riding the bus?
   a. ☐ 5 or more days per week
   b. ☐ 2-4 days per week
   c. ☐ less than 2 days per week

4. What is the purpose of your most common bus trip?
   a. ☐ commuting to or from work
   b. ☐ personal business/medical appointment
   c. ☐ school/ college
   d. ☐ shopping
   e. ☐ social/recreational purposes
   f. ☐ other (please specify) _____

5. How many bus routes do you normally take to reach your final destination?
   a. ☐ One bus route
   b. ☐ Two bus routes
   c. ☐ Three or more bus routes

6. What are the three bus routes (numbers) that you most often ride?
   a. _____ (most frequent)
   b. _____
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7. How long have you been riding Tulsa Transit?
   a. ☐ Less than 6 months
   b. ☐ Between 6 months and 1 year
   c. ☐ Between 1 year and 5 years
   d. ☐ More than 5 years

8. Which type of fare payment do you normally use?
   a. ☐ $ 1.25 Adult cash fare
   b. ☐ $ 1.00 Youth cash fare
   c. ☐ $ .60 Senior/Medicare cash fare
   d. ☐ $ .60 Disable persons cash fare
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   f. ☐ Adult 31-Day pass
   g. ☐ reduced fare 31-Day pass
   h. ☐ Local 10-ride fare card
   i. ☐ Express 10-ride fare card
   j. ☐ Reduced fare 10-ride fare card
   k. ☐ Youth 10-ride fare card
   l. ☐ $ 3 day pass
   m. ☐ $ 1.50 Reduced day pass
   n. ☐ Free-Super Senior
   o. ☐ Token or 2-ride Special ticket

9. How many motor vehicles are available to members of your household?
   a. ☐ None b. ☐ 1 c. ☐ 2
   d. ☐ 3 e. ☐ 4 or more

10. Including yourself, how many people over the age of 18 live in your household?
    a. ☐ 1 b. ☐ 2 c. ☐ 3 d. ☐ 4
    e. ☐ 5 or more

11. You are :
    a. ☐ Female b. ☐ Male

12. Your age:
    a. ☐ Under 18
    b. ☐ 18-24
    c. ☐ 25-34
    d. ☐ 35-44
    e. ☐ 45-54
    f. ☐ 55-64
    g. ☐ 65 or older

13. What is your estimated "TOTAL HOUSEHOLD INCOME" before tax?
    a. ☐ Under $15,000
    b. ☐ $15,000- $24,999
    c. ☐ $25,000- $34,999
    d. ☐ $35,000- $49,999
    e. ☐ $50,000- $74,999
    f. ☐ $75,000- $99,999
    g. ☐ $100,000 or more

14. What is your Race/Ethnicity? (only one)
    a. ☐ African American
    b. ☐ Caucasian/White
    c. ☐ Hispanic/Latino
    d. ☐ Native American
    e. ☐ Oriental/Asian
    f. ☐ Other:_____

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TULSA TRANSIT

BD

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BUS RIDER SURVEY

Your name and mailing address are required for us to mail you the coupons.

Name: _____

Mailing address: _____
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(Include apartment #, if applicable, and city, state, zip)

Address of where you live: (if different from above)
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11. You are :
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12. Your age:
    a. ☐ Under 18
    b. ☐ 18-24
    c. ☐ 25-34
    d. ☐ 35-44
    e. ☐ 45-54
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    f. ☐ $75,000- $99,999
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TULSA TRANSIT

APPENDIX C

QUESTIONNAIRES FOR SCENARIO C

CF

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Mailing address: _____
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   a. ☐ 5 or more days per week
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    a. ☐ Under 18 e. ☐ 45-54
    b. ☐ 18-24 f. ☐ 55-64
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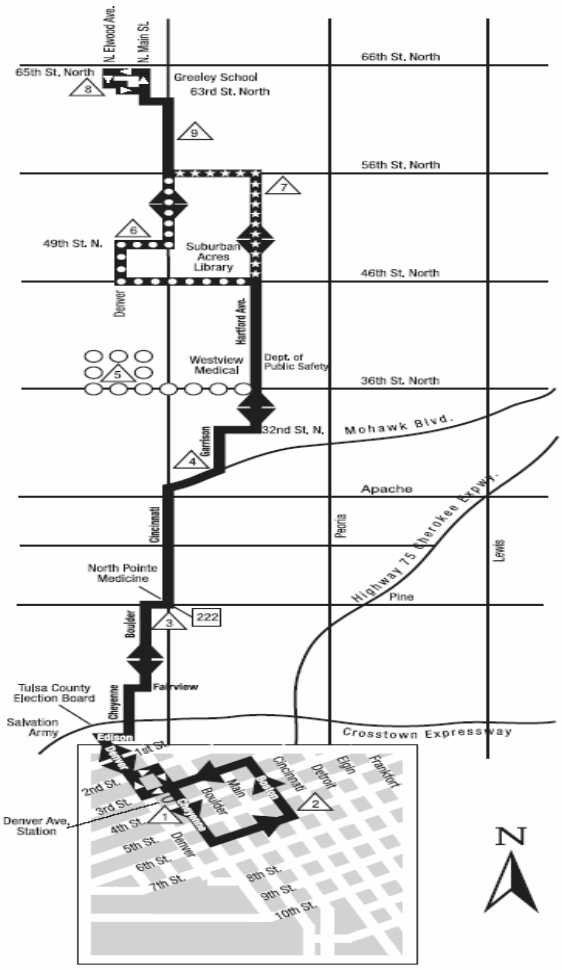
TULSA TRANSIT

APPENDIX D

Tulsa Transit System Routes 101, 105, and 222 Maps

101 SUBURBAN ACRES

MONDAY - FRIDAY / SATURDAY



- Dept. of Public Safety
- Greeley School
- North Point Medicine
- Salvation Army
- Suburban Acres Library
- Tulsa County Election Board
- Westview Medical Clinic

Timing Point (see Timetables on this schedule. Timing points with two times denote both arrival and departure times.)

Intersecting Routes

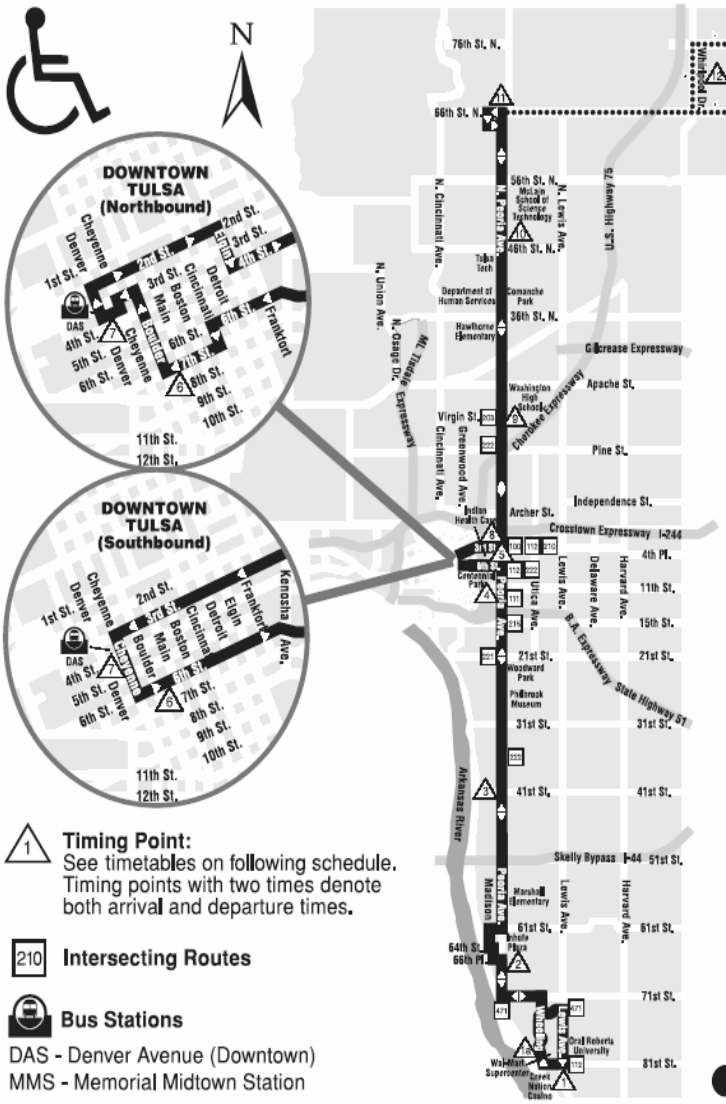
Mid-day Service Weekday Only

Route travels on 46th St. North & Denver

Route travels on Hartford & 56th St. North

(Alternate routes shown on Map and Timetables)

105 PEORIA • *MONDAY - FRIDAY / SATURDAY*



Service to Cherokee Industrial Park is Monday through Friday only. Not all trips will travel to Cherokee Industrial Park.

- Brookside Commercial District
- Cherokee Industrial Park
- Comanche Park
- Creek Nation Casino
- Dept. of Human Services
- Hawthorne Elementary
- Indian Health Care
- James Inhofe Plaza
- Marriott Hotel
- Marshall Elementary
- McLain Shopping Center
- Oral Roberts University
- Philbrook Museum
- Seminole Hills Shopping Center
- McLain School of Science Technology
- Tulsa Technology Center
- Wal-Mart Supercenter
- Washington High School
- Woodward Park

Note: 105 pulls into Wal-Mart lot.

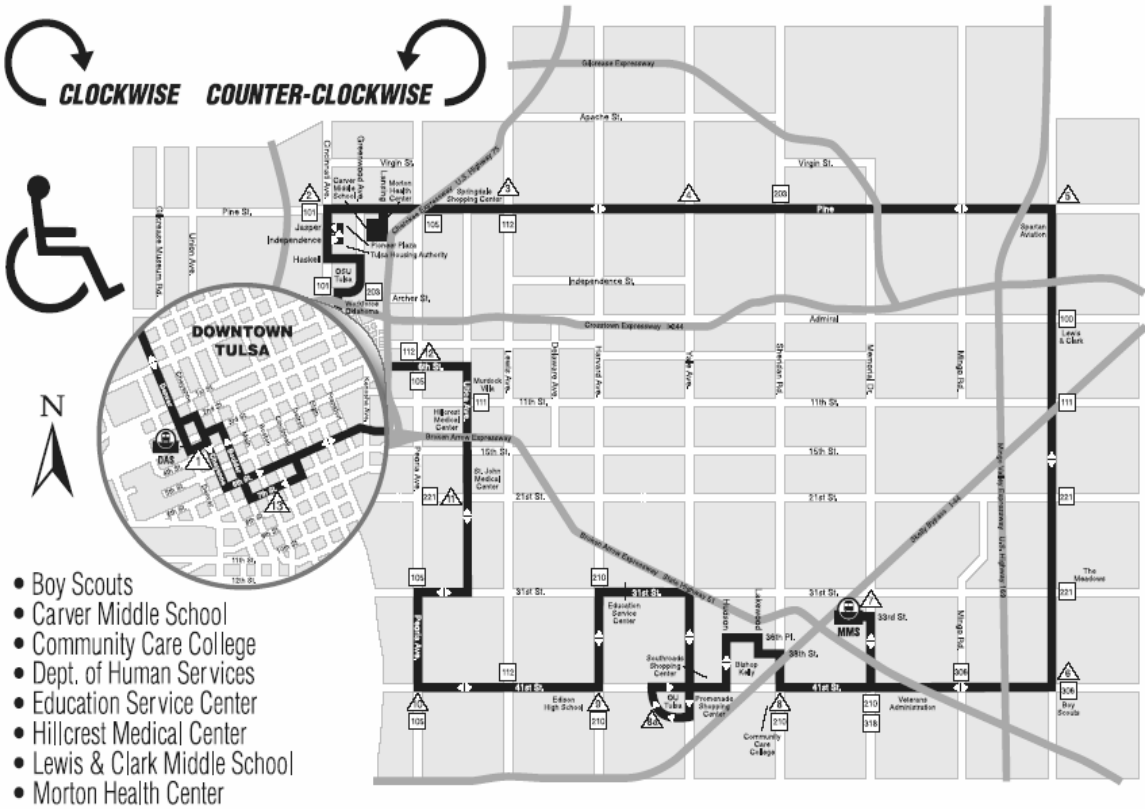
Timing Point:
See timetables on following schedule. Timing points with two times denote both arrival and departure times.

Intersecting Routes

Bus Stations
DAS - Denver Avenue (Downtown)
MMS - Memorial Midtown Station

105 PEORIA

222 PINE / 41ST STREET • *MONDAY - FRIDAY / SATURDAY*



- Boy Scouts
- Carver Middle School
- Community Care College
- Dept. of Human Services
- Education Service Center
- Hillcrest Medical Center
- Lewis & Clark Middle School
- Morton Health Center
- Pioneer Plaza
- Promenade Mall
- Red Bud Shopping Center
- Spartan School of Aeronautics
- Southroads Shopping Ctr.
- Tulsa Housing Authority
- Utica Square Shopping Center
- Veterans Administration
- Workforce Oklahoma

Please see timetable note for service to Morton.

1 **Timing Point:**
See timetables on following schedule. Timing points with two times denote both arrival and departure times.

210 **Intersecting Routes**

Bus Stations
DAS - Denver Avenue (Downtown)
MMS - Memorial Midtown Station

APPENDIX E

LOGISTIC REGRESSION MODELS

SOFTWARE OUTPUTS

The LOGISTIC Procedure

Model Information

Data Set	WORK.BABAK
Response Variable	number
Number of Response Levels	2
Frequency Variable	a
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	1020
Sum of Frequencies Used	1020

Response Profile

Ordered Value	number	Total Frequency
1	0	112
2	1	908

Probability modeled is number='0'.

Class Level Information

Class	Value	Design Variables	
Treatment	A1	1	0
	A2	0	1
	A3	-1	-1

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	708.055	684.068
SC	712.982	698.851
-2 Log L	706.055	678.068

The LOGISTIC Procedure

R-Square 0.0271 Max-rescaled R-Square 0.0542

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	27.9864	2	<.0001
Score	29.7487	2	<.0001
Wald	27.8536	2	<.0001

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
Treatment	2	27.8536	<.0001

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-2.1974	0.1093	404.3008	<.0001
Treatment A1	1	0.7165	0.1358	27.8478	<.0001
Treatment A2	1	-0.3803	0.1640	5.3783	0.0204

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
Treatment A1 vs A3	2.866	1.755	4.681
Treatment A2 vs A3	0.957	0.535	1.712

Association of Predicted Probabilities and Observed Responses

Percent Concordant	46.9	Somers' D	0.261
Percent Discordant	20.8	Gamma	0.386
Percent Tied	32.4	Tau-a	0.051
Pairs	101696	c	0.630

The LOGISTIC Procedure

Model Information

Data Set	WORK.BABAK
Response Variable	number
Number of Response Levels	2
Frequency Variable	a
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	4
Number of Observations Used	4
Sum of Frequencies Read	680
Sum of Frequencies Used	680

Response Profile

Ordered Value	number	Total Frequency
1	0	108
2	1	572

Probability modeled is number='0'.

Class Level Information

Class	Value	Design Variables
Treatment	bd	1
	bf	-1

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	597.291	590.577
SC	601.813	599.621
-2 Log L	595.291	586.577

The LOGISTIC Procedure

R-Square	0.0127	Max-rescaled R-Square	0.0218

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	8.7140	1	0.0032
Score	8.6299	1	0.0033
Wald	8.4586	1	0.0036

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
Treatment	1	8.4586	0.0036

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.7006	0.1081	247.6287	<.0001
Treatment bd	1	0.3143	0.1081	8.4586	0.0036

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
Treatment bd vs bf	1.875	1.228	2.864

Association of Predicted Probabilities and Observed Responses

Percent Concordant	33.0	Somers' D	0.154
Percent Discordant	17.6	Gamma	0.304
Percent Tied	49.4	Tau-a	0.041
Pairs	61776	c	0.577

The LOGISTIC Procedure

Model Information

Data Set	WORK.BABAK
Response Variable	number
Number of Response Levels	2
Frequency Variable	a
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	718
Sum of Frequencies Used	718

Response Profile

Ordered Value	number	Total Frequency
1	0	350
2	1	368

Probability modeled is number='0'.

Class Level Information

Class	Value	Design Variables	
Treatment	CF	1	0
	CM	0	1
	CN	-1	-1

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	996.908	789.469
SC	1001.485	803.198
-2 Log L	994.908	783.469

The LOGISTIC Procedure

R-Square	0.2551	Max-rescaled R-Square	0.3402

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	211.4390	2	<.0001
Score	199.9087	2	<.0001
Wald	176.3095	2	<.0001

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
Treatment	2	176.3095	<.0001

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.2399	0.0899	7.1234	0.0076
Treatment CF	1	1.0223	0.1326	59.4398	<.0001
Treatment CM	1	0.5319	0.1302	16.6989	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
Treatment CF vs CN	13.152	8.633	20.036
Treatment CM vs CN	8.053	5.334	12.160

Association of Predicted Probabilities and Observed Responses

Percent Concordant	64.6	Somers' D	0.549
Percent Discordant	9.7	Gamma	0.738
Percent Tied	25.6	Tau-a	0.275
Pairs	128800	c	0.774

VITA

BABAK MEMARIAN

Candidate for the Degree of

Master of Science

Thesis: Comparative Assessment of On-Board Transit Survey Methods

Major Field: Civil Engineering

Personal Data: Born in New Jersey, U.S.A, on May 30th, 1977, son of Hamzeh and Esmat Memarian.

Education: Bachelor of Science in Civil Engineering from Tehran Azad University, Iran, April 2001.

Completed the requirements for Degree of Master of Science in Civil Engineering at Oklahoma State University in July 2008.

Experience: Research Assistant, Civil Engineering Department, Oklahoma State University, Stillwater, January 2007- Present.

Teacher Assistant, Civil Engineering Department, Oklahoma State University, Stillwater, August 2007-December 2007.

Concrete Lab Assistant, Civil Engineering Department, Oklahoma State University, Stillwater, August 2006- December 2006.

Estimator, Professional Associated Construction Services Inc, Orange County California, April 2004- July 2004.

Professional Memberships: Chi-Epsilon- Civil Engineering National Honor Society, April 2007.

Iranian Construction Engineers Association, February 2002.

Name: Babak Memarian Date of Degree: July, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: COMPARATIVE ASSESSMENT OF ON-BOARD TRANSIT SURVEY METHODS

Pages in Study: 102 Candidate for the Degree of Master of Science

Major Field: Civil Engineering

Scope and Method of Study: This study performed a literature review and case studies on various methods of conducting on-board surveys. Three test scenarios were developed to assess the effect of: 1) length of questionnaire, 2) different incentives, and 3) surveyors on the response rate, unit cost, and duration of a survey. These scenarios were tested on three selected routes of Tulsa Transit.

Findings and Conclusions: Using short questionnaires with six essential O/D questions obtained a higher response rate and a lower unit cost compared to questionnaires with 14 and 29 questions. As an incentive to complete a questionnaire, offering a drawing to win 31 days free pass obtained a higher response rate, but increased the unit cost compared to offering a two free-ride. Using surveyors, either male or female, increased the response rate compared to the method of using boxes, while it increased the unit cost of the survey.

ADVISOR'S APPROVAL: Dr. Hyungseok (David) Jeong