Using “Fair Division” Methods for Allocating Transportation Funds

Research Report 0-6727

Conducted for

Texas Department of Transportation
P.O. Box 5080
Austin, Texas 78763

August 2013

Center for Transportation Infrastructure Systems
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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. TX-0-6727	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Using "Fair Division" Methods for Allocating Transportation Funds:		5. Report Date August 2013 6. Performing Organization Code
7. Author(s) C. Chang, H. Taboada, J. Espiritu, T. Fullerton, E. Montes, and A. Walke		8. Performing Organization Report No. TX 0-6727
9. Performing Organization Name and Address Center for Transportation Infrastructure Systems The University of Texas at El Paso El Paso, Texas 79968-0516		10. Work Unit No. 11. Contract or Grant No. 0-6727
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Technical Report Sept. 1, 2011 –Aug. 31, 2013 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation
Project title: Using "Fair Division" Methods for Allocating Transportation Funds

16. Abstract

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17. Key Words Fair division, funding allocation, transportation projects	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161, www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	92	

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ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation to TxDOT for providing funding to conduct research project 0-6727 "Using Fair Division Methods for Allocating Transportation Funds".

We want to acknowledge the Project Manager Cary Choate, and the Project Monitoring Committee members of this project consisting of John Ibarra, John Sabala, Michelle Veale, Sara Bagwell, Robert Ramirez, and Teresa Lemons for their support. Special thanks to Ron Hagquist who introduced this research topic to TxDOT.

ABSTRACT

The objective of this project is to investigate fair division algorithms and methods for the allocation of transportation funds and/or resources among competing interests at the Texas Department of Transportation (TxDOT). The project involves identifying critical tier allocation areas and formulating an overall comprehensive model to enhance current allocation decision making processes. Enhanced allocation methods should lead to more envy-free, efficient, and equitable distribution of funds and resources.

This research project was conducted in two phases. Phase one of this project involved a comprehensive literature review on funding allocation and fair division methods. Critical tier allocation transportation areas in which to use fair division methods at the Texas Department of Transportation (TxDOT) were discussed with TxDOT's project monitoring committee during this phase. In Phase two, the Fair Division Transportation Funding Allocation Model (FDTFAM) was developed and applied to a case study using data provided by TxDOT. Results from the case study showed that FDTFAM is ready for implementation.

IMPLEMENTATION STATEMENT

In this report a new fair division methodology is proposed to assist TXDOT in evaluating fairness in transportation and maintenance funds allocation. The proposed methodology is based on the underlying notions and concepts of fair division, proportionality, envy-freeness, equitability, and efficiency. At this time, FDTFAM can be presented at workshops showing applications through case studies.

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CHAPTER 1: INTRODUCTION

This research project was conducted in two phases. Phase one of this project involved a comprehensive literature review on funding allocation and fair division methods. Critical tier allocation transportation areas in which to use fair division methods at the Texas Department of Transportation (TxDOT) were discussed with TxDOT's project monitoring committee during this phase. In Phase two, the Fair Division Transportation Funding Allocation Model (FDTFAM) was developed and applied to a case study with data provided by TxDOT. Results from the case study showed that FDTFAM should be considered for implementation.

FUNDING ALLOCATION AND PROJECT SELECTION

Several funding sources are available in order to provide the money needed for transportation projects contained in the Metropolitan Transportation Plans and the Transportation Improvement Programs. The three main sources are federal, state, and local funding. Federal funds are allocated to the states using a formula based on a ratio of urbanized population in the individual state to the total nationwide urbanized area population (TxDOT 2012a). The Federal Highway Administration (FHWA) or the Federal Transit Administration (FTA) distributes the metropolitan planning (PL) funds to the states based on this formula. Then, the Association of Texas Metropolitan Planning Organizations (TEMPO) distributes these funds to the MPOs based on another population formula which is approved by the FHWA. At the end, each MPO may also award part of the money to its local government for transportation planning work or to individual projects. Federal funds are aimed to support metropolitan planning and must be used to plan for and evaluate any mode of transportation (MnDOT 2012). Federal funds include the Transportation Equity Act for the 21st Century (FHWA 2012) which is used to reduce congestion and to improve air quality and the Economic Stimulus Bill which was created to stimulate economic growth and develop the transportation system (TxDOT 2012b).

The state also provides funding to each MPO. This money is collected from motor fuel taxes, motor vehicle taxes, and vehicle registration fees. A portion of this money is then distributed to TxDOT to provide maintenance and rehabilitation to the roads and maintain reliable traffic controls. Also, state funding is provided to support public transportation using formulas based on population, passengers per revenue mile, and land area (Eschbach 2010). In addition, TxDOT is required to match 20 percent of the federal transportation funds on a statewide basis. Local governments also provide funding for transportation projects. The funding generally comes from taxes and is awarded on a project basis.

Currently, the Texas Department of Transportation (TxDOT) uses a five step project selection process in order to allocate funds to any project. The typical five steps in the project selection process include:

1. Identify a need
2. Build a successful financial plan to receive funding
3. Project planning

4. Project development
5. Construction

Projects are selected by the Texas Transportation Commission based on the following funding categories:

- Preventive Maintenance and Rehabilitation
- Metropolitan and Urban Area Corridor Projects
- Non-traditionally Funded Transportation Projects
- Statewide Connectivity Corridor Projects
- Congestion Mitigation and Air Quality Improvement
- Bridges
- Metropolitan Mobility/Rehabilitation
- Safety
- Transportation Enhancements
- Supplemental Transportation Projects
- District Discretionary
- Strategic Priority

Then, the district staff or the local Metropolitan Planning Organization (MPO) staff must create a funding strategy for the suggested project. The availability of funding is a major factor in determining whether a project is selected. After this, once a project is supported at the local level, it competes with similar projects for funding. Then, TxDOT must work with the city and county officials to create a project development plan involving transportation planning, design and right of way acquisition. Finally, companies are allowed to bid on the project and the construction contracts are awarded for the qualified bid with the lowest price. After the Texas Transportation Commission approves the contract the construction begins (TxDOT 2011).

RESEARCH PROBLEM

Current funding allocation and planning methods are very complex due to limited budgets and conflicting interests. Funding allocation can be approached using different methods, such as conventional methods including formulas based on pavement indicators and optimization methods which most of the time try to maximize benefits while having budget constraints. Formula-based allocation methods provide an allocation of funds based on the necessities of the given agency. These formulas are created by assigning weights to certain indicators, like population or highway miles, in order to determine the total need of each individual participant. However, these methods may lead to a disagreement if the decisions are not perceived as fair or equitable by all the participants. For example, if funding allocation formulas are based on population, small districts or cities may not receive enough money to fund their projects. This situation could create envy among districts because larger (more populous) districts will receive more funding than smaller districts with fewer inhabitants. The same situation will occur if the formulas are based on highway miles. Larger districts with more highway miles will receive more funding than smaller districts with fewer miles. Under this funding allocation method, most of the small districts will perceive the allocation of funds as unfair.

PROJECT OBJECTIVE

The main objective of this research project is to investigate fair division algorithms and methods for the allocation of transportation funds, identify critical tier allocation areas, and formulate an overall comprehensive model to enhance current allocation decision making processes at TxDOT. Enhanced allocation methods should lead to envy-free, efficient, and equitable distribution of funds and resources. The use of fair allocation methods should result in more effective and equitable practices when allocating limited funds among competing projects because it takes into account individual subjective preferences from participants. Fair division methods aim to distribute funds among participants in such a manner that all of them believe they have received a fair share and they do not envy anybody else. These concepts will eliminate or mitigate the envy that small districts feel towards large districts when conventional allocation methods are used.

ORGANIZATION OF REPORT

This report documents the activities developed during the project summarizing the findings and recommendations. The report is composed of 6 chapters. This chapter provides an introduction to the research project. It describes the objectives, the nature of the research problem, and describes the organization of the report.

Chapter 2 describes the literature on funding allocation and fair division methods.

Chapter 3 contains current practices on funding allocation and project selection at TxDOT.

Chapter 4 describes the Fair Division Transportation Funding Allocation Model developed using the allocation methods described in the literature review section.

Chapter 5 shows the application of the Fair Division Transportation Funding Allocation Model in a case study.

Chapter 6 contains the conclusions and recommendations of the model.

CHAPTER 2:

LITERATURE REVIEW ON FUNDING ALLOCATION AND FAIR DIVISION METHODS

Every day, the increasing driving population demands more and improved highways to be able to perform different tasks that range from regular assignments, like commuting to work, to very complex activities, like transportation of goods across the country. In order to be able to construct such an infrastructure system, the Departments of Transportation (DOTs) must be able to provide the money necessary to build and maintain the roads needed to achieve this goal. Primarily, funding for transportation projects is capitalized from gasoline and diesel taxes; truck, bus, and trailer taxes; heavy vehicle usage fees; and taxes on alternative fuels (Bass 2010). Despite the millions of dollars obtained using the current funding methods, the DOTs are unable to satisfy all the demands of all their cities and counties because it is not only necessary to provide new roads and highways; but, it is also important to be able to perform maintenance and rehabilitation to the existing roads and public transportation services to prevent their failure. Therefore, an allocation method to maximize the benefits in the system using limited funds is a necessity for most DOTs nowadays.

FUNDING ALLOCATION METHODS

Funding allocation can be approached using different methods. Conventional methods include weighted formulas based on performance indicators and other criteria such as population or highway miles. However, formula-based allocation methods may lead to the public's disagreement if the decisions are not perceived as fair or equitable. For example, if funding allocation is based on population, small districts or cities may not receive enough money to fund their projects. Due to multiple interests and different perspectives from each participant requesting funds, it is very difficult for all the participants to agree on the funding allocation criteria. Alternative approaches include optimization methods applied with the aim of maximizing benefits subject to budget constraints, or minimizing costs while achieving performance targets established by the agency.

In this literature review, several documents with case studies were analyzed to investigate the most important and innovative techniques used to allocate funds, such as optimization and genetic algorithms. Optimization methods look for optimal solutions to the problem formulation. In the past decades, multiple optimization methods have been developed to solve a wide range of optimization problems. These solving methods vary in the type of problems that they can solve and the process used to solve them. A summary of the most common optimization methods are described as follows.

Single Objective Optimization Models

These models are used when the problem to be solved only has one objective (minimize or maximize), one or more constraints, and more than one variable. This is the simplest optimization model and depending on the constraints and objective formula it might be solved manually. These models give optimal solutions to the problem. Some examples include the linear and the integer programming (Sarker and Newton 2008).

Linear Programming

A linear programming model is a single objective optimization model where the variables are assumed to be real numbers and the objective function and all constraints functions are developed as linear functions. This model is used to find the positive values of the unknown variables, which will satisfy the constraints while maximizing or minimizing the linear objective function (Sarker and Newton 2008).

Integer Programming

Integer programming is an extension of the general linear programming problem. The decision variables of an optimal solution to a general linear programming problem may take on either nonnegative fractional values or integer values. In some cases, fractional values are not acceptable as solutions (Sarker and Newton 2008). Integer programming gives positive integer values of unknown variables. There are three types of integer programming models:

- Integer: where all the decision variables are integers.
- Binary integer: where all the decision variable values are binary (either zero or one) only.
- Mixed integer or mixed integer linear: linear programs with some integer and some real decision variables.

Multi-objective Optimization Models

These models are used when the problem to be solved has two or more objectives (usually one minimizes and the other maximizes), one or more constraints, and more than one variable. These types of problems are more complex and usually require software with optimization capabilities to solve the mathematical formulation. These models provide optimal solutions to the problem. Some examples include goal and nonlinear programming.

Goal Programming

Goal programming is used to solve multi-objective optimization problems. In this model, a specific numeric goal is established for each goal function (constraint), and then a solution is derived that minimizes the (weighted) sum of deviations of these goal functions from their respective goals (Sarker and Newton 2008).

Nonlinear Programming

A nonlinear programming model is similar to a linear programming model with one exception; it contains nonlinear terms whether in the objective function or in the constraint equations or both (Sarker and Newton 2008).

Heuristic Techniques

Heuristic techniques are used to solve optimization problems but may not guarantee optimal solutions; however, they produce acceptable solutions. These methods are used when an exhaustive search approach to the problem is impractical. It is used to speed up the search process and is based on conventional optimization techniques or traditional artificial intelligence techniques (Sarker and Newton 2008). Some examples of heuristic methods include the hill climbing, the simulated annealing, the tabu search, the genetic algorithm, and the ant colony optimization algorithms.

Hill Climbing

In this method, the model does not accept a new solution unless it is better than the best solution found so far. This algorithm is more likely to end up with a local optimum and is very sensitive in regard to the starting point (Sarker and Newton 2008).

Simulated Annealing

This method is based on the "annealing" technique which is a heat treatment process that involves heating and cooling. It simulates heating up a solid to a point where its atoms can move freely and then cooling it down to allow them to rearrange themselves. This mechanism allows the model to avoid local optimums. The algorithm behaves like a random search at high temperature (solutions with higher probability) and like a hill climbing method at low temperature (solutions with a probability close to zero) (Sarker and Newton 2008).

Tabu Search

Tabu search is an iterative process that unlike the hill-climbing approach, accepts lower-quality solutions in any intermediate iteration. In order to prevent cycling, it forbids movements previously done in the model. These movements are recorded in a list called "tabu list" which is updated in every iteration (Sarker and Newton 2008).

Genetic Algorithms

This algorithm, unlike the previous optimization methods, start with a randomly generated population (set of solutions) and then move from one population to another. The algorithm continues until the stopping criteria are met. It uses search operators like crossover and mutation to generate new solutions, and natural selection to select only the best solutions (Sarker and Newton 2008).

Ant Colony Optimization

This algorithm follows the ant behavior to solve problems. Ants tend to leave pheromones on the paths traveled. The level of pheromones increases over time, and the shortest paths contain a higher level. Ants prefer to take the paths with higher levels of pheromones because it results in the best path (Sarker and Newton 2008).

Based on the different characteristics and capabilities of the optimization methods available for the solution of the fair division problem, it was concluded that the best solving method is the genetic algorithm. Genetic algorithms provide solutions to multi-objective problems, and are able to search for multiple solutions, thus preventing a local optimum. This algorithm is recommended in the case of the funding allocation problem because it is able to search for a large combination of solutions by using crossovers and mutations among sets of solutions or populations .

Table 1 presents case studies with allocation of funds using optimization and linear programming techniques.

Table 1. Summary on Funding Allocation Case Studies.

Item Number	Name	Author	Year	Brief Summary
1-043	Optimal Fund-Allocation Analysis for Multidistrict Highway Agencies	Wen Tat Chan, T.F. Fwa, M. ASCE and J.Y. Tan	2003	This paper considers the genetic-algorithm (GA) optimization technique to allocate the total funds available to the district or regional agencies in order to best achieve specified central and regional agencies' goals subject to operational and resource constraints. The practicality of the solution procedure is demonstrated with a simple pavement maintenance fund allocation problem of a three-region management structure administered by a central highway agency, and with different goals or objectives specified by the central and regional authorities.
1-044	Optimal Maintenance Policy and Fund Allocation in Water Distribution Networks	Huynh T. Luong and Nagen N. Nagarur	2005	In this research paper, a mathematical model is developed to support the decision to allocate funds among pipes of the network as well as the decision to repair or replace the pipes in the state of failure. The objective function of the model is to maximize the total weighted long-run availability of the whole system. The concept of hydraulic reliability is employed to determine the weight of pipes in the maintenance program. The deterioration behavior of the pipe is depicted by a semi-Markov process, and the Dantzig–Wolfe decomposition algorithm is applied to deal with the large-scale characteristic of the resulting program.
1-045	The Cost Allocation Problem for the First Order Interaction Joint Replenishment Model	Shoshana Anily and Moshe Haviv	2007	This paper presents an infinite-horizon deterministic joint replenishment problem with first order interaction. Under this model, the setup transportation/reorder cost associated with a group of retailers placing an order at the same time equals some group-independent major setup cost plus retailer-dependent minor setup costs.
1-046	Asymptotic Behavior of an Allocation Policy for Revenue Management	William L. Cooper	2002	This paper presents the concept of how revenue management has become an important tool in the airline, hotel, and rental car industries. Asymptotic properties of revenue management policies derived from the solution of a deterministic optimization problem are described. The primary results state that, within a stochastic and dynamic framework, solutions arising out of a single well-known linear program can be used to generate allocation policies for which the normalized revenue converges in distribution to a constant upper bound on the optimal value.

Table 1. Summary on Funding Allocation Case Studies. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-047	Hybrid Multiobjective Optimization Model for Regional Pavement-Preservation Resource Allocation	Zheng Wu, Gerardo W. Flintsch and Tanveer Chowdhury	2008	This paper presents an alternative method for the central administration to set short-term pavement preservation budgeting under a wider information context, linking budget allocation to multiple criteria and performance targets through structured procedure and interactive communication. The result is a practical decision support model that enables the central administration in a decentralized state DOT to identify optimal maintenance actions and budget allocations across the component districts that are consistent with agency needs and resource limitations and understand the trade-off between the preservation cost and the associated network benefit.
1-048	Using a Pavement Management System for Allocating Resources: Case Study of Hungary	Marianna Csicsely-Tarpay, Raimo Tapio and Antti Talvitie	2007	This paper presents the use of a network-level pavement management system (PMS) for allocating resources to various road maintenance actions and distributing them to a country's different (road management) regions. The case study is set in Hungary, where efforts have been made to apply state-of-the-art techniques in road management.
1-049	Global Optimization Procedures for the Capacitated Euclidean and ℓ_p Distance Multifacility Location-Allocation Problems	Hanif D. Sherali, Intesar Al-loughani and Shivaram Subramanian	2000	This paper presents a procedure for determining global minima for the capacitated Euclidean and ℓ_p distance location-allocation problems. Given the fixed location of *m* existing facilities, or customers on a plane and their associated demands, this problem seeks the location of *n* new facilities or sources having known capacities, as well as the allocation of their supplies, to satisfy the demand requirements of customers at a minimum total cost.
1-050	A Unified Optimization Procedure for Road Asset Management	Koji Tsunokawa and Dinh Van Hiep	2008	This paper presents a unified and coherent procedure for optimizing the allocation of a system-wide budget over its constituent subsystems, be it infrastructure components or sub-networks. The net present value (NPV) will be used as the common denominator for measuring the desirability of management programs for all asset subsystems. Using an asset subsystem optimizer (ASSO) the NPVs are first predicted for several budget levels to construct the NPV function of each asset subsystem. For a given system-wide budget, the NPV functions of all subsystems are then used to find the optimal allocation among all subsystems. Once optimal budget allocation has been found, optimal management strategy for each subsystem can be found by running the ASSO with the optimally allocated budget.

Table 1. Summary on Funding Allocation Case Studies. (Continued)

Item Number	Name	Author	Year	Brief Description
1-051	The Regional Allocation of Infrastructure Investment: The Role of Equity, Efficiency and Political Factors	A.Castells and A. Sole-Olle	2005	This paper analyses the main determinants of the regional allocation of infrastructure investment. The estimated investment equation is derived from a general specification of the government's objective function, which accounts both for the equity–efficiency trade-off and for deviations from this rule that arise because of political factors. The equation is estimated from panel data on investment and the capital stock of transportation infrastructure for the Spanish departments during the period 1987–1996. The results suggest that efficiency criteria play only a limited role in the geographical distribution of government infrastructure investment. Specific regional infrastructure needs and political factors both appear to be factors that do explain the regional allocation of infrastructure investment.
1-052	Resource Allocation for Decreased Project Duration	Lee Ford Joglekar	2007	To perceive and model development projects, the system dynamics approach was applied and allocation policy design was investigated. The authors focused on how three policy features impact development project durations: (1) whether to base allocations on current or future conditions, (2) how quickly to adjust resources and (3) how much control to exert over resource adjustment speed. Based on model analysis, Lee et. al. found that minimum resource allocation delay does not produce minimum durations, and increasing uncertainty decreases durations under certain conditions. Accordingly, they proposed tuning managerial delays as a potential advancement in project management and investigated the application of tuning these delays to resource allocation policy design.

Making Decisions with Multiple Objectives

Every day, decision makers must balance judgments about uncertainties with their preferences for possible consequences or outcomes. In order to arrive at the best possible solution, decision makers must identify the objectives, analyze the value tradeoffs, and be able to balance risks associated with each alternative. Keeney and Raiffa (1993) suggest the use of a five-step paradigm of decision analysis to analyze each alternative and relate it to possible consequences, outcomes, utilities, and uncertainty related with each option. Main components of the paradigm include: preanalysis, structural analysis, uncertainty analysis, utility and value analysis, and optimization analysis. In the preanalysis, the decision maker must identify the problem and the possible alternatives. The structural analysis examines the choices and chance events per alternative; it is generally represented in a tree diagram. The uncertainty analysis allows the decision maker to assign probabilities to each alternative based on experience, assumptions or results from tests. The utility or value analysis assigns utility values to consequences associated with different alternatives or paths of the tree. In the optimization analysis, the decision maker must analyze the alternatives, probabilities, and assigned utilities in order to select the alternative that maximizes the expected utilities and has the greatest probability of occurrence. Table 2 presents the books and reports based on multiple objective decisions.

Table 2. Summary on Decision Making Documents.

Item Number	Name	Author	Year	Brief Summary
1-035	Decisions with Multiple Objectives: Preferences and Tradeoffs	Ralph L. Keeney and Howard Raiffa	1976	Book
1-036	Decisions with Multiple Objectives: Preferences and Value Tradeoffs	Ralph L. Keeney and Howard Raiffa	1993	Book
1-037	Value-Focused Thinking: A Path to Creative Decisionmaking	Ralph L. Keeney	1992	Book
1-038	Smart Choices: A Practical Guide to Making Better Decisions	John S. Hammond, Ralph L. Keeney, and Howard Raïffa	1999	Book
1-039	A Decision Analysis with Multiple Objectives: the Mexico City Airport	Ralph L. Keeney	1973	This paper reports an analysis done for the Secretaria de Obras Publicas (Ministry of Public Works) of Mexico to help select the most "effective" strategy for developing the airport facilities of the Mexico City metropolitan area to insure quality air service for the remainder of the century. Effectiveness is a complex function including attributes of cost, safety, capacity of the airport facilities, noise levels, social disruption, and access times. A decision analytic model was used for evaluating strategies. The attributes were adapted to account for impacts over time, and probability density functions and a utility function were assessed over the six attributes.
1-040	Decision Analysis: An Overview	Ralph L. Keeney	1982	This article describes what decision analysis is, what it can and cannot do, why one should care to do this, and how one does it. To accomplish these purposes, it is necessary first to describe the decision environment. The article also presents an overview of decision analysis and provides additional sources for its foundations, procedures, history, and applications.

Table 2. Summary on Decision Making Documents. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-041	Multiplicative Utility Functions	Ralph L. Keeney	1972	This paper presents sufficient conditions for a multiattribute utility function to be either multiplicative or additive. The number of requisite assumptions to imply the main result is equal to the number of attributes (effectiveness). Because the assumptions involve only trade-offs between two attributes at a time or lotteries over one attribute, it is reasonable to expect that decision makers can ascertain whether these assumptions are appropriate for their specific problems. Procedures are given for verifying the assumptions and assessing the resulting utility functions.
1-042	Structuring Objectives for Problems of Public Interest	Ralph L. Keeney	1987	This paper outlines and illustrates a procedure to constructively involve stakeholders in the process of identifying objectives for problems of public interest. The illustration concerns the evaluation of alternatives to ship spent nuclear fuel from power plants to a repository. Objectives were developed from group discussions with individuals in the nuclear industry, In state governments, and in environmental and public interest organizations. Using guidelines outlined in the paper, hierarchies of objectives were structured to represent each of these stakeholders. From these, a combined hierarchy was structured that addressed health and safety; economics; equity; environmental, social, and political impacts; flexibility; and scheduling.

FAIR DIVISION METHODS

Fair division has been a central topic in the economic literature and several concepts of fairness have been suggested based on these theories. Fair division studies the problem of allocating a set of indivisible goods to a set of people, called players or participants, from an envy-free perspective. An allocation is envy-free if every player likes his own share at least as much as the share of any other player (Lipton 2004). Division of a resource among multiple participants is a frequent problem in multiplayer systems and fair, efficient, and decentralized allocation procedures are highly valued. Fair division of goods must provide envy-free procedures; however, envy-free division is only guaranteed for a small number of participants. Fair division of goods is commonly used because it provides an efficient, envy-free, equitable and proportional manner to divide goods. Proportionality is achieved if each participant believes that it received at least 1/n of the goods being allocated. Envy-freeness is accomplished if each participant believes that it received at least as valuable a share as that received by any other participant and has no incentive to trade its share with anyone else. Equitability is achieved when the share received by each participant is identical in terms of their individual utility functions. An efficient solution is provided when there is no other partition which will improve the perceived share of at least one participant without decreasing the perceived share of any other participant (Nuchia 2001). Several methods have been used to achieve a fair allocation of divisible and indivisible goods, such as, the Divide and Choose Procedure, the Moving Knife, the Last-

Diminisher “Trimming Algorithm”, the Knaster’s Procedure, and the Adjusted Winner (AW) Procedure.

Divide and Choose Procedure

This method suggests that each one of the participants receives at least 1/*n* of the good in question, where *n* is the number of participants. The proportion is defined by the participant’s own valuation. For example, consider the problem where two individuals resolve to share a divisible good. This problem can easily be solved in two steps using the Divide and Choose procedure. First, one individual divides the good to what represents a half to him. Then the second selects what appears to him to be the biggest share. This method guarantees that both participants will be satisfied because both believe that they have an equal or fair share (Robertson & Webb, 1998).

The Moving Knife Technique

The moving knife technique is used to describe how to distribute a cake in a fair manner. In this method, a knife is moved on a rectangular homogenous cake from left to right until one of the participants calls a cut. Then, the piece that was cut is given to the person who called this cut because that is the part that he believes is fair. This process is repeated with the other *n*-1 participants and with what remains of the cake (Dubins 1967).

Last-Diminisher “Trimming Algorithm”

In this procedure, participant 1 cuts a piece of cake of the size 1/*n* and participant 2 takes the piece and trims it if he believes that its size is greater than 1/*n*. The piece is passed successively and trimmed until it reaches player *n*–1. Finally, the participant *n* can take the piece; otherwise, it is given to the last person who trimmed it. This process is repeated with the remaining pieces until only one participant is left (Robertson & Webb, 1998).

Knaster’s Procedure

Knaster’s procedure resembles an auction because each good is assigned to the highest bidder and the amount of money that is bidden is divided among the participants. This procedure requires that each individual invest an initial amount of money to be used as a deposit for each participant. This deposit will be used to pay those individuals who receive less or nothing at the end of the bidding or as compared to everybody else.

Adjusted Winner (AW) Procedure

The AW algorithm provides an envy-free, equitable and efficient solution to the division of assets among participants and does not require a deposit per participant. In this procedure, the goods are divided as in Knaster’s procedure; however, the assets are adjusted to make the number of points of each participant equal to each other in order to achieve equitability (Brams and Taylor, *1994).*

Point Allocation

Point Allocation (PA) is a simple and commonly used approach. In PA a hypothetical number of points, e.g. 3, 5 or 10 is applied per criteria and/or alternatives. This allocation is based strictly upon a decision maker's subjective judgments (Saunders 2011). In this procedure, each participant assigns a value to every good under consideration; then, the participant with the highest score per good gets the corresponding item. An envy ratio (assigned score to actual score) is calculated and minimized under certain constraints to achieve envy-freeness.

In this project, the research team will be using a combination of the Adjusted Winner and the Point Allocation methods because it guarantees the minimization of envy among the participants. These procedures were selected because they provide a subjective measure of the goods that are allocated, in this case, funding allocation across projects. The Point Allocation method allows the participants (or districts) to give priority to projects that they need the most in order to receive funding for them while the Adjusted Winner allows multiple runs to achieve equality among participants. In order to use the point allocation method, several factors need to be established, such as the principal funding categories, the participants (or districts), total funds, and the point assignment. This method is mostly used in the solution of political conflicts such as the Israeli-Palestinian Conflict (Massoud 2000) where the two countries had problems involving 9 issues. Based on a survey created to provide measures to the issues, both countries arrived at an efficient, equitable, and envy-free division. Each country obtained 4 issues in which they gave high values and compromised on one issue.

Literature review on fair division methods is very broad and is focused mainly on theory and abstract examples. The majority of the papers on this subject provide only theoretical examples or case studies with allocation on political issues. The application of these methods to TxDOT can be achieved by the addition of multiple participants and the creation of new variables to account for project selections, allocation of funds, and minimization of envy. Table 3 shows the literature review on fair division methods.

Table 3. Summary of Fair Division Methods.

Item Number	Name	Author	Year	Brief Summary
1-001	On approximately fair allocations of indivisible goods	R.J. Lipton, E. Markakis, E. Mossel and A. Saberi	2004	This report uses a case study to fairly allocate a set of indivisible goods to a set of people from an algorithmic perspective. The criterion used in this case study is envy-freeness. This model considers the division of indivisible goods as non-envy-free; therefore, it makes an optimization problem of finding an allocation with minimum possible envy.
1-002	Dividing the Indivisible: Procedures for Allocating Cabinet Ministries to Political Parties in a Parliamentary System	Steven J. Brams and Todd R. Kaplan	2002	In this paper, political parties use a divisor method of apportionment to choose ten cabinet ministries in Northern Ireland. This report studies the consequences of this sophisticated allocation such as Pareto-optimal and nonmonotonicty. This mechanism combines sequential choices with a structured form of trading that result in sincere choices for two parties. This report shows that envy cannot be eliminated; only reduced.
1-003	Cake Division with Minimal Cuts: Envy-Free Procedures for 3 Persons, 4 Persons, and Beyond	Julius B. Barbanel and Steven J. Brams	2004	This report shows that the minimal number of parallel cuts required to divide a cake into n pieces is n - 1. A new 3-person procedure, requiring 2 parallel cuts, is given that produces an envy-free division, whereby each person thinks he or she receives at least a tied-for-largest piece. An extension of this procedure leads to a 4-person division, using 3 parallel cuts, that makes at most one person envious. Finally, a 4-person envy-free procedure is given, but it requires up to 5 parallel cuts, and some pieces may be disconnected. All these procedures improve on extant procedures by using fewer moving knives, making fewer people envious or using fewer cuts.
1-004	Equity, Envy, and Efficiency	Hal R. Varian	1973	This paper considers the problem of dividing a fixed amount of goods among a fixed number of agents. This report compares the different theories of normative economics and examines the relationship between envy and efficiency and establishes general results for the existence of fair allocations. In this case it is shown that the only allocations that are coalition-fair in a large economy are competitive equilibrium with equal incomes.
1-005	How to Allocate hard Candies Fairly	Marco Dall'Aglio and Raffaele Mosca	2007	This report considers the problem of allocating a finite number of indivisible items to two players with additive utilities. The solution proposed uses all the maximum allocations and repeated use of an Adjusted Winner, an effective procedure that deals with divisible items, to find new candidate solutions, and to suggest which items should be assigned to the players.
1-006	A General Branch-and-Bound Algorithm for Fair Division Problems	Rudolf Vetschera	2010	The purpose of this research is to provide a branch-and-bound algorithm for solving fair division problems with indivisible items. This algorithm is applicable to a wide class of fairness criteria. Computational results show that the algorithm exhibits a good performance for several numbers of problems. The main applications of the algorithm are located in computational studies of fairness criteria and fair division problems.

Table 3. Summary of Fair Division Methods. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-007	The Win-Win Solution: Guaranteeing Fair Shares to Everybody	Steven J. Brams and Todd R. Kaplan	1999	Book
1-008	Dissension on the Shores of the Uruguay River: Adjusted Winner and the Pulp Mill Conflict between Argentina and Uruguay	Davis Herron	2007	In this paper, a conflict between Argentina and Uruguay is analyzed. The problem involves Argentina and its opposition towards the construction of *Papeleras* (Pulp Mills) along the Uruguay river (which is shared by these two countries) because it will cause pollution. This paper applies the AW procedure to the current conflict between Argentina and Uruguay in order to derive several settlements to illustrate to both states that AW represents a viable option to the settlement of the pulp mill conflict.
1-009	Fair Division: Adjusted Winner Procedure (AW) and the Israeli-Palestinian Conflict	Tansa G. Massoud	2000	In this paper, the Adjusted Winner (AW) method is used to propose a plausible solution to the final status issues between Israel and the Palestinians. The AW method provides equitability efficiency, and envy freeness. Based on data from an original survey, results show that when the issues of security and borders are kept separate, Israel is likely to have its demands met on the issues of security, East Jerusalem, normalization of relations, and water. The Palestinians will win on the issues of sovereignty, Israeli settlements in the West Bank, Israeli settlements in Gaza, and Palestinian refugees. Both sides will need to compromise on the issue of boundaries.
1-010	Cake Cutting Algorithms: Be Fair if You Can	Jack Robertson and William Webb	1998	Book
1-011	Sharing a Cake	A. K. Austin	1982	This article considers the problem of sharing the cake fairly when there are more than two people. It tries to implement the moving knife technique which ensures justice for an honest person even when there is dishonest collusion by the other people. The article considers homogeneous and non-homogeneous cakes.
1-012	How to Cut a Cake Fairly	L. E. Dubins and E. H. Spanier	1967	In this paper, an article written by H. Steinhaus called "Sur la Division Pragmatique" is analyzed. This paper consists of two parts. In part I, some of the ideas contained in the article of Steinhaus are restated in a simple and general form, such ideas include the moving knife technique, the one cut and the other choose, the bisection problem and the ham sandwich problem. In part II, the mathematical details are presented in a more technical form.

Table 3. Summary of Fair Division Methods. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-013	Fair Division	Steven J. Brams	2005	In this review, a brief survey of three different literatures is given: (i) division of a single heterogeneous good (e.g., a cake with different flavors or toppings); (ii) division, in whole or part, of several divisible goods; and (iii) allocation of several indivisible goods. In each case, it is assumed the different people, called *players*, may have different preferences for the items being divided. For (i) and (ii), it describes and illustrates procedures for dividing divisible goods fairly, based on different criteria of fairness. For (iii), it discusses problems that arise in allocating indivisible goods, illustrating trade-offs that must be made when not all criteria of fairness can be satisfied simultaneously.
1-014	Fair Division: from Cake-Cutting to Dispute Resolution	Steven J. Brams and Alan D. Taylor	1996	Book
1-015	Fair Division by Point Allocation	Steven J. Brams and Alan D. Taylor	1994	In this paper, two fair-division procedures that are applicable to negotiations between two parties over multiple issues are analyzed. Both procedures, which involve the parties' allocating points across the issues, guarantee the envy-freeness and equitability of a settlement. The first procedure ensures that the settlement is Pareto-optimal, but it is vulnerable to strategic manipulation, whereas the second procedure is relatively invulnerable to manipulation, but it is not Pareto-optimal.
1-016	An Algorithm for Envy-Free Allocations in an Economy with Indivisible Objects and Money	Flip Klijn	2000	This paper studies envy-free allocations for economies with indivisible objects, quasi-linear utility functions, and an amount of money. It gives a polynomial bounded algorithm for ending envy-free allocations. Connectedness of envy-graphs, which are used in the algorithm, characterizes the extreme points of the polytopes of side payments corresponding with envy-free allocations.
1-017	Resource Allocation and the Public Sector	Duncan K. Foley	1967	This essay develops a theory of resource allocation and competitive equilibrium for economies with public goods which are defined as commodities and services that every person uses. Examples are police protection and defense. A brief discussion of the problem of interpersonal utility comparisons is presented and an operational definition of equitable allocation is proposed.

Table 3. Summary of Fair Division Methods. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-018	Improving Optimality of n Agent Envy-Free Divisions	Stephen W. Nuchia and Sandip Sen	2001	This paper presents an approach by which the outcome of any algorithm for arbitrary n, or guaranteed algorithms for small number of agents, can be improved in terms of optimality. It proposes a two-stage protocol where the first stage identifies possible beneficial exchanges, and the second stage chooses the maximal set of such exchanges that is still envy-free. Then, it maps the second stage into a matching problem and presents a graph-theoretic algorithm that improves the efficiency of the initial allocations while maintaining the envy-free property.
1-019	On Games of Fair Division	H W. Kuhn	1967	This essay discusses three of the main methods of fair division: the Divide and Choose Method, the Moving Knife, and the Knaster Procedure. This article addresses some of the old questions about these methods by giving them new formulations or by adding minor precision arguments.
1-020	An Empirical Evaluation of Fair-Division Algorithms	Nicolas Dupuis-Roy and Frederic Gosselin,	2009	This paper presents an experiment that investigated the satisfaction of two pairs of players who divided goods between themselves. A genetic algorithm was used to search for the best division candidates. Results show that some of the best divisions found by the genetic algorithm were rated as more mutually satisfactory than the ones derived from six typical fair-division algorithms. Analysis on temporal fluctuation and non-additivity of preferences could partially explain this result.
1-021	Maximin Share and Minimax Envy in Fair-Division Problems	Marco Dall'Aglio and Theodore P. Hill	2003	This paper considers fair-division or cake-cutting problems with value functions which are normalized positive measures (i.e., the values are probability measures) maximin-share and minimax-envy inequalities which are derived for both continuous and discrete measures. The tools used include classical and recent basic convexity results, as well as ad hoc constructions. Examples are given to show that the envy-minimizing criterion is not Pareto optimal, even if the values are mutually absolutely continuous. In the discrete measure case, sufficient conditions are obtained to guarantee the existence of envy-free partitions.
1-022	Counterexamples in the Theory of Fair Division	Theodore P. Hill and Kent E. Morrison	2008	This article talks about the general classes of errors that have appeared along with confusion about the necessity and sufficiency of certain hypotheses. This paper analyz es the Moving-Knife Procedure to try to correct the scientific record and to point out with concrete examples some of the pitfalls that have led to these mistakes in continuity, additivity, pareto optimality, and incentive compatibility.

Table 3. Summary of Fair Division Methods. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-023	Envy Freeness in Experimental Fair Division Problems	Dorothea K. Herreiner and Clemens D. Puppe	2007	This paper presents and discusses results from free-form bargaining experiments on fair division problems in which inter- and intrapersonal criteria can be distinguished. It finds that interpersonal comparisons play the dominant role and that the effect of the intrapersonal criterion of envy freeness is limited to situations in which other fairness criteria are not applicable.

CHAPTER 3:

CURRENT PRACTICES ON FUNDING ALLOCATION AND PROJECT SELECTION AT TXDOT

The Texas Department of Transportation (TxDOT), in cooperation with local and regional officials, is responsible for planning, designing, building, operating and maintaining the transportation system. In this chapter, critical tier allocation areas at TxDOT that can benefit from fair division methods are discussed. The identification of critical tier allocation transportation areas included research on sources of funding and project selection practices at TxDOT and MPOs.

FUNDING FOR PUBLIC TRANSPORTATION

In 2012, U.S. public transportation provided 10.5 billion trips (APTA 2013). These services are provided by many different agencies, including state transit authorities, urban transit districts, and rural transit districts. The federal and the state government provide financial assistance to these institutions based on formulas according to population in areas classified as non-urbanized or urbanized. Non-urbanized areas have a population of less than 50,000 and urbanized areas have a population greater than 50,000 but less than 200,000.

Federal Funding for Public Transportation

Federal funding for public transportation comes primarily through the U.S. Department of Transportation which is authorized by the Safe, Accountable, Flexible, and Efficiency Transportation Equity Act-A Legacy for Users (SAFETEA-LU). This act provides funding for the U.DOT and its subsidiary agencies, including the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA). The FTA allocates funding for transit systems in urbanized and rural areas and for programs for the elderly and people with disabilities. It also allocates funds using formulas based on:

- Population and population density
- Land areas
- Passenger miles per vehicle revenuer mile, passenger miles per vehicle hour, vehicle revenue miles per capita, vehicle revenue hours per capita, passenger miles per capita, and passenger trips per capita
- Bus vehicle revenue miles
- 50% of operating deficits
- Transit enhancement activities (historic preservation, landscaping, public art, pedestrian access, bicycle access, and enhanced access for people with disabilities)
- Low-income population
- Metropolitan transportation planning needs

The FTA allocates most of the funds based on the total population and population density of the areas.

State Funding for Public Transportation

The Texas Public Transportation funding formula allocates the funds to public transportation providers based on the needs of the system and its performance. The state funding for public transportation is divided into 35% to urban areas and 65% to rural areas. The needs allocation in the rural areas is based on the population and the land area. Needs allocations in urban areas are based on the providers that serve the general public and the ones that serve the elderly and people with disabilities (Eschbach 2010). The rural area's performance-based funds are allocated using the following criteria:

- 33% for local investment divided by operating cost
- 33% for revenue miles divided by operating cost
- 33% for passengers per revenue mile

The Urban area's performance-based funds are allocated under the following criteria:

- 30% for local investment divided by operating cost
- 20% for revenue miles divided by operating cost
- 30% for passengers per revenue mile
- 20% for passengers per capita

Table 4 lists reference items that present the current practices, project selection, and funding procedures used by TxDOT.

Table 4. Summary on TxDOT Background Documents.

Item Number	Name	Author	Year	Brief Summary
1-024	Project Summary: 0-6199 Estimated Impact of the 2010 Census on the PTN Funding Formula	TxDOT	2010	This report is a project summary of the project that estimates the results of the 2010 Census and identifies how the results impacts formula-driven funding allocations. In this research, the population was estimated and the number and size of urbanized areas in the state were projected. Using the projections, the population change impact on federal and state funding for rural transit districts and the state funding for urban transit districts were documented. Finally, the report summarizes the policy implications of the 2010 Census for the allocation of public transportation funds using the Texas Transit Funding Formula.
1-025	Estimated Impacts Of The 2010 Census On The Texas Transit Funding Formula	Karl Eschbach, Michael Cline, Linda Cherrington, Suzie Edrington, Patricia Ellis, and Edgar Kraus	2010	This research report evaluates the impacts of the changes in urbanized area population and non-urbanized (rural) population and land area for 2010 on the current Texas Transit Funding Formula for allocation of Federal Section 5311 and state rural and urban funds. The research project identifies areas with the potential to exceed 200,000 in population and those non-urbanized areas that have potential to become urbanized (over 50,000 people) in 2010. This research provides a comprehensive assessment of the changes for the state as a whole and for individual transit service providers.
1-026	Establish a New, Simpler Approach to Allocating Funds	Window on State Government	2001	This article describes the current planning, programming and funding approach of the Texas Department of Transportation. It emphasizes the need to eliminate the current funding allocation processes and to establish a new, simple approach that funds both strategic priorities and regional needs in a predictable, equitable and understandable manner.
1-027	Best Practices for Pavement Edge Maintenance-Farm-to-Market Road System in Texas	William D. Lawson and Shabbir Hossain M.	2007	This paper discusses the problem of pavement edge drop-offs as a maintenance, safety, and liability issue for the Texas Department of Transportation (TxDOT). The objectives for this research project are to identify and to communicate best practices effectively for pavement edge maintenance. Both objectives were accomplished by capturing more than 3,700 years of institutional knowledge from maintenance leaders representing all 25 TxDOT districts. This research focuses on maintenance practices for naturally occurring edge drop-offs, with an emphasis on low-volume roads.
1-028	TxDOT Project Selection Process 2010	TxDOT	2008	This report describes the Project Selection Process in Texas and shows the funding categories used by TxDOT in 2010.
1-029	TxDOT Project Selection Process 2011	TxDOT	2009	This report describes the Project Selection Process in Texas and shows the funding categories used by TxDOT in 2011.

Table 4. Summary on TxDOT Background Documents. (Continued)

Item Number	Name	Author	Year	Brief Summary
1-030	TxDOT Project Selection Process 2012	TxDOT	2011	This report describes the Project Selection Process in Texas and shows the funding categories planned by TxDOT for the year 2012.
1-031	2012 Unified Transportation Program (UTP)	TxDOT	2011	The Unified Transportation Program (UTP) is a plan reflecting the projects and programs that may be delivered from the available forecasted funding over a ten year period of time. This report shows a summary of funding by category or program for the years 2012-2021 and projects lists and reports by categories.
1-032	TxDOT Revenue and 2012 Unified Transportation Program	North Central Texas Council of Government	2011	In this presentation, the North Central Texas Council of Government (NCTCG) makes recommendations in funding of projects to TxDOT and the Unified Transportation Program.
1-033	Transportation Funding: Understanding State Road and Highway Funding in Texas	TxDOT	2011	This report discusses the estimated construction and maintenance needs in Texas.
1-034	2010 Unified Transportation Program Development	Christie Jestis	2010	In this presentation, the funding situation of TxDOT in 2010 is discussed. The presentation gives estimates of projects cost in the eastern and western areas.

TXDOT PROJECT SELECTION PROCESS

Project prioritization, determination of goals and strategies are based on demographic and economic trends, technological innovations, transportation-related initiatives, system performance and condition, and feedback through the planning and project selection process. In order to evaluate the needs of a region, the collaboration of state, regional and local authorities is essential. The metropolitan mobility transportation needs are determined by the Metropolitan Planning Organization in each region (TxDOT 2011a).

The overall criteria for selecting projects should be aligned with at least one of the following goals (TxDOT 2011a):

- develop an organizational structure and strategies designed to address the future multimodal transportation needs of all Texans,
- enhance safety for all Texas transportation system users,
- maintain the existing Texas transportation system,
- promote congestion relief strategies,
- enhance system connectivity,

- facilitate the development and exchange of comprehensive multimodal funding strategies with transportation program and project partners.

Projects are also assessed on their impacts to:

- address local, regional or statewide transportation issues
- provide a short-term, mid-term or long-term solution

Funding allocation and project selection processes are very complex. Each year, TxDOT funds projects that are selected through a comprehensive plan called the Unified Transportation Program. The Unified Transportation Program (UTP) is a list of candidate projects to be constructed and/or developed during a ten year period. Before any project is considered for funding, it must pass through a project selection process. In order to facilitate this process, TxDOT has identified 12 major funding categories in which all projects must be classified before the selection begins. Table 5 shows the 12 funding categories, the relevant project selection process and the usual funding provided (TxDOT 2011b).

The UTP includes distribution of funding over the 12 funding categories for the maintenance of the existing system and for all highway construction programs (dollar amounts are in billions):

Category 1- Preventive Maintenance and Rehabilitation	$10.96
Category 2- Metropolitan and Urban Area Corridor Projects	$1.99
Category 3- Non-Traditionally Funded Transportation Projects	$3.68
Category 4- Statewide Connectivity Corridor Projects	$0.02
Category 5- Congestion Mitigation and Air Quality Improvement	$1.12
Category 6- Structures Replacement and Rehabilitation	$2.50
Category 7- Metropolitan mobility and Rehabilitation	$2.03
Category 8- Safety	$1.24
Category 9- Transportation Enhancements	$0.65
Category 10- Supplemental Transportation Projects	$0.63
Category 11- District Discretionary	$0.64
Category 12- Strategic Priority	$2.47
Total=	$27.92

*Source: 2012 Unified Transportation Program

Table 5. Summary on TxDOT's Funding Categories. (TxDOT 2011b)

FUNDING CATEGORY	PROJECT SELECTION	USUAL FUNDING
1 - Preventive Maintenance and Rehabilitation	Projects selected by districts. Commission allocates funds through Allocation Program.	Federal 90% State 10% or Federal 80% State 20% or State 100%
2 - Metropolitan and Urban Area Corridor Projects	Projects selected by Metropolitan Planning Organizations (MPOs) in consultation with TxDOT. Commission allocates funds through Allocation Program.	Federal 80% State 20% or State 100%
3 - Non-Traditionally Funded Transportation Projects	Project selection varies based on the funding source, such as Proposition 12, Proposition 14, Pass-Through Toll Finance, Regional Toll Revenue and Local Participation.	Federal 80% State 20% or State 100% or Local 100%
4 - Statewide Connectivity Corridor Projects	Projects selected by commission based on corridor ranking. Project total costs cannot exceed commission-approved statewide allocation.	Federal 80% State 20% or State 100%
5 - Congestion Mitigation and Air Quality Improvement	Projects selected by MPOs in consultation with TxDOT and funded by districts' Allocation Program. Commission allocates funds based on population percentages within areas failing to meet air quality standards.	Federal 80% State 20% or Federal 80% Local 20% or Federal 90% State 10%
6 - Bridges	Projects selected by the Bridge Division as a statewide program based on the Federal Highway Bridge Program and the Federal Railroad Grade Separation Program eligibility and ranking. Commission allocates funds through Statewide Allocation Program.	Federal 90% State 10% or Federal 80% State 20% or Federal 80% State 10% Local 10%
7 - Metropolitan Mobility/Rehabilitation	Projects selected by MPOs in consultation with TxDOT. Funded by district's Allocation Program. Commission allocates funds according to the federal formula.	Federal 80% State 20% or Federal 80% Local 20% or State 100%
8 - Safety	Projects selected statewide by federally mandated safety indices and prioritized listing. Commission allocates funds through Statewide Allocation Program. Projects selected and approved by commission on a per-project basis for Federal Safe Routes to School Program.	Federal 90% State 10% or Federal 90% Local 10% or Federal 100% or State 100%
9 - Transportation Enhancements	Local entities nominate projects and TxDOT, in consultation with FHWA, reviews them. Projects selected and approved by commission on a per-project basis. Projects in the Safety Rest Area Program are selected by the Maintenance Division.	Federal 80% State 20% or Federal 80% Local 20%
10 - Supplemental Transportation Projects	Projects selected statewide by Traffic Operations Division or Texas Parks and Wildlife Department or district. Commission allocated funds to districts or approves participation in federal programs with allocation formulas. Coordinated Border Infrastructure Program funds are allocated to districts according to the federal formula.	State 100% or Federal 80% State 20% or Federal 100%
11 - District Discretionary	Projects selected by districts. Commission allocates funds through Allocation Program.	Federal 80% State 20% or Federal 80% Local 20% or State 100%
12 - Strategic Priority	Commission selects projects which generally promote economic opportunity, increase efficiency on military deployment routes or to retain military assets in response to the federal military base realignment and closure report, or maintain the ability to respond to both man-made and natural emergencies.	Federal 80% State 20% or State 100%

The UTP has two major components: mobility and preservation. The mobility section includes projects that increase the capacity of the transportation system (categories 2, 3, 4, 5, and 7) while the preservation section includes the maintenance and rehabilitation projects found in categories 1, 6, and 7 (TxDOT 2011a). Table 6 shows a prioritized list of funding categories based on the total amounts for funding from the 2012 Unified Transportation Plan.

Table 6. Ranked list of Funding Categories based on Total Funds Allocated in FY 2012.

Rank No.	Funding Category	Amount in Billions
1	Category 1- Preventive Maintenance and Rehabilitation	10.96
2	Category 3- Non-Traditionally Funded Transportation Projects	3.68
3	Category 6- Structures Replacement and Rehabilitation	2.5
4	Category 12- Strategic Priority	2.47
5	Category 7- Metropolitan mobility and Rehabilitation	2.03
6	Category 2- Metropolitan and Urban Area Corridor Projects	1.99
7	Category 8- Safety	1.24
8	Category 5- Congestion Mitigation and Air Quality Improvement	1.12
9	Category 9- Transportation Enhancements	0.65
10	Category 11- District Discretionary	0.64
11	Category 10- Supplemental Transportation Projects	0.63
12	Category 4- Statewide Connectivity Corridor Projects	0.02

Based on funds allocated among funding categories, it is observed that the most important funding categories are those related to maintenance and rehabilitation and increasing the capacity of the existing system. Maintenance and rehabilitation are needed in order to keep the existing roads in good condition while expanding capacity decreases congestion and increases mobility.

Figure 1 shows the funding allocation schematic diagram for TxDOT presented by Ron Hagquist in the project's pre-proposal meeting. Maintenance of the transportation system corresponds to categories 1 and 6, while the capacity section includes categories 2, 3, 4, 5, and 7. After a meeting in October 2011 with Ron Hagquist, the team was advised to focus on the capacity section of the allocation process using information from the Metropolitan Planning Organizations (MPOs) to illustrate the process of selecting candidate projects. Fair division methods will be focused on the allocation of funds to add capacity to the existing transportation system in order to mitigate congestion and to address the future needs of a growing population.

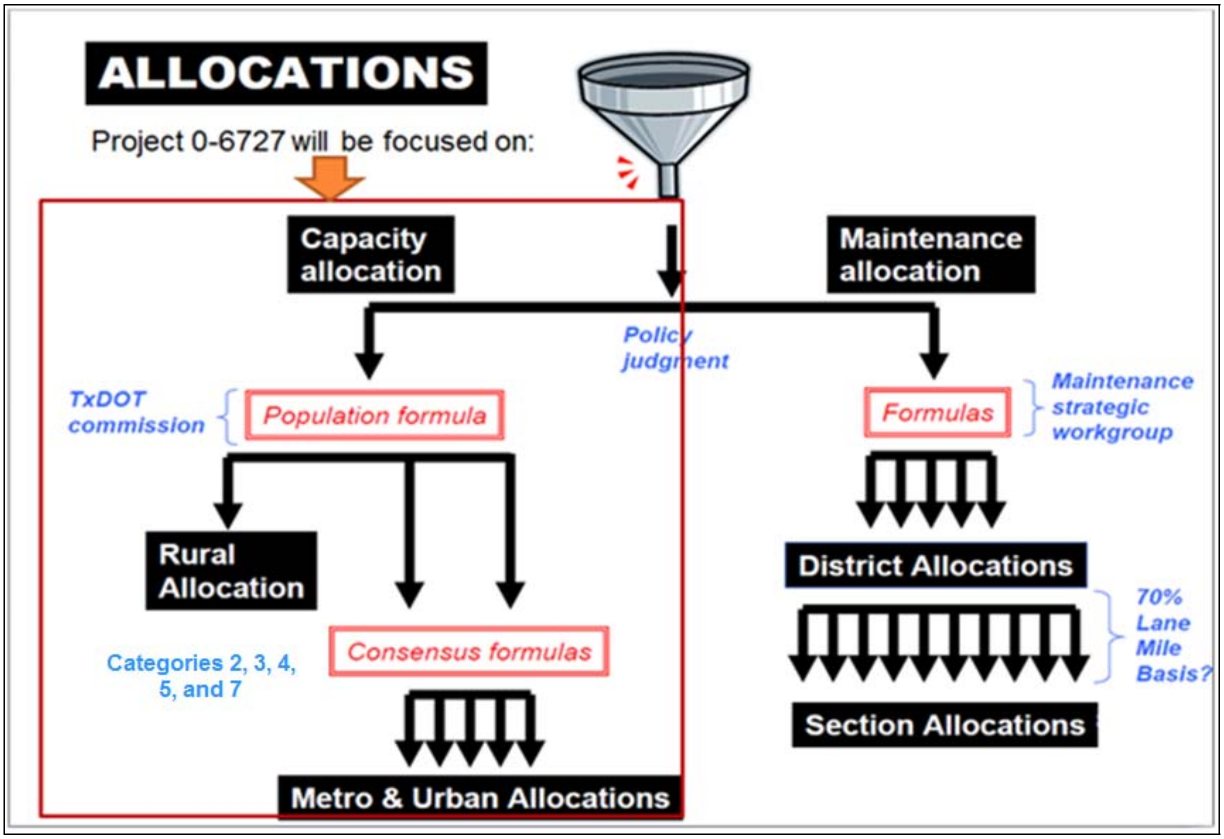

Figure 1. Funding Allocation Schematic Diagram for TxDOT. (Hagquist 2011-revised by UTEP)

THE ROLE OF THE METROPOLITAN PLANNING ORGANIZATIONS (MPO)

The Metropolitan Planning Organization (MPO) is the agency in charge of creating long and short range transportation plans in order to improve the road system in a specified area. These plans include all proposed transportation projects needed by the region. Under federal law, one Metropolitan Planning Organization must be designated for each urban area with a population of 50,000 or more. The MPO provides a continuing, cooperative, and comprehensive transportation planning process that results in plans and programs that consider all transportation modes and supports metropolitan community development and social goals. Each of the MPOs receives federal funding for transportation planning, and state and local funds for mandated planning activities (TEMPO 2011). Currently, there are twenty-five MPOs in the state of Texas:

- Abilene MPO
- Amarillo MPO
- Austin MPO (CAMPO)
- Beaumont-Port Arthur MPO (SETRPC)
- Brownsville MPO
- Bryan-College Station MPO
- Corpus Christi MPO
- Dallas- Fort Worth MPO (NCTCOG)

- El Paso MPO
- Harlingen/ San Benito MPO
- Hidalgo County MPO
- Houston MPO (HGAC)
- Killeen-Temple MPO (KTMPO)
- Laredo MPO
- Longview MPO
- Lubbock MPO
- Midland-Odessa MPO (MOTOR)
- San Angelo MPO
- San Antonio- Bexar County MPO
- Sherman- Denison MPO
- Texarkana MPO
- Tyler Area MPO
- Victoria MPO
- Waco MPO
- Wichita Falls MPO

All MPOs are required to produce a Metropolitan Transportation Plan (MTP), a Transportation Improvement Program (TIP), and a Unified Planning Work Program (UPWP). The MTP is a long range transportation plan. This plan includes the policies, strategies, and projects that will facilitate the efficient movement of people and goods in the metropolitan area for the next 25 years. By contrast, the Transportation Improvement Program is a short term transportation plan. The TIP contains the transportation projects and strategies from the Metropolitan Transportation Plan that the MPO plans to construct over the next 4 years. In the Unified Planning Work Program, the MPOs create a detailed two-year transportation planning work program. The UPWP assures that the MTP and the TIP projects are constructed according to federal and state laws and regulations.

Metropolitan Transportation Plan

The Metropolitan Transportation Plan (MTP) is a comprehensive, multimodal blueprint for transportation systems and services intended to solve the mobility needs of a given metropolitan area through the next 25 years. Plans, projects, programs, and policies are proposed as transportation recommendations to improve the overall quality of life of area residents. Every five years, the regional MPO in cooperation with TxDOT, local governments, and transportation agencies, develops a new MTP (NCTCOG 2011).

Transportation Improvement Program

The Transportation Improvement Program (TIP) is a staged, multiyear program of projects approved for funding by federal, state, and local sources. Every two to three years, the regional MPO in cooperation with TxDOT, local governments, and transportation agencies, develops a new TIP (NCTCOG 2011).

Unified Planning Work Program

The Unified Planning Work Program (UPWP) is a two-year transportation planning work program detailing transportation planning, programs and services (work) to be performed in the region. It contains a listing of planning projects, programs and services performed by public and private transportation planning agencies and partnerships whose projects will have a regionally significant impact in the area. The UPWP coordinates metropolitan transportation and air quality planning activities (El Paso MPO 2011). Figure 2 shows an affinity diagram illustrating the characteristics of the three different transportation plans.

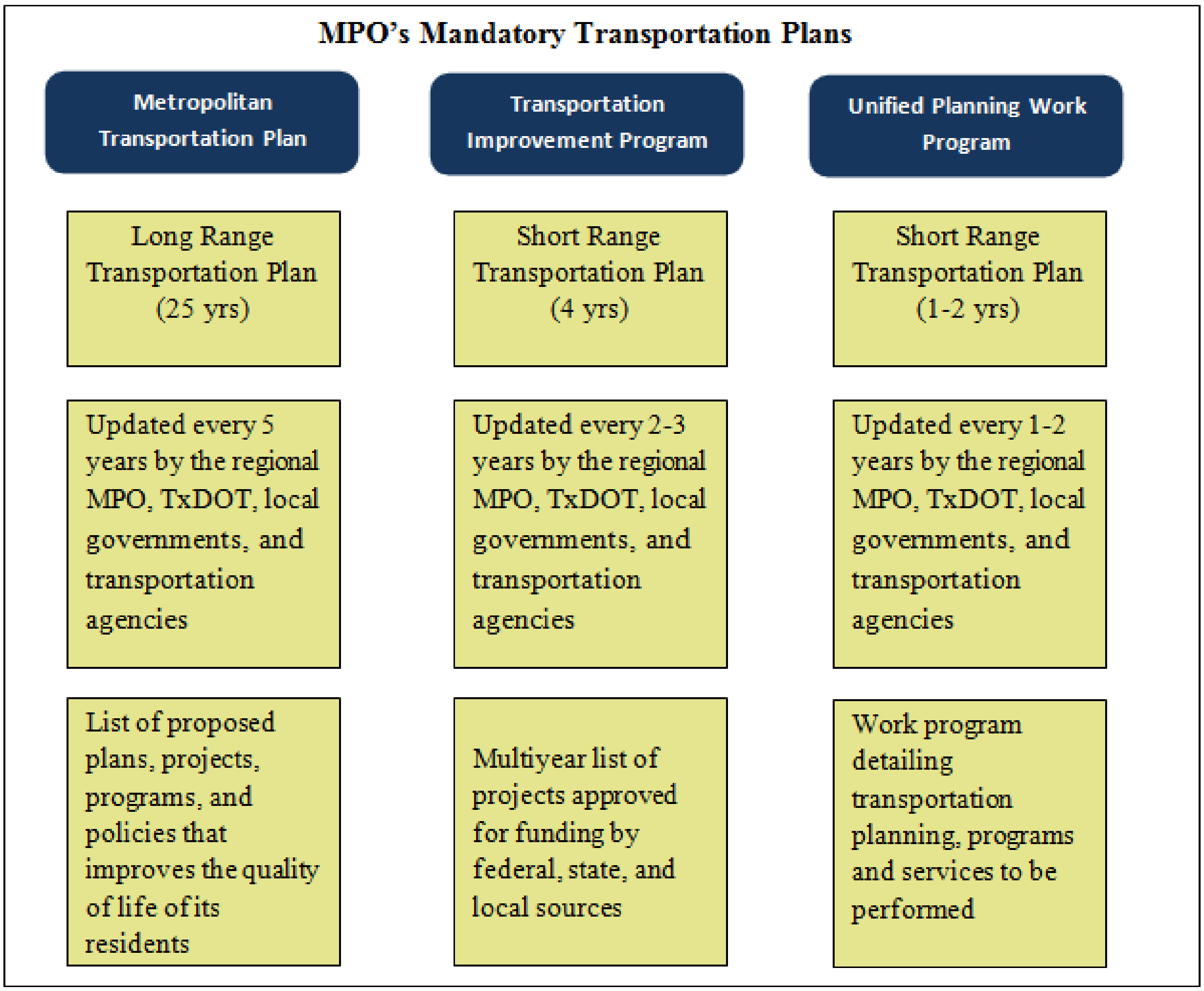

Figure 2. Descriptive Characteristics of MPOs' Transportation Plans.

CHAPTER 4:

FAIR DIVISION TRANSPORTATION FUNDING ALLOCATION MODEL

Fair Division models have been used to solve a wide variety of disputes. This chapter describes the application of fair division methodologies to address a funding allocation problem with a practical model. The model uses fair division methods investigated in the literature review and practical expert knowledge to allocate transportation funds maximizing desirability (preferences) and minimizing envy among participants.

In the fair division literature review it was mentioned that in order for an allocation to be fair, four characteristics were desired: proportionality, envy-freeness, equitability, and efficiency. In order to be proportional, each participant must receive at least $1/n$ of what they asked for (where n is the total number of participants). An envy-free distribution means that every participant must think that he/she received the largest or most valuable portion of something- based on his/her own valuation- and hence does not envy anyone else. Equitability is achieved when each participant feels they received the same value as the other participants while efficiency means that there is not another allocation that is better for one participant and as good for all the other participants.

Researchers have shown that the four characteristics may be achieved when considering two participants (Brams 1996), however, in the allocation of transportation funds, it is not always possible to achieve these four criteria because there are often more than two parties requesting funds and the projects to be allocated are indivisible. Nonetheless, the methodologies and approaches that underlie fair division methods allow searching for solutions which minimize envy among participants. Based on the literature review done in previous tasks, it was determined that there is not available a fair division method which can be directly applied to the allocation of transportation funds (Dupois-Roy 2009). Therefore, a new Fair Division Transportation Allocation Model was developed to allocate transportation funds.

The Fair Division Transportation Funding Allocation Model (FDTFAM) is based on a combination of the Adjusted Winner and the Point Allocation procedures for allocating funds. This Adjusted Winner algorithm is used to provide envy-free, equitable, and efficient distributions by dividing the indivisible goods based on the participant's preference or desirability. FDTFAM also applies the Point Allocation concept to define the individual subjective preferences of the participants. Due to the simplicity of the model, two methods are proposed to solve the problem formulation: ranking and optimization. The methods look for maximizing the total desirability of the projects while minimizing the total envy.

ENVY DEFINITION

Envy is said to exist when a participant feels that he or she received proportionally less of the monetary value requested than the other participants. Envy could be defined as the difference in ratios of allocated to requested funds between two participants.

$$\varepsilon_{ij} = \begin{cases} |\rho_i - \rho_j|, & if\ (\rho_i - \rho_j) < 0 \\ 0, & otherwise \end{cases}$$

where:
ρ_i = Allocated to requested funding ratio of i^{th} participant
ρ_j = Allocated to requested funding ratio of j^{th} participant
ε_{ij} = envy sensed by the i^{th} with respect to the j^{th} participant
n = number of participants

Equation 1, represents the estimated envy by the i^{th} participant with respect to the j^{th} participant if the i^{th} participant received proportionally less of what it requested than the j^{th} participant by comparing their respective allocated to requested funding ratios. No envy is felt by the i^{th} participant with respect to the j^{th} participant if the i^{th} participant received more that the j^{th} participant.

The higher the envy, the higher the difference between each participant's ratios of allocated to requested funds. These ratios represent the percentage (in decimals) that each participant received with respect to their individual total requested funds; i.e. a 1.0 ratio indicates that the participant received 100% of what it requested.

DESCRIPTION OF THE FAIR DIVISION TRANSPORTATION FUNDING ALLOCATION MODEL (FDTFAM)

The fair division algorithm uses a modified version of the Adjusted Winner (AW) and the Point Allocation procedures, and incorporates the minimization of envy. The model provides a list of preferences that participants have with respect to projects; each participant secretly distributes 100 points across all the projects in the allocation according to the importance it attaches to winning each project. High points represent high preference; therefore, the algorithm funds the projects arranged in a decreasing order list. Rates of Return (ROR) could also be used in order to provide preferences over the projects. Usually, participants will give more preference to projects with higher ROR. Can AW be manipulated to benefit one side? It turns out that exploitation of the procedure by one side is practically impossible unless that side knows exactly how the other side will allocate its points. In the absence of such information, attempts at manipulation can backfire miserably, with the manipulator ending up with less than the minimum number of points its honesty guarantees it.

A solution to the fair division problem attempts to make all of the recipients believe that they have been allocated a fair share of a resource. Previous definitions of fair share are based on the bid a recipient places on the desired asset. In addition, the resource is to be divided by the participants (*i.e.* no arbitrator is involved in the allocation). Based on these concepts, a bi-objective formulation was developed for the FDTFAM. The bi-objective formulation strives to maximize the desirability of the projects while trying to minimize envy under budget constraints.

Envy is said to exist when a player feels that he or she received less monetary value than the others. In this algorithm, envy is defined as the difference in ratios of allocated to requested funds between two participants. The higher the envy, the higher the difference between each participant's ratios of allocated to requested funds. Envy-free distributions are only guaranteed for a small number of participants (usually two); therefore, the algorithm aims to minimize the envy felt by the participants because an envy-free allocation is impossible among multiple participants. The goal of the algorithm is to minimize the differences between the ratios of allocated to requested money among all the participants in order to minimize envy.

Based on the literature review, it was determined that, in order to allocate transportation funds, some project information needed to be gathered such as the projects' descriptions, costs and expected rates of return. Figure 3 shows a graphical representation of the steps performed in the Fair Division Transportation Funding Allocation Model. The FDTFAM is divided into 8 stages or steps.

The Fair Division Transportation Funding Allocation Model first determines the funding allocation categories to be used. Once the categories are defined, the projects to be selected for funding are included in the model along with their description, cost, rate of return (ROR) if available, and corresponding funding category. Then, the projects are classified per funding category. After the projects are defined, each participant is given 100 points to distribute among all their projects. These points measure the desirability that a participant assigns to a given project. Each participant can use their own criteria when assigning the points. Desirability represents how desirable a certain item is to the corresponding participant; in this case, how much a given participant wants a project to be funded on a 100-point scale. Desirability is different for each participant because it depends on individual preferences or priorities. Higher points represent higher preference or higher desirability.

After the 100 points are assigned to the projects desired by each participant, there are two methods to allocate the funds either the ranking or the optimization method.

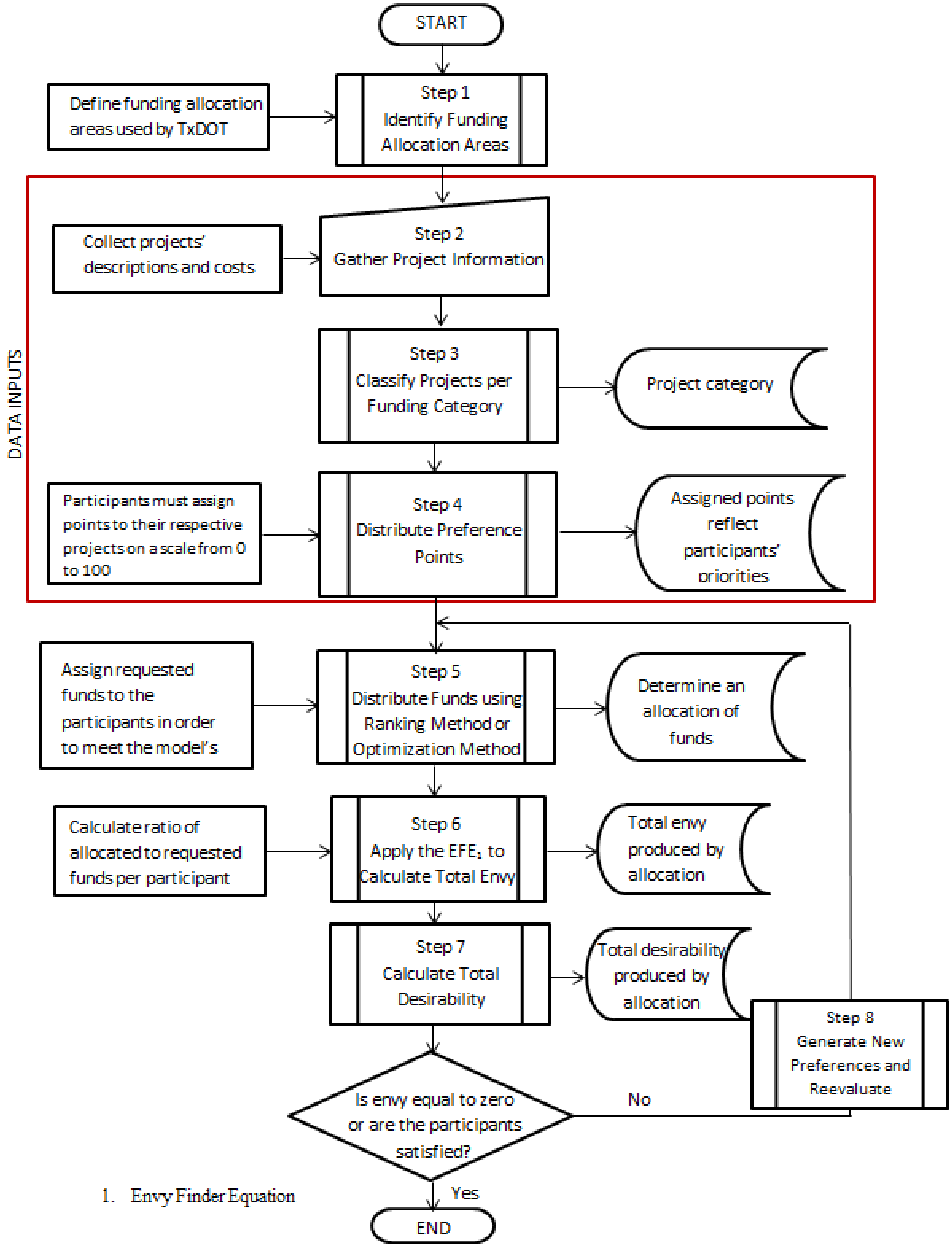

Figure 3. Fair Division Transportation Funding Allocation Model (FDTFAM) Flowchart.

RANKING METHOD USING THE DYNAMIC BUBBLE-UP (DBU) TECHNIQUE

In the ranking method, projects are ranked in each category based on these points which indicates its desirability. In this model, funds are distributed using the Dynamic Bubble Up technique (DBU) (Chang 2007). In DBU, projects are ranked from high to low desirability. Then, the ranked list of projects (one list per category) is used to allocate funds beginning with the project with the highest desirability. In this step, a budget constraint per category must be given. Projects will be funded if the available budget is less than or equal to the requested money per project. If a project is funded, the second highest-point project "bubbles up" to the top for funding. This process is repeated until no money is left or all the projects are funded. This process is repeated in all categories. FDTFAM will end when all the participants are satisfied with the projects selected for funding after the allocation.

OPTIMIZATION METHOD USING A GENETIC ALGORITHM

In the optimization method, the allocation of funds process is done by optimization instead of the ranking method. Once the desirability of projects is established by the assignation of preference points, the projects must be matched with funding categories. Then, the optimization model must be executed to select the projects that produce minimization of envy while maximizing desirability.

In the optimization method, a set of objective formulas need to be created to arrive to the optimal or best solution possible. In this case, the two objective functions are to minimize envy (using the envy definition) and to maximize the total points or desirability allocated to all the participants under budget constraints. In this way, the participants will have a low envy allocation while receiving funds for the projects with higher desirability, i.e. higher preference points.

Multiple Objective Optimization for Funding Allocation

$$\max\left[\sum_{i=1}^{n} P_i(\mathrm{X}_i)\right] \text{and } \min\left[\sum_{i=1}^{n} \varepsilon_{ij}(\mathrm{X}_i)\right]$$

Subject to:

$$\sum_{i=1}^{n} C_i(X_i) \leq b_k, \quad \forall k = 1,2,\dots,m$$

$$\sum_{k=1}^{m} x_{ki} \geq 1, \ \forall i = 1,2,\dots,n$$

$$x_{ki} \in \{0,1\}$$

Where:
n = number of participants

$X_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,m_i})$
m = number of funding categories
x_{ki} = project that belongs to the k^{th} funding category requested by participant i
$\varepsilon_{ij}(X_i)$ = envy sensed by the i^{th} with respect to the j^{th} participant
P_i (X_i) = desirability allocated per participant i
$C_i (X_i)$ = total funds allocated per participant i
b_k = budget available per funding category k

To solve the multi-objective model formulation, we selected the software SolveXL because of its software capabilities, ease of use, and ability to work with excel spreadsheets. This software uses the Non-dominated Sorting Genetic Algorithm (NSGA-II) which is based on an evolutionary process (natural selection) with substitutes for evolutionary operators including selection, genetic crossover, and genetic mutation. The population is sorted into a hierarchy of sub-populations based on the ordering of Pareto dominance. Similarity between members of each sub-group is evaluated, and the resulting groups and similarities are used to promote a diverse front of non-dominated solutions. NSGA-II varies from a simple genetic algorithm only in the way the selection operator works. The crossover and mutation operators remain as usual. Before the selection is performed, the population is ranked on the basis of an individual's non domination (Srinivas 1994).

After the money is distributed, the envy ratios are calculated using the Envy Finder Equation (EFE). EFE is used to calculate the total envy obtained after the allocation process. It simply considers each participant's estimated envy with respect to the funds allocated to the rest of the participants. According to this equation, no envy is felt by the i^{th} participant with respect to the j^{th} participant if the i^{th} participant received more that the j^{th} participant.

$$\text{EFE} = \sum_{i=1}^{n} \varepsilon_{ij}(X_i)$$

Where:

ε_{ij} = envy sensed by the i^{th} with respect to the j^{th} participant $= \begin{cases} |\rho_i - \rho_j|, & if\ (\rho_i - \rho_j) < 0 \\ 0, & otherwise \end{cases}$

X_i = 1 if corresponding project is selected, 0 otherwise
ρ_i = Allocated to requested funding ratio of i^{th} participant
ρ_j = Allocated to requested funding ratio of j^{th} participant

The first phase of the EFE is to calculate the total amount of money requested by each participant and the total actual amount given to each participant in all categories. Then, the ratios of total assigned to total requested money per participant are calculated. Once these ratios are known, the ratio of each participant must be compared to the ratio of every other participant. When the difference among these ratios is negative (implying that another participant received a larger share), the absolute value of this difference is called the envy ratio. Once the individual envy ratios are calculated, all the individual envy ratios must be added together to calculate the total envy produced by the distribution of funds.

Also, the total desirability generated in the allocation is calculated by simply adding the preference points that each participant obtained at the end of the distribution. If the total envy achieved by the allocation is equal to zero or satisfies the participants then the model stops; if not, new possible distributions are analyzed based on participants' desire for projects. In reality, it is almost unfeasible to achieve a total envy equal to zero in a distribution that involves more than two participants. Therefore, the process is repeated until all the participants are satisfied with their allocated shares.

CHAPTER 5:

APPLICATION OF THE FAIR DIVISION TRANSPORTATION FUNDING ALLOCATION MODEL

In order to show the applicability of the Fair Division Transportation Funding Allocation Model, a case study was developed. The data were provided by TxDOT and included 121 projects from 21 districts. All projects correspond to funding category 12. Districts requested from 1 to 31 projects. The total budget requested by all districts was $ 211,896,568. The lowest cost project was $ 10,655 while the highest cost project was $ 38,975,000. Each district was required to divide 100 points among their own projects based on their preferences and priorities. Higher points mean higher preference or higher desirability. Details about the project costs and priorities are in Table 7.

BUDGET SCENARIOS

Four budget constraint scenarios were developed using FDTFAM to allocate available funds:

- Scenario 1: the budget available for funding was 50% of the total funds requested by all the districts
- Scenario 2: the budget available for funding was 75% of the total funds requested by all the districts
- Scenario 3: the budget available for funding was 80% of the total funds requested by all the districts
- Scenario 4: the budget available for funding was 90% of the total funds requested by all the districts

The funds were distributed among participants or districts using the ranking method (bubble up technique) and the optimization method described in Chapter 4.

Table 7. Data Provided by the Districts.

Districts	Total Amount Requested by District	Number of Projects Requested	Project With Highest Points Requested	Project With Highest Points	Project With Lowest Points Requested	Project With Lowest Points
ABILENE	$ 1,269,158	1	$ 1,269,158[1]	100	-	-
AMARILLO	$ 3,434,400	1	$ 3,434,400[1]	100	-	-
ATLANTA	$ 7,026,999	2	$ 5,996,999[1]	55	$ 1,030,000[2]	45
AUSTIN	$ 12,066,250	4	$ 5,242,500[1]	50	$ 123,750[2]	5
BEAUMONT	$ 2,361,205	1	$ 2,361,205[1]	100	-	-
BRYAN	$ 11,812,973	31	$ 3,041,060[1] $ 2,308,713 $ 705,200 $ 563,800 $ 325,000	8	$ 32,900[2]	1
CHILDRESS	$ 3,577,463	12	$ 514,404[1] $ 510,000	20	$ 276,000 $ 275,000 $ 269,541 $ 258,363 $ 239,112 $ 223,685 $ 135,000 $ 120,000[2]	5
CORPUS CHRISTI	$ 125,001	2	$ 85,000[1]	90	$ 40,001[2]	10
DALLAS	$ 43,627,157	4	$ 38,975,000[1]	85	$ 2,325,000 $ 2,242,157 $ 85,000[2]	5
EL PASO	$ 5,101,374	2	$ 3,225,000[1] $1,876,374	50	-	-
FORT WORTH	$ 4,240,180	2	$ 2,438,839[1]	55	$ 1,801,341[2]	45
HOUSTON	$ 5,446,910	5	$ 2,585,000[1]	50	$ 210,274[2]	5
LAREDO	$ 2,790,300	3	$ 1,280,000[1]	60	$ 573,000[2]	10
LUBBOCK	$ 19,242,002	2	$ 17,342,001[1]	90	$ 1,900,001[2]	10
LUFKIN	$ 163,594	1	$ 163,594[1]	100	-	-
PARIS	$ 3,137,019	1	$ 3,137,019[1]	100	-	-
PHARR	$ 18,918,327	31	$ 10,000,000[1]	16	$ 65,617 $ 59,385 $ 40,670 $ 38,505 $ 10,655[2]	1
SAN ANTONIO	$ 37,694,952	9	$ 11,000,001[1]	25	$ 1,589,224 $ 1,200,000 $ 1,054,400 $ 650,000[2]	5
WACO	$ 15,786,052	3	$ 10,793,051[1]	65	$ 173,000[2]	10
WICHITA FALLS	$ 2,375,252	1	$ 2,375,252[1]	100	-	-
YOAKUM	$ 11,700,000	3	$ 5,700,000[1]	45	$ 2,000,000[2]	20
Total	$ 211,896,568	121				

[1] Indicates the highest cost project per district
[2] Indicates the lowest cost project per district

CASE STUDY RESULTS

The project information provided by the districts was analyzed for funding using the ranking and the optimization methods. The results obtained show different distributions of funds that help to achieve each of the methods' goals. The ranking method strives to maximize the desirability obtained in the distribution while the optimization method tries to minimize envy while maximizing desirability under budget constraints. Details about the number of projects selected in each District, and corresponding envy are included in Appendix A. A summary of the results is shown in Table 8. In this case study, a total of 121 projects were requested for funding and the total requested funds were $ 211,896,568.

Table 8. Comparison Table of Results between Ranking and Optimization Methods.

Scenario's Budget	Ranking				Optimization			
	Total Allocated	Projects Allocated	Total Envy	Total Desirability	Total Allocated	Projects Allocated	Total Envy	Total Desirability
SCENARIO 1: 50% of total requested $105,948,284	$105,936,792	21	93.12	1411= Avg. 67.2 per district	$104,886, 255	83	61.37	1753= Avg. 83.5 per district
SCENARIO 2: 75% of total requested $158,922,426	$158,912,948	36	58.43	1748= Avg. 83.2 per district	$158,777, 926	88	37.92	1921= Avg. 91.5 per district
SCENARIO 3: 80% of total requested $169,517,254	$169,509,303	39	47.55	1777= Avg. 84.6 per district	$169,068, 874	93	29.30	1966= Avg. 93.6 per district
SCENARIO 4: 90% of total requested $190,706,911	$190,697,678	53	25.12	1897= Avg. 90.3 per district	$190,581, 647	101	13.65	2015= Avg. 96.0 per district

Based on the results obtained in this case study, the following can be concluded:

1) It is observed that total envy decreases as the budget available for funding increases.

2) Scenario 1 is the scenario with the highest envy (using both solving methods), as shown in Table 2. In this scenario, the total budget available was 50% of the total requested funds. Fewer projects were selected as compared to the other scenarios. For example, scenario 1 selected twenty-one (21) projects for funding in the ranking method while scenario four selected fifty-three (53) projects using the same method.

3) Scenario 4 in which the available budget was 90% of the total requested is the scenario with the lowest envy, as shown in Table 2. A total envy of 25.12 was obtained with the ranking method and 13.65 with the optimization method. The reason for this decrease in envy was due to the high funds available that allowed more projects to be funded thus increasing the allocated/requested ratios of all participants.

4) The optimization method minimized the envy and maximized the desirability (points) in all four scenarios, as compared to the ranking method.

5) Districts that requested only one (1) project obtained funding for that project in all scenarios, using the ranking and the optimization methods. The project costs varied from ($163,594 to $ 3,434,400). In the ranking method, they had a priority due to the high points that were assigned. In the optimization method, they were selected for funding because if funded, their allocated/requested ratio per district would be one and the total points assigned to that district are 100.

6) Bryan and Pharr districts requested 31 projects each. This situation ended up giving them a very low allocated/requested funding ratio (as compared to all other districts) due to the lower points that were assigned to the projects. Bryan assigned 8 pts. to the highest preference project and Pharr assigned 16 pts.

    a. The ranking method resulted in 6 projects for Bryan and 5 projects for Pharr in scenario 4 (90% funds available).

    b. The optimization method resulted in 25 projects to Bryan and 22 projects to Pharr in the scenario 4 (90% of funds available).

Optimization Method Results using the Non-dominated Sorting Genetic Algorithm (NSGAII)

Figures 4 to 7 represent the results obtained using the optimization software SolveXL which uses the Non-dominated Sorting Genetic Algorithm. The bi-objective model tries to find solutions, by funding different projects, which will minimize total envy while maximizing desirability. Each point in the graph represents one possible solution to the problem; it is shown in terms of the total envy and total desirability that it generates. Total envy and desirability results were normalized in order to simplify the results and the comparison among scenarios. The ideal solutions to this problem are the points with low envy and high desirability; therefore, the frontier points are possible solutions to the problem. The best solution of the optimization problem will be the point that is closest to the coordinate (0,1) meaning that it will have a low envy and at the same time with a high desirability.

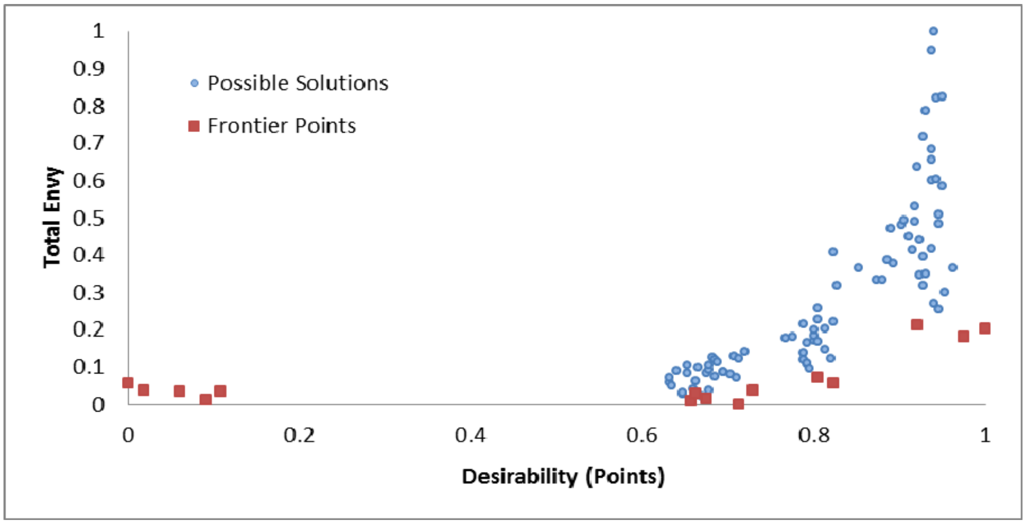

Figure 4. Possible Funding Allocation Solutions in Scenario 1 with Optimization.

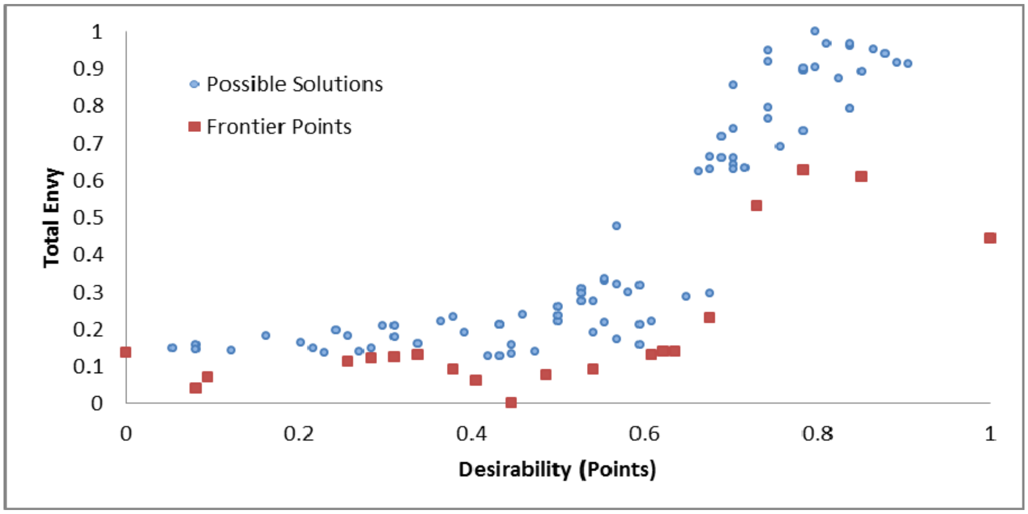

Figure 5. Possible Funding Allocation Solutions in Scenario 2 with Optimization.

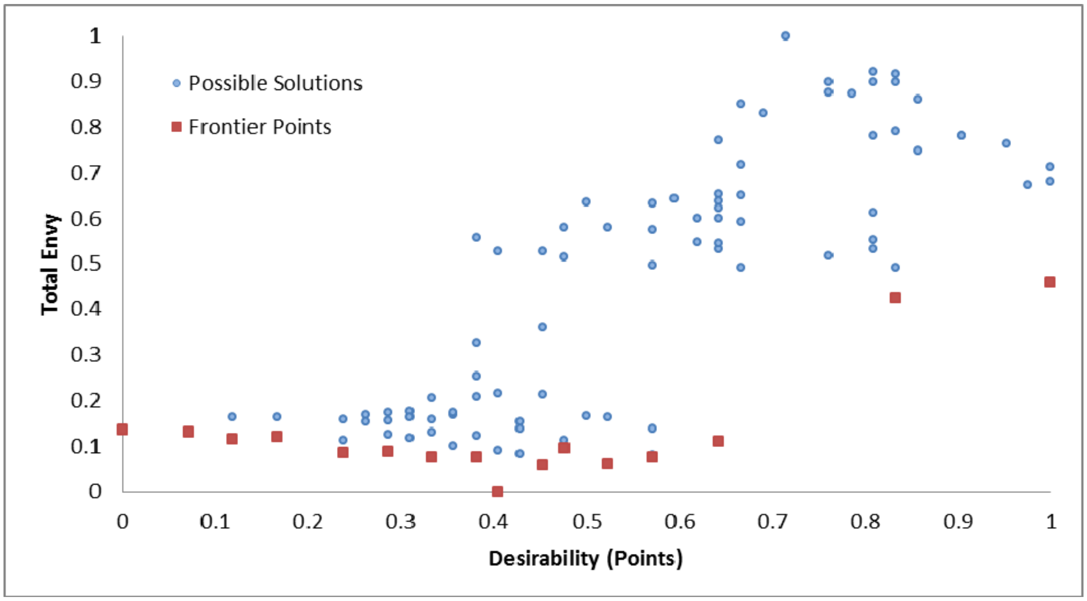

Figure 6. Possible Funding Allocation Solutions in Scenario 3 with Optimization.

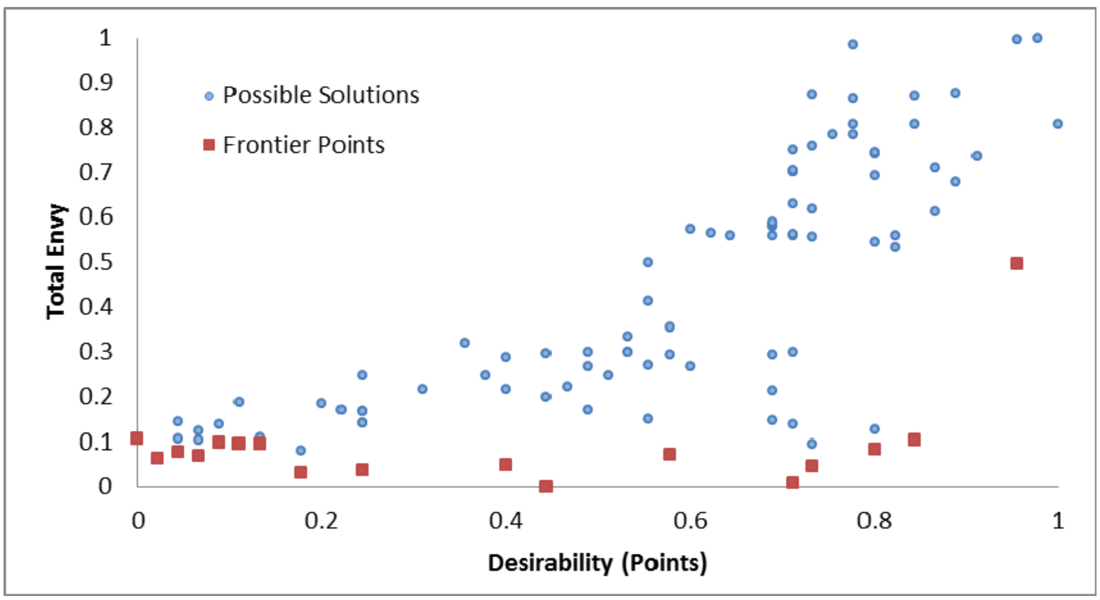

Figure 7. Possible Funding Allocation Solutions in Scenario 4 with Optimization.

COMPARING THE RESULTS FROM RANKING AND OPTIMIZATION

Ranking allocation (Bubble Up) strives to maximize desirability per scenario and the optimization method attempts to maximize desirability and minimize envy; therefore, optimization gives lower envy and higher desirability allocations using almost the same budget as the ranking method. The optimization method tries to give the districts an almost equal allocated/requested ratio. This technique minimizes the differences among the districts' allocated to requested funding ratios and reduces total envy.

From this case study, it can be seen that the optimization method funds more projects because it does not provide funding to some high cost projects that are selected by the ranking method. This change allows a greater number of lower cost projects to be funded. The changes in projects selected for funding result in differences among total envy and desirability (points) between the two methods while using almost the same budget. Tables 9 and 10 also show that the mean values of total envy and its variation decreases as the budget increases in both methods. This means that the districts are achieving a more even distribution based on their own preferences. Their allocated/requested ratios are closer; therefore, they do not produce higher envy ratios. Tables 11 and 12 also show that the mean values of total desirability increase with increasing budget while its variation decreases using both methods. This means that with increasing budgets more projects are selected for funding; therefore, more desirability (points) is achieved.

Table 9. Summary of Total Envy Results using the Ranking Method.

Scenario	Projects Selected for Funding	Envy per District						
		Minimum	1st Quartile	Median	3rd Quartile	Maximum	Mean	STDV
1	21	0.00	0.00	0.97	6.57	13.67	4.43	5.48
2	36	0.00	0.00	0.00	1.44	17.50	2.78	5.61
3	39	0.00	0.00	0.00	1.42	18.23	2.26	4.87
4	53	0.00	0.00	0.00	0.57	9.09	1.20	2.57

Table 10. Summary of Total Envy Results using the Optimization Method.

Scenario	Projects Selected for Funding	Envy per District						
		Minimum	1st Quartile	Median	3rd Quartile	Maximum	Mean	STDV
1	83	0.00	0.00	0.00	1.41	17.28	2.92	5.67
2	88	0.00	0.00	0.00	0.00	17.48	1.81	4.88
3	93	0.00	0.00	0.00	0.00	12.16	1.40	3.41
4	101	0.00	0.00	0.00	0.00	7.43	0.65	1.71

Table 11. Summary of Desirability Results using the Ranking Method.

Scenario	Projects Selected for Funding	Desirability per District						
		Minimum	1st Quartile	Median	3rd Quartile	Maximum	Mean	STDV
1	21	0	50	90	100	100	67.19	39.90
2	36	0	90	100	100	100	83.24	31.05
3	39	0	90	100	100	100	84.62	29.56
4	53	39	95	100	100	100	90.33	19.08

Table 12. Summary of Desirability Results using the Optimization Method.

Scenario	Projects Selected for Funding	Desirability per District						
		Minimum	1st Quartile	Median	3rd Quartile	Maximum	Mean	STDV
1	83	5	90	100	100	100	83.48	31.57
2	88	10	100	100	100	100	91.48	22.48
3	93	40	100	100	100	100	93.62	14.89
4	101	60	100	100	100	100	95.95	9.95

CHAPTER 6:

CONCLUSIONS AND RECOMMENDATIONS

In this project, the research team found that the most critical allocation funding categories are related to: maintenance and rehabilitation projects (Categories 1, 6, and 7) and projects that increase the capacity of the existing roads (Categories 2, 3, 4, and 5). Maintenance and rehabilitation projects help to maintain the existing roads in good functional and structural condition while those projects that increase the existing transportation system's capacity mitigate congestion, addressing the future transportation needs of a growing population.

There are limited federal, state, and local funds available to perform all the projects needed. Funds are currently distributed mainly based on demographics and the size of the transportation network. The distribution of funds using formulas based on population and lane miles is perceived as unfair by small Districts. Under this method, larger cities always receive more funding and smaller Districts believe that are receiving an unequal share. Small districts have funding needs regardless of their size or population; therefore, all districts should receive a fair share according to their own necessities and priorities. Fair division methods provide tools that create distributions among *n* participants considering four characteristics: proportionality, equitability, efficiency, and envy-freeness.

CONCLUDING REMARKS

A Fair Division Transportation Funding Allocation Model (FDTFAM) was developed to address the problem of allocating transportation funds. The methodology is based on the underlying notions and concepts of fair division: proportionality, envy-freeness, equitability, and efficiency. The objective of this model is to maximize the desirability of the projects while trying to minimize envy under budget constraints.

The method consists of two main steps, the allocation of funds either using the ranking or the optimization method followed by the Envy Finder Equation (EFE) to obtain the total envy perceived by the participants due to the allocation results. This two-step approach requires the participants to express their preferences at front. The FDTFAM is solved using the ranking or the optimization method. The ranking method has a single objective, maximize desirability for each district and it is solved in Excel spreadsheet. The optimization method has a bi-objective model to minimize envy and maximize desirability. The optimization software SolveXL which works in an Excel environment was used in this research for the case study. The optimization method resulted in more projects selected for funding than the ranking method for the same budget constraint and minimizes the total envy and maximizes the total desirability.

Once the allocation process is completed, the EFE is used to calculate the total envy produced by the allocation as perceived by the participants. FDTFAM was tested under five different scenarios to evaluate its applicability. Based on the results from the case studies, the conclusions are:

- Envy is minimized when the participants reflect their "true needs" by assigning more points to the most needed projects.

- If points were assigned to projects in direct proportion to their monetary values, low total envy would be obtained; however, this method does not take into account the participants' preferences.

- If different numbers of points are assigned to the participants to distribute among their projects, the total envy produced would increase due to this difference. The participants with fewer points would feel envy since the beginning of the allocation.

- Envy is minimized when points truly reflect the participants' preferences and are provided without any bias.

RECOMMENDATION

The FDTFAM can be applied at different levels of management and extended to any TxDOT area of interest. The implementation of FDTFAM is recommended to provide decision makers with an alternative approach to allocate funds that can be compared to traditional methods. Implementation of the method can be conducted through workshops to demonstrate the applicability of FDTFAM using case studies.

GLOSARY OF FAIR DIVISION TERMS

Allocated to requested ratio: The ratio produced by dividing the total allocated funds to total requested funds per participant.

Desirability: The worthiness or value that a certain item; in this case projects, represent to a participant. In this model, desirability is measured in preference points on a 100 point scale.

Efficiency: There is no other allocation that is better for one participant and as good for all the other participants.

Envy: The difference in ratios of allocated to requested funds between two participants.

Envy-freeness: Every participant thinks that he or she received the largest or most valuable portion of something-based on his/her own valuation- and hence does not envy anyone else.

Equitability: Each participant feels that he or she received the same value as the other person.

Fair Division Methods: Methods used to divide a resource in a way that all the participants believe that they have received a fair share based on proportionality, efficiency, equitability, and envy-freeness.

Participants: Persons, districts, or Metropolitan Planning Organizations (MPOs) that will participate in the distribution of funds.

Proportionality: Each participant must receive at least $1/n$ of what they requested (n is the total number of participants).

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APPENDIX A

SUMMARY OF
RESULTS FROM THE CASE STUDY

Ranking Method

Scenario 1: Budget available is $ 105,948,284 which is 50% of total requested by the Districts ($ 211,896,568)

Table A.1. Summary of Results of Distribution of Funds in Scenario 1 with the Ranking Method.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	1	$ 5,242,500	0.43	6.57	50
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	0	$ -	0.00	13.67	0
CHILDRESS	12	$ 3,577,463	1	$ 514,404	0.14	11.23	20
CORPUS CHRISTI	2	$ 125,001	1	$ 85,000	0.68	3.32	90
DALLAS	4	$ 43,627,157	1	$ 38,975,000	0.89	0.97	85
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	1	$ 2,585,000	0.47	5.99	50
LAREDO	3	$ 2,790,300	1	$ 1,280,000	0.46	6.21	60
LUBBOCK	2	$ 19,242,002	1	$ 17,342,001	0.90	0.89	90
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	1	$ 10,655	0.00	13.66	1
SAN ANTONIO	9	$ 37,694,952	0	$ -	0.00	13.67	0
WACO	3	$ 15,786,052	1	$ 10,793,051	0.68	3.27	65
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	0	$ -	0.00	13.67	0
Total	121	$ 211,896,568	21	$ 105,936,792	**Total**	**93.12**	**1411**

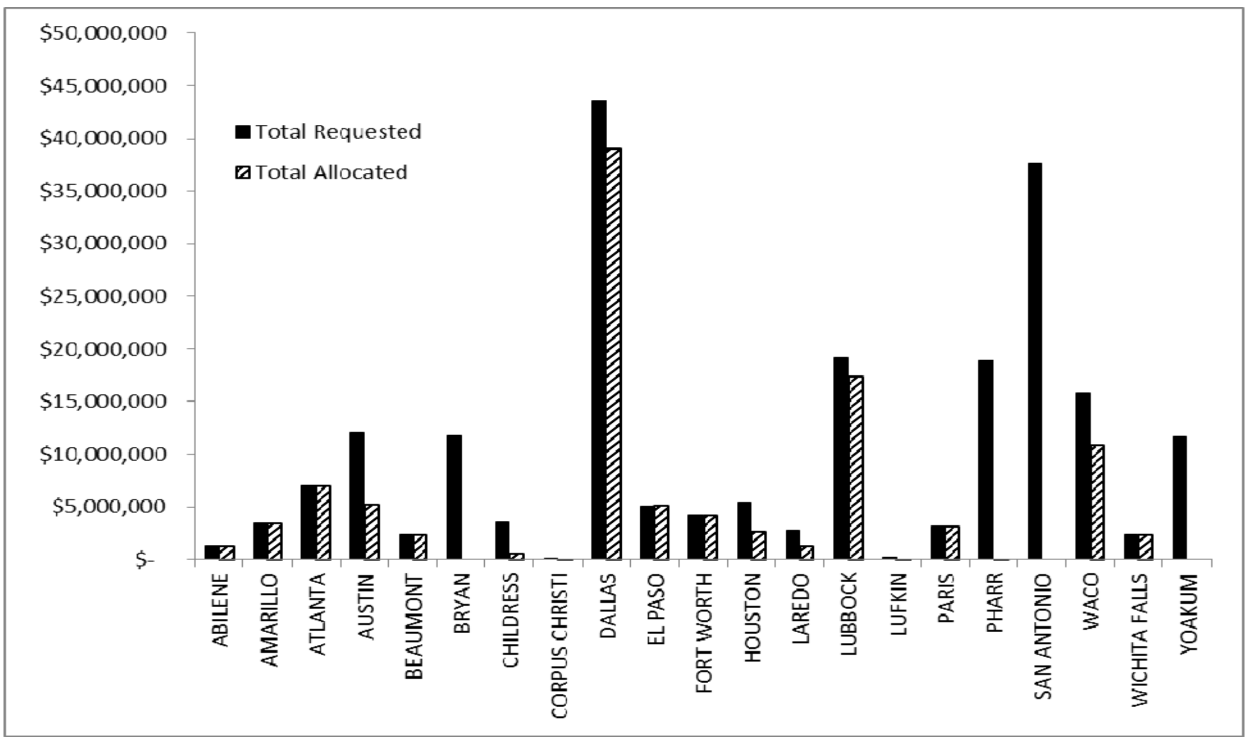

Figure A.1. Funding Allocation Results per District in Scenario 1 with the Ranking Method.

Ranking Method

Scenario 2: Budget available is $ 158,922,426 which is 75% of total requested by the Districts ($ 211,896,568)

Table A.2. Summary of Results of Distribution of Funds in Scenario 2 with the Ranking Method.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	3	$ 11,942,500	0.99	0.11	95
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	1	$ 72,300	0.01	17.38	3
CHILDRESS	12	$ 3,577,463	2	$ 1,024,404	0.29	12.05	40
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	1	$ 38,975,000	0.89	1.44	85
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	4	$ 5,236,636	0.96	0.48	95
LAREDO	3	$ 2,790,300	2	$ 2,217,300	0.79	3.02	90
LUBBOCK	2	$ 19,242,002	1	$ 17,342,001	0.90	1.32	90
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	0	$ -	0.00	17.50	0
SAN ANTONIO	9	$ 37,694,952	3	$ 25,555,573	0.68	5.00	60
WACO	3	$ 15,786,052	2	$ 15,613,052	0.99	0.12	90
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	36	$ 158,912,948	**Total**	**58.43**	**1748**

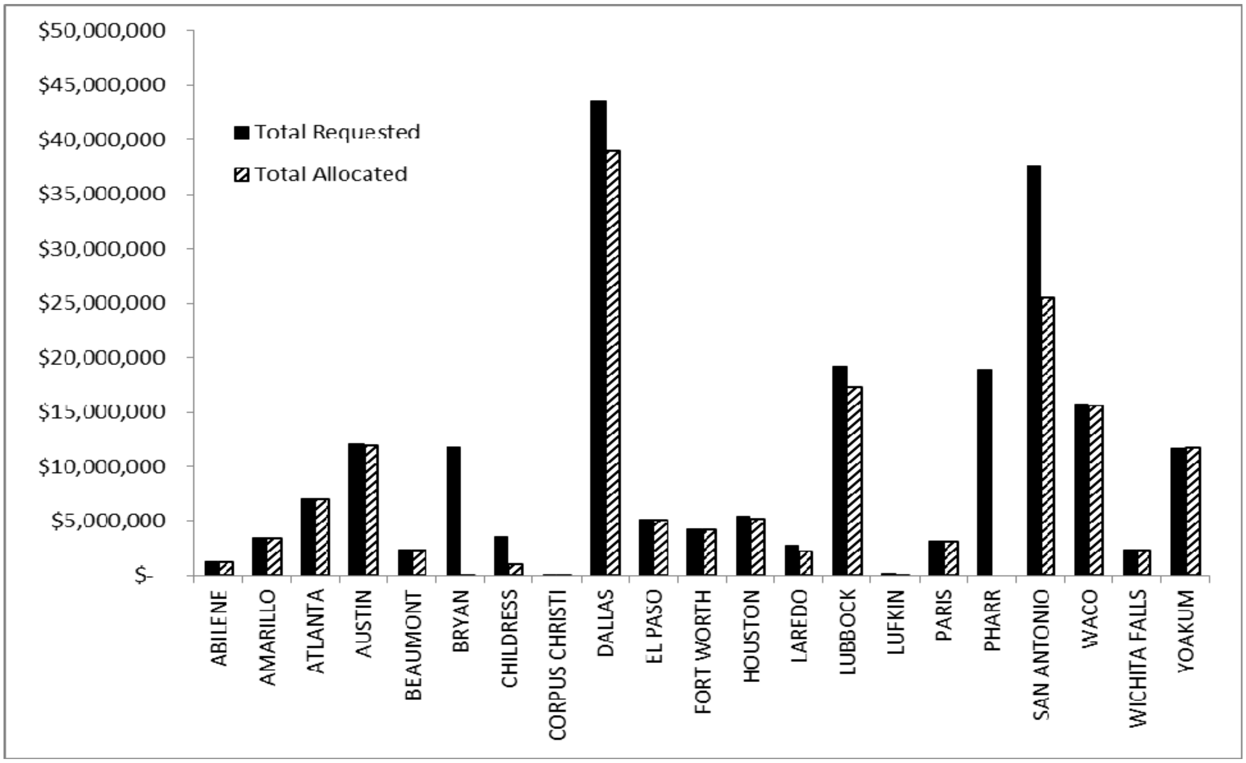

Figure A.2. Funding Allocation Results per District in Scenario 2 with the Ranking Method.

Ranking Method

Scenario A.3: Budget available is $ 169,517,254 which is 80% of total requested by the Districts ($ 211,896,568)

Table 3. Summary of Results of Distribution of Funds in Scenario 3 with the Ranking Method.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	3	$ 11,942,500	0.99	0.12	95
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	0	$ -	0.00	18.23	0
CHILDRESS	12	$ 3,577,463	2	$ 1,024,404	0.29	12.50	40
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	2	$ 39,060,000	0.90	1.52	90
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	4	$ 5,236,636	0.96	0.52	95
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	1	$ 17,342,001	0.90	1.42	90
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	2	$ 10,010,655	0.53	7.89	17
SAN ANTONIO	9	$ 37,694,952	3	$ 25,555,573	0.68	5.21	60
WACO	3	$ 15,786,052	2	$ 15,613,052	0.99	0.13	90
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	39	$ 169,509,303	**Total**	**47.55**	**1777**

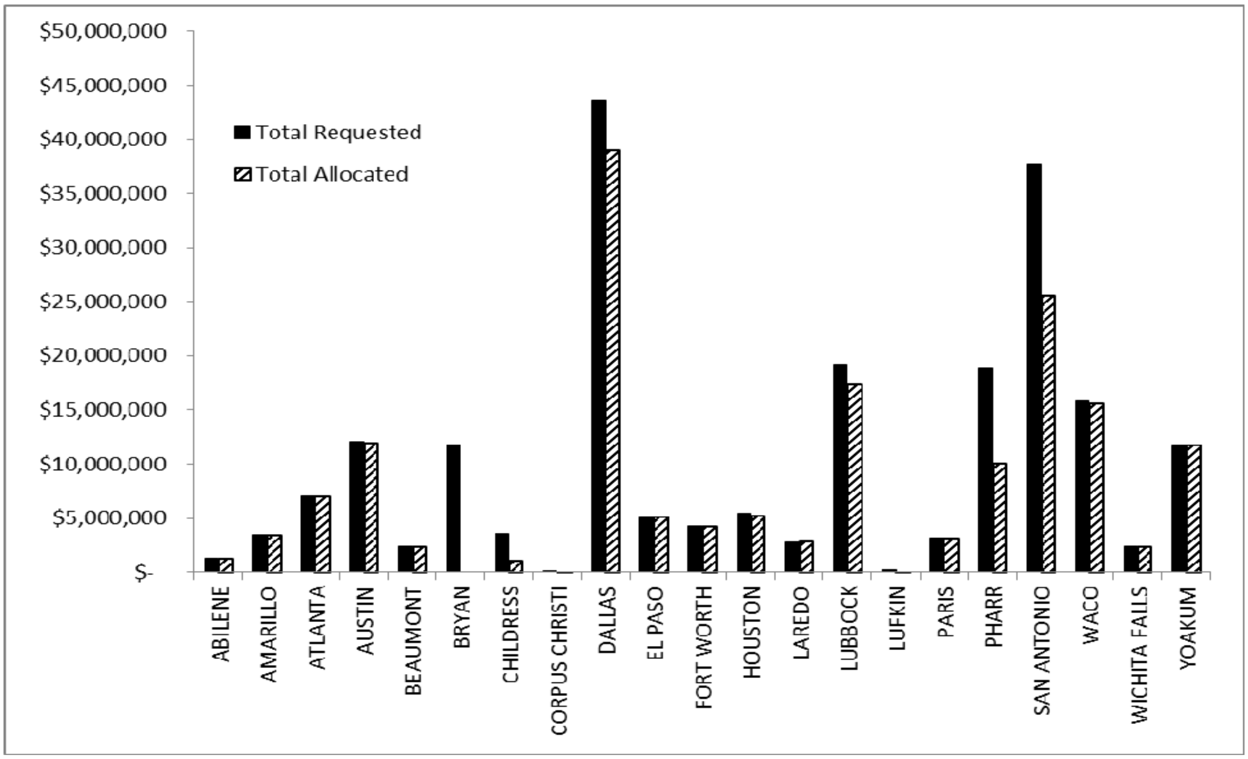

Figure A.3. Funding Allocation Results per District in Scenario 3 with the Ranking Method.

Ranking Method

Scenario 4: Budget available is $ 190,706,911 which is 90% of total requested by the Districts ($ 211,896,568)

Table A.4. Summary of Results of Distribution of Funds in Scenario 4 with the Ranking Method.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	3	$ 11,942,500	0.99	0.14	95
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	6	$ 6,987,173	0.59	7.22	43
CHILDRESS	12	$ 3,577,463	4	$ 1,780,762	0.50	9.09	60
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	1	$ 38,975,000	0.89	1.66	85
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	4	$ 5,236,636	0.96	0.57	95
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	2	$ 19,242,002	1.00	0.00	100
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	5	$ 13,821,743	0.73	4.57	39
SAN ANTONIO	9	$ 37,694,952	5	$ 33,201,328	0.88	1.87	80
WACO	3	$ 15,786,052	3	$ 15,786,052	1.00	0.00	100
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	53	$ 190,697,678	**Total**	**25.12**	**1897**

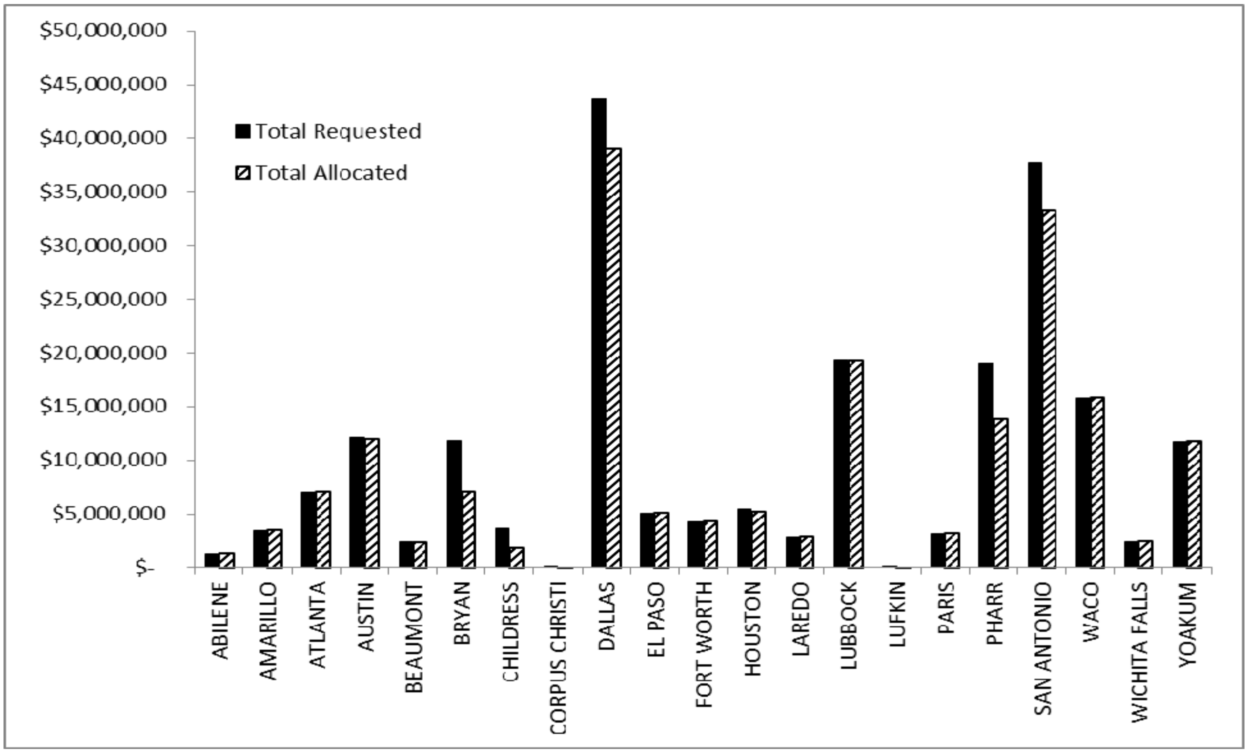

Figure A.4. Funding Allocation Results per District in Scenario 4 with the Ranking Method.

Scenario 1: Budget available is $ 105,948,284 which is 50% of total requested by the Districts ($ 211,896,568)

Table A.5. Summary of Results of Distribution of Funds in Scenario 1 with Optimization.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	4	$ 12,066,250	1.00	0.00	100
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	20	$ 9,439,473	0.80	3.04	74
CHILDRESS	12	$ 3,577,463	11	$ 3,307,922	0.92	1.05	95
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	1	$ 85,000	0.00	17.28	5
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	5	$ 5,446,910	1.00	0.00	100
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	1	$ 17,342,001	0.90	1.41	90
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	19	$ 6,008,461	0.32	11.23	54
SAN ANTONIO	9	$ 37,694,952	1	$ 2,645,755	0.07	15.91	10
WACO	3	$ 15,786,052	1	$ 4,820,001	0.31	11.45	25
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	83	$ 104,886,255	**Total**	**61.37**	**1753**

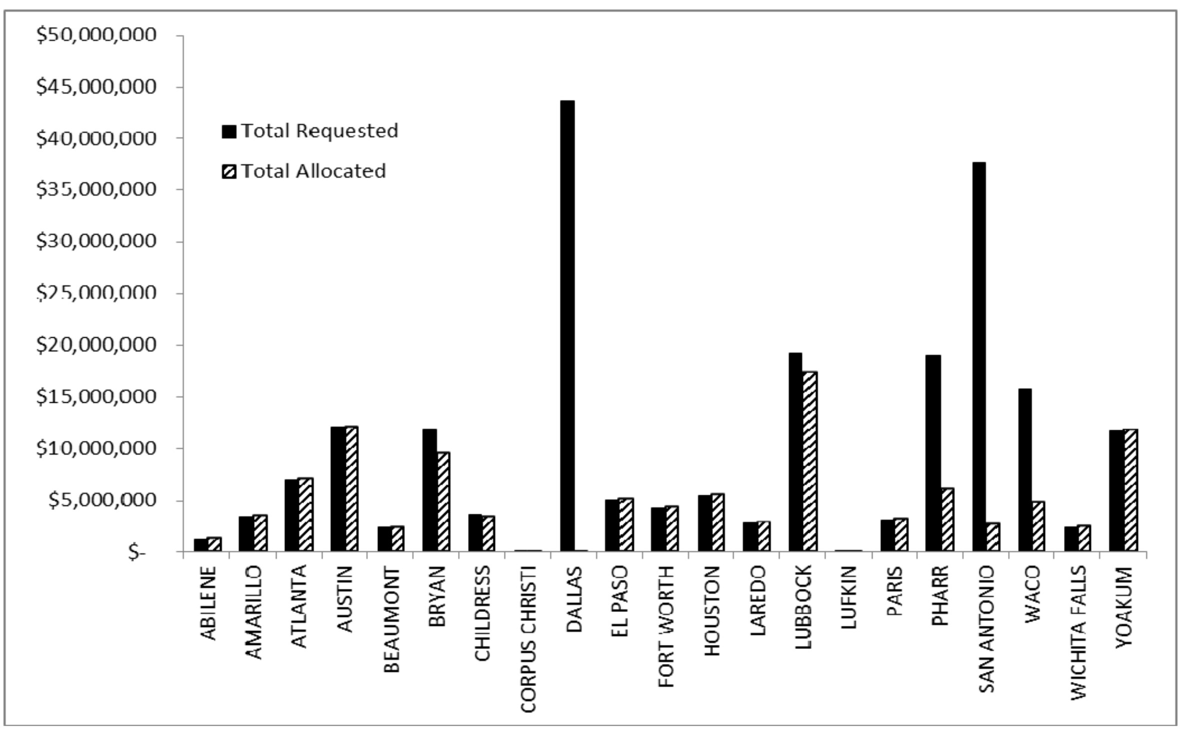

Figure A.5. Funding Allocation Results per District in Scenario 1 with Optimization.

Scenario 2: Budget available is $ 158,922,426 which is 75% of total requested by the Districts ($ 211,896,568)

Table A.6. Summary of Results of Distribution of Funds in Scenario 2 with Optimization.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	4	$ 12,066,250	1.00	0.00	100
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	21	$ 9,276,773	0.79	3.76	73
CHILDRESS	12	$ 3,577,463	10	$ 3,203,351	0.90	1.78	90
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	4	$ 43,627,157	1.00	0.00	100
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	5	$ 5,446,910	1.00	0.00	100
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	2	$ 19,242,002	1.00	0.00	100
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	18	$ 3,759,194	0.20	14.91	48
SAN ANTONIO	9	$ 37,694,952	1	$ 2,645,755	0.07	17.48	10
WACO	3	$ 15,786,052	3	$ 15,786,052	1.00	0.00	100
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	88	$ 158,777,926	**Total**	**37.92**	**1921**

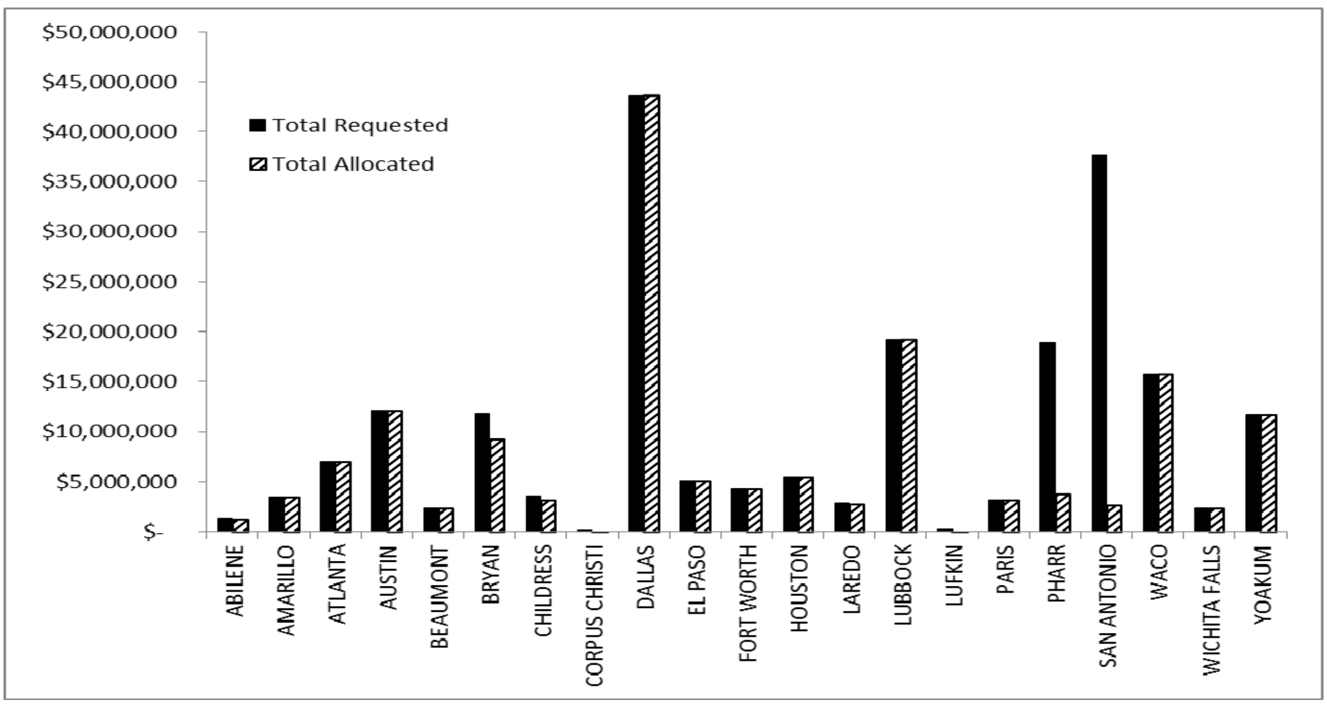

Figure A.6. Funding Allocation Results per District in Scenario 2 with Optimization.

Optimization Method

Scenario 3: Budget available is \$ 169,517,254 which is 80% of total requested by the Districts (\$ 211,896,568)

Table A.7. Summary of Results of Distribution of Funds in Scenario 3 with Optimization.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	4	$ 12,066,250	1.00	0.00	100
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	21	$ 9,464,073	0.80	3.37	77
CHILDRESS	12	$ 3,577,463	10	$ 3,203,351	0.90	1.67	90
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	2	$ 39,060,000	0.90	1.68	90
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	5	$ 5,446,910	1.00	0.00	100
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	2	$ 19,242,002	1.00	0.00	100
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	21	$ 8,136,374	0.43	10.42	69
SAN ANTONIO	9	$ 37,694,952	5	$ 12,939,380	0.34	12.16	40
WACO	3	$ 15,786,052	3	$ 15,786,052	1.00	0.00	100
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	93	$ 169,068,874	**Total**	**29.30**	**1966**

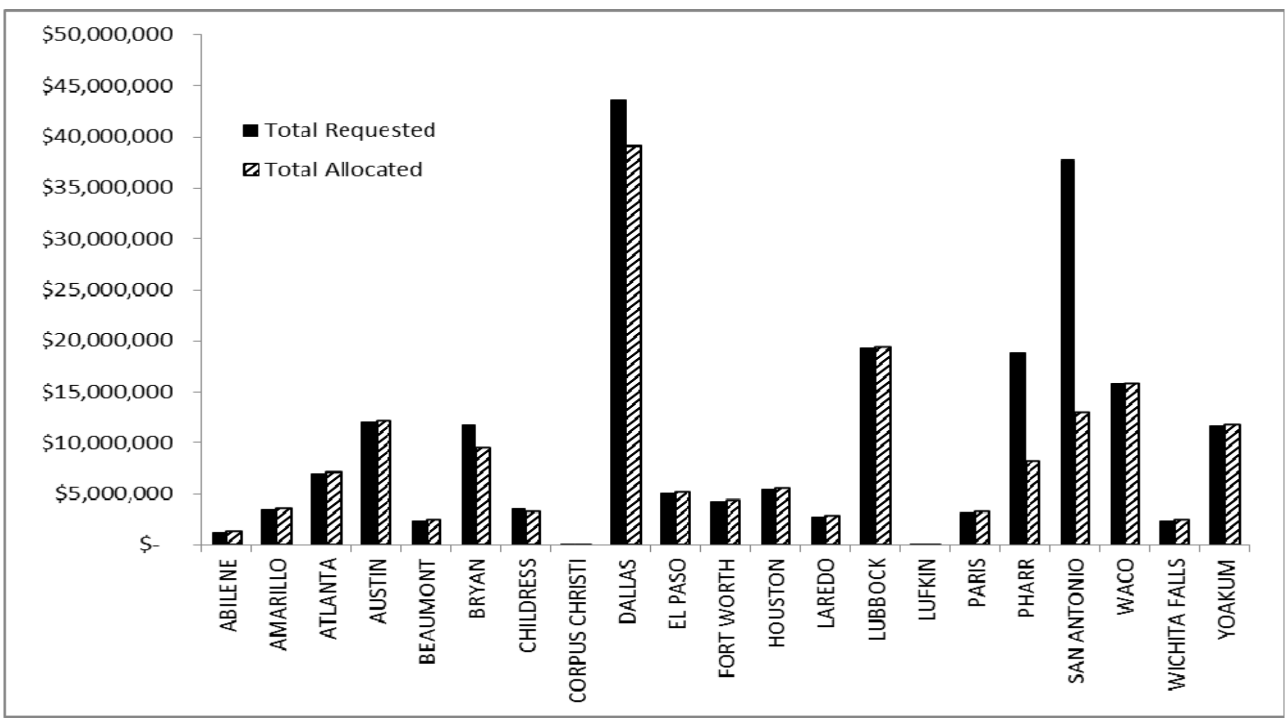

Figure A.7. Funding Allocation Results per District in Scenario 3 with Optimization.

Scenario 4: Budget available is $ 190,706,911 which is 90% of total requested by the Districts ($ 211,896,568)

Table A.8. Summary of Results of Distribution of Funds in Scenario 4 with Optimization.

DISTRICTS	NUMBER OF PROJECTS REQUESTED	TOTAL REQUESTED	NUMBER OF PROJECTS ALLOCATED	TOTAL ALLOCATED	ρ= Allocated to Requested Funding Ratio	ENVY PER DISTRICT	TOTAL POINTS PER DISTRICT
ABILENE	1	$ 1,269,158	1	$ 1,269,158	1.00	0.00	100
AMARILLO	1	$ 3,434,400	1	$ 3,434,400	1.00	0.00	100
ATLANTA	2	$ 7,026,999	2	$ 7,026,999	1.00	0.00	100
AUSTIN	4	$ 12,066,250	4	$ 12,066,250	1.00	0.00	100
BEAUMONT	1	$ 2,361,205	1	$ 2,361,205	1.00	0.00	100
BRYAN	31	$ 11,812,973	25	$ 10,772,273	0.91	1.47	88
CHILDRESS	12	$ 3,577,463	11	$ 3,338,351	0.93	1.08	95
CORPUS CHRISTI	2	$ 125,001	2	$ 125,001	1.00	0.00	100
DALLAS	4	$ 43,627,157	3	$ 41,302,157	0.95	0.85	95
EL PASO	2	$ 5,101,374	2	$ 5,101,374	1.00	0.00	100
FORT WORTH	2	$ 4,240,180	2	$ 4,240,180	1.00	0.00	100
HOUSTON	5	$ 5,446,910	5	$ 5,446,910	1.00	0.00	100
LAREDO	3	$ 2,790,300	3	$ 2,790,300	1.00	0.00	100
LUBBOCK	2	$ 19,242,002	2	$ 19,242,002	1.00	0.00	100
LUFKIN	1	$ 163,594	1	$ 163,594	1.00	0.00	100
PARIS	1	$ 3,137,019	1	$ 3,137,019	1.00	0.00	100
PHARR	31	$ 18,918,327	22	$ 15,908,374	0.84	2.81	77
SAN ANTONIO	9	$ 37,694,952	6	$ 22,994,796	0.61	7.43	60
WACO	3	$ 15,786,052	3	$ 15,786,052	1.00	0.00	100
WICHITA FALLS	1	$ 2,375,252	1	$ 2,375,252	1.00	0.00	100
YOAKUM	3	$ 11,700,000	3	$ 11,700,000	1.00	0.00	100
Total	121	$ 211,896,568	101	$ 190,581,647	**Total**	**13.65**	**2015**

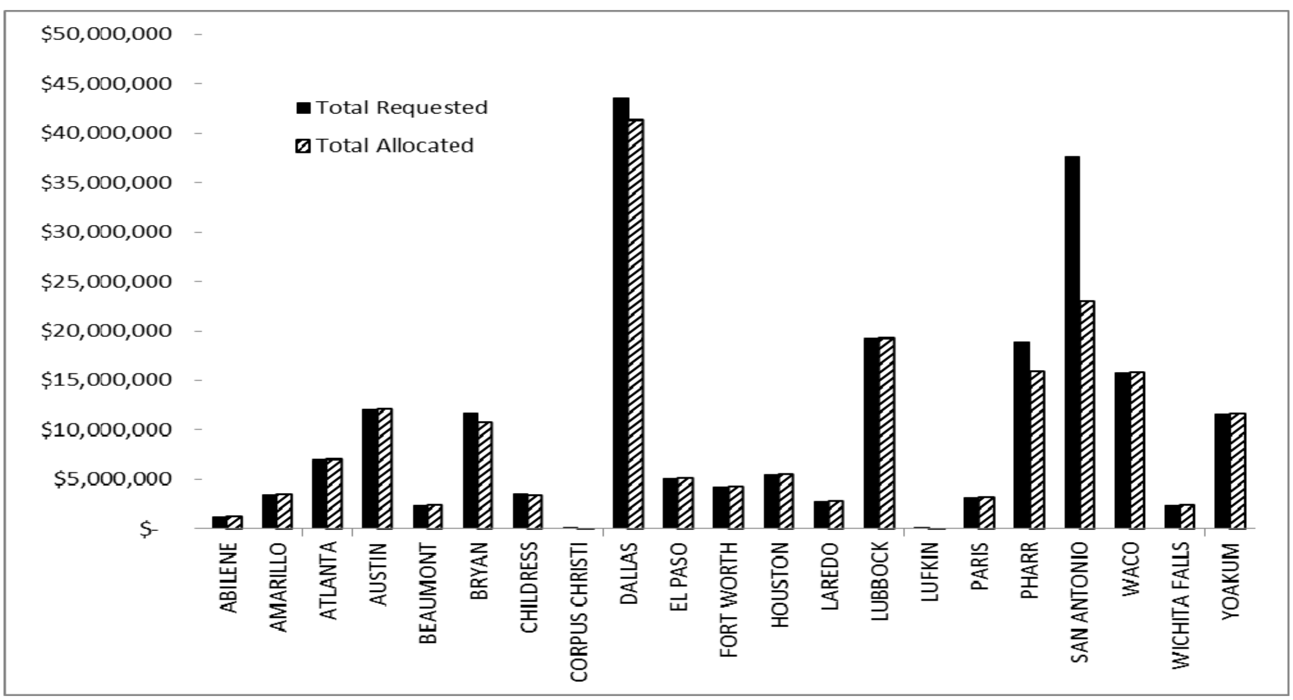

Figure A.8. Funding Allocation Results per District in Scenario 4 with Optimization.

APPENDIX B

PROJECT SELECTION BY SCENARIO

Table B.1. Project Selection for Scenario 1 using Ranking Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left
						$ 105,948,284
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 102,513,884
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 99,376,865
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 97,001,613
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 94,640,408
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 93,371,250
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 93,207,656
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 75,865,655
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 75,780,655
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 36,805,655
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 26,012,604
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 24,732,604
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 18,735,605
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 16,296,766
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 11,054,266
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 7,829,266
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 5,244,266
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 3,367,892
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	N	$ 3,367,892
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 1,566,551
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 536,551
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	N	$ 536,551
LAREDO	LA SALLE	FM 624	$ 937,300	30	N	$ 536,551
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	N	$ 536,551
WACO	CORYELL	FM 183	$ 4,820,001	25	N	$ 536,551
AUSTIN	LLANO	SH 71	$ 3,600,000	25	N	$ 536,551
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	N	$ 536,551
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	N	$ 536,551
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	N	$ 536,551
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	N	$ 536,551
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 22,147
CHILDRESS	FOARD	FM 98	$ 510,000	20	N	$ 22,147
PHARR	KENEDY	US 77	$ 10,000,000	16	N	$ 22,147
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	N	$ 22,147
HOUSTON	GALVESTON	FM 517	$ 849,463	15	N	$ 22,147
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 22,147
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	N	$ 22,147
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	N	$ 22,147
HOUSTON	GALVESTON	SH 146	$ 602,173	10	N	$ 22,147
LAREDO	LA SALLE	SH 44	$ 573,000	10	N	$ 22,147
CHILDRESS	DONLEY	US 287	$ 385,000	10	N	$ 22,147
CHILDRESS	KNOX	SH 6	$ 371,358	10	N	$ 22,147
WACO	BELL	IH 35	$ 173,000	10	N	$ 22,147
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	N	$ 22,147
PHARR	HIDALGO	US 83	$ 1,799,376	9	N	$ 22,147
BRYAN	WALKER	FM 1696	$ 3,041,060	8	N	$ 22,147
BRYAN	MILAM	FM 2269	$ 2,308,713	8	N	$ 22,147
PHARR	STARR	US 83	$ 1,682,814	8	N	$ 22,147
BRYAN	WALKER	SH 75	$ 705,200	8	N	$ 22,147
BRYAN	WALKER	FM 980	$ 563,800	8	N	$ 22,147
BRYAN	GRIMES	SH 30	$ 325,000	8	N	$ 22,147
PHARR	HIDALGO	FM 494	$ 606,561	7	N	$ 22,147
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 22,147
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 22,147
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 22,147
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 22,147
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 22,147
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 22,147
PHARR	CAMERON	FM 1420	$ 328,898	5	N	$ 22,147
CHILDRESS	FOARD	SH 6	$ 276,000	5	N	$ 22,147
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	N	$ 22,147

Table B.1. Project for Scenario 1 using Ranking Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	N	$ 22,147
CHILDRESS	DICKENS	FM 265	$ 258,363	5	N	$ 22,147
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 22,147
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	N	$ 22,147
HOUSTON	GALVESTON	SH 146	$ 210,274	5	N	$ 22,147
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 22,147
AUSTIN	HAYS	SH 80	$ 123,750	5	N	$ 22,147
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	N	$ 22,147
DALLAS	DALLAS	US 75	$ 85,000	5	N	$ 22,147
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 22,147
PHARR	CAMERON	SH 100	$ 438,027	4	N	$ 22,147
PHARR	WILLACY	US 77	$ 414,360	4	N	$ 22,147
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 22,147
PHARR	CAMERON	FM 508	$ 309,984	3	N	$ 22,147
BRYAN	FREESTONE	FM 1365	$ 236,900	3	N	$ 22,147
BRYAN	GRIMES	FM 1696	$ 225,300	3	N	$ 22,147
BRYAN	WALKER	FM 1791	$ 198,600	3	N	$ 22,147
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	N	$ 22,147
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 22,147
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 22,147
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	N	$ 22,147
BRYAN	WALKER	IH 45	$ 43,400	3	N	$ 22,147
BRYAN	WASHINGTON	FM 577	$ 34,000	3	N	$ 22,147
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 22,147
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 22,147
BRYAN	FREESTONE	SH 179	$ 368,800	2	N	$ 22,147
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 22,147
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 22,147
BRYAN	BRAZOS	OSR	$ 277,000	2	N	$ 22,147
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 22,147
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 22,147
PHARR	CAMERON	FM 802	$ 170,237	2	N	$ 22,147
PHARR	CAMERON	FM 2925	$ 165,809	2	N	$ 22,147
BRYAN	LEON	SH 7	$ 164,400	2	N	$ 22,147
BRYAN	MILAM	US 190	$ 161,000	2	N	$ 22,147
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 22,147
PHARR	CAMERON	FM 1847	$ 156,330	2	N	$ 22,147
BRYAN	LEON	IH 45	$ 147,000	2	N	$ 22,147
PHARR	CAMERON	FM 1575	$ 146,644	2	N	$ 22,147
PHARR	STARR	FM 755	$ 143,855	2	N	$ 22,147
BRYAN	WASHINGTON	FM 390	$ 139,400	2	N	$ 22,147
BRYAN	BRAZOS	SH 308	$ 136,800	2	N	$ 22,147
PHARR	HIDALGO	FM 1925	$ 134,343	2	N	$ 22,147
BRYAN	WALKER	US 190	$ 134,200	2	N	$ 22,147
PHARR	WILLACY	FM 1015	$ 124,249	2	N	$ 22,147
PHARR	CAMERON	FM 2925	$ 120,847	2	N	$ 22,147
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 22,147
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 22,147
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 22,147
PHARR	CAMERON	FM 800	$ 89,101	2	N	$ 22,147
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 22,147
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 22,147
PHARR	WILLACY	FM 490	$ 52,800	2	N	$ 22,147
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	N	$ 22,147
PHARR	HIDALGO	FM 1926	$ 23,033	2	N	$ 22,147
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 22,147
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 22,147
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 22,147
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 22,147
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 22,147
PHARR	WILLACY	SP 413	$ 10,655	1	Y	$ 11,492

Table B.2. Project Selection for Scenario 2 using Ranking Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left
						$ 158,922,426
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 155,488,026
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 152,351,007
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 149,975,755
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 147,614,550
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 146,345,392
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 146,181,798
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 128,839,797
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 128,754,797
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 89,779,797
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 78,986,746
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 77,706,746
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 71,709,747
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 69,270,908
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 64,028,408
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 60,803,408
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 58,218,408
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 56,342,034
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 50,642,034
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 48,840,693
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 47,810,693
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 43,810,693
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 42,873,393
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	Y	$ 31,873,392
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 27,053,391
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 23,453,391
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	Y	$ 15,897,820
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 12,797,820
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 10,797,820
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 9,597,820
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 9,083,416
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 8,573,416
PHARR	KENEDY	US 77	$ 10,000,000	16	N	$ 8,573,416
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	Y	$ 1,573,415
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 723,952
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 723,952
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	N	$ 723,952
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	N	$ 723,952
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 121,779
LAREDO	LA SALLE	SH 44	$ 573,000	10	N	$ 121,779
CHILDRESS	DONLEY	US 287	$ 385,000	10	N	$ 121,779
CHILDRESS	KNOX	SH 6	$ 371,358	10	N	$ 121,779
WACO	BELL	IH 35	$ 173,000	10	N	$ 121,779
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 81,778
PHARR	HIDALGO	US 83	$ 1,799,376	9	N	$ 81,778
BRYAN	WALKER	FM 1696	$ 3,041,060	8	N	$ 81,778
BRYAN	MILAM	FM 2269	$ 2,308,713	8	N	$ 81,778
PHARR	STARR	US 83	$ 1,682,814	8	N	$ 81,778
BRYAN	WALKER	SH 75	$ 705,200	8	N	$ 81,778
BRYAN	WALKER	FM 980	$ 563,800	8	N	$ 81,778
BRYAN	GRIMES	SH 30	$ 325,000	8	N	$ 81,778
PHARR	HIDALGO	FM 494	$ 606,561	7	N	$ 81,778
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 81,778
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 81,778
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 81,778
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 81,778
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 81,778
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 81,778
PHARR	CAMERON	FM 1420	$ 328,898	5	N	$ 81,778
CHILDRESS	FOARD	SH 6	$ 276,000	5	N	$ 81,778
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	N	$ 81,778

Table B.2. Project Selection for Scenario 2 using Ranking Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	N	$ 81,778
CHILDRESS	DICKENS	FM 265	$ 258,363	5	N	$ 81,778
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 81,778
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	N	$ 81,778
HOUSTON	GALVESTON	SH 146	$ 210,274	5	N	$ 81,778
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 81,778
AUSTIN	HAYS	SH 80	$ 123,750	5	N	$ 81,778
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	N	$ 81,778
DALLAS	DALLAS	US 75	$ 85,000	5	N	$ 81,778
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 81,778
PHARR	CAMERON	SH 100	$ 438,027	4	N	$ 81,778
PHARR	WILLACY	US 77	$ 414,360	4	N	$ 81,778
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 81,778
PHARR	CAMERON	FM 508	$ 309,984	3	N	$ 81,778
BRYAN	FREESTONE	FM 1365	$ 236,900	3	N	$ 81,778
BRYAN	GRIMES	FM 1696	$ 225,300	3	N	$ 81,778
BRYAN	WALKER	FM 1791	$ 198,600	3	N	$ 81,778
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	N	$ 81,778
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 81,778
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 81,778
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	Y	$ 9,478
BRYAN	WALKER	IH 45	$ 43,400	3	N	$ 9,478
BRYAN	WASHINGTON	FM 577	$ 34,000	3	N	$ 9,478
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 9,478
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 9,478
BRYAN	FREESTONE	SH 179	$ 368,800	2	N	$ 9,478
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 9,478
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 9,478
BRYAN	BRAZOS	OSR	$ 277,000	2	N	$ 9,478
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 9,478
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 9,478
PHARR	CAMERON	FM 802	$ 170,237	2	N	$ 9,478
PHARR	CAMERON	FM 2925	$ 165,809	2	N	$ 9,478
BRYAN	LEON	SH 7	$ 164,400	2	N	$ 9,478
BRYAN	MILAM	US 190	$ 161,000	2	N	$ 9,478
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 9,478
PHARR	CAMERON	FM 1847	$ 156,330	2	N	$ 9,478
BRYAN	LEON	IH 45	$ 147,000	2	N	$ 9,478
PHARR	CAMERON	FM 1575	$ 146,644	2	N	$ 9,478
PHARR	STARR	FM 755	$ 143,855	2	N	$ 9,478
BRYAN	WASHINGTON	FM 390	$ 139,400	2	N	$ 9,478
BRYAN	BRAZOS	SH 308	$ 136,800	2	N	$ 9,478
PHARR	HIDALGO	FM 1925	$ 134,343	2	N	$ 9,478
BRYAN	WALKER	US 190	$ 134,200	2	N	$ 9,478
PHARR	WILLACY	FM 1015	$ 124,249	2	N	$ 9,478
PHARR	CAMERON	FM 2925	$ 120,847	2	N	$ 9,478
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 9,478
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 9,478
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 9,478
PHARR	CAMERON	FM 800	$ 89,101	2	N	$ 9,478
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 9,478
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 9,478
PHARR	WILLACY	FM 490	$ 52,800	2	N	$ 9,478
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	N	$ 9,478
PHARR	HIDALGO	FM 1926	$ 23,033	2	N	$ 9,478
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 9,478
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 9,478
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 9,478
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 9,478
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 9,478
PHARR	WILLACY	SP 413	$ 10,655	1	N	$ 9,478

Table B.3. Project Selection for Scenario 3 using Ranking Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left $ 169,517,254
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 166,082,854
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 162,945,835
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 160,570,583
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 158,209,378
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 156,940,220
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 156,776,626
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 139,434,625
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 139,349,625
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 100,374,625
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 89,581,574
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 88,301,574
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 82,304,575
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 79,865,736
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 74,623,236
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 71,398,236
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 68,813,236
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 66,936,862
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 61,236,862
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 59,435,521
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 58,405,521
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 54,405,521
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 53,468,221
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	Y	$ 42,468,220
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 37,648,219
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 34,048,219
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	Y	$ 26,492,648
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 23,392,648
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 21,392,648
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 20,192,648
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 19,678,244
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 19,168,244
PHARR	KENEDY	US 77	$ 10,000,000	16	Y	$ 9,168,244
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	Y	$ 2,168,243
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 1,318,780
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 1,318,780
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	N	$ 1,318,780
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	N	$ 1,318,780
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 716,607
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 143,607
CHILDRESS	DONLEY	US 287	$ 385,000	10	N	$ 143,607
CHILDRESS	KNOX	SH 6	$ 371,358	10	N	$ 143,607
WACO	BELL	IH 35	$ 173,000	10	N	$ 143,607
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 103,606
PHARR	HIDALGO	US 83	$ 1,799,376	9	N	$ 103,606
BRYAN	WALKER	FM 1696	$ 3,041,060	8	N	$ 103,606
BRYAN	MILAM	FM 2269	$ 2,308,713	8	N	$ 103,606
PHARR	STARR	US 83	$ 1,682,814	8	N	$ 103,606
BRYAN	WALKER	SH 75	$ 705,200	8	N	$ 103,606
BRYAN	WALKER	FM 980	$ 563,800	8	N	$ 103,606
BRYAN	GRIMES	SH 30	$ 325,000	8	N	$ 103,606
PHARR	HIDALGO	FM 494	$ 606,561	7	N	$ 103,606
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 103,606
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 103,606
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 103,606
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 103,606
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 103,606
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 103,606
PHARR	CAMERON	FM 1420	$ 328,898	5	N	$ 103,606
CHILDRESS	FOARD	SH 6	$ 276,000	5	N	$ 103,606
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	N	$ 103,606

Table B.3. Project Selection for Scenario 3 using Ranking Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	N	$ 103,606
CHILDRESS	DICKENS	FM 265	$ 258,363	5	N	$ 103,606
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 103,606
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	N	$ 103,606
HOUSTON	GALVESTON	SH 146	$ 210,274	5	N	$ 103,606
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 103,606
AUSTIN	HAYS	SH 80	$ 123,750	5	N	$ 103,606
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	N	$ 103,606
DALLAS	DALLAS	US 75	$ 85,000	5	Y	$ 18,606
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 18,606
PHARR	CAMERON	SH 100	$ 438,027	4	N	$ 18,606
PHARR	WILLACY	US 77	$ 414,360	4	N	$ 18,606
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 18,606
PHARR	CAMERON	FM 508	$ 309,984	3	N	$ 18,606
BRYAN	FREESTONE	FM 1365	$ 236,900	3	N	$ 18,606
BRYAN	GRIMES	FM 1696	$ 225,300	3	N	$ 18,606
BRYAN	WALKER	FM 1791	$ 198,600	3	N	$ 18,606
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	N	$ 18,606
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 18,606
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 18,606
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	N	$ 18,606
BRYAN	WALKER	IH 45	$ 43,400	3	N	$ 18,606
BRYAN	WASHINGTON	FM 577	$ 34,000	3	N	$ 18,606
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 18,606
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 18,606
BRYAN	FREESTONE	SH 179	$ 368,800	2	N	$ 18,606
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 18,606
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 18,606
BRYAN	BRAZOS	OSR	$ 277,000	2	N	$ 18,606
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 18,606
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 18,606
PHARR	CAMERON	FM 802	$ 170,237	2	N	$ 18,606
PHARR	CAMERON	FM 2925	$ 165,809	2	N	$ 18,606
BRYAN	LEON	SH 7	$ 164,400	2	N	$ 18,606
BRYAN	MILAM	US 190	$ 161,000	2	N	$ 18,606
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 18,606
PHARR	CAMERON	FM 1847	$ 156,330	2	N	$ 18,606
BRYAN	LEON	IH 45	$ 147,000	2	N	$ 18,606
PHARR	CAMERON	FM 1575	$ 146,644	2	N	$ 18,606
PHARR	STARR	FM 755	$ 143,855	2	N	$ 18,606
BRYAN	WASHINGTON	FM 390	$ 139,400	2	N	$ 18,606
BRYAN	BRAZOS	SH 308	$ 136,800	2	N	$ 18,606
PHARR	HIDALGO	FM 1925	$ 134,343	2	N	$ 18,606
BRYAN	WALKER	US 190	$ 134,200	2	N	$ 18,606
PHARR	WILLACY	FM 1015	$ 124,249	2	N	$ 18,606
PHARR	CAMERON	FM 2925	$ 120,847	2	N	$ 18,606
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 18,606
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 18,606
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 18,606
PHARR	CAMERON	FM 800	$ 89,101	2	N	$ 18,606
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 18,606
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 18,606
PHARR	WILLACY	FM 490	$ 52,800	2	N	$ 18,606
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	N	$ 18,606
PHARR	HIDALGO	FM 1926	$ 23,033	2	N	$ 18,606
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 18,606
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 18,606
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 18,606
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 18,606
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 18,606
PHARR	WILLACY	SP 413	$ 10,655	1	Y	$ 7,951

Table B.4. Project Selection for Scenario 4 using Ranking Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left $ 190,706,911
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 187,272,511
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 184,135,492
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 181,760,240
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 179,399,035
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 178,129,877
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 177,966,283
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 160,624,282
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 160,539,282
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 121,564,282
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 110,771,231
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 109,491,231
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 103,494,232
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 101,055,393
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 95,812,893
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 92,587,893
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 90,002,893
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 88,126,519
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 82,426,519
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 80,625,178
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 79,595,178
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 75,595,178
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 74,657,878
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	Y	$ 63,657,877
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 58,837,876
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 55,237,876
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	Y	$ 47,682,305
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 44,582,305
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 42,582,305
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 41,382,305
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 40,867,901
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 40,357,901
PHARR	KENEDY	US 77	$ 10,000,000	16	Y	$ 30,357,901
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	Y	$ 23,357,900
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 22,508,437
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	Y	$ 17,508,437
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	Y	$ 14,862,682
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	Y	$ 12,962,681
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 12,360,508
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 11,787,508
CHILDRESS	DONLEY	US 287	$ 385,000	10	Y	$ 11,402,508
CHILDRESS	KNOX	SH 6	$ 371,358	10	Y	$ 11,031,150
WACO	BELL	IH 35	$ 173,000	10	Y	$ 10,858,150
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 10,818,149
PHARR	HIDALGO	US 83	$ 1,799,376	9	Y	$ 9,018,773
BRYAN	WALKER	FM 1696	$ 3,041,060	8	Y	$ 5,977,713
BRYAN	MILAM	FM 2269	$ 2,308,713	8	Y	$ 3,669,000
PHARR	STARR	US 83	$ 1,682,814	8	Y	$ 1,986,186
BRYAN	WALKER	SH 75	$ 705,200	8	Y	$ 1,280,986
BRYAN	WALKER	FM 980	$ 563,800	8	Y	$ 717,186
BRYAN	GRIMES	SH 30	$ 325,000	8	Y	$ 392,186
PHARR	HIDALGO	FM 494	$ 606,561	7	N	$ 392,186
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 392,186
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 392,186
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 392,186
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 392,186
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 392,186
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 392,186
PHARR	CAMERON	FM 1420	$ 328,898	5	Y	$ 63,288
CHILDRESS	FOARD	SH 6	$ 276,000	5	N	$ 63,288
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	N	$ 63,288

Table B.4. Project Selection for Scenario 4 using Ranking Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	N	$ 63,288
CHILDRESS	DICKENS	FM 265	$ 258,363	5	N	$ 63,288
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 63,288
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	N	$ 63,288
HOUSTON	GALVESTON	SH 146	$ 210,274	5	N	$ 63,288
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 63,288
AUSTIN	HAYS	SH 80	$ 123,750	5	N	$ 63,288
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	N	$ 63,288
DALLAS	DALLAS	US 75	$ 85,000	5	N	$ 63,288
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 63,288
PHARR	CAMERON	SH 100	$ 438,027	4	N	$ 63,288
PHARR	WILLACY	US 77	$ 414,360	4	N	$ 63,288
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 63,288
PHARR	CAMERON	FM 508	$ 309,984	3	N	$ 63,288
BRYAN	FREESTONE	FM 1365	$ 236,900	3	N	$ 63,288
BRYAN	GRIMES	FM 1696	$ 225,300	3	N	$ 63,288
BRYAN	WALKER	FM 1791	$ 198,600	3	N	$ 63,288
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	N	$ 63,288
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 63,288
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 63,288
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	N	$ 63,288
BRYAN	WALKER	IH 45	$ 43,400	3	**Y**	$ 19,888
BRYAN	WASHINGTON	FM 577	$ 34,000	3	N	$ 19,888
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 19,888
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 19,888
BRYAN	FREESTONE	SH 179	$ 368,800	2	N	$ 19,888
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 19,888
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 19,888
BRYAN	BRAZOS	OSR	$ 277,000	2	N	$ 19,888
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 19,888
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 19,888
PHARR	CAMERON	FM 802	$ 170,237	2	N	$ 19,888
PHARR	CAMERON	FM 2925	$ 165,809	2	N	$ 19,888
BRYAN	LEON	SH 7	$ 164,400	2	N	$ 19,888
BRYAN	MILAM	US 190	$ 161,000	2	N	$ 19,888
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 19,888
PHARR	CAMERON	FM 1847	$ 156,330	2	N	$ 19,888
BRYAN	LEON	IH 45	$ 147,000	2	N	$ 19,888
PHARR	CAMERON	FM 1575	$ 146,644	2	N	$ 19,888
PHARR	STARR	FM 755	$ 143,855	2	N	$ 19,888
BRYAN	WASHINGTON	FM 390	$ 139,400	2	N	$ 19,888
BRYAN	BRAZOS	SH 308	$ 136,800	2	N	$ 19,888
PHARR	HIDALGO	FM 1925	$ 134,343	2	N	$ 19,888
BRYAN	WALKER	US 190	$ 134,200	2	N	$ 19,888
PHARR	WILLACY	FM 1015	$ 124,249	2	N	$ 19,888
PHARR	CAMERON	FM 2925	$ 120,847	2	N	$ 19,888
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 19,888
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 19,888
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 19,888
PHARR	CAMERON	FM 800	$ 89,101	2	N	$ 19,888
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 19,888
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 19,888
PHARR	WILLACY	FM 490	$ 52,800	2	N	$ 19,888
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	N	$ 19,888
PHARR	HIDALGO	FM 1926	$ 23,033	2	N	$ 19,888
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 19,888
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 19,888
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 19,888
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 19,888
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 19,888
PHARR	WILLACY	SP 413	$ 10,655	1	**Y**	$ 9,233

Table B.5. Project Selection for Scenario 1 using Optimization Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left
						$ 105,948,284
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 102,513,884
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 99,376,865
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 97,001,613
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 94,640,408
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 93,371,250
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 93,207,656
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 75,865,655
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 75,780,655
DALLAS	DENTON	FM 423	$ 38,975,000	85	N	$ 75,780,655
WACO	HAMILTON	US 281	$ 10,793,051	65	N	$ 75,780,655
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 74,500,655
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 68,503,656
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 66,064,817
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 60,822,317
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 57,597,317
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 55,012,317
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 53,135,943
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 47,435,943
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 45,634,602
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 44,604,602
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 40,604,602
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 39,667,302
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	N	$ 39,667,302
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 34,847,301
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 31,247,301
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	N	$ 31,247,301
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 28,147,301
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 26,147,301
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 24,947,301
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 24,432,897
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 23,922,897
PHARR	KENEDY	US 77	$ 10,000,000	16	N	$ 23,922,897
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	N	$ 23,922,897
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 23,073,434
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 23,073,434
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	Y	$ 20,427,679
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	N	$ 20,427,679
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 19,825,506
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 19,252,506
CHILDRESS	DONLEY	US 287	$ 385,000	10	Y	$ 18,867,506
CHILDRESS	KNOX	SH 6	$ 371,358	10	Y	$ 18,496,148
WACO	BELL	IH 35	$ 173,000	10	N	$ 18,496,148
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 18,456,147
PHARR	HIDALGO	US 83	$ 1,799,376	9	Y	$ 16,656,771
BRYAN	WALKER	FM 1696	$ 3,041,060	8	Y	$ 13,615,711
BRYAN	MILAM	FM 2269	$ 2,308,713	8	Y	$ 11,306,998
PHARR	STARR	US 83	$ 1,682,814	8	Y	$ 9,624,184
BRYAN	WALKER	SH 75	$ 705,200	8	Y	$ 8,918,984
BRYAN	WALKER	FM 980	$ 563,800	8	Y	$ 8,355,184
BRYAN	GRIMES	SH 30	$ 325,000	8	Y	$ 8,030,184
PHARR	HIDALGO	FM 494	$ 606,561	7	N	$ 8,030,184
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 8,030,184
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 8,030,184
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 8,030,184
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 8,030,184
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 8,030,184
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 8,030,184
PHARR	CAMERON	FM 1420	$ 328,898	5	Y	$ 7,701,286
CHILDRESS	FOARD	SH 6	$ 276,000	5	Y	$ 7,425,286
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	Y	$ 7,150,286

Table B.5. Project Selection for Scenario 1 using Optimization Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	N	$ 7,150,286
CHILDRESS	DICKENS	FM 265	$ 258,363	5	Y	$ 6,891,923
CHILDRESS	WHEELER	US 83	$ 239,112	5	Y	$ 6,652,811
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	Y	$ 6,429,126
HOUSTON	GALVESTON	SH 146	$ 210,274	5	Y	$ 6,218,852
CHILDRESS	FOARD	FM 98	$ 135,000	5	Y	$ 6,083,852
AUSTIN	HAYS	SH 80	$ 123,750	5	Y	$ 5,960,102
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	Y	$ 5,840,102
DALLAS	DALLAS	US 75	$ 85,000	5	Y	$ 5,755,102
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 5,755,102
PHARR	CAMERON	SH 100	$ 438,027	4	Y	$ 5,317,075
PHARR	WILLACY	US 77	$ 414,360	4	N	$ 5,317,075
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 5,317,075
PHARR	CAMERON	FM 508	$ 309,984	3	Y	$ 5,007,091
BRYAN	FREESTONE	FM 1365	$ 236,900	3	Y	$ 4,770,191
BRYAN	GRIMES	FM 1696	$ 225,300	3	N	$ 4,770,191
BRYAN	WALKER	FM 1791	$ 198,600	3	Y	$ 4,571,591
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	Y	$ 4,405,791
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 4,405,791
BRYAN	BRAZOS	FM 2038	$ 102,700	3	Y	$ 4,303,091
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	N	$ 4,303,091
BRYAN	WALKER	IH 45	$ 43,400	3	Y	$ 4,259,691
BRYAN	WASHINGTON	FM 577	$ 34,000	3	N	$ 4,259,691
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 4,259,691
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 4,259,691
BRYAN	FREESTONE	SH 179	$ 368,800	2	N	$ 4,259,691
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 4,259,691
BRYAN	MILAM	FM 485	$ 283,800	2	Y	$ 3,975,891
BRYAN	BRAZOS	OSR	$ 277,000	2	Y	$ 3,698,891
BRYAN	MADISON	SH 21	$ 271,800	2	Y	$ 3,427,091
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 3,427,091
PHARR	CAMERON	FM 802	$ 170,237	2	Y	$ 3,256,854
PHARR	CAMERON	FM 2925	$ 165,809	2	Y	$ 3,091,045
BRYAN	LEON	SH 7	$ 164,400	2	Y	$ 2,926,645
BRYAN	MILAM	US 190	$ 161,000	2	Y	$ 2,765,645
PHARR	WILLACY	FM 490	$ 157,424	2	Y	$ 2,608,221
PHARR	CAMERON	FM 1847	$ 156,330	2	Y	$ 2,451,891
BRYAN	LEON	IH 45	$ 147,000	2	Y	$ 2,304,891
PHARR	CAMERON	FM 1575	$ 146,644	2	Y	$ 2,158,247
PHARR	STARR	FM 755	$ 143,855	2	N	$ 2,158,247
BRYAN	WASHINGTON	FM 390	$ 139,400	2	Y	$ 2,018,847
BRYAN	BRAZOS	SH 308	$ 136,800	2	Y	$ 1,882,047
PHARR	HIDALGO	FM 1925	$ 134,343	2	Y	$ 1,747,704
BRYAN	WALKER	US 190	$ 134,200	2	Y	$ 1,613,504
PHARR	WILLACY	FM 1015	$ 124,249	2	Y	$ 1,489,255
PHARR	CAMERON	FM 2925	$ 120,847	2	Y	$ 1,368,408
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 1,368,408
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 1,368,408
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 1,368,408
PHARR	CAMERON	FM 800	$ 89,101	2	Y	$ 1,279,307
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 1,279,307
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 1,279,307
PHARR	WILLACY	FM 490	$ 52,800	2	Y	$ 1,226,507
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	N	$ 1,226,507
PHARR	HIDALGO	FM 1926	$ 23,033	2	Y	$ 1,203,474
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 1,203,474
PHARR	CAMERON	FM 510	$ 59,385	1	Y	$ 1,144,089
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 1,144,089
PHARR	CAMERON	FM 800	$ 38,505	1	Y	$ 1,105,584
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	Y	$ 1,072,684
PHARR	WILLACY	SP 413	$ 10,655	1	Y	$ 1,062,029

Table B.6. Project Selection for Scenario 2 using Optimization Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left $ 158,922,426
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 155,488,026
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 152,351,007
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 149,975,755
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 147,614,550
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 146,345,392
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 146,181,798
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 128,839,797
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 128,754,797
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 89,779,797
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 78,986,746
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 77,706,746
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 71,709,747
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 69,270,908
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 64,028,408
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 60,803,408
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 58,218,408
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 56,342,034
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 50,642,034
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 48,840,693
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 47,810,693
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 43,810,693
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 42,873,393
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	N	$ 42,873,393
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 38,053,392
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 34,453,392
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	N	$ 34,453,392
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 31,353,392
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 29,353,392
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 28,153,392
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 27,638,988
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 27,128,988
PHARR	KENEDY	US 77	$ 10,000,000	16	N	$ 27,128,988
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	N	$ 27,128,988
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 26,279,525
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 26,279,525
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	Y	$ 23,633,770
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	Y	$ 21,733,769
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 21,131,596
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 20,558,596
CHILDRESS	DONLEY	US 287	$ 385,000	10	Y	$ 20,173,596
CHILDRESS	KNOX	SH 6	$ 371,358	10	Y	$ 19,802,238
WACO	BELL	IH 35	$ 173,000	10	Y	$ 19,629,238
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 19,589,237
PHARR	HIDALGO	US 83	$ 1,799,376	9	N	$ 19,589,237
BRYAN	WALKER	FM 1696	$ 3,041,060	8	Y	$ 16,548,177
BRYAN	MILAM	FM 2269	$ 2,308,713	8	Y	$ 14,239,464
PHARR	STARR	US 83	$ 1,682,814	8	N	$ 14,239,464
BRYAN	WALKER	SH 75	$ 705,200	8	Y	$ 13,534,264
BRYAN	WALKER	FM 980	$ 563,800	8	N	$ 13,534,264
BRYAN	GRIMES	SH 30	$ 325,000	8	Y	$ 13,209,264
PHARR	HIDALGO	FM 494	$ 606,561	7	Y	$ 12,602,703
DALLAS	DALLAS	IH 20	$ 2,325,000	5	Y	$ 10,277,703
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	Y	$ 8,035,546
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	N	$ 8,035,546
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 8,035,546
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 8,035,546
SAN ANTONIO	KERR	SH 16	$ 650,000	5	N	$ 8,035,546
PHARR	CAMERON	FM 1420	$ 328,898	5	Y	$ 7,706,648
CHILDRESS	FOARD	SH 6	$ 276,000	5	Y	$ 7,430,648
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	Y	$ 7,155,648

Table B.6. Project Selection for Scenario 2 using Optimization Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	Y	$ 6,886,107
CHILDRESS	DICKENS	FM 265	$ 258,363	5	Y	$ 6,627,744
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 6,627,744
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	Y	$ 6,404,059
HOUSTON	GALVESTON	SH 146	$ 210,274	5	Y	$ 6,193,785
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 6,193,785
AUSTIN	HAYS	SH 80	$ 123,750	5	Y	$ 6,070,035
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	Y	$ 5,950,035
DALLAS	DALLAS	US 75	$ 85,000	5	Y	$ 5,865,035
PHARR	CAMERON	SH 48	$ 756,380	4	Y	$ 5,108,655
PHARR	CAMERON	SH 100	$ 438,027	4	N	$ 5,108,655
PHARR	WILLACY	US 77	$ 414,360	4	Y	$ 4,694,295
PHARR	CAMERON	SH 4	$ 452,881	3	N	$ 4,694,295
PHARR	CAMERON	FM 508	$ 309,984	3	Y	$ 4,384,311
BRYAN	FREESTONE	FM 1365	$ 236,900	3	Y	$ 4,147,411
BRYAN	GRIMES	FM 1696	$ 225,300	3	Y	$ 3,922,111
BRYAN	WALKER	FM 1791	$ 198,600	3	Y	$ 3,723,511
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	Y	$ 3,557,711
BRYAN	BRAZOS	FM 1687	$ 117,700	3	N	$ 3,557,711
BRYAN	BRAZOS	FM 2038	$ 102,700	3	Y	$ 3,455,011
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	Y	$ 3,382,711
BRYAN	WALKER	IH 45	$ 43,400	3	N	$ 3,382,711
BRYAN	WASHINGTON	FM 577	$ 34,000	3	Y	$ 3,348,711
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 3,348,711
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 3,348,711
BRYAN	FREESTONE	SH 179	$ 368,800	2	Y	$ 2,979,911
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 2,979,911
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 2,979,911
BRYAN	BRAZOS	OSR	$ 277,000	2	Y	$ 2,702,911
BRYAN	MADISON	SH 21	$ 271,800	2	Y	$ 2,431,111
BRYAN	MADISON	OSR	$ 213,800	2	Y	$ 2,217,311
PHARR	CAMERON	FM 802	$ 170,237	2	Y	$ 2,047,074
PHARR	CAMERON	FM 2925	$ 165,809	2	Y	$ 1,881,265
BRYAN	LEON	SH 7	$ 164,400	2	Y	$ 1,716,865
BRYAN	MILAM	US 190	$ 161,000	2	Y	$ 1,555,865
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 1,555,865
PHARR	CAMERON	FM 1847	$ 156,330	2	N	$ 1,555,865
BRYAN	LEON	IH 45	$ 147,000	2	Y	$ 1,408,865
PHARR	CAMERON	FM 1575	$ 146,644	2	Y	$ 1,262,221
PHARR	STARR	FM 755	$ 143,855	2	N	$ 1,262,221
BRYAN	WASHINGTON	FM 390	$ 139,400	2	N	$ 1,262,221
BRYAN	BRAZOS	SH 308	$ 136,800	2	Y	$ 1,125,421
PHARR	HIDALGO	FM 1925	$ 134,343	2	Y	$ 991,078
BRYAN	WALKER	US 190	$ 134,200	2	N	$ 991,078
PHARR	WILLACY	FM 1015	$ 124,249	2	N	$ 991,078
PHARR	CAMERON	FM 2925	$ 120,847	2	Y	$ 870,231
PHARR	CAMERON	US 77	$ 119,695	2	Y	$ 750,536
PHARR	CAMERON	FM 1419	$ 118,850	2	Y	$ 631,686
PHARR	CAMERON	FM 802	$ 104,304	2	Y	$ 527,382
PHARR	CAMERON	FM 800	$ 89,101	2	Y	$ 438,281
PHARR	WILLACY	FM 507	$ 86,693	2	Y	$ 351,588
BRYAN	MILAM	FM 486	$ 69,000	2	Y	$ 282,588
PHARR	WILLACY	FM 490	$ 52,800	2	Y	$ 229,788
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	Y	$ 178,188
PHARR	HIDALGO	FM 1926	$ 23,033	2	Y	$ 155,155
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 155,155
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 155,155
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 155,155
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 155,155
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 155,155
PHARR	WILLACY	SP 413	$ 10,655	1	Y	$ 144,500

Table B.7. Project Selection for Scenario 3 using Optimization Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left
						$ 169,517,254
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 166,082,854
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 162,945,835
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 160,570,583
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 158,209,378
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 156,940,220
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 156,776,626
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 139,434,625
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 139,349,625
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 100,374,625
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 89,581,574
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 88,301,574
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 82,304,575
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 79,865,736
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 74,623,236
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 71,398,236
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 68,813,236
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 66,936,862
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 61,236,862
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 59,435,521
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 58,405,521
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 54,405,521
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 53,468,221
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	N	$ 53,468,221
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 48,648,220
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 45,048,220
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	N	$ 45,048,220
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 41,948,220
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 39,948,220
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 38,748,220
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 38,233,816
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 37,723,816
PHARR	KENEDY	US 77	$ 10,000,000	16	N	$ 37,723,816
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	Y	$ 30,723,815
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 29,874,352
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	N	$ 29,874,352
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	Y	$ 27,228,597
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	Y	$ 25,328,596
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 24,726,423
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 24,153,423
CHILDRESS	DONLEY	US 287	$ 385,000	10	Y	$ 23,768,423
CHILDRESS	KNOX	SH 6	$ 371,358	10	Y	$ 23,397,065
WACO	BELL	IH 35	$ 173,000	10	Y	$ 23,224,065
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 23,184,064
PHARR	HIDALGO	US 83	$ 1,799,376	9	Y	$ 21,384,688
BRYAN	WALKER	FM 1696	$ 3,041,060	8	Y	$ 18,343,628
BRYAN	MILAM	FM 2269	$ 2,308,713	8	Y	$ 16,034,915
PHARR	STARR	US 83	$ 1,682,814	8	Y	$ 14,352,101
BRYAN	WALKER	SH 75	$ 705,200	8	Y	$ 13,646,901
BRYAN	WALKER	FM 980	$ 563,800	8	Y	$ 13,083,101
BRYAN	GRIMES	SH 30	$ 325,000	8	Y	$ 12,758,101
PHARR	HIDALGO	FM 494	$ 606,561	7	Y	$ 12,151,540
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 12,151,540
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	N	$ 12,151,540
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	Y	$ 10,562,316
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	N	$ 10,562,316
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	Y	$ 9,507,916
SAN ANTONIO	KERR	SH 16	$ 650,000	5	Y	$ 8,857,916
PHARR	CAMERON	FM 1420	$ 328,898	5	Y	$ 8,529,018
CHILDRESS	FOARD	SH 6	$ 276,000	5	Y	$ 8,253,018
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	Y	$ 7,978,018

Table B.7. Project Selection for Scenario 3 using Optimization Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	Y	$ 7,708,477
CHILDRESS	DICKENS	FM 265	$ 258,363	5	Y	$ 7,450,114
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 7,450,114
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	Y	$ 7,226,429
HOUSTON	GALVESTON	SH 146	$ 210,274	5	Y	$ 7,016,155
CHILDRESS	FOARD	FM 98	$ 135,000	5	N	$ 7,016,155
AUSTIN	HAYS	SH 80	$ 123,750	5	Y	$ 6,892,405
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	Y	$ 6,772,405
DALLAS	DALLAS	US 75	$ 85,000	5	Y	$ 6,687,405
PHARR	CAMERON	SH 48	$ 756,380	4	Y	$ 5,931,025
PHARR	CAMERON	SH 100	$ 438,027	4	Y	$ 5,492,998
PHARR	WILLACY	US 77	$ 414,360	4	Y	$ 5,078,638
PHARR	CAMERON	SH 4	$ 452,881	3	Y	$ 4,625,757
PHARR	CAMERON	FM 508	$ 309,984	3	Y	$ 4,315,773
BRYAN	FREESTONE	FM 1365	$ 236,900	3	Y	$ 4,078,873
BRYAN	GRIMES	FM 1696	$ 225,300	3	Y	$ 3,853,573
BRYAN	WALKER	FM 1791	$ 198,600	3	N	$ 3,853,573
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	N	$ 3,853,573
BRYAN	BRAZOS	FM 1687	$ 117,700	3	Y	$ 3,735,873
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 3,735,873
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	N	$ 3,735,873
BRYAN	WALKER	IH 45	$ 43,400	3	Y	$ 3,692,473
BRYAN	WASHINGTON	FM 577	$ 34,000	3	Y	$ 3,658,473
BRYAN	ROBERTSON	FM 46	$ 494,400	2	N	$ 3,658,473
BRYAN	MILAM	FM 437	$ 376,100	2	N	$ 3,658,473
BRYAN	FREESTONE	SH 179	$ 368,800	2	Y	$ 3,289,673
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 3,289,673
BRYAN	MILAM	FM 485	$ 283,800	2	N	$ 3,289,673
BRYAN	BRAZOS	OSR	$ 277,000	2	Y	$ 3,012,673
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 3,012,673
BRYAN	MADISON	OSR	$ 213,800	2	Y	$ 2,798,873
PHARR	CAMERON	FM 802	$ 170,237	2	Y	$ 2,628,636
PHARR	CAMERON	FM 2925	$ 165,809	2	Y	$ 2,462,827
BRYAN	LEON	SH 7	$ 164,400	2	Y	$ 2,298,427
BRYAN	MILAM	US 190	$ 161,000	2	Y	$ 2,137,427
PHARR	WILLACY	FM 490	$ 157,424	2	N	$ 2,137,427
PHARR	CAMERON	FM 1847	$ 156,330	2	Y	$ 1,981,097
BRYAN	LEON	IH 45	$ 147,000	2	Y	$ 1,834,097
PHARR	CAMERON	FM 1575	$ 146,644	2	N	$ 1,834,097
PHARR	STARR	FM 755	$ 143,855	2	Y	$ 1,690,242
BRYAN	WASHINGTON	FM 390	$ 139,400	2	Y	$ 1,550,842
BRYAN	BRAZOS	SH 308	$ 136,800	2	Y	$ 1,414,042
PHARR	HIDALGO	FM 1925	$ 134,343	2	Y	$ 1,279,699
BRYAN	WALKER	US 190	$ 134,200	2	Y	$ 1,145,499
PHARR	WILLACY	FM 1015	$ 124,249	2	Y	$ 1,021,250
PHARR	CAMERON	FM 2925	$ 120,847	2	Y	$ 900,403
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 900,403
PHARR	CAMERON	FM 1419	$ 118,850	2	N	$ 900,403
PHARR	CAMERON	FM 802	$ 104,304	2	Y	$ 796,099
PHARR	CAMERON	FM 800	$ 89,101	2	Y	$ 706,998
PHARR	WILLACY	FM 507	$ 86,693	2	Y	$ 620,305
BRYAN	MILAM	FM 486	$ 69,000	2	Y	$ 551,305
PHARR	WILLACY	FM 490	$ 52,800	2	N	$ 551,305
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	Y	$ 499,705
PHARR	HIDALGO	FM 1926	$ 23,033	2	N	$ 499,705
PHARR	CAMERON	BU 77-X	$ 65,617	1	N	$ 499,705
PHARR	CAMERON	FM 510	$ 59,385	1	N	$ 499,705
PHARR	CAMERON	BU 77-W	$ 40,670	1	Y	$ 459,035
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 459,035
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 459,035
PHARR	WILLACY	SP 413	$ 10,655	1	Y	$ 448,380

Table B.8. Project Selection for Scenario 4 using Optimization Method

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking-Selected?	Budget Left
						$ 190,706,911
AMARILLO	RANDALL	PR 5	$ 3,434,400	100	Y	$ 187,272,511
PARIS	RED RIVER	FM 410	$ 3,137,019	100	Y	$ 184,135,492
WICHITA FALLS	COOKE	FM 902	$ 2,375,252	100	Y	$ 181,760,240
BEAUMONT	LIBERTY	FM 1008	$ 2,361,205	100	Y	$ 179,399,035
ABILENE	KENT	FM 1081	$ 1,269,158	100	Y	$ 178,129,877
LUFKIN	POLK	US 59	$ 163,594	100	Y	$ 177,966,283
LUBBOCK	BAILEY	US 84	$ 17,342,001	90	Y	$ 160,624,282
CORPUS CHRISTI	ARANSAS	FM 1069	$ 85,000	90	Y	$ 160,539,282
DALLAS	DENTON	FM 423	$ 38,975,000	85	Y	$ 121,564,282
WACO	HAMILTON	US 281	$ 10,793,051	65	Y	$ 110,771,231
LAREDO	LA SALLE	SH 44	$ 1,280,000	60	Y	$ 109,491,231
ATLANTA	HARRISON	IH 20	$ 5,996,999	55	Y	$ 103,494,232
FORT WORTH	JOHNSON	FM 2331	$ 2,438,839	55	Y	$ 101,055,393
AUSTIN	BASTROP	FM 535	$ 5,242,500	50	Y	$ 95,812,893
EL PASO	EL PASO	US 62	$ 3,225,000	50	Y	$ 92,587,893
HOUSTON	BRAZORIA	SH 35	$ 2,585,000	50	Y	$ 90,002,893
EL PASO	EL PASO	US 54	$ 1,876,374	50	Y	$ 88,126,519
YOAKUM	VICTORIA	US 59	$ 5,700,000	45	Y	$ 82,426,519
FORT WORTH	JOHNSON	FM 2331	$ 1,801,341	45	Y	$ 80,625,178
ATLANTA	TITUS	US 271	$ 1,030,000	45	Y	$ 79,595,178
YOAKUM	VICTORIA	FM 447	$ 4,000,000	35	Y	$ 75,595,178
LAREDO	LA SALLE	FM 624	$ 937,300	30	Y	$ 74,657,878
SAN ANTONIO	BEXAR	IH 35	$ 11,000,001	25	N	$ 74,657,878
WACO	CORYELL	FM 183	$ 4,820,001	25	Y	$ 69,837,877
AUSTIN	LLANO	SH 71	$ 3,600,000	25	Y	$ 66,237,877
SAN ANTONIO	COMAL	IH 35	$ 7,555,571	20	Y	$ 58,682,306
AUSTIN	TRAVIS	FM 3177	$ 3,100,000	20	Y	$ 55,582,306
YOAKUM	VICTORIA	US 77	$ 2,000,000	20	Y	$ 53,582,306
HOUSTON	MONTGOMERY	FM 1485	$ 1,200,000	20	Y	$ 52,382,306
CHILDRESS	WHEELER	US 83	$ 514,404	20	Y	$ 51,867,902
CHILDRESS	FOARD	FM 98	$ 510,000	20	Y	$ 51,357,902
PHARR	KENEDY	US 77	$ 10,000,000	16	Y	$ 41,357,902
SAN ANTONIO	BEXAR	IH 10	$ 7,000,001	15	Y	$ 34,357,901
HOUSTON	GALVESTON	FM 517	$ 849,463	15	Y	$ 33,508,438
SAN ANTONIO	FRIO	IH 35	$ 5,000,000	10	Y	$ 28,508,438
SAN ANTONIO	MEDINA	FM 462	$ 2,645,755	10	N	$ 28,508,438
LUBBOCK	CASTRO	FM 145	$ 1,900,001	10	Y	$ 26,608,437
HOUSTON	GALVESTON	SH 146	$ 602,173	10	Y	$ 26,006,264
LAREDO	LA SALLE	SH 44	$ 573,000	10	Y	$ 25,433,264
CHILDRESS	DONLEY	US 287	$ 385,000	10	Y	$ 25,048,264
CHILDRESS	KNOX	SH 6	$ 371,358	10	Y	$ 24,676,906
WACO	BELL	IH 35	$ 173,000	10	Y	$ 24,503,906
CORPUS CHRISTI	NUECES	SH 361	$ 40,001	10	Y	$ 24,463,905
PHARR	HIDALGO	US 83	$ 1,799,376	9	Y	$ 22,664,529
BRYAN	WALKER	FM 1696	$ 3,041,060	8	Y	$ 19,623,469
BRYAN	MILAM	FM 2269	$ 2,308,713	8	Y	$ 17,314,756
PHARR	STARR	US 83	$ 1,682,814	8	N	$ 17,314,756
BRYAN	WALKER	SH 75	$ 705,200	8	Y	$ 16,609,556
BRYAN	WALKER	FM 980	$ 563,800	8	Y	$ 16,045,756
BRYAN	GRIMES	SH 30	$ 325,000	8	Y	$ 15,720,756
PHARR	HIDALGO	FM 494	$ 606,561	7	Y	$ 15,114,195
DALLAS	DALLAS	IH 20	$ 2,325,000	5	N	$ 15,114,195
DALLAS	COLLIN	FM 1138	$ 2,242,157	5	Y	$ 12,872,038
SAN ANTONIO	GUADALUPE	IH 35	$ 1,589,224	5	Y	$ 11,282,814
SAN ANTONIO	FRIO	FM 140	$ 1,200,000	5	Y	$ 10,082,814
SAN ANTONIO	KERR	SH 16	$ 1,054,400	5	N	$ 10,082,814
SAN ANTONIO	KERR	SH 16	$ 650,000	5	Y	$ 9,432,814
PHARR	CAMERON	FM 1420	$ 328,898	5	Y	$ 9,103,916
CHILDRESS	FOARD	SH 6	$ 276,000	5	Y	$ 8,827,916
CHILDRESS	DICKENS	FM 1868	$ 275,000	5	Y	$ 8,552,916

Table B.8. Project Selection for Scenario 4 using Optimization Method (Continued)

DISTRICT	COUNTY	HIGHWAY	TOTAL AUTHORIZED AMOUNT	Preference Points	Ranking Selected?	Budget Left
CHILDRESS	DICKENS	FM 2794	$ 269,541	5	Y	$ 8,283,375
CHILDRESS	DICKENS	FM 265	$ 258,363	5	Y	$ 8,025,012
CHILDRESS	WHEELER	US 83	$ 239,112	5	N	$ 8,025,012
CHILDRESS	HARDEMAN	SH 6	$ 223,685	5	Y	$ 7,801,327
HOUSTON	GALVESTON	SH 146	$ 210,274	5	Y	$ 7,591,053
CHILDRESS	FOARD	FM 98	$ 135,000	5	Y	$ 7,456,053
AUSTIN	HAYS	SH 80	$ 123,750	5	Y	$ 7,332,303
CHILDRESS	BRISCOE	FM 378	$ 120,000	5	Y	$ 7,212,303
DALLAS	DALLAS	US 75	$ 85,000	5	Y	$ 7,127,303
PHARR	CAMERON	SH 48	$ 756,380	4	N	$ 7,127,303
PHARR	CAMERON	SH 100	$ 438,027	4	Y	$ 6,689,276
PHARR	WILLACY	US 77	$ 414,360	4	Y	$ 6,274,916
PHARR	CAMERON	SH 4	$ 452,881	3	Y	$ 5,822,035
PHARR	CAMERON	FM 508	$ 309,984	3	Y	$ 5,512,051
BRYAN	FREESTONE	FM 1365	$ 236,900	3	Y	$ 5,275,151
BRYAN	GRIMES	FM 1696	$ 225,300	3	Y	$ 5,049,851
BRYAN	WALKER	FM 1791	$ 198,600	3	Y	$ 4,851,251
BRYAN	WASHINGTON	FM 1155	$ 165,800	3	Y	$ 4,685,451
BRYAN	BRAZOS	FM 1687	$ 117,700	3	Y	$ 4,567,751
BRYAN	BRAZOS	FM 2038	$ 102,700	3	N	$ 4,567,751
BRYAN	WASHINGTON	FM 1948	$ 72,300	3	Y	$ 4,495,451
BRYAN	WALKER	IH 45	$ 43,400	3	Y	$ 4,452,051
BRYAN	WASHINGTON	FM 577	$ 34,000	3	Y	$ 4,418,051
BRYAN	ROBERTSON	FM 46	$ 494,400	2	Y	$ 3,923,651
BRYAN	MILAM	FM 437	$ 376,100	2	Y	$ 3,547,551
BRYAN	FREESTONE	SH 179	$ 368,800	2	Y	$ 3,178,751
BRYAN	WASHINGTON	SH 105	$ 350,500	2	N	$ 3,178,751
BRYAN	MILAM	FM 485	$ 283,800	2	Y	$ 2,894,951
BRYAN	BRAZOS	OSR	$ 277,000	2	Y	$ 2,617,951
BRYAN	MADISON	SH 21	$ 271,800	2	N	$ 2,617,951
BRYAN	MADISON	OSR	$ 213,800	2	N	$ 2,617,951
PHARR	CAMERON	FM 802	$ 170,237	2	N	$ 2,617,951
PHARR	CAMERON	FM 2925	$ 165,809	2	Y	$ 2,452,142
BRYAN	LEON	SH 7	$ 164,400	2	Y	$ 2,287,742
BRYAN	MILAM	US 190	$ 161,000	2	Y	$ 2,126,742
PHARR	WILLACY	FM 490	$ 157,424	2	Y	$ 1,969,318
PHARR	CAMERON	FM 1847	$ 156,330	2	Y	$ 1,812,988
BRYAN	LEON	IH 45	$ 147,000	2	Y	$ 1,665,988
PHARR	CAMERON	FM 1575	$ 146,644	2	Y	$ 1,519,344
PHARR	STARR	FM 755	$ 143,855	2	Y	$ 1,375,489
BRYAN	WASHINGTON	FM 390	$ 139,400	2	Y	$ 1,236,089
BRYAN	BRAZOS	SH 308	$ 136,800	2	Y	$ 1,099,289
PHARR	HIDALGO	FM 1925	$ 134,343	2	Y	$ 964,946
BRYAN	WALKER	US 190	$ 134,200	2	Y	$ 830,746
PHARR	WILLACY	FM 1015	$ 124,249	2	Y	$ 706,497
PHARR	CAMERON	FM 2925	$ 120,847	2	Y	$ 585,650
PHARR	CAMERON	US 77	$ 119,695	2	N	$ 585,650
PHARR	CAMERON	FM 1419	$ 118,850	2	Y	$ 466,800
PHARR	CAMERON	FM 802	$ 104,304	2	N	$ 466,800
PHARR	CAMERON	FM 800	$ 89,101	2	Y	$ 377,699
PHARR	WILLACY	FM 507	$ 86,693	2	N	$ 377,699
BRYAN	MILAM	FM 486	$ 69,000	2	N	$ 377,699
PHARR	WILLACY	FM 490	$ 52,800	2	Y	$ 324,899
BRYAN	WASHINGTON	FM 1948	$ 51,600	2	Y	$ 273,299
PHARR	HIDALGO	FM 1926	$ 23,033	2	Y	$ 250,266
PHARR	CAMERON	BU 77-X	$ 65,617	1	Y	$ 184,649
PHARR	CAMERON	FM 510	$ 59,385	1	Y	$ 125,264
PHARR	CAMERON	BU 77-W	$ 40,670	1	N	$ 125,264
PHARR	CAMERON	FM 800	$ 38,505	1	N	$ 125,264
BRYAN	WASHINGTON	FM 1697	$ 32,900	1	N	$ 125,264
PHARR	WILLACY	SP 413	$ 10,655	1	N	$ 125,264