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16. Abstract
This report documents the work performed during phase two of Project 0-5534, "Asset Management – Texas Style." This phase included gathering historical Texas Department of Transportation (TxDOT) right-of-way acquisition information, analyzing statistical information, and then developing simulation and optimization tools for TxDOT right-of-way sections and budget decision makers. These tools are designed to provide decision support as optimal strategies for use of early right-of-way acquisition methods are considered at project, district, and state levels. Implementation planning includes cooperative use of the tools with selected districts. This project also included a research team review of TxDOT's fleet vehicle replacement strategies and assessment of potential use of business science tools to assist decision makers in this area of operations.

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DEVELOPMENT OF DECISION-MAKING SUPPORT TOOLS FOR EARLY RIGHT- OF-WAY ACQUISITIONS

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permitting purposes. The engineer in charge of the project was Paul E. Krugler, P.E. #43317. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

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CHAPTER 1:
INTRODUCTION

This research project was conducted in two phases. Phase one of this project explored the potential for beneficial use of simulation, optimization, and decision analysis tools to assist the Texas Department of Transportation (TxDOT) in optimizing strategies for acquiring right-of-way parcels, particularly strategies regarding the timing of parcel purchasing. The findings of phase one are reported in Technical Report 0-5534-1, "Asset Management Literature Review and Potential Applications of Simulation, Optimization, and Decision Analysis Techniques for Right of Way and Transportation Planning and Programming." A recommendation from phase one was to select a single business science tool as the core approach to decision support, and that the other methods may be incorporated where they offer the greatest benefit as feasible within the limitations of this research project. Consequent meetings with the TxDOT project monitoring committee resulted in the selection of simulation as the most suitable business science tool for evaluating right-of-way acquisition timing options. The tool development plan included use of optimization to provide early acquisition budget recommendations to users.

ORGANIZATION OF THE REPORT

This report includes the results of phase two of this research project, including gathering necessary historical right-of-way acquisition information, analysis of this information, and the development of decision-support tools to assist TxDOT in obtaining cost savings through improved timing of right-of-way parcel acquisitions.

The report is composed of eight chapters. This chapter provides an introduction to phase two of this research project. It describes project objectives, the nature of the research problem, and describes the organization of this report.

Chapter 2 describes the processes of gathering historical right-of-way information, the analysis of this information, and the application of this information in creating a simulation model named TAMSIM.

Chapter 3 presents TAMSIM, the simulation-based right-of-way acquisition decision-support tool developed during phase two of this project. TAMSIM methodology, required inputs,

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and tool outputs are described to assist new users of this tool in determining most likely total right-of-way costs to be anticipated should various purchasing strategies be selected.

Chapter 4 describes sensitivity testing performed by the research team to explore TAMSIM functionality characteristics.

Chapter 5 presents the optimization-based right-of-way acquisition decision-support tool named EROW. The EROW dynamic programming approach, required inputs, and tool outputs are described to assist new users of this tool in determining optimal budgeting for early right-of-way acquisitioning.

Chapter 6 describes the research team's analysis of TxDOT's fleet management and vehicle replacement methodologies and resulting recommendations for potentially enhancing this area of TxDOT asset management using business science tools.

Chapter 7 includes the implementation plan for moving the developed right-of-way decision-support tools into routine use within TxDOT.

Chapter 8 summarizes the conclusions and recommendations resulting from phase two of this project.

The tools developed during phase two of this project, TAMSIM and EROW, are included on a CD-ROM in a jacket inside the cover of this report.

TXDOT CHALLENGES IN RIGHT-OF-WAY ACQUISITION

The process of acquiring necessary right of way for a highway construction project can considerably impact the project's completion time and total cost. The degree of impact to these important considerations fluctuates based upon a number of variables associated with project and parcel characteristics. One of the ways to reduce potential negative impact from the right-of-way acquisition portion of the project is to acquire portions of the right of way earlier than the conventional process. TxDOT currently has limited authority to acquire right of way prior to completion and approval of required environmental studies, which is the conventional time for the Right of Way Division (ROW Division) to issue a right-of-way release to the district office to begin purchase negotiations. The stipulations for beginning the purchasing process in advance of that time are that landowner hardship is involved, the property is to be donated, or when property improvements are imminent. The latter category of advance acquisition is termed a protective

buy and is generally restricted to situations where improvements are not only planned, but construction is thought to possibly begin in the near future.

In addition to challenges associated with limited ability to pursue purchasing early in the project planning process, another challenge to TxDOT is determining the budget amount that should be allocated to acquiring parcels early. TxDOT has limited experience with these early purchases, and determining when the rate of return from early right-of-way purchases exceeds rates of return for other uses of budget resources is formidable.

Experience has shown that waiting until normally required steps in project planning have been completed before acquiring certain right-of-way parcels can result in substantially increased purchase costs for the State of Texas. Landowners have in the past improved properties within the projected facility footprint during the transportation facility planning process. In some cases this has been done with apparent full knowledge that a State of Texas purchase would occur in the future. Even when physical improvements are not made, landowners may continue to plan new "best uses" of their property, which can then result in huge increases in purchase costs. A fairly common situation found by TxDOT ROW procurement personnel is that an investor or investment group has purchased property within the projected footprint and has proceeded to plan a new housing or commercial development, again, very likely with full knowledge that the State of Texas will be purchasing the property for transportation improvements. Investors well-understand that current interpretation of state law requires the State to purchase the property considering this new best use probability.

However, before seeking expanded legislative authority for acquiring right of way at earlier times in the project planning process, it is necessary to have a mature understanding of the potential impact that expanding early acquisition may have on project costs. The complexity of the issues and variability in situations surrounding acquisition of right-of-way parcels has made quantification of these impacts, particularly on a statewide basis, extremely difficult if not impossible.

PROJECT OBJECTIVE

The objective of this project was narrowed by the sponsor to focus on creating decision-support tools to assist TxDOT in optimizing right-of-way acquisition strategies, particularly regarding the timing of acquisitions in locations where land speculation activities as well as

actual or planned property improvements may substantially increase right-of-way costs to the State of Texas. Two decision-support tools were designed and developed to meet this objective.

A simulation tool was designed to model project right-of-way related costs and milestone time durations during the Plan Authority and Develop Authority planning phases, both with and without early right-of-way acquisition occurring. These costs include not only the purchase of the right of way itself, but also cost estimates associated with the possible delay in construction start time due to lack of right of way.

The second decision-support tool is an optimization process for estimating the rate of return appropriate to anticipate from incremental increases in the budget amount made available for early right-of-way acquisition. The results from the optimization tool are valuable during the budget planning process. The tool compares anticipated rates of returns from acquiring right of way early to a rate of return expected from other potential uses of the evaluated budgetary amount, as entered by the user. Results are numerically and graphically displayed.

EARLY ACQUISITION DEFINITION

Early acquisition of right of way as this expression is used in this report is defined to be the purchase of parcels that is initiated during the time span between the availability of the design schematics and the completion and approval of the environmental study resulting in conventional right-of-way release from the ROW Division. This approximates the defined time period for "advance" acquisition to occur as referenced in TxDOT right-of-way related manuals.

CHAPTER 2:
RIGHT-OF-WAY ACQUISITION DATA GATHERING AND ANALYSIS

Development of a simulation tool requires determination of data attributes for the variables included in the process being simulated. Acquisition costs and time durations are the key variables involved with right-of-way acquisition simulation and were therefore the focus of research team data analyses. The Right of Way Information System (ROWIS) database was the primary source of right-of-way acquisition data to be analyzed. Interviews with key TxDOT personnel involved in right-of-way acquisition practices were also conducted to complement the information obtained from ROWIS. Results from the data analyses are the basis for the TAMSIM decision-support tool. This chapter describes the data gathering, presents the analyses conducted, and introduces the application of statistical data to TAMSIM.

RIGHT-OF-WAY ACQUISITION DATA GATHERING

Historical Data from TxDOT's Right-of-Way Information System

ROWIS is a relational database and data management program used by the ROW Division and district offices (Gibson et al. 2005). ROWIS captures key attributes of the property acquisition process. These key attributes can largely be categorized into four groups:

- *project level attributes*: district, county, highway, control-section-job (CSJ) number, parcel number, etc.;
- *parcel level attributes*: property type, taken area, remainder area, type of damages, type of improvements, type of acquisition, etc.;
- *time attributes*: environmental clearance date, right-of-way release date, appraisal report date, value approved date, possession date, etc.; and
- *cost attributes*: land value, damage value, improvement value, total appraised value, total approved value, total acquisition cost, etc.

ROWIS data received from TxDOT consisted of a number of tables retrieved from the relational database according to the different attribute levels of the contained records. The different levels of records in the raw data tables include the project level, parcel level, component level, as well as others. The simulation model is focused on parcel level activities, which are later summed for a project level analysis. Since the simulation model was to be built

on these analyzed historical records, it was crucial that well-representative data sets be selected from the raw data provided by TxDOT. In order to better reflect recent trends occurring in the ever-changing right-of-way acquisition realm, older records, those with parcel possession dates prior to year 2003, were filtered out and not included in research team analyses. Records were carefully checked to avoid input errors and data inconsistency, i.e., typographical errors, violations of precedence relationship between important dates, etc. All cost terms were adjusted by the appropriate House Price Index (HPI) factor to take into account the inflation rates affecting property costs (OFHEO 2008). A more detailed description of the filtering process is provided in the following section.

With the close collaboration of the TxDOT Right of Way Division a total of four sets of ROWIS data were received during the course of this project, as shown in Table 1. The fourth data set, which is the most comprehensive and updated set, provided the statistical data attributes for the simulation model described in Chapter 3.

Table 1. ROWIS Data Sets Received from TxDOT.

	1st ROWIS Data Set April 2007	2nd ROWIS Data Set July 2007	3rd ROWIS Data Set November 2007	4th ROWIS Data Set April 2008
Geographical Location	5 counties from 1 district (SAT)	67 counties from 9 districts (ABL, AUS, BRY, CRP, ELP, FTW, HOU, WAC, WFS)	18 counties from 3 districts (FTW, HOU, SAT)	141 counties from all 25 districts
Time Period [a]	1985 – 2007	1985 – 2007	2003 – 2007	2003 – April 2008
Number of Projects [b]	27	323	128	579
Number of Parcels [b]	296	5,313	2,127	7,559

(a) Based on parcel possession dates
(b) The project and parcel numbers are those from the combined tables after the data filtering process

Data Filtering and Aggregating

The fourth ROWIS data set was received from TxDOT in the form of five different tables in order to minimize data redundancy and to keep related attributes within the same table. However, the tables of data could not be used without checking data integrity. ROWIS data records are placed in the database by authorized district personnel as activities and events occur

on right-of-way related projects. Even though ROWIS is carefully designed to ensure the quality of data being entered through numerous pull-down menus and check boxes (TxDOT 2006), a degree of human error is virtually unavoidable in complex right-of-way projects lasting over a number of years. Common errors include data omission, typographical errors, and precedence violation between entered dates. The data filtering process utilized included the following steps:

- Delete records with the following blank date fields:
  - blank Environmental Clearance Date,
  - blank Right of Way Release Date,
  - blank Appraisal Report Date,
  - blank Value Approved Date, and
  - blank Possession Date.
- Delete records with old date values:
  - records with parcel possession dates before year 2003, and
  - records with erroneously old dates for environmental clearance, ROW release, appraisal report, and value approved (for example, a record with environmental clearance year of 1900).
- Delete records with no Acquisition Type Code.
- Delete records with the following precedence violations:
  - Right of Way Release Date is earlier than Environmental Clearance Date.
  - Appraisal Report Date is earlier than Right of Way Release Date.
  - Value Approved Date is earlier than Appraisal Report Date.
  - Possession Date is earlier than Value Approved Date.
- Delete records without cost values.

The data filtering process above removed approximately 37 percent of the records provided to the research team. Remaining data was then processed further to standardize land area units, sum multiple payments on individual parcels, and multiply cost values by appropriate Texas HPI factors to standardize property dollar values. Texas HPI factors used are those published by the Federal Housing Finance Agency (FHFA).

After filtering, the remaining records in the five tables were combined for further analysis. The combining process was performed within the MS Access® database due to the complex relationship between the tables. Figure 1 represents the multiple one-to-many

relationships between the tables. For example, one record from the Possessed Parcels table may correspond to multiple records from the Parcel Payments table and the Parcel Appraisals table. The Possessed Parcels table acted as the center of the merges during the combining process because the focus of this study primarily involves parcel level aggregation.

1. Possessed Parcels

No.	1. POSSESSED PARCELS Field Name
1	District
2	Hwy Type
3	Hwy Nbr
4	County
5	Project CSJ
6	ROW CSJ
7	Parcel Nbr
8	How Acquired
9	Possession Type
10	Env. Clearance Date
11	ROW Release Date
12	Appraisal Report Date
13	Value Approved Date
14	Possession Date
15	Estimated Let Date
16	Total Est Acq Costs
17	Total Paid Ant
18	Parcel Outsourced Flag
19	Parcel Release Type
20	Approved Sign Value
21	Approved Damages Value
22	Approved Land Value
23	Approved Easement Value
24	Total Approved Value
	11,967 records

2. Parcel Payments

No.	2. PARCEL PAYMENTS Field Name
1	District
2	ROW CSJ Nbr
3	Parcel Nbr
4	Expense Category
5	Payment Amount
6	Payment Status
7	Status Date
8	Task
	65,922 records

3. Parcel Components

No.	3. PARCEL COMPNENTS Field Name
1	District
2	ROW CSJ
3	Parcel
4	Component_Name
5	Property Type
6	Taken Area (Eng)
7	Rem Area (Eng)
8	Eng Units
9	Taken Area (Met)
10	Rem Area (Met)
11	Metric Unit
12	Cost Per Unit
13	Unit
14	App Report Date
15	Taking Type
16	Interest Type
	13,727 records

4. Parcel Appraisals

No.	4. PARCEL APPRAISALS Field Name
1	District
2	ROW CSJ
3	Parcel
4	Component
5	Improvement
6	Improvement Type
7	Appraised Value
8	Specific Damages
9	Special Damages
10	Report Date
	40,307 records

5. Advanced Acquisitions

No.	5. ADVANCED ACQUISITION Field Name
1	District
2	Hwy Type
3	Hwy Nbr
4	County
5	Project CSJ
6	ROW CSJ
7	Parcel Nbr
8	How Acquired
9	Possession Type
10	Env. Clearance Date
11	ROW Release Date
12	Appraisal Report Date
13	Value Approved Date
14	Possession Date
15	Estimated Let Date
16	Total Est Acq Costs
17	Total Paid Ant
18	Parcel Outsourced Flag
19	Parcel Release Type
20	Approved Sign Value
21	Approved Damages Value
22	Approved Land Value
23	Approved Easement Value
24	Total Approved Value
25	TYPE OF ADV ACQ
	187 records

ERROR CHECKING, FILTERING, AND COMBINING PROCESS

Filtered and Combined Table (38 Fields and 7,559 Records)

No.	Field Name	No.	Field Name	No.	Field Name	No.	Field Name
1	District	11	Possession Type	21	Parcel Release Type	31	Total Appr Value (HPI Adjusted, as of 2007)
2	County	12	Acq Type Code	22	TYPE OF ADV ACQ	32	Total Cost (HPI Adjusted, as of 2007)
3	Hwy Type	13	Env Clearance Date	23	Approved Sign Value	33	HPI Adjusted PaymentsOfCount
4	Hwy Nbr	14	ROW Release Date	24	Approved Damages Value	34	Gap
5	Project CSJ	15	Appraisal Report Date	25	Approved Land Value	35	Taking Type
6	ROW CSJ	16	Value Approved Date	26	Approved Easement Value	36	Interest Type
7	Parcel Nbr	17	Possession Date	27	Total Approved Value	37	Cost Per SF
8	Property Type	18	Estimated Let Date	28	Value Appr Year	38	App Report Year
9	Property Type Code	19	Total Est Acq Costs	29	HPI of Value Appr Year		
10	How Acquired	20	Parcel Outsourced Flag	30	Total Paid Ant		

Figure 1. Relationship Diagram between ROWIS Tables.

Milestone Dates of Right-of-Way Parcel Acquisition Activities

Project development is a time-consuming process that varies typically from 3 to 10 years. During this process environmental clearance and right-of-way acquisition take up a significant portion of the total time before construction begins. The right-of-way acquisition process

typically begins with right-of-way release after environmental clearance is obtained. Right-of-way release is followed by appraisal, negotiation, possession, and relocation. Milestone dates through the right-of-way acquisition conventional process are summarized in Figure 2 (Gibson et al. 2005).

In Figure 2, the duration from environmental clearance to right-of-way release, D1, is common to all parcels of a project. However, the durations from right-of-way release to possession, D2, usually varies among individual parcels. Hence, the parcel environmental clearance to possession time duration of interest at the project level is the time duration required to acquire the last parcel.
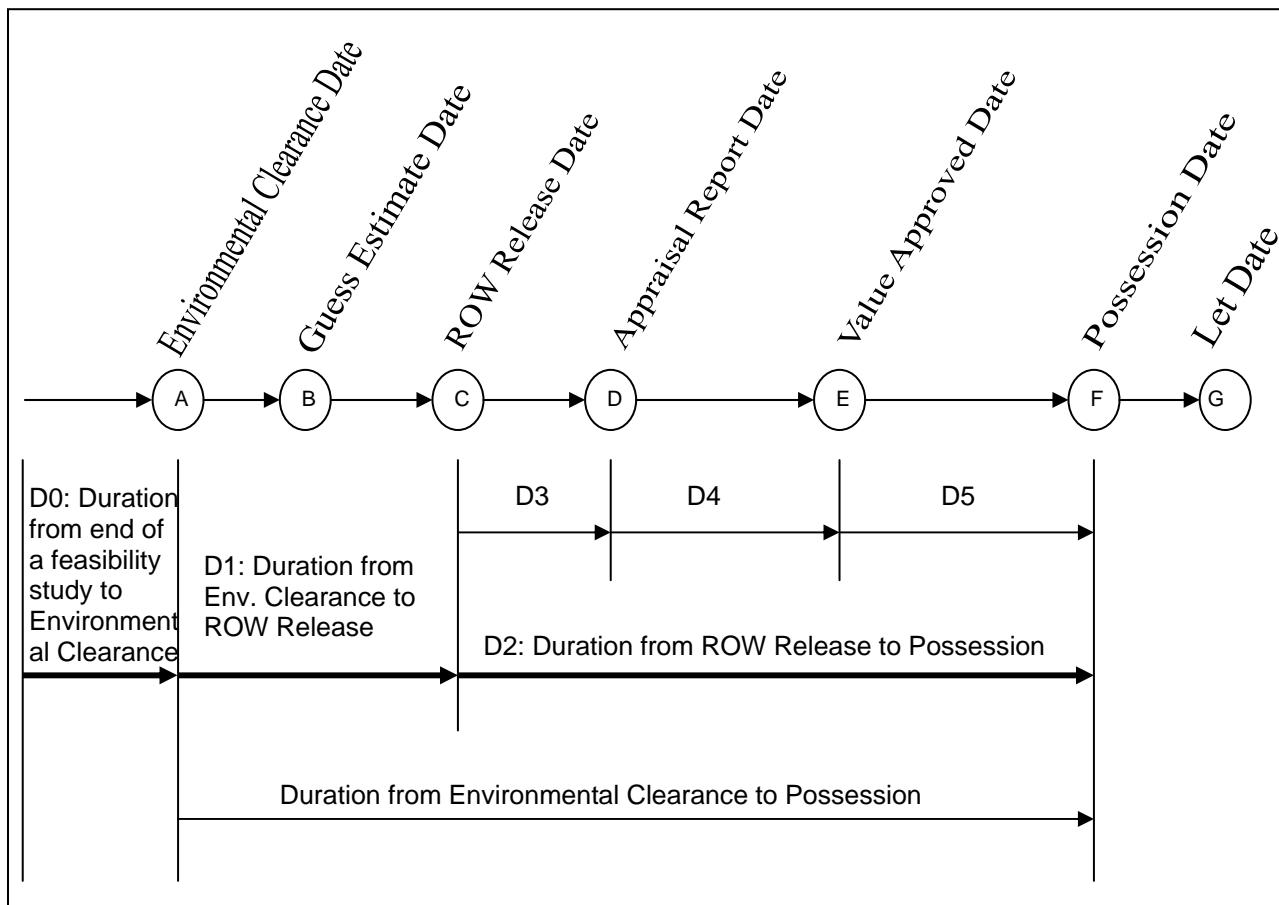
Figure 2. Milestone Dates and Durations for the Right-of-Way Acquisition Process.

Definitions of the milestone dates shown in Figure 2 are as follows:

- Environmental Clearance Date: During the plan authority phase an environmental assessment is performed for approval by the Environmental Affairs Division (ENV

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Division). The environmental clearance date is the date when the ENV Division approves the environmental study. Typically, the right-of-way acquisition process can not start until the environmental clearance is approved and right-of-way release has been granted.

- Guess Estimate Date: A rough estimate of necessary parcel acquisition cost is needed at an early stage of the project development process, well before the right-of-way acquisition process is approved to begin. District right-of-way section personnel prepare these estimates based on various factors such as historical purchase records of parcels with similar characteristics, current market values, and expert knowledge about the acquisition process. According to the historical data gathered from the San Antonio District right-of-way office, these "guess estimates" are usually conducted after environmental clearance and before the release of the right of way for acquisition. Due to considerable inaccuracies associated with guess estimates, which often are required within several days of the request, and other complicating factors, this cost and its date are not included in current simulation modeling.

- Right of Way Release Date: After environmental clearance, the district office requests an authorization from the ROW Division to start the right-of-way acquisition process. The right-of-way release date is the date that the ROW Division advises the district that they have the approval and authority to begin the right-of-way acquisition process (TxDOT 2006). Typically, the right-of-way acquisition process can not start until the right-of-way release for the project is received by the district from the ROW Division. Any parcel acquisition made before conventional right-of-way release is referred to as an *advance acquisition* in TxDOT's right-of-way related manuals. Under current legislative authority, advance acquisition is possible only for hardship acquisitions, protective buying, and donations (TxDOT 2006).

- Appraisal Report Date: After receiving right-of-way release from the ROW Division, the district often assigns an independent contract appraiser to determine the current value of the parcels required by the construction project. Each parcel's appraised value is then submitted to the district right-of-way section on Form ROW-A-10, Tabulation of Values, which includes land value, improvements value, and cost of damages (TxDOT 2006).

- Value Approved Date: Before initiation of landowner negotiations, the appraised value is reviewed by the district right-of-way section and the ROW Division. The Value Approved Date is the date at which the ROW Division advises that the value placed on the parcel, including all improvements to the parcel, is acceptable (TxDOT 2006).

- Possession Date: After the appraised value is approved, a parcel goes into the negotiation process. Depending on the result of negotiations with the property owner, the parcel acquisition process follows one of two tracks to completion, a negotiated settlement or condemnation proceedings. The Possession of Parcel date is defined for negotiated parcels as the date of completion of ROW-N-72, Title Company's Closing Statement, and is defined for condemned parcels as the date of deposit shown on ROW-E-ND, Notice of Deposit (TxDOT 2006).

- Let Date: The let date is the estimated date on which the project will be placed in a letting for receiving contractor bids to provide the construction. This date is not considered in the current simulation program because the goal of this study is limited to estimating right-of-way costs and the time at which the right-of-way acquisition process will be completed (TxDOT 2003).

Interviews of Experienced Right-of-Way Section Personnel

Selected TxDOT personnel with experience in right-of-way acquisition were interviewed to better understand the reasons why districts prefer in some cases early acquisition instead of the conventional acquisition process.

Frances Willison, Director Right of Way, Houston District; Scott B. Hall, District Right of Way Administrator, Fort Worth District; Denise Baxter, Right of Way Agent, Fort Worth District; Randall Redmond, Director of Transportation Planning and Development, Tyler District; and Thomas L. Doss, Right of Way Administrator, Tyler District, were interviewed from the districts. The research team also met with Donald Toner, Jr., Keith Sliger, and Kerry Fulton of the Texas Turnpike Authority (TTA) division. All of these right-of-way professionals provided valuable information about TxDOT processes, methods, and situations in which right-of-way costs can escalate rapidly.

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District right-of-way section personnel reported they mainly have used the protective buy and hardship provisions of currently available early acquisition processes when advance or early acquisition was to be pursued. One district also mentioned donations still occurring occasionally. All interviewed individuals described parcels where considerable amounts of State of Texas funding either were saved or could have been saved if early acquisition could or would have been used to avoid cost escalation. Some examples follow:

- A parcel cost estimate was $0.5 million as pasture land in 2001. This property was purchased for $3.3 million in 2004 as residential property. The district estimated that the cost could have gone up to $6 million if purchasing had been delayed further.
- A parcel cost increased from $0.17/sq ft up to $0.23/sq ft in 3 years.
- A parcel cost for pasture land went from $7,000 per acre to $22,000 per acre in 3 years.
- Total parcel costs for a group of parcels went from an estimated $5.4 million to $10 million when not acquired early.
- Total parcel costs for a group of parcels went from an estimated $5 million to $15 million.

Speculator activity was mentioned as being a significant factor in right-of-way cost increases, particularly in metropolitan and urban areas. In short-term speculation, it was reported that properties can change ownership many times in a short period of time, with each sale at an increased price. Oftentimes short-term speculators become active when they believe that the State has begun right-of-way purchasing for a transportation project.

Some speculator activity has the appearance of having the sole purpose of creating increased purchase costs to the State of Texas. One example is subdividing larger land tracts to create multiple purchases by the State at the higher cost per unit area normally involved with smaller parcel purchases. Another example is preparing drawings and plans for new home subdivisions even though it was common public knowledge and almost certainly known by the landowners that the land for the new subdivision was to be purchased by the State for transportation-related construction. Property owners have also been observed to subdivide properties in a manner that causes remaining land areas to become landlocked after the State purchases necessary rights of way, thereby causing damage costs to be incurred by the State of Texas for those properties outside of the immediate areas being purchased.

In the opinion of experienced right-of-way TxDOT personnel, acquiring certain parcels of property at an earlier date than would occur under standard acquisition methods has the potential of avoiding some of the property cost escalations being experienced. The following set of recommendations represents a general consensus of thought for applying asset management principles to right-of-way early acquisition:

- Projects should be evaluated on a case-by-case basis to determine if early acquisition of certain parcels would be beneficial.

- Protective buying can reduce costs to the State of Texas if: (a) parcels are located in an area where cost can increase rapidly, (b) a significant percentage of the total number of parcels will be purchased early, and (c) parcels are acquired early enough to avoid speculation and/or improvements being added to the properties.

- Speculation, improvements to the property, and damages to the remainder of the property are considered to be the major factors causing significantly increased land costs during the TxDOT project planning process.

- Good communication with cities and counties will help identify areas where cost can increase significantly from initial estimates. This knowledge can position the district office to take action to minimize the impact of potential cost escalation.

- Parcels should be purchased when they are vacant whenever possible. Waiting to purchase vacant property allows the opportunity for improvements to be planned or even constructed.

ANALYSIS OF HISTORICAL RIGHT-OF-WAY ACQUISITION DATA

The analysis of ROWIS data was centered on parcel acquisition time duration and total parcel cost as these are critical elements of the TAMSIM model. The analysis was conducted using different grouping schemes for the right-of-way acquisition information being analyzed. The objective of the analyses was to identify common characteristics for each group of parcels and projects. The four grouping schemes for the data analyses were:

- acquisition type: negotiation (NE) versus eminent domain (ED),
- county type by population: metropolitan, urban, and rural,
- acquisition method: in-house versus outsourced procurement, and
- acquisition timing: early acquisition versus conventional acquisition.

Researchers analyzed a total of 7,559 parcel acquisition records dating from September 2002 through April 2008. For each grouping scheme, data sets were filtered to include only complete parcel information sets. Incomplete records were not included in the analysis. As a result, the actual number of parcels used in the analysis varies for each grouping scheme. The data used in these analyses are provided in Appendix A on the CD-ROM found inside the cover of this report.

Data Analysis by Acquisition Type

Even though there are a number of types of acquisitions recorded in ROWIS, most of the acquisitions fall into one of the following two general categories: *Negotiation and Eminent Domain*. Administrative settlement was a third category considered separately in the earlier research report from this project. However, in a broad sense, an administrative settlement is regarded as a type of possession by negotiation. Hence, it is categorized and analyzed as a type of negotiation in the current analysis.

Table 2 compares time durations experienced during negotiation and eminent domain acquisitions. As mentioned above, administrative settlement cases are included in the negotiation category. Parcels acquired by eminent domain take the longest average durations, 59 months from environmental clearance to possession and 39 months from right-of-way release to possession. Notice that the median values are smaller than corresponding average values for both negotiation and eminent domain parcel acquisitions. Also notice that the median and average durations are in relatively close proximity compared to the maximum durations experienced. These data characteristics suggest that the average values are affected heavily by a relatively small number of difficult cases requiring very long time durations.

Table 2. Time Durations by Acquisition Type [a].

Acquisition Type	Number of Parcels	Time Duration from Environmental Clearance to Possession (months)				Time Duration from ROW Release to Possession (months)			
		Median	Max.	Average	Std. Dev.	Median	Max.	Average	Std. Dev.
Negotiation	6,705	29.2	391.5	37.4	32.9	15.6	252.2	20.5	20.0
Eminent Domain	825	45.1	247.6	59.4	44.2	29.6	235.3	38.7	31.5
All Parcel Acquisitions	7,530	31.0	391.5	39.8	35.0	16.8	252.2	22.5	22.3

(a) From 4th ROWIS data set received in April 2008

Table 3 shows cost data for negotiation and eminent domain parcel acquisitions. In this table, the eminent domain land cost average is $6.66/sq ft, which is twice as much as the negotiated land cost average of $3.29/sq ft. The cost difference between the two acquisition types is larger when total acquisition costs are considered. Average total acquisition cost under eminent domain is more than three times larger compared to negotiation acquisition. Notice that in both cases median values for acquisition costs are much smaller than average values. These results imply that the distributions are skewed positive with elongated tails to the right.

Table 3. Costs by Acquisition Type [a].

Acquisition Type	Number of Parcels	Land Cost ($/sq ft)				Total Acquisition Cost ($, thousands)			
		Median	Max.	Average	Std. Dev.	Median	Max.	Average	Std. Dev.
Negotiation	6,705	0.38	96.14	3.29	6.92	14.7	20,095	105.7	552.2
Eminent Domain	825	1.83	69.14	6.66	9.80	56.9	11,417	350.3	965.7
All Parcel Acquisitions	7,530	0.45	96.14	3.66	7.36	16.8	20,095	132.5	616.0

(a) From 4th ROWIS data set received in April 2008

Data Analysis by County Type (Population)

The ROWIS data set received in April 2008 contains parcel acquisition records occurring in 141 of the 254 counties in Texas. These 141 counties are distributed across the state and

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represent a large variety of socioeconomic characteristics. Counties with populations of 400,000 or above are classified as metropolitan counties, those with populations between 50,000 and 400,000 are classified as urban counties, and those with populations below 50,000 are classified as rural counties.

Table 4 shows the analysis of data with the records grouped by county type. There are nine counties having populations greater than 400,000. Among them, Harris County is the largest and includes the City of Houston. There are also 37 urban counties and 95 rural counties.

Table 4. Categorization by County Type (Population).

County Type	Number of Counties with Parcel Acquisitions in ROWIS	Number of Parcel Acquisitions in ROWIS	County Name	Total Population (Census 2000)
Metropolitan (pop. > 400K)	9	2,191	Harris	3,400,578
			Dallas	2,218,899
			Tarrant	1,446,219
			Bexar	1,392,931
			Travis	812,280
			El Paso	679,622
			Hidalgo	569,463
			Collin	491,675
			Denton	432,976
Urban (50K < pop. < 400K)	37	2,423	Fort Bend	354,452
			Cameron	335,227
			…	…
Rural (pop. < 50K)	95	2,475	Wise	48,793
			Lamar	48,499
			…	…

Table 5 shows time durations by county type. The average time duration between environmental clearance and parcel possession is the longest for metropolitan counties (52 months) followed by urban counties (38 months) and rural counties (30 months). The time durations between right-of-way release and parcel possession follow the same pattern.

Metropolitan counties averaged approximately 31 months, urban counties averaged about 21 months, and rural counties only 17 months.

Table 5. Time Durations by County Type (Population) [a].

County Type	Number of Parcels	Time Duration from Environmental Clearance to Possession (months)		Time Duration from ROW Release to Possession (months)	
		Average	Std. Dev.	Average	Std. Dev.
Metropolitan (pop. > 400K)	2,191	52	41	31	33
Urban (50K < pop. < 400K)	2,423	38	34	21	16
Rural (pop. < 50K)	2,475	30	26	17	11
All County Types	7,089	40	35	23	22

(a) From 4th ROWIS data set received in April 2008

Table 6 shows parcel costs by county type. Each cost value occurring before 2007 was adjusted to current value in 2007 using House Price Indices. Metropolitan counties have the highest average cost at about $9/sq ft, and rural counties have the lowest average cost of about $0.64/sq ft.

As observed for land costs per square foot, metropolitan counties show the highest average total acquisition costs (over $274,000). When these values are compared with those from rural counties, the average total acquisition cost for a parcel in a metropolitan county is about nine times the average total acquisition cost for a parcel in a rural county. Overall, the ratios between metropolitan and rural counties in Table 6 are much larger than the ratios in Table 5, meaning that cost variables are more sensitive than time durations between socio-geographic areas.

Table 6. Costs by County Type (Population)[a] .

County Type	Number of Parcels	Land Cost ($/sq ft)		Total Acquisition Cost ($, thousands)	
		Average	Std. Dev.	Average	Std. Dev.
Metropolitan (pop. > 400K)	2,191	9.04	10.74	274.3	1,044.9
Urban (50K < pop. < 400K)	2,423	2.53	4.41	105.6	294.1
Rural (pop. < 50K)	2,475	0.64	2.29	32.0	87.5
All County Types	7,089	3.88	7.53	132.5	616.0

(a) From 4th ROWIS data set received in April 2008

Data Analysis by Acquisition Method

Since 2003, TxDOT has adopted outsourcing as an alternative method to using in-house capabilities to acquire parcels. Figure 3 shows outsourcing use for parcel acquisition by TxDOT districts. Outsourcing was used to acquire 4,414 parcels, or 58 percent of the total number of parcels. As shown in pie chart (A), more than half of the districts are using outsourcing. Pie chart (B) shows the number of parcels by agent type.
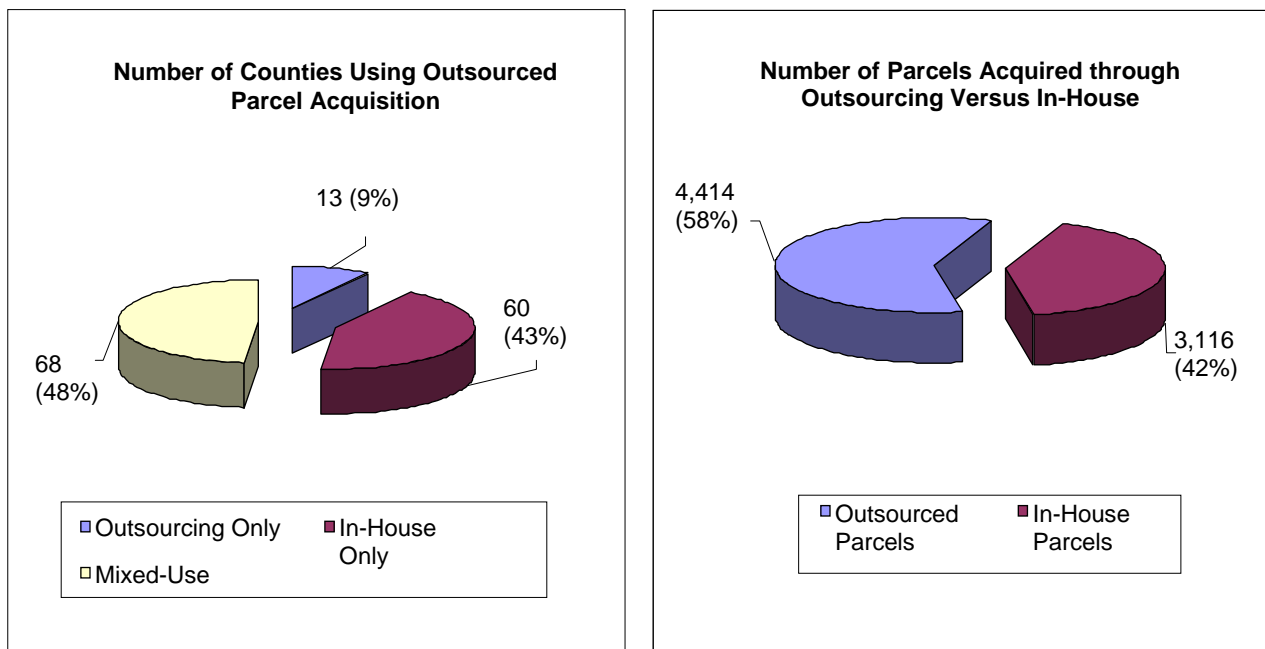
(A) Number of Counties Using Outsourcing

(B) Number of Parcels by Agent Type

Figure 3. Use of Outsourcing for Parcel Acquisition.

Table 7 shows average durations and average total costs dependent upon if the parcel acquisition was outsourced or performed with in-house capabilities. As shown in the table, the average duration and cost of parcels acquired using outsourcing were slightly lower than the averages of those parcels acquired in-house. There is also a significantly lower standard deviation in parcel acquisition durations when acquisitioning was outsourced. This difference may be due, in part, to the practice of districts taking back responsibility for acquisition when an outsource acquisition effort goes to eminent domain proceedings.

Table 7. Outsourcing: Cost and Duration [a].

Acquisition Method	Number of Parcels	Duration from ROW Release to Possession (months)		Total Acquisition Cost ($, thousands)	
		Average	Std. Dev.	Average	Std. Dev.
In-House	3,116	25	29	136.5	676.1
Outsourced	4,414	21	15	129.7	569.7
All Acquisition Methods	7,530	23	22	132.5	616.0

(a) From 4th ROWIS data set received in April 2008

Data Analysis by Acquisition Timing

Records of parcels acquired through early acquisition were identified in the data set. Only 66 parcels from the entire data set, less than 1 percent, were acquired through early acquisition. Table 8 compares costs and time durations for parcels acquired through early acquisition to parcels obtained through conventional acquisition. A significant reduction of time duration is observed from right-of-way release to possession when early acquisition is pursued, 22 months for conventional acquisition to 11 months for early acquisition. However, the total average acquisition cost is higher for parcels acquired through early acquisition ($468,828) than the average cost of parcels acquired through conventional acquisition ($132,864). The apparent reason for this average cost difference is that the majority of parcels acquired through early acquisition are located in metropolitan counties where land values are usually much higher even though parcel sizes tend to be smaller.

Table 8. Comparison of Early and Conventional Acquisition Costs and Durations [a].

Acquisition Timing	Number of Parcels	Duration from ROW Release to Possession (months)		Total Acquisition Cost ($, thousands)	
		Average	Std. Dev.	Average	Std. Dev.
Early Acquisitions	66	11	15	468.8	1,161.2
Conventional Acquisitions	7,121	22	22	132.9	617.5
All Acquisitions	7,187	22	21	136.0	625.3

(a) From 4th ROWIS data set received in April 2008

Table 9 shows time durations and costs of parcels by type of early acquisition and whether the purchase was made through negotiation or eminent domain proceedings. The average time duration for early acquisition through negotiation was 9 months for hardship cases and 10 months for protective buy cases, while time durations for early acquisition through eminent domain proceedings were 26 months for hardship cases and 15 months for protective buy cases. As was shown in Table 2, through a conventional acquisition process, acquiring a parcel takes an average of about 21 months from right-of-way release to possession through negotiation and an average of about 39 months for parcels acquired by eminent domain proceedings.

Regarding costs, the average total acquisition cost when a parcel was acquired through negotiation under hardship provisions was $187,038, and it is $772,997 for parcels acquired through eminent domain proceedings. Also, the total acquisition costs for parcels acquired through protective buy by negotiation averaged $375,409, and averaged $3,395,691 for parcels acquired through protective buy through eminent domain proceedings. Limited conclusions can immediately be drawn from this difference. It is likely that properties having higher value will more frequently be taken to eminent domain proceedings by the landowners.

Table 9. Early Acquisition by Acquisition Type [a].

Type of Early Acquisition	Acquisition Type	Number of Parcels	Average Time Duration from ROW Release to Possession (months)	Average Total Acquisition Cost ($, thousands)
Hardship	Negotiation	12	9	187.0
	Eminent Domain	6	26	773.0
All Hardship Acquisitions		18	15	382.4
Protective Buy	Negotiation	46	10	375.4
	Eminent Domain	2	15	3,395.7
All Protective Buy Acquisitions		48	10	501.3
All Early Acquisitions		66	11	468.8

(a) From 4th ROWIS data set received in April 2008

Most of the parcels purchased through early acquisition are located in metropolitan areas. The number of records for parcels acquired through early acquisition (66 records) is too small for comparing statistics with the conventional acquisition process (7,121 records). Lack of early acquisition records placed increased importance on research team interviews of TxDOT personnel with experience in early acquisition.

Relationship Analysis of Parcel Costs and Time Durations

Average acquisition costs and average time durations are plotted to observe if there is any relationship or trend between these two variables. Figure 4 shows land costs versus time duration. Most of the time durations are scattered, around 10 to 20 months, regardless of the land costs. Figure 5 shows total parcel costs versus time durations. Most of the data are within the region of less-than-50-month duration and less than $60,000 for the total cost. Data are scattered, and no correlation is observed from these plots.
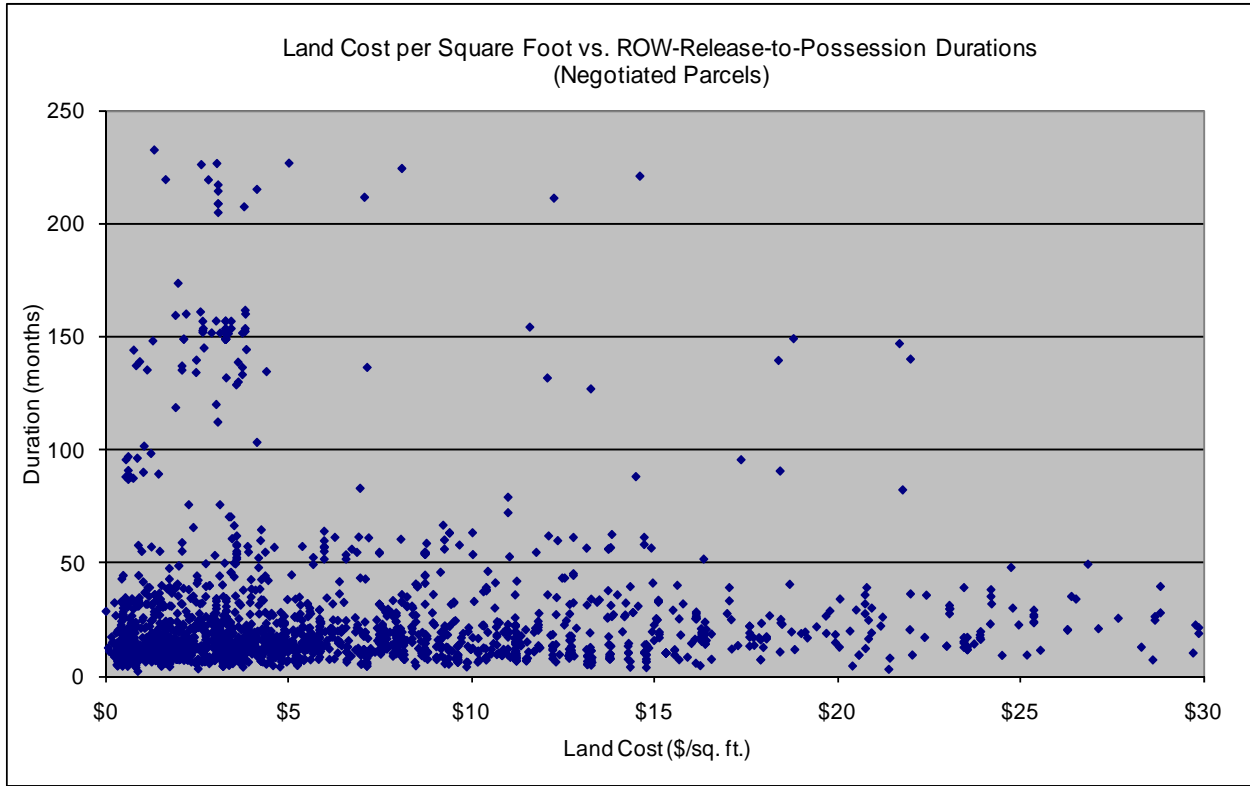
Figure 4. Land Cost vs. Time Duration Scatter Graph - Negotiated Parcels.
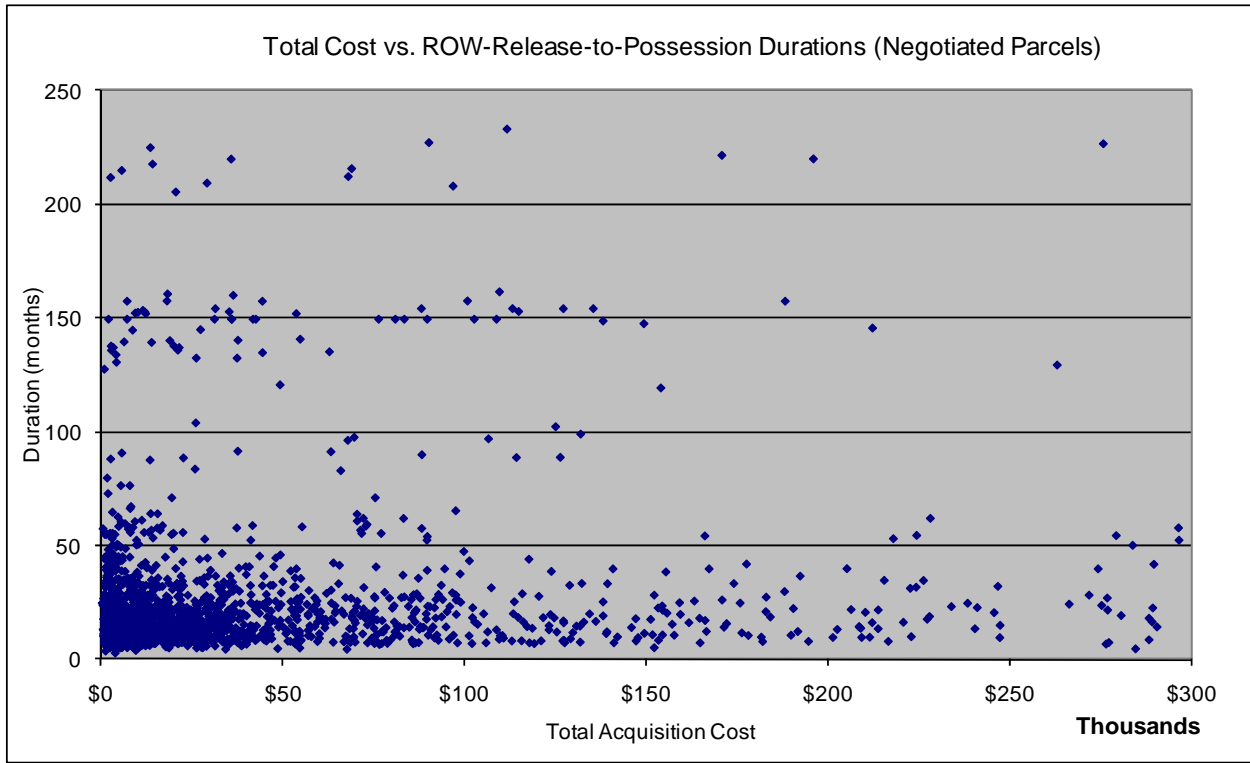

Figure 5. Total Parcel Cost vs. Time Duration Scatter Graph - Negotiated Parcels.

Table 10 displays results of a statistical analysis evaluating potential correlation between negotiated time durations and parcel costs. Correlation coefficients were calculated. The correlation coefficient between right-of-way release to possession time duration and the land cost is 0.012, while the correlation coefficient between this same time duration and the total parcel cost is 0.061. These are very small values, which confirm what was observed from the plotted data in Figures 4 and 5. No correlation exists between these two variables. When there is a perfect positive relationship between two variables, the correlation coefficient becomes 1. The coefficient reduces to zero when there is no correlation whatsoever between the variables.

Table 10. Correlation Coefficients between Negotiated Parcel Costs and Durations.

	Land Cost ($/sq ft)	**Total Parcel Cost ($, thousands)**	**Duration from Right-of-Way Release to Possession (months)**
Land Cost ($/sq ft)	1	0.265	0.012
Total Parcel Cost ($, thousands)	0.265	1	0.061
Duration from Right-of-Way Release to Possession (months)	0.012	0.061	1

APPLICATION OF STATISTICAL DATA TO TAMSIM

TAMSIM Model Basis

A simulation model requires statistical information for variable data to be processed during its use. Appropriate statistics derived from the latest and largest ROWIS data set were incorporated into TAMSIM during the tool development process. As stated earlier, the volume of data pertinent to early parcel acquisitions was minimal, allowing what is believed to be an adequate but not particularly strong set of statistical criteria for the development of TAMSIM. As TxDOT's experience with early parcel acquisitions increases, it will be possible to refine TAMSIM with stronger statistical criteria for early parcel acquisitioning.

Time durations and parcel costs during the right-of-way acquisition process are the major data inputs for TAMSIM. These inputs are described in the following sections. Chapter 3 provides a comprehensive discussion of TAMSIM.

Time Durations

Time durations were analyzed to become the underlying input to the simulation model for estimating parcel acquisition times and costs. There are three major time durations used in the simulation program. Reference to Figure 2 is helpful in describing the time durations included in TAMSIM. The first duration is the time between completion of the feasibility study and when environmental clearance is obtained (D0). The second duration is the time between environmental clearance and when right-of-way release (D1) is obtained from the ROW Division. The last time duration is from right-of-way release until parcel possession (D2). ROWIS does not currently incorporate the initial date attribute necessary to calculate the duration until environmental clearance (D0). Therefore, TAMSIM receives this duration information by direct entry of the user on the Basic Data screen. The duration from the end of the feasibility study to environmental clearance (D0) and the duration from environmental clearance to right-of-way release (D1) are considered project level durations because they do not depend upon events at the individual parcel level. Hence D0 and D1 apply to all of the individual parcels in the same project. In contrast, durations D3, D4, and D5 shown in Figure 2 are parcel-specific time durations.

Costs Terms

A number of different cost values are stored in the ROWIS database to document parcel acquisition activity. Among them, *Land Cost per Square Foot*, *Total Approved Value*, and *Total Acquisition Cost* were selected for analysis and inclusion in the TAMSIM model. In the cost tables, *Total Approved Value* represents the amount of money approved by the ROW Division after the district submits Form A-10 that includes the appraised values of the land, improvements, and damages. *Total Acquisition Cost* represents the sum of all entered "Payment Amount" values until a parcel is acquired. It includes the actual expenses under the "ROW Acquisition Expenses" item of Expense Category, e.g., court cost, appraisal cost, title company work, etc. Since there are several payment categories for a parcel, all payments for each parcel are summed to obtain the total cost. *Total Acquisition Cost* is the final representative cost term in the right-of-way process selected for analysis. The current version of TAMSIM estimates *Total Acquisition Cost* as the output of simulation runs.

CHAPTER 3:
TAMSIM: A SIMULATION PROGRAM FOR RIGHT-OF-WAY ACQUISITION

APPLICATIONS FOR TAMSIM

TAMSIM is envisioned to have two primary applications: as a policy tool at the state level and as a decision-support project tool at the district level. When used as a policy tool, a generic project can be simulated to determine the effect that various proposed policies regarding early acquisition of right of way may have on statewide right-of-way costs. At the district level, TAMSIM can be used by right-of-way section managers to determine the likely effects on a specific project if some of its parcels are acquired early. Due to the nature of TAMSIM input and the fact that in some sense each project is unique, the value and dependability of TAMSIM output are directly related to the user's depth of right-of-way acquisition experience and familiarity with the local right-of-way market.

TAMSIM OVERVIEW

TAMSIM is a simulation program designed to provide statistical measures of the impact that right-of-way acquisition timing can have on a project's costs and completion date. As a simulation model, it takes into account inherent variabilities that are part of the right-of-way acquisition process. These variabilities include the possibility of condemnation proceedings becoming required, the length of time for negotiations to be completed, and the costs involved in taking possession of parcels. The tool recognizes that natural variation occurs in time durations involved in the process, occasionally requiring an unusually long period of time to complete, in which case there could be added costs due to a late start on construction. Conversely, there is the possibility that the acquisition process could take an unusually short period of time, in which case there could be cost benefits associated with an early start on construction. The potential for possible cost increases or for cost savings are included in the model. TAMSIM includes sequential time durations between events in the project development and right-of-way purchasing processes. All time duration measures within TAMSIM are relative to time zero, which is defined as the point in time at which the initial roadway schematics become available.

There are four major phases in the development process of a TxDOT construction project: Feasibility Study, Plan Authority, Develop Authority, and Construct Authority. During the Plan Authority phase of a project, an initial set of schematics is created to indicate parcels of

land necessary to acquire for the project. In some cases alternative roadway alignments are considered at this early point in planning, each with differing right-of-way acquisition needs. TAMSIM analysis allows the consideration of multiple roadway alignments.

The purpose of the simulation model is to provide mean and standard deviation estimates for right-of-way costs and time durations at the project level. The simulation tool is designed for primary use by TxDOT districts toward the beginning of the Plan Authority phase, as the schematics are being developed. TAMSIM estimates total project right-of-way costs incurred throughout the Plan Authority and Develop Authority phases of the project and estimates the time at which all right-of-way acquisition will be finalized so that the Construct Authority phase can begin.

TAMSIM DATA INPUT

As was described in Chapter 2, attributes of data from ROWIS and hard files were determined for use in developing the TAMSIM model. Due to the effort and time required to extract data from hard files, most of the data analysis efforts involved ROWIS data. Figure 6 is a simplified version of Figure 2 showing important dates and durations available in ROWIS. The time related data needed for the simulation are the durations from environmental clearance to right-of-way release and the durations from right-of-way release to possessions of parcels.

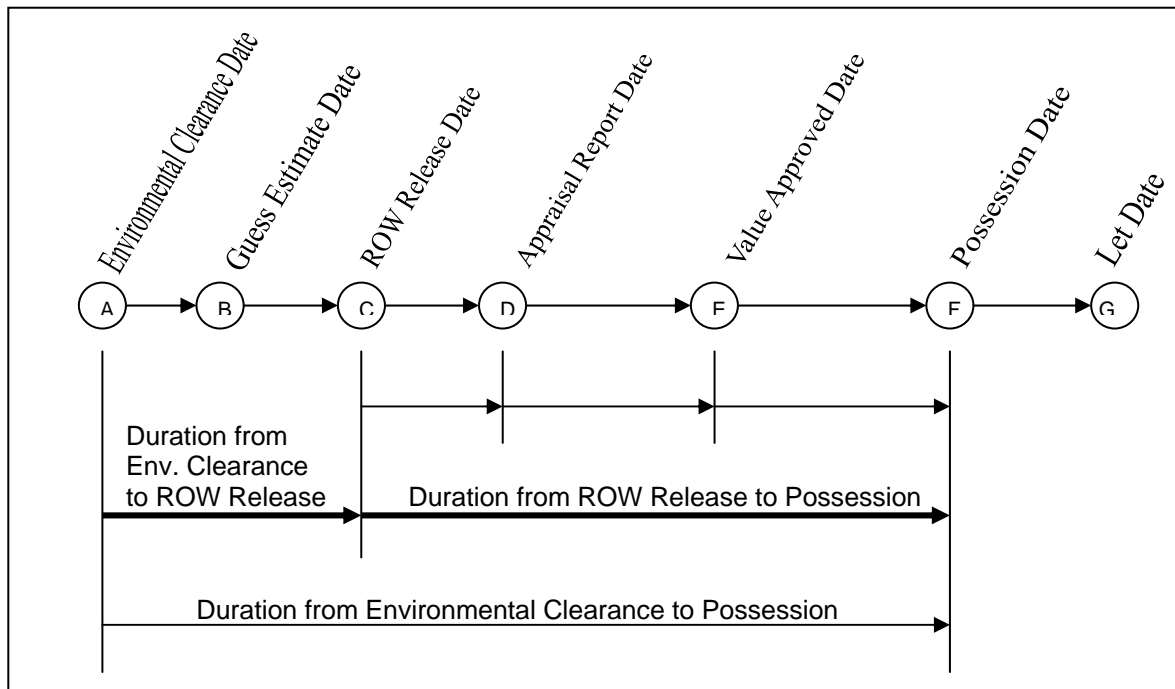**Figure 6. Dates and Time Durations for the Simulation Model.**

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Upon opening TAMSIM, the initial screen (Figure 7) offers the user a choice of continuing an earlier project analysis or beginning analysis of a new project. If the new project option is selected, the next screen to appear is the Parcel Generator screen (Figure 8).
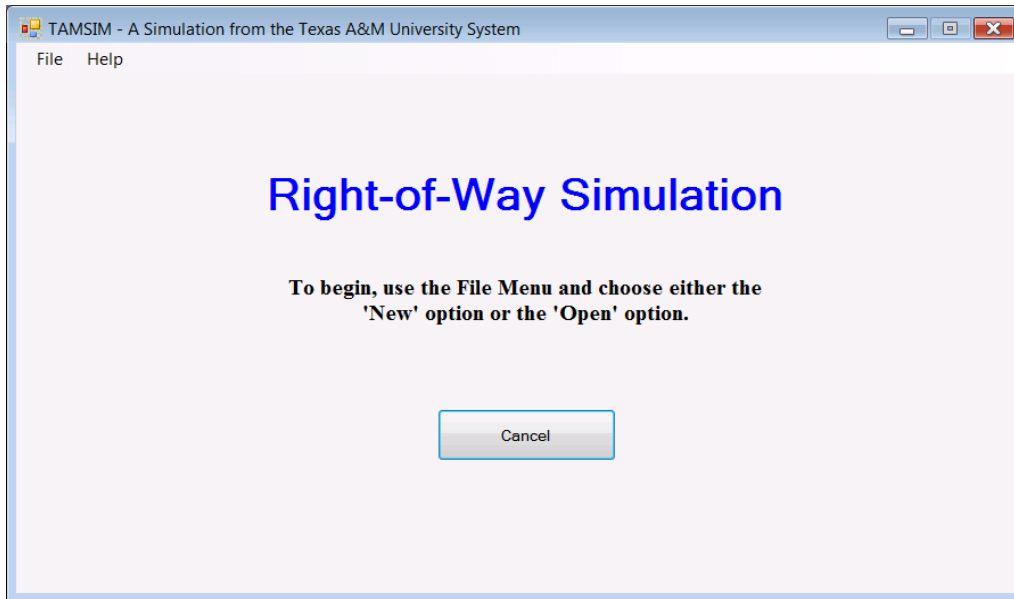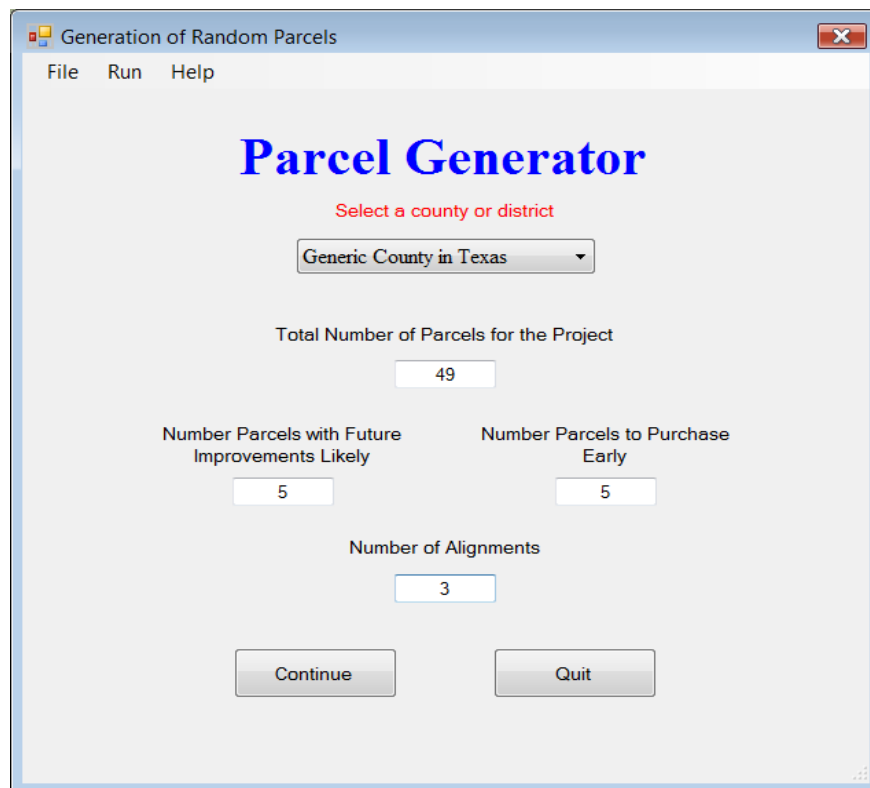

Figure 7. TAMSIM Initial Screen.

Figure 8. TAMSIM Screen for Parcel Generation.

The purpose of the Parcel Generator screen is to allow the user to describe the set of parcels for the project that is to be simulated. There are five key characteristics of the parcel set for the user to select. The first is the location of the project. The user is provided a drop-down menu from which to select the best descriptor of the project location. The remaining four characteristics to be entered by the user are 1) the total number of parcels involved on the project, 2) the number of these parcels likely to receive improvements in the opinion of the user, 3) the number of parcels to purchase early in the simulation to be performed, and 4) the number of different roadway alignments to be considered in the analysis.

The number of parcels likely to receive improvements or to see abnormally large cost increases due to speculator activity during the Plan Authority or Develop Authority phases of project development is a critical input, which should be determined by the most experienced right-of-way personnel available to the district. These data are critical because early acquisition for these parcels is most likely to be economically worthwhile; thus, normally the number of parcels to purchase early will be less than or equal to the number of parcels in which future improvements are likely.

The simulation to be performed will generate costs and time durations based on data attributes determined from the analyses of ROWIS data described in Chapter 2. These data attributes were determined for groups of data. When the user selects the project location descriptor from the drop-down menu on the Parcel Generator screen, this selection causes the simulation to run using data variability attributes found in parcel data sets from similar locations. TAMSIM also places default data in data entry fields based on historical data from these similar locations. Virtually all project and parcel data values and information initially displayed by TAMSIM can be changed by the user. Modification of the TAMSIM default information to better reflect the specific project and individual parcels will enhance accuracy and value of TAMSIM output. The data attributes for a Generic County in Texas were derived from all analyzed parcel acquisition data. The data attributes for a Metropolitan area were obtained from analyzing parcel acquisition information from all counties with populations larger than 400,000. The Urban area attributes are from counties with a population between 50,000 and 400,000, and the Rural area attributes are from those counties with a population less than 50,000 population. Adequate data was available to individually include Dallas, Harris, and Tarrant Counties as location options having specific data attributes for simulation.

Within a specific project, the duration of time that it takes to acquire a parcel is not independent of the duration of time to acquire another parcel within the same project. The same is true of the cost to purchase a parcel; therefore, the mean and standard deviation for both duration and costs were obtained by analyzing parcels within specific projects. In order to have meaningful data, it was decided to only include data from projects with a minimum number of parcels. For determining generic county project data attributes, only projects with at least 25 parcels were considered. For determining data attributes for metropolitan, urban, or rural areas, researchers considered only projects with at least 20 parcels. For individual counties, it was decided that if a county had at least five projects containing 10 or more parcels, then such a county would be included as an option in the drop-down menu to supply unique data attributes for the simulation tool. Dallas, Harris, and Tarrant were the only counties with this level of parcel acquisition data available.

An alignment refers to a collection of parcels that will be accepted or rejected as a unit during the environmental clearance process. Because TAMSIM is designed to be used before the environmental clearance has been obtained, there is a possibility that some of the parcels listed in various alignments will not be necessary for the final approved corridor.

The Alignment screen (see Figure 9) is used to identify the multiple alignments when appropriate. When more than one alignment is specified on the Parcel Generator screen, the Alignment screen will appear for the user. If only one alignment is considered, then all parcels listed will be included in the final approved corridor, and the tool by-passes the Alignment screen. Alignments are organized into groups such that one, and only one, alignment from each group will be accepted for the final approved corridor. Alignments within one group must always be listed consecutively on the Alignments screen with the first alignment of each group being identified by a check box. Since only one alignment from each group will be selected for inclusion in the final approved corridor, the sum of likelihoods associated with the alignments within one group must equal 1.0. The data fields on the Alignment screen shown in Figure 9 are as follows:

1. *Alignment Description (Num and ID).* The first two fields represent descriptive data for the alignment. The first field is automatically filled, and the number assigned to the alignment cannot be modified. The second field is available so that alignments can be named by the user to facilitate later identification.

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2. *Start New Group*. Alignments form groups so that one and only one alignment within a group will be selected for a project. Alignments associated with one group must be listed together, and the first alignment that begins a new group must be indicated with a check mark in this column.
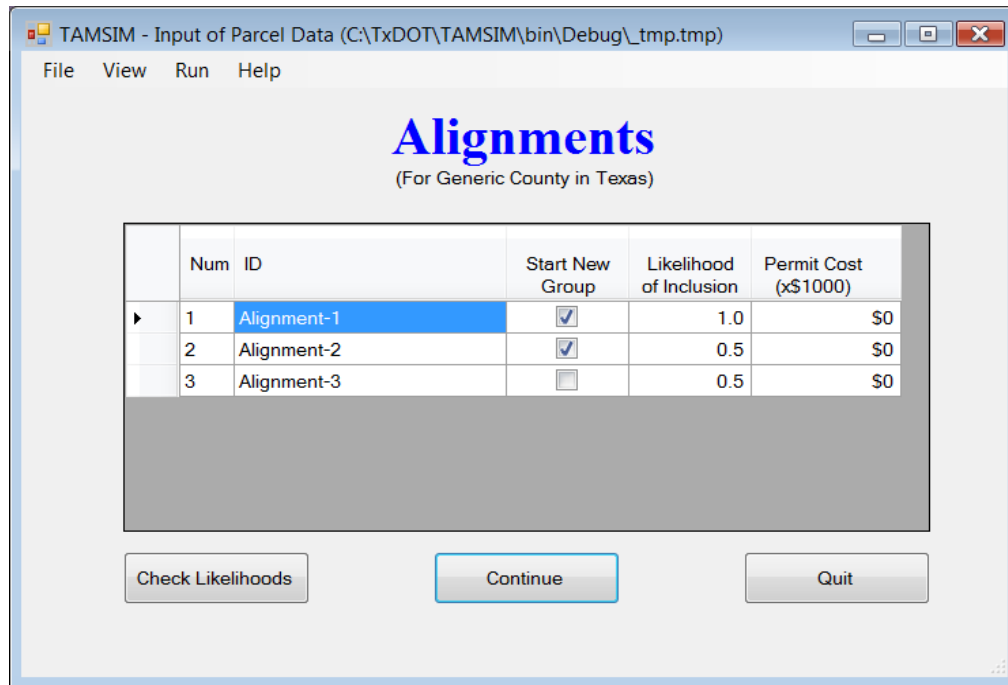
Figure 9. TAMSIM Screen for Optional Alignments.

3. *Likelihood of Inclusion*. The simulation model is designed to be run toward the end of the Feasibility phase or the Plan Authority phase of a project, before it is known with certainty what the final approved corridor will be; thus, it is possible that an alignment (i.e., a set of parcels) identified during the Feasibility phase as possibly being within the required corridor may not end up within the final corridor as approved during environmental clearance. If it is known with certainty that an alignment will be included in the final approved corridor, then 1.0 should be entered for the "Likelihood of Inclusion"; otherwise, a value less than 1.0 should be entered. If 0 is entered, then that alignment will never be included within the final plan during simulation, which is equivalent to deleting that alignment (and any associated parcels) from the project.

4. *Permit Cost*. If there is a permit cost and/or other unique cost associated with an individual alignment, it is entered in the final column of data.

There are three categories of input data in addition to the alignment information: project level data, parcel specific data, and possession time/cost data. Project level data (see Figure 10) include such factors as inflation rate, target date for the beginning of the Construct Authority phase of the project, penalty costs for not starting the Construct Authority phase by the target date, cost benefits if the Construct Authority phase starts early, estimates for the length of time from the end of the Feasibility phase until environmental clearance is obtained, estimates for the length of time from obtaining environmental clearance until right-of-way release is obtained, the rate of property cost increase (in addition to standard inflation) resulting from TxDOT planning activity, the event that causes the additional cost increase to begin, and an offset applied to the event causing the additional cost increase.

Figure 10. TAMSIM Screen for Project Level Data.

The final three data inputs (namely, the additional property cost increase, the event causing the additional increase to begin, and the time offset) refer to cost increases in property values that are in addition to normal inflation (but not caused by additional improvements to the property). Based on several interviews of experienced TxDOT ROW acquisition personnel, it appears the most common reason attributed to additional cost increases is the purchase of land by speculators. It is not always clear when speculative activity begins during the project planning process. The triggers appear to vary in different metropolitan and urban areas. Therefore, TAMSIM allows the user to indicate the time anticipated for additional parcel cost increases to begin occurring. This time is defined by entries in the "Speculation begins" and "Offset for Speculation" data entry fields. For example, assume that for a particular project the analyst feels that speculation will likely begin two months after the right-of-way release is obtained, then the option "ROW Release Obtained" would be selected using the drop-down menu for "Speculation begins," and "2 months" would be chosen using the drop-down menu for "Offset for Speculation." The offset can be any number of months between plus 24 months and minus 24 months.

Parcel level data are those data that depend only on parcel type (Figure 11). Several of the data items depend on probabilistic events, and when generating these random events, parcels are considered independently.

A short description of each data type included for parcel-level information follows:

1. *Parcel Number and Identification*: The parcel number cannot be changed, but the ID can be changed to be more descriptive for a specific parcel.

2. *Associated Alignment*: The simulation model is designed to be run toward the end of the Feasibility phase or the Plan Authority phase of a project, before it is known with certainty what the final approved corridor will be; thus, it is possible that parcels identified during the feasibility phase as possibly being within the required corridor may not end up within the final corridor as approved during environmental clearance. Parcels that are accepted or rejected as a unit are associated with an alignment and such an alignment is identified in the third column. The probability that an alignment will be included in the final approval is given on the Alignments screen. If all parcels identified in the project are to be included in the final corridor, then only one alignment will be

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used, and the Alignment screen never appears. In this case, all parcels are associated with alignment 1 on the Parcel Data screen.
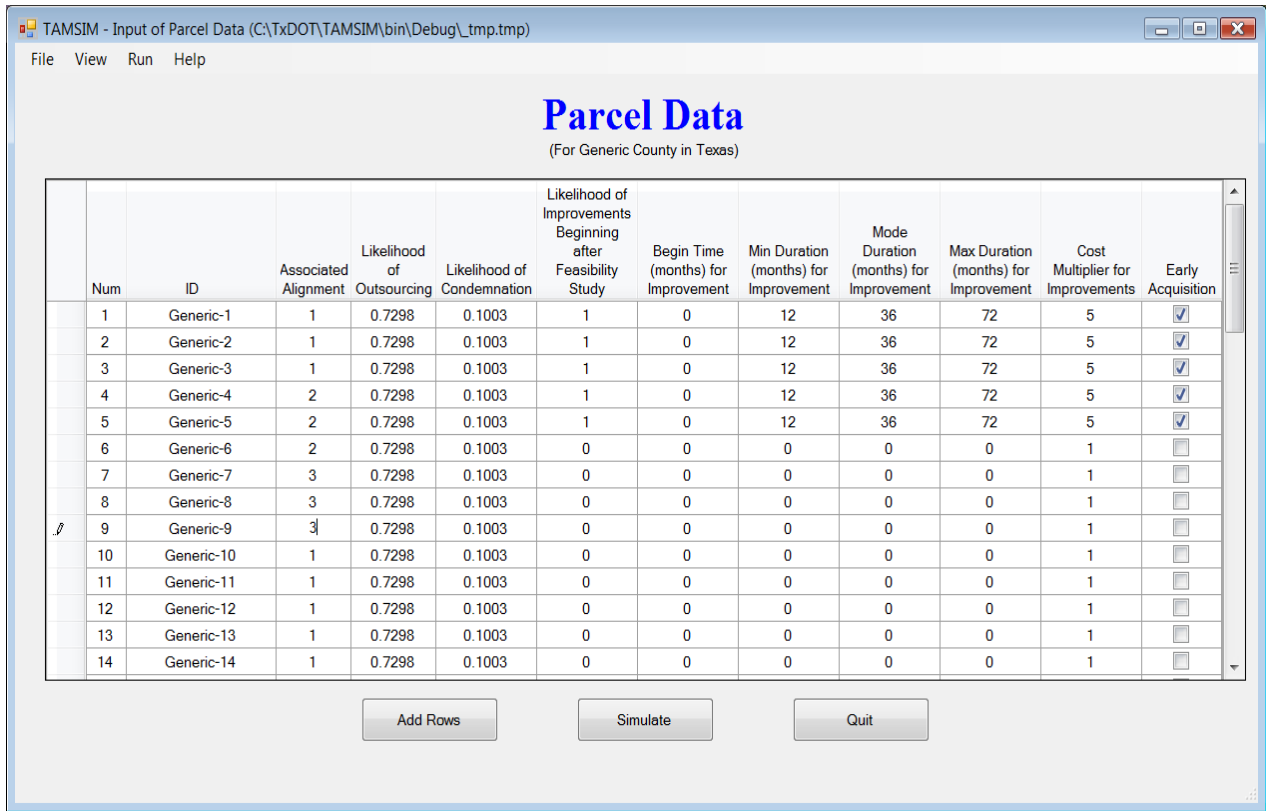
Figure 11. TAMSIM Screen for Parcel Level Data.

3. *Likelihood of Outsourcing*: A number between zero and one is entered representing the probability that the parcel will be obtained through the use of non-TxDOT personnel. Outsourcing may make a difference with respect to the time duration of taking possession of the parcel although the analysis performed indicates that the cost of the parcel seems to be independent of outsourcing. Enter 1 in this column if it is known with certainty that the parcel will be acquired through an outside contractor. Enter 0 if it is known with certainty that acquisition will be obtained by in-house personnel.

4. *Likelihood of Condemnation*: A number between 0 and 1 is entered representing the probability that the parcel will be obtained through condemnation proceedings. If a parcel is obtained through condemnation, the probability distribution laws related to both the cost of the parcel and the time duration to take possession are affected. Enter 1 if it is

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known with certainty that this parcel will go through condemnation proceedings and 0 if, in the opinion of the analyst, there is no chance that it will go through condemnation.

5. *Likelihood of Improvements Beginning after the Feasibility Study Phase of the Project*: A number between 0 and 1 represents the probability that improvements will be made to the parcel. The usual reason for considering early acquisition is that parcel improvements are being considered. If no improvements are expected, then this probability would be set to 0 and early acquisition would be unlikely. When this entry is 0, the remaining entries for that parcel are ignored. However, if improvements are a possibility, then a positive value would be entered here, and it is important to fill in the remaining data entries.

6. *Time Duration over which Improvement Will Likely Occur*: The next four entries refer to establishing a probability law that will reflect the timing over which the improvements will be made.

7. *Cost Multiplier for Improvements*: During the simulation, a random value based on a probability law defined through the next screen will be generated that will represent the cost of each parcel. If improvements are made on the parcel, then this random value will be multiplied by the value (any number greater than one) entered here to determine the total cost of the parcel.

8. *Early Acquisition Indicator*: If there is a check mark under this entry, then the parcel will be acquired early during the simulation to be performed. The total project right-of-way costs and the time at which all parcels are purchased will be computed without early acquisition unless this box is checked for a parcel.

The Parcel Possession/Cost Data screen (see Figure 12) includes the data that define the various probability distributions used to generate the length of time that it takes to purchase a given parcel and the final cost of the parcel. Within a specific project, the duration of time that it takes to acquire a parcel is not independent of the duration of time to acquire another parcel within the same project. Because of this dependency, the mean duration for acquiring parcels of a project is first generated. The data associated with the mean over all parcels within a project is on the first line of the Parcel Possession/Cost Data screen (this line is number zero.) All other lines on this screen refer to individual parcels. Thus, if information is known about a specific parcel, data for that parcel can be changed, and it will be handled separately. If data on line zero is changed, all parcels are affected.

TAMSIM - Time Until Possession (C:\TxDOT\TAMSIM\bin\Debug_tmp.tmp)

File   View   Run   Help

Parcel Possession/Cost Data

(For Generic County in Texas)

Parcel Num	Name	Min-5% Duration in months	Median Duration in months	Mean Duration in months	StDev Duration in months	Max-95% in months	Multiplier for outsource	Multiplier for condemn	MinCost (land, improve, damage x$1000)	MedCost (land, improve, damage x$1000)	MeanCost (land, improve, damage x$1000)	StDevCost (land, improve, damage x$1000)	Max-95% (land, improve, damage x$1000)	Multiplier for condemn
0	Standard...	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721
1	Generic-1	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721
2	Generic-2	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721
3	Generic-3	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721
4	Generic-4	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721
5	Generic-5	7.7	18.3	21.1	12.0	43.8	0.986	1.501	5.4	51.5	131.3	307.9	489.0	1.721

Simulate   Quit

Figure 12. TAMSIM Screen for Possession Time and Cost Data.

All probability distributions for the duration of time to acquire a parcel and its cost are based on the lognormal distribution. The lognormal distribution was chosen based on a curve fitting several data sets of parcel costs and durations. It is also a logical distribution to use because its skewed nature implies that unusually long times or unusually large costs should be expected. Because a lognormal distribution is skewed and thus its characteristics are sometimes non-intuitive, additional information about the distribution is displayed on the screen. At the start of each replication, a mean value for the duration of time needed to acquire a parcel will be generated as well as the mean cost for the parcel. These means are displayed on the first line (line number 0) on the Parcel Possession/Cost Data screen. The duration of time, T, needed to acquire a specific parcel is determined according to the following:

$$T = e^S \qquad\qquad 3\text{-}1$$

where S has a normal distribution with

$$E[S] = \beta_0 + \beta_1 \ln\left(\tau_{proj}\right) + \beta_2 \mathbf{1}_{\{condemn\}} + \beta_3 \mathbf{1}_{\{outsource\}} \quad and \quad var(S) = \sigma_1^2$$

where τ_{proj} is the mean duration of parcel acquisition times for the project, $\mathbf{1}_{\{condemn\}}$ equals 1 if the parcel is condemned and zero otherwise, and $\mathbf{1}_{\{outsource\}}$ equals 1 if the parcel is outsourced and zero otherwise. The values for the constants β_0, β_1, β_2, β_3, and σ_1 are fixed in the Access data base and cannot be changed through program control. The parcel cost is similar. First the mean value for cost of all parcels within the project, χ_{proj}, will be generated based on the data in the

first row (line number 0) of the Parcel Possession/Cost Data screen. Then the cost of the individual parcel, X, will be generated as follows:

$$X = e^Y \qquad\qquad\qquad 3\text{-}2$$

where Y has a normal distribution with

$$E[Y] = \beta_4 + \beta_5 \ln\left(X_{proj}\right) + \beta_6 \mathbf{1}_{\{condemn\}} \qquad and \qquad var(Y) = \alpha_0 + \alpha_1 X_{proj}$$

where χ_{proj} is the mean cost of parcels for the project, $\mathbf{1}_{\{condemn\}}$ equals 1 if the parcel is condemned and zero otherwise. The values for the constants α_0, α_1, β_4, β_5, and β_6 are fixed in the Access data base and cannot be changed through program control. Notice that the variance of the cost for parcels depends on the mean cost. The value for α_1 is positive; thus, a project that has a large average cost per parcel will also have a large variance of parcel costs. The following table gives the values of these constants as currently used in TAMSIM.

Table 11. Table of TAMSIM Data Values.

Parameter	Generic	Metro	Urban	Rural	Dallas	Harris	Tarrant
Likelihood of Outsourcing	0.7298	0.7384	0.6901	0.7052	0.5848	0.6679	0.8143
Project Level Inflation	0.2	0.4	0.15	0	0.4	0.4	0.4
Likelihood of Condemnation	0.1003	0.1879	0.0888	0.0863	0.1579	0.3547	0.0286
Number Parcels	49	42	42	43	28	24	40
Mean (duration)	2.907	3.306	2.877	2.734	3.116	3.342	2.796
Stdev (duration)	0.530	0.614	0.487	0.384	0.318	0.209	0.362
β0 (duration)	-0.0349	-0.0828	-0.0979	-0.0936	-0.1673	-0.0348	-0.2815
β1 (duration)	0.9846	0.9975	1.0043	0.9344	1.0273	0.9900	1.0640
β2 (duration)	0.4063	0.2545	0.3952	0.5076	0.4900	0.1643	0.0001
β3 (duration)	-0.0145	0.0014	-0.0017	-0.0014	-0.1109	-0.0323	0.0863
σ (duration)	0.2924	0.2792	0.2976	0.2933	0.3271	0.2413	0.2483
Mean (cost)	3.942	5.439	3.953	3.032	5.303	6.231	4.086
Stdev (cost)	1.368	1.46	1.121	0.851	1.171	1.271	2.081
β4 (cost)	-0.2845	-0.1019	-0.2873	-0.2529	-0.2554	-0.6203	-0.2786
β5 (cost)	0.8486	0.7997	0.8583	0.8345	0.8093	0.8540	0.8907
β6 (cost)	0.5431	0.6116	06252	0.3833	0.6173	0.6591	0.9035
α0	All areas: α0 = 0.6514						
α1	All areas: α1 = 0.1653						

TAMSIM METHODOLOGY

     The simulation program essentially performs a statistical experiment. As with any experiment, several data points are needed in order to obtain good estimators. When TAMSIM is

initially opened, the user has the option of entering and/or changing any data and then executing the simulation. The simulation develops multiple data points, with each data point being a single realization of the project.

The number of realizations, or replications, of the project to be developed during the simulation run is selected by the user on the Basic Data screen. Each replication involves generating parcel purchase times according to various probability distributions as defined by the data input screens for the time of environmental clearance, the time of right-of-way release, and the times of possession for each parcel. Parcel purchase costs are also generated according to probability distributions for acquisition of each parcel. Each replication will produce different times and costs due to the random probabilistic nature of a simulation.

Each realization of the project is generated on a parcel by parcel basis. Cost and time duration values are generated for each parcel based upon appropriate data attributes for parcels from the selected project location. TAMSIM repeats this process for all parcels, and the total acquisition cost for right of way is determined by summing all parcel costs. The time when construction may begin is determined by the time when the last parcel was acquired during the project realization. The generated total parcel acquisition cost and time duration to completion of purchasing each represent one data point. TAMSIM generates project realizations, each with associated data points generated, until the number of replications specified by the user on the Basic Data screen is reached. All data points are then statistically analyzed, and TAMSIM displays estimates for mean, median, and standard deviation for total parcel costs and time durations to complete parcel purchasing. After each replication, the total project cost and duration are determined both with and without early acquisition so that a comparison is possible using the same realizations for both situations.

The difference in cost with and without early acquisition will be affected by two factors: 1) the cost of improvement made to the property after the Feasibility Study phase and 2) the additional increase in property value that often occurs once TxDOT begins purchasing parcels. When the cost of a parcel is generated according to Eq. (3-2), it represents total parcel costs except that costs of improvements occurring after the Feasibility Study phase are not included. Separate values are generated representing the cost of improvements made during the Plan Authority and Develop Authority phases and representing the duration over which these improvements will occur. Values for these variables are generated according to the data on the

Parcel Level Data screen (Figure 11), the final cost of improvements being assumed linear during the improvement time. For example, consider a specific parcel for which data were entered indicating that the improvements would start at time 0 (i.e., as soon as the initial schematics are available), and the time duration over which the improvement occurs would be between 5 and 15 months, with the most likely occurrence being 8 months. Furthermore, suppose that these improvements are expected to double the price of the parcel (i.e., an improvement multiplier of 2 was used). Now for a particular project realization, if the time duration for these improvements to occur was randomly generated to be 10 months, and the time duration generated to purchase the parcel early was 5 months, the final cost of the parcel would be 150 percent of the cost of the parcel as generated from Eq. (3-2). Under the "no early acquisition scenario," the final cost of the parcel would be 200 percent of the cost generated from Eq. (3-2), assuming that the Environmental Clearance plus right-of-way release were longer than 10 months.

The cost increase rate due to TxDOT activities (generally attributed to speculators) is a location-specific value needed for the simulation program that could not be obtained directly from ROWIS data, since the ROWIS cost data would already include such a cost increase. The user inputs this cost increase rate on the Basic Data screen (Figure 10) based on local experience with speculator activity. TAMSIM begins applying this rate of cost increase at the time defined by the user on that same screen. To illustrate how this cost increase is used within the calculations, assume that t_0 denotes the time of the event that begins property costs increases (for instance, at right-of-way release), and let r be the rate increase in the cost. Now consider a parcel that was purchased at time t_1 and, if early acquisition could be used, would be purchased at time t_2. Finally, assume that c_0 is the unobserved cost of the parcel at time t_0, c_1 is the observed cost of the parcel at time t_1, and c_2 is the estimated cost of early acquisition at time t_2. In this case, the cost of the parcel when it is purchased without early acquisition would be

$$c_1 = c_0 \times \exp\{r(t_1 - t_0)\} \qquad\qquad 3\text{-}3$$

Continuous compounding is assumed, and the normal inflation rate is ignored since a present value based on the normal inflation rate will be calculated. The difficulty is that the data give

estimates for c_1 and not c_0; therefore, the generation of costs will produce a value for the final purchase cost only; namely, c_1. For comparison purposes, the cost at early acquisition, or at time t_2, needs to be estimated. Using Eq. (3-3) to solve for c_0, the following equations are obtained:

$$c_2 = c_1 \times \exp\{-r(t_1-t_0)\} \qquad \textit{for } t_2 < t_0 \qquad\qquad \textit{and} \qquad\qquad\qquad 3\text{-}4$$
$$c_2 = c_1 \times \exp\{-r(t_1-t_2)\} \qquad \textit{for } t_2 < t_0$$

Thus, the cost of the parcel at the time of early acquisition depends on the generated variable cost value of the parcel at its final time of purchase.

TAMSIM OUTPUT

Each replication of the project creates a realization of time duration and total cost to acquire each parcel. After the run of all project replications is complete, the Summary Statistics screen (Figure 13) appears showing the anticipated effect of the early acquisition scenario that was analyzed. The summary includes mean values, standard deviation, and the 10, 50, and 90 percentile values for both total parcel costs and time duration to complete purchasing activities. If the cost differences shown under the "Impact of Early Acquisition" portion of the screen are negative, early acquisition is projected to have reduced costs.
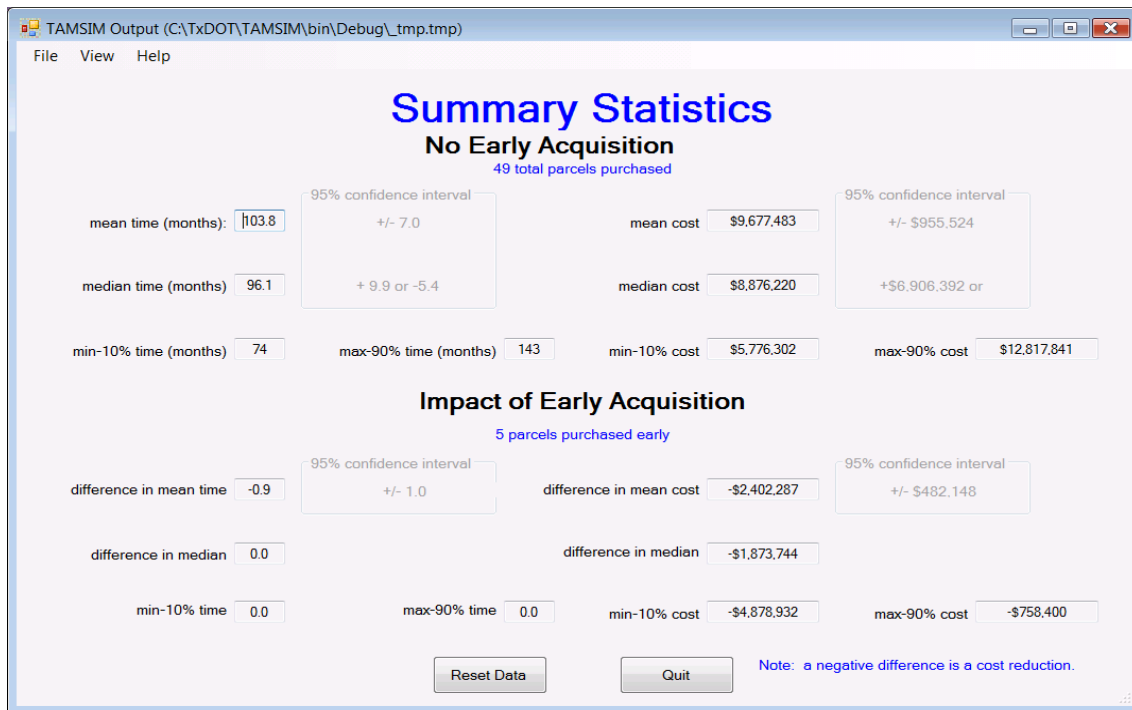
Figure 13. TAMSIM Screen for the Summary of Results.

The user may view all results from the simulation that has been run on the Detailed Results screen (Figure 14). This screen can be accessed only after the simulation has been executed. Immediately under the title of this screen is a drop-down menu that allows the choice of project replication number. By changing the replication number, the user may observe results from any individual project realization.

The costs and time durations both with and without early acquisition are displayed for each project realization. The difference in cost with and without early acquisition is due to the additional increase in property value due to speculative activities plus the improvements made to the parcel during the Plan Authority phase of the project. It is interesting to note that speculative-related cost increases in property values often begin with the first TxDOT purchase of a parcel. It is, therefore, possible that the early acquisition of relatively few parcels on a project could in some cases *increase* the total cost of a project because of an earlier start of speculative activity on parcels not purchased early.

Figure 14. TAMSIM Screen for Detailed Results.

There are three types of data displayed on the Detailed Results screen for each parcel. These are:

1. *Parcel Description (Number, Name)*. The first two fields represent descriptive data for the task or parcel. Asterisks before the name of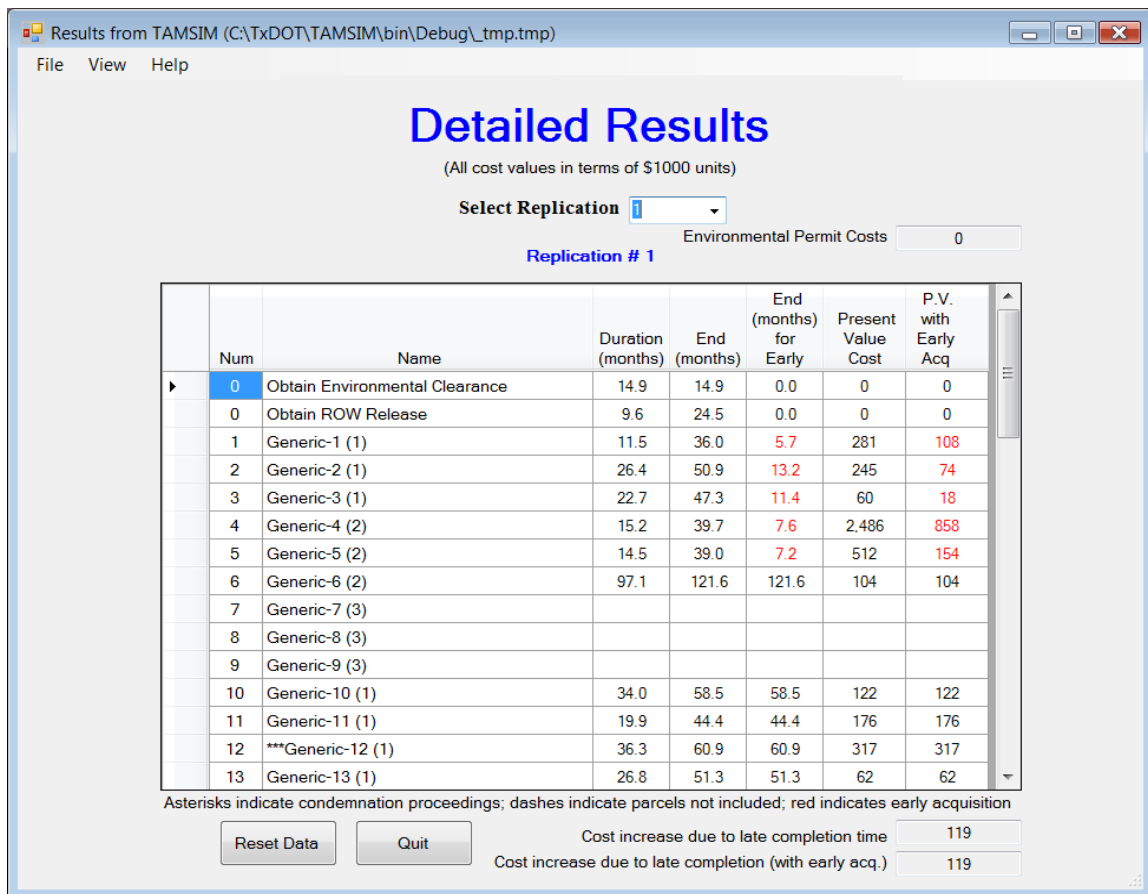 a parcel indicate that the parcel was purchased through eminent domain for that replication. The number in parentheses indicates the alignment that contains the parcel.

2. *Duration (Duration, End)*. The first row in the grid always refers to the time for obtaining the environmental clearance, and the second row refers to the time for obtaining the release to begin the right-of-way acquisition process. Each row after that until the final row refers to the task of obtaining possession of a specific parcel. Time duration values are always measured in terms of the number of months after the design schematics have become available. The value for the ending time in the final (or "Stop") row of the grid is the maximum ending parcel possession time. There are two ending times presented, 1) the time required to purchase the property if no early acquisitions are made and 2) the time required under the early acquisition simulation. If a parcel is purchased through early acquisition, the value will be red. If the task durations are blank, then the alignment associated with the parcel as specified on the Parcel Data screen was not included in the final approved corridor.

3. *Costs (Present Value Cost, Present Value Cost with Early Acquisition)*. The final two columns refer to the predicted cost of the parcel with and without early acquisition. Red numbers indicate that these parcels were purchased early. These costs are always in terms of present value, i.e., costs in terms of dollars at time 0 (namely, when the design schematics become available). The cost of improvements made on the parcel after time 0 is based on data entered on the Parcel Data screen. Cost is based on the probability that an improvement will actually occur as well as the timing and amount of improvement that occurred. Since it is assumed that the parcel acquisition costs are always entered by the user in terms of present-day dollars, normal inflation will not affect costs. Any appreciation in property value that is above the inflation costs will, however, cause an increase in present-day dollar cost of the parcel depending on the time at which the appreciation starts as specified on the Basic Data screen. If a parcel is purchased through early acquisition, the value will be red. If the task durations are blank, then the alignment

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associated with the parcel as specified on the Parcel Data screen was not included in the final approved corridor.

In addition to the parcel related data, the cost increase due to late completion of purchasing or a cost savings due to early completion is also given. These costs are also determined based on the cost data entered by the user on the Basic Data screen.

TAMSIM creates two text files to allow communication of simulation results to EROW, the optimization program described in Chapter 5 for assisting budget planners in determining optimal budget amounts for early right-of-way acquisition. The first file created is called Cost.out and contains the average value over all replications of the amount of purchase cost spent for early acquisitions. The second file created is called Save.out and contains the average amount of reduction in total right-of-way costs due to early acquisitions; thus, a negative number in the Save.out file refers to an increase in average total cost. Each run of TAMSIM will produce one number to each file as a separate row. If no files with these names are in the folder containing TAMSIM.exe, they will be created automatically by TAMSIM when the user elects to save a simulation run.

TAMSIM HELP INFORMATION

TAMSIM includes comprehensive Help information to assist tool users. This information can be accessed at any time via the Help tab at the top of the screen or by hitting the F1 key. Information contained in the TAMSIM Help section is included as Appendix B.

POSSIBLE TAMSIM ENHANCEMENT

There are currently no costs or disadvantages within the TAMSIM model associated with early parcel acquisition. Thus, TAMSIM always views early acquisition of a parcel as advantageous. A potential enhancement to TAMSIM was identified as this project was concluded. It appears possible to establish within TAMSIM a discriminating factor associated with the public benefit of a completed project should early acquisition funding have been used in that manner instead of for early right-of-way acquisition. This factor would serve as a cost consideration when early acquisition occurs within the simulation process. Then, an optimization procedure could be developed so that TAMSIM would not only yield total acquisition costs but

would also produce a recommendation for which specific parcels should be purchased early. EROW, the optimization program described in Chapter 4, will provide similar recommendations for selecting projects most suited for early acquisition, which are system-level recommendations. Project-level recommendations for individual parcels to be acquired early are not provided at this time.

CHAPTER 4:
TAMSIM SENSITIVITY ANALYSIS

A TAMSIM sensitivity analysis was conducted with hypothetical project information. The six hypothetical projects used current TAMSIM default data entries, except as modified for analysis, for projects identified as being located in Metro, Urban, Rural, Dallas, Harris, and Tarrant Counties. Table 12 shows the default values for each hypothetical project. The sensitivity analysis consisted in running simulations to estimate costs and savings for each project under the following five speculation-begin scenarios:

1. Environmental Clearance Obtained,
2. First Parcel Purchased (not early),
3. Schematics Available (time 0),
4. First Parcel Purchased (early), and
5. ROW Release Obtained.

For each speculation-begin scenario the number of parcels acquired early was varied from 1 to the total number of parcels.

Table 12. Sensitivity Project Characteristics.

Project Name	Total Number of Parcels	Number of Parcels for Possible Improvement	Cost Multiplier for Improvement	Additional Cost Increase Due to Speculation (%/yr)	Likelihood of Outsourcing	Likelihood of Condemnation
Metro	42	7	5	40	0.7384	0.1879
Urban	42	5	4	15	0.6901	0.0888
Rural	43	2	3	10	0.7052	0.0863
Dallas	28	5	5	40	0.5848	0.1579
Harris	24	5	6	40	0.6679	0.3547
Tarrant	40	6	5	40	0.8143	0.0286

COSTS AND SAVINGS ANALYSIS

Costs and savings without and with early acquisition were obtained from the sensitivity analysis. TAMSIM was run for each speculation-begin scenario varying the number of parcels acquired early. Therefore, TAMSIM was run 42 times for the Metro project, 42 times for the

Urban project, 43 times for the Rural project, 28 times for the Dallas project, 24 times for the Harris project, and 40 times for the Tarrant project, under each of the five speculation-begin scenarios. Data used in a project was the same for the five speculation-begin scenarios.

As an example, Table 13 shows costs and savings for the Metro project for the "environmental clearance obtained" speculation-begin scenario. A description of the parameters shown in this table follows:

- *Case Number:* From1 through 42, and is the same as the number of parcels to be acquired early.
- *Project Total Cost without Early Acquisition:* This is the project cost if no parcels are acquired early.
- *Project Total Cost with Early Acquisition:* This is the project costs with the specified number of parcels acquired early. It is calculated by subtracting the value of expected savings from early acquisition from project total costs without early acquisition.
- *Present Value with Early Acquisition:* This value is the individual present value of a parcel if acquired early.
- *Total Cost of Parcels Acquired Early:* This is the cumulative value of parcel present values with early acquisition.
- *Expected Savings from Early Acquisition:* This is the anticipated amount of savings to be obtained from parcels acquired early.

Costs and savings results from sensitivity testing were graphed to better display results. These show cost savings due to early acquisitions, total project costs with early acquisitions, total project costs without early acquisition, and total costs of parcels acquired early. Results for the each speculation-begin scenario for the Metro project are included and discussed herein.

Table 13. Costs and Savings for the Metro Project under the "Environmental Clearance Obtained" Speculation-Begin Scenario.

Case #	Project Total Cost without Early Acquisition ($1,000s)	Project Total Cost with Early Acquisition ($1,000s)	Present Value with Early Acquisition ($1,000s)	Total Cost of Parcels Acquired Early ($1,000s)	Expected Savings from Early Acquisition ($1,000s)
0	$147,320	$147,320	$0	$0	$0
1	$147,320	$96,939	$1,614	$1,614	$50,381
2	$147,320	$83,713	$318	$1,932	$63,607
3	$147,320	$77,887	$200	$2,132	$69,433
4	$147,320	$56,335	$627	$2,759	$90,985
5	$147,320	$41,896	$413	$3,172	$105,424
6	$147,320	$35,298	$165	$3,337	$112,022
7	$147,320	$23,578	$401	$3,738	$123,742
8	$147,320	$23,263	$120	$3,859	$124,057
9	$147,320	$22,972	$107	$3,966	$124,348
10	$147,320	$22,733	$106	$4,072	$124,587
11	$147,320	$22,393	$156	$4,228	$124,927
12	$147,320	$22,104	$173	$4,401	$125,216
13	$147,320	$21,591	$83	$4,484	$125,729
14	$147,320	$21,385	$76	$4,561	$125,935
15	$147,320	$20,602	$371	$4,932	$126,718
16	$147,320	$20,323	$118	$5,050	$126,997
17	$147,320	$19,970	$229	$5,279	$127,350
18	$147,320	$19,792	$60	$5,339	$127,528
19	$147,320	$19,479	$101	$5,440	$127,841
20	$147,320	$19,256	$71	$5,511	$128,064
21	$147,320	$18,776	$168	$5,679	$128,544
22	$147,320	$18,018	$267	$5,945	$129,302
23	$147,320	$17,601	$137	$6,082	$129,719
24	$147,320	$17,020	$184	$6,266	$130,300
25	$147,320	$16,732	$247	$6,513	$130,588
26	$147,320	$16,567	$106	$6,619	$130,753
27	$147,320	$16,239	$105	$6,724	$131,081
28	$147,320	$15,574	$477	$7,201	$131,746
29	$147,320	$15,385	$82	$7,282	$131,935
30	$147,320	$15,071	$83	$7,366	$132,249
31	$147,320	$14,823	$116	$7,481	$132,497
32	$147,320	$14,351	$225	$7,707	$132,969
33	$147,320	$13,735	$166	$7,873	$133,585
34	$147,320	$13,506	$84	$7,957	$133,814
35	$147,320	$12,626	$378	$8,335	$134,694
36	$147,320	$12,477	$48	$8,383	$134,843
37	$147,320	$12,205	$124	$8,507	$135,115
38	$147,320	$11,753	$134	$8,640	$135,567
39	$147,320	$11,142	$167	$8,807	$136,178
40	$147,320	$10,912	$129	$8,936	$136,408
41	$147,320	$9,963	$578	$9,515	$137,357
42	$147,320	$9,591	$115	$9,630	$137,729

"Environmental Clearance Obtained" Speculation-Begin Scenario

Figure 15 displays the costs and savings for the Metro project under the "environmental clearance obtained" speculation-begin scenario. The slope of the savings is positive throughout the graph; that is, savings continue to increase as the number of parcels obtained by early acquisition increases. The savings start at $50,381,000, if obtaining only parcel 1 by early acquisition in case 1. The maximum savings that can be obtained is $137,729,000, when all 42 parcels are obtained by early acquisition in case 42. By analyzing the slope of the line for the total project cost with early acquisition, it can be observed that there is a significance difference in the total costs between case 3 and case 4. This is due to the $21,552,000 increase in savings when parcel 4 is acquired early in case 4. The slope for savings from early acquisition rapidly increases from case 1 through case 7. For case 7, the savings from early acquisition reaches $123,742,000. Purchases of additional parcels early thereafter increase savings at a much slower rate. The lines for the total project cost with early acquisition and for cost of early acquisition almost meet in case 42 at $9,629,000 with a difference of $38,000.
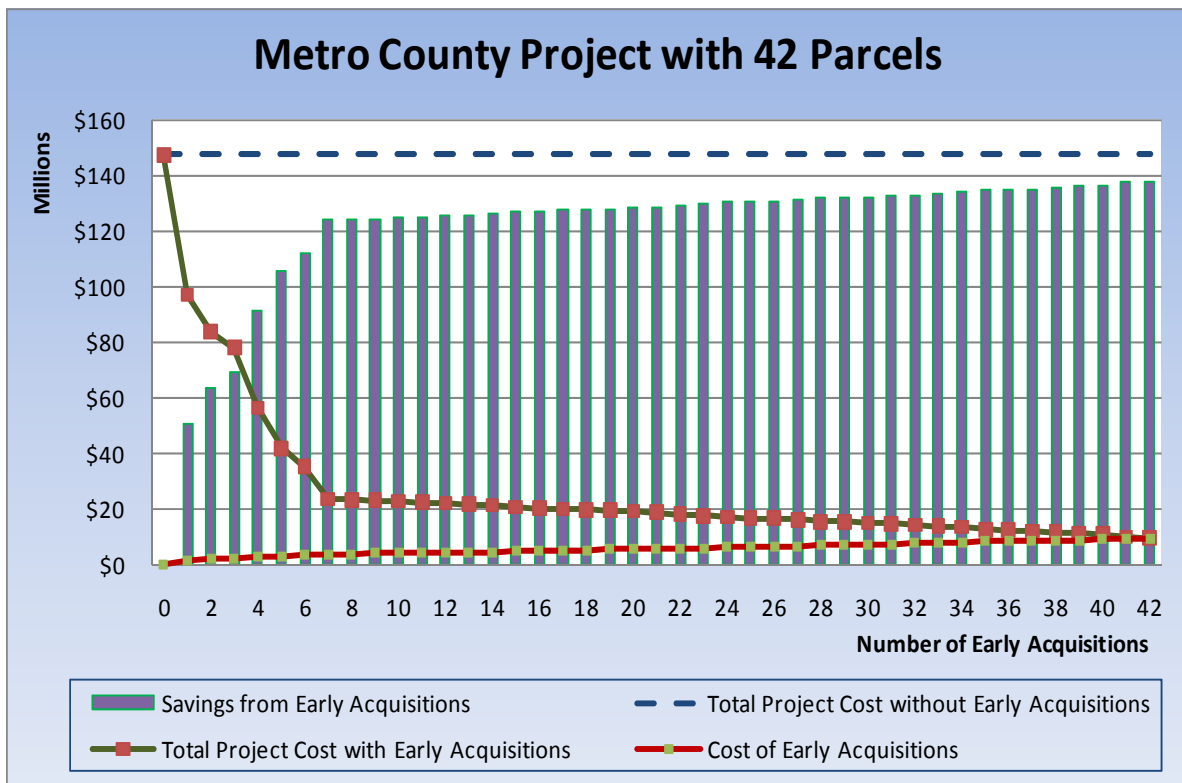

Figure 15. Metro Project Costs and Savings under the "Environmental Clearance Obtained" Scenario.

"First Parcel Purchased (Not Early)" Speculation-Begin Scenario

When the first parcel is purchased by early acquisition in the Metro project under the "first parcel purchased (not early)" speculation-begin scenario, the savings from early acquisition are $48,452,000. The savings from early acquisition again increase rapidly from case 1 to case 7, when the savings reach a value of $119,597,000. After case 7, the savings from early acquisition followed a constant slope. When all 42 parcels are obtained by early acquisition, the cost with early acquisition is $20,027,000, while the total project cost without early acquisitions remains on $147,320,000. The maximum savings from early acquisition when all 42 parcels are acquired early is $127,293,000. Figure 16 shows these estimates.
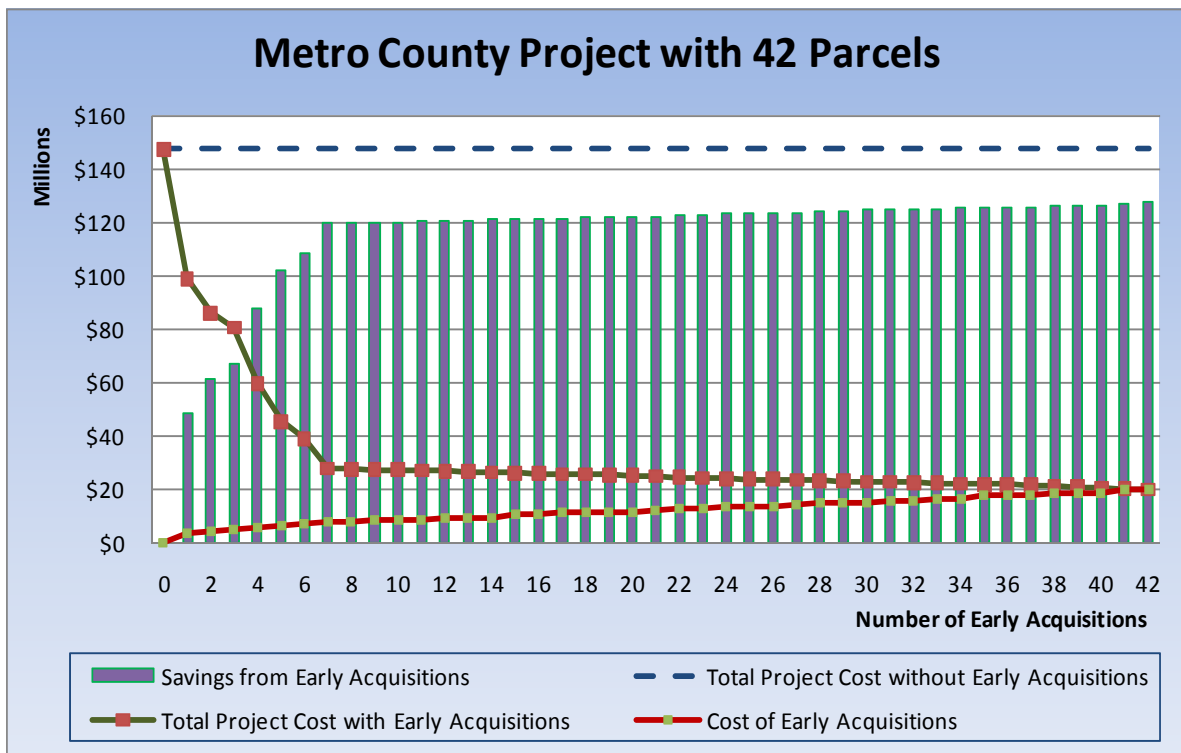
Figure 16. Metro Project Costs and Savings under the "First Parcel Purchased (not early)" Scenario.

"Schematics Available (Time 0)" Speculation-Begin Scenario

The total project cost with early acquisitions of the Metro project under the "schematics available (time 0)" speculation-begin scenario, if all 42 parcels in the project are obtained by early acquisitions, is $7,083,000. The total project cost without early acquisitions is

$147,320,000, and the maximum savings from early acquisitions when all 42 parcels are acquired early is $140,237,000. On the other hand, if just one parcel is obtained by early acquisition, the savings are $50,708,000. In case 7, the slope for the savings from early acquisitions somewhat stabilizes with a savings from early acquisitions of $124,593,000. The estimates for this Metro County scenario can be observed in Figure 17.
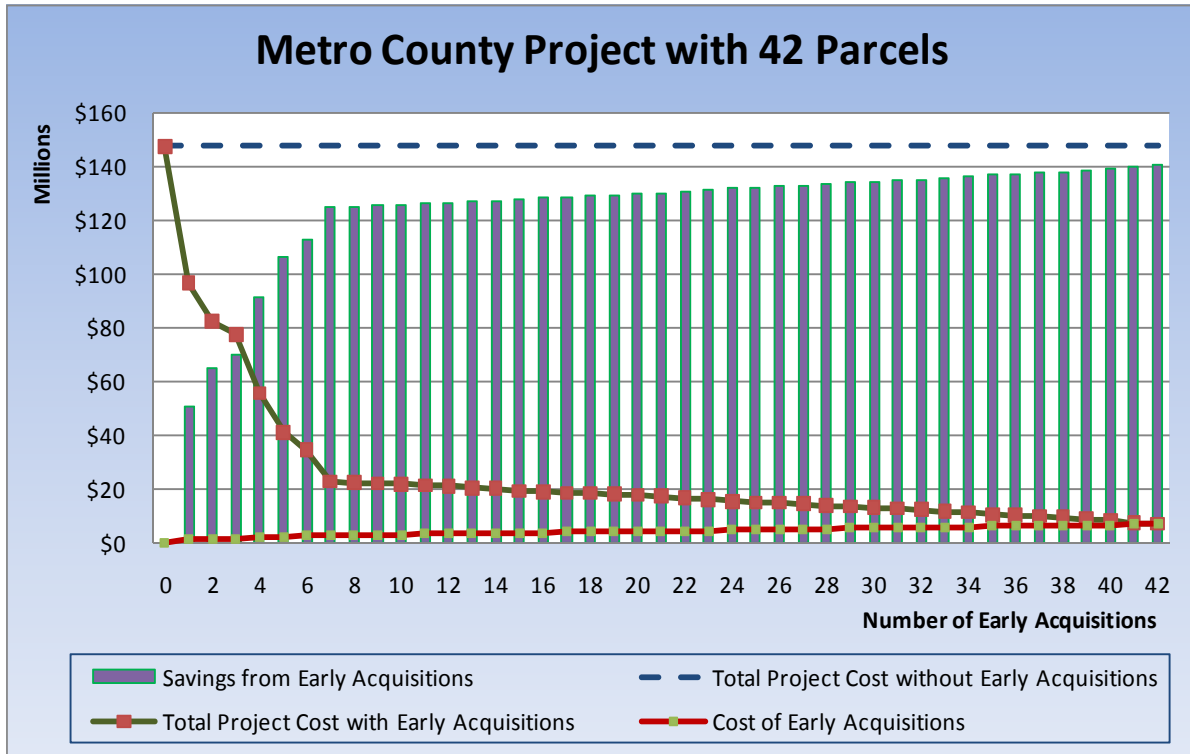
Figure 17. Metro Project Costs and Savings under the "Schematics Available (time 0)" Scenario.

"First Parcel Purchased (Early)" Speculation-Begin Scenario

The costs and savings for the Metro project under the "first parcel purchased (early)" speculation-begin scenario can be observed in Figure 18. The total project cost without any early parcel acquisitions is $147,320,000. However, the total project cost with early acquisitions if all 42 parcels are acquired early is $24,977,000. The difference between these two total costs, or the maximum possible savings, is $122,343,000. At the other extreme, when only one parcel is obtained by early acquisition, the savings from early acquisitions is $48,452,000.
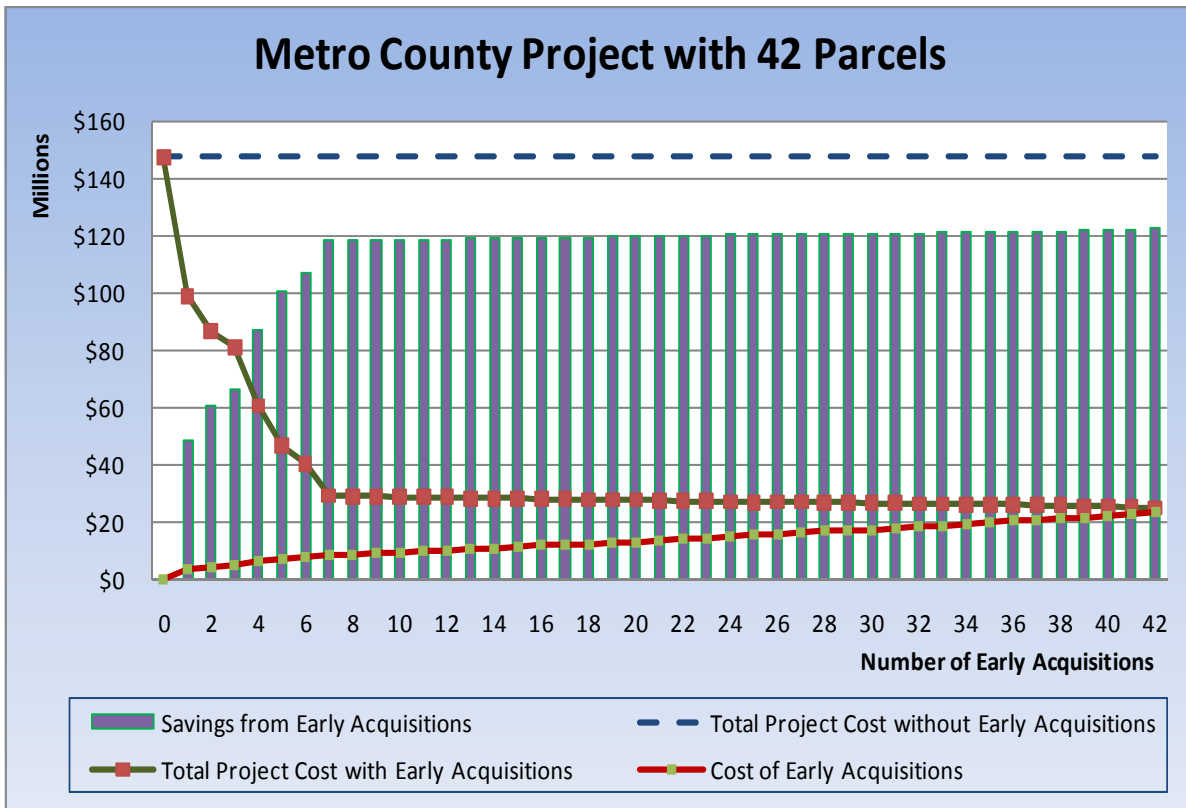
Figure 18. Metro Project Costs and Savings under the "First Parcel Purchased (early)" Scenario.

"ROW Release Obtained" Speculation-Begin Scenario

Figure 19 shows the costs and savings for the Metro project under the "ROW release obtained" speculation-begin scenario. The total Metro project cost without early acquisitions is $147,320,000. Nevertheless, the total project cost if all 42 parcels within the Metro project are obtained by early acquisition is $11,678,000. The difference between the costs with and without early acquisitions shows a total estimated savings of $135,642,000 being possible. In the case of only one parcel being obtained by early acquisition, the savings from the early acquisition is only $50,104,000. As in all of the scenarios, the total savings plot shows a diminished rate of savings increase after all parcels anticipated to have improvements made on them have been acquired early.
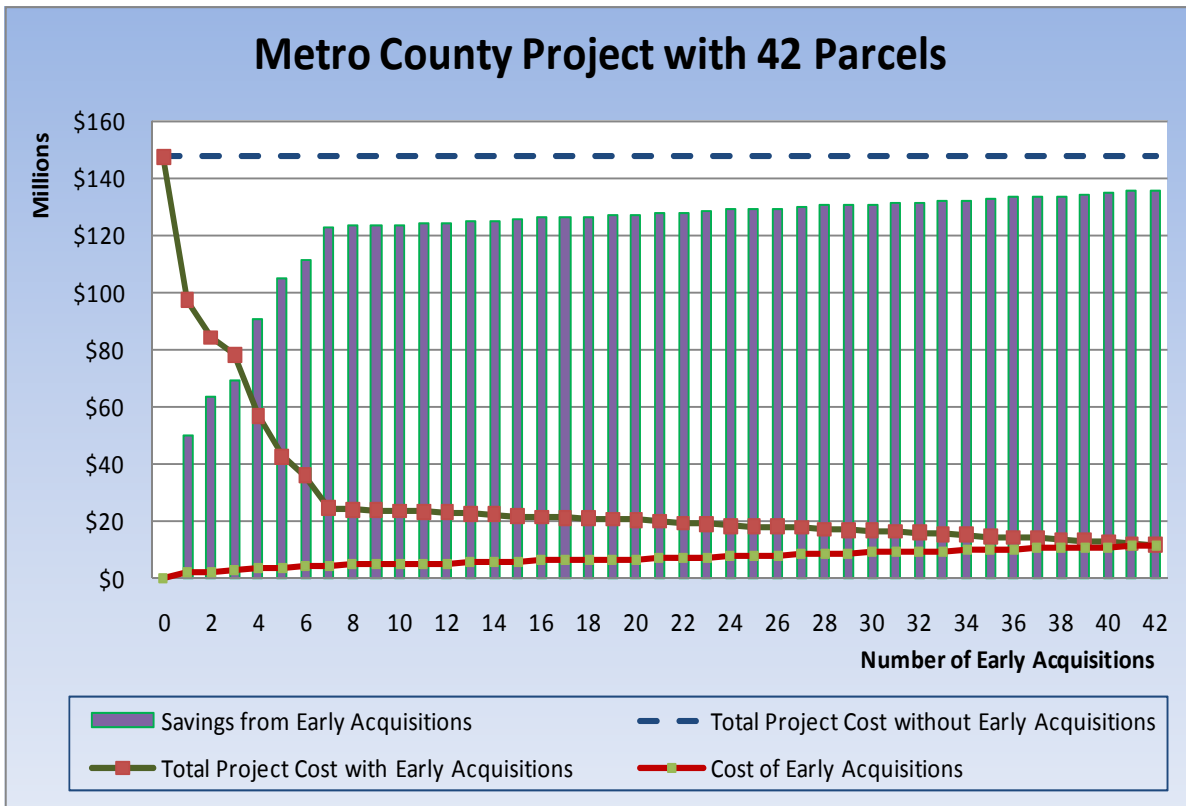
Figure 19. Metro Project Costs and Savings under the "ROW Release Obtained" Scenario.

TIME DURATION ANALYSIS

Estimated time durations required to complete the right-of-way acquisition process were also analyzed. For each project type and speculation-begin scenario, the cases with the highest and lowest time duration savings were selected for comparison. Table 14 shows estimated time durations without early acquisition, estimated time durations with early acquisition, and the estimated reduced time to acquire parcels when the specified numbers of parcels are acquired early.

To compare the differences in time durations between projects, a time reduction ratio was calculated and is shown in the last column of Table 14. The time reduction ratio was calculated by dividing the estimated reduction in time duration by the estimated time duration required without any parcels being acquired early. When all parcels are acquired early, Tarrant has the highest time reduction ratio and Metro has the lowest time reduction ratio.

Table 14. Estimated Time Durations to Complete Right-of-Way Acquisitions.

County Type	Time Duration without Early Acquisition (months)	Parcels Obtained by Early Acquisition	Time Duration with Early Acquisition (months)	Reduction in Time (months)	Time Reduction Ratio
Metro	102.6	1	102.2	-0.4	0.004
		7	100.3	-2.3	0.022
		42	36.1	-66.5	0.648
Urban	76.8	1	76.6	-0.2	0.003
		5	76.3	-0.5	0.007
		42	22.8	-54	0.703
Rural	65.1	1	64.9	-0.2	0.003
		2	64.8	-0.3	0.005
		43	17.4	-47.7	0.733
Dallas	83.1	1	82.7	-0.4	0.005
		5	81.6	-1.5	0.018
		28	26.1	-57	0.686
Harris	78.5	1	78.3	-0.2	0.003
		5	77.2	-1.3	0.017
		24	23.5	-55	0.701
Tarrant	60.3	1	60.3	0	0
		6	60.1	-0.2	0.003
		40	14.5	-45.8	0.760

CONCLUSIONS FROM SENSITIVITY ANALYSIS

Project Costs and Savings

Table 15 displays a summary of maximum costs and savings for all five speculation-begin scenarios. Data includes total project costs without early acquisitions, total project costs with all parcels acquired early, and total expected savings from early acquisition if all parcels were acquired early. The cost savings ratio shown in the last column is the total expected savings with all parcels acquired early divided by the total project cost without early acquisition. Dallas shows the highest cost savings ratios followed by Metro. The lowest cost savings ratio occurred for the Rural project, as would be expected. It is also observed that for all projects the highest

increased cost savings ratio occurs for the scenario when speculation begins as soon as schematics become available. This is also an expected finding as that scenario exposes the parcels to speculation-related cost increases for the longest period of time.

Table 15. Summary of Maximum Total Project Costs and Savings.

Project	Speculation Scenario	Total Project Cost without Early Acquisitions ($1,000)	Total Project Cost with Early Acquisitions ($1,000)	Total Expected Savings from Early Acquisitions ($1,000)	Cost Savings Ratio
Metro	Environmental Clearance Obtained	$147,320	$26,812	$120,508	0.82
	First Parcel Purchased (not early)	$147,320	$33,145	$114,175	0.78
	Schematics Available (time 0)	$147,320	$25,355	$121,965	0.83
	First Parcel Purchased (early)	$147,320	$35,830	$111,490	0.76
	ROW Release Obtained	$147,320	$28,065	$119,255	0.81
Urban	Environmental Clearance Obtained	$11,817	$4,652	$7,165	0.61
	First Parcel Purchased (not early)	$11,817	$5,109	$6,708	0.57
	Schematics Available (time 0)	$11,817	$4,440	$7,377	0.62
	First Parcel Purchased (early)	$11,817	$5,311	$6,506	0.55
	ROW Release Obtained	$11,817	$4,806	$7,011	0.59
Rural	Environmental Clearance Obtained	$1,967	$1,513	$454	0.23
	First Parcel Purchased (not early)	$1,967	$1,595	$372	0.19
	Schematics Available (time 0)	$1,967	$1,435	$532	0.27
	First Parcel Purchased (early)	$1,967	$1,618	$349	0.18
	ROW Release Obtained	$1,967	$1,550	$417	0.21
Dallas	Environmental Clearance Obtained	$88,764	$14,254	$74,510	0.84
	First Parcel Purchased (not early)	$88,764	$17,352	$71,412	0.80
	Schematics Available (time 0)	$88,764	$13,498	$75,266	0.85
	First Parcel Purchased (early)	$88,764	$20,283	$68,481	0.77
	ROW Release Obtained	$88,764	$14,997	$73,767	0.83
Harris	Environmental Clearance Obtained	$381,424	$93,099	$288,325	0.76
	First Parcel Purchased (not early)	$381,424	$105,486	$275,938	0.72
	Schematics Available (time 0)	$381,424	$89,884	$291,540	0.76
	First Parcel Purchased (early)	$381,424	$110,906	$270,518	0.71
	ROW Release Obtained	$381,424	$95,635	$285,789	0.75
Tarrant	Environmental Clearance Obtained	$138,718	$60,801	$77,917	0.56
	First Parcel Purchased (not early)	$138,718	$70,145	$68,573	0.49
	Schematics Available (time 0)	$138,718	$55,774	$82,944	0.60
	First Parcel Purchased (early)	$138,718	$72,865	$65,853	0.47
	ROW Release Obtained	$138,718	$64,354	$74,364	0.54

Time Durations for Acquiring All Parcels

The project with the longest time duration for acquiring all parcels, without early acquisition being employed, is Metro with 102.6 months. Tarrant was observed to have the shortest time duration at 60.3 months. The highest time reduction factor (0.760) occurs for

Tarrant when all parcels are acquired early. In all projects, it was found that the time reduction factor increases as would be expected as the number of parcels acquired early increases.

Summary of Sensitivity Testing Findings

No anomalies or unexpected results were identified by the limited TAMSIM sensitivity testing performed at the conclusion of this project. The performed sensitivity testing is not considered adequate in itself to assure proper TAMSIM modeling and choice of statistical attribute factors. TAMSIM results obtained during initial implementation activities should be closely observed and compared to results expected by experienced district ROW procurement personnel. Adjustments to better improve simulation may be expected, although major adjustments are not anticipated.

CHAPTER 5:
EROW: AN OPTIMIZATION PROGRAM FOR DETERMINING BUDGET ALLOCATION FOR EARLY RIGHT-OF-WAY ACQUISITIONS

Given the total budget available for purchasing right of way, the rate of return for alternative use of right-of-way budget funding, and the TAMSIM output for different early acquisition scenarios of right-of-way projects under consideration, it is possible to determine which of the available project options should be pursued. In so doing, an optimal overall budget for early right-of-way acquisition is also determined. This chapter describes the proposed optimization approach designed for this purpose and its software implementation, EROW.

INTRODUCTION TO EROW

The TAMSIM simulation tool described in the previous chapter provides a convenient method of estimating expected costs and savings resulting from early acquisition of a specified number of parcels included in a given right-of-way project. This information can be utilized in deciding how many parcels, if any, should be acquired early for the considered project. One could argue that with a small number of potential early acquisition scenarios for a given project it should be relatively easy to select the best one to be pursued for that project, say, by performing an incremental rate of return analysis. However, such a choice may not be optimal from the district-wide or statewide perspective, when numerous other projects and options are taken into consideration. To obtain a broader based optimal solution, all available options for the same project must be considered within a system-level optimization model, which ensures that at most only one of the options corresponding to each considered project will be selected in the optimal solution. As a result, the project option selected in the system-level optimal solution may not compare favorably to other options for the same project possible when overarching budget limitations and other projects are not considered. Thus, the problem becomes much more complex when the number of projects is large and budget constraints are taken into account. In fact, the resulting combinatorial optimization problem, the multiple choice knapsack, is known to be NP-hard, meaning that the problem is computationally intractable in theory. Despite this discouraging theoretical property, researchers effectively solve the problem in practice by using pseudo-polynomial dynamic programming (DP) algorithms. The run time of such algorithms

scales well with the increase in the number of projects and available options for each project, with potential complications possible only when the available budget is extremely large. However, this potential complication can be handled by minimally reducing the model's precision with respect to possible budget levels considered. A degree of precision reduction should not be problematic from the practical perspective (e.g., neglecting the difference of $1,000 is acceptable with a billion dollar budget). The DP approach has several advantages over the mixed integer linear programming (MILP) model that the research team originally developed during initial stages of this project, namely: (i) rather than outputting the so-called benefit values, which can be difficult to interpret, DP can output the actual savings for *all considered budget values*; (ii) DP simplifies the usage of the benefit coefficients and allows for a much greater flexibility in selecting the benefit coefficients. In fact, any nonlinear function can be used without complicating the model; (iii) the DP algorithm is easy to implement and does not require use of off-the-shelf optimization packages. Based on these advantages, the dynamic programming approach became the method of choice for this application.

The remainder of this chapter provides a brief background on dynamic programming and incremental rate of return analysis, which is followed by a description of the DP algorithm and a small example illustrating the approach. Next, the input data requirements are described. This is followed by a detailed description of EROW, the software package developed.

BACKGROUND

Dynamic Programming

Dynamic programming is a methodology used to solve certain types of optimization problems. It was developed in the 1950s by Richard Bellman, who also wrote the first textbook on the subject (Bellman 1957). The idea is to solve a large-scale problem by breaking it down into a number of smaller problems, which can then be easily solved in a recursive fashion. Many of the problems solved using DP algorithms share the following common characteristics.

- The problem can be subdivided into separate stages.
- There are a number of states associated with each stage.
- At each stage, a decision has to be made on how to transform the state at the current stage into the state at the following stage.

- An optimal decision at each state does not depend on the previous decisions or states (*principle of optimality*).
- There is a recursive relationship representing the optimal decision for each state at stage *i* in terms of previously computed optimal decisions for states at subsequent stages *i+1, i+2, …* (for backward recursion).

The resource allocation problem being dealt with in considering right-of-way budgets can be viewed as a version of the classical *knapsack problem*, which can be used to illustrate the DP approach. In the knapsack problem, a given a set of *n* items can be placed in a knapsack of a certain capacity *W*. Each item *i* is characterized by its size (weight) w_i and its benefit b_i. The goal is to find the quantity of each item to put in the knapsack to maximize benefits while staying within the capacity constraint. If x_i is the quantity of item *i* to be included, then the problem can be formalized by the following integer program:

$$\text{maximize } \sum_{i=1}^{n} b_i \, x_i \qquad\qquad\qquad 4\text{-}1$$

so that $\quad \sum_{i=1}^{n} w_i \, x_i \ \leq\ W,$

x_i *is a nonnegative integer.*

To solve this problem using DP, the first step is to define stages. For example, use *n* stages representing items. The state s_i at stage *i* represents the space still available for filling at this and consecutive stages, i.e., the total weight units available for items *j, j+1, ..., n* to be placed in the knapsack. The decision at stage *i* is how many units of item *i* to place in the knapsack. This value is denoted as x_i. Let $f_i\,(s_i)$ be the optimal benefit of using s_i units of capacity at stages *i, i+1, ..., n*. This gives

$$f_i(s_i)=\begin{cases} b_n \left\lfloor \dfrac{s_n}{w_n} \right\rfloor, & \text{if } i = n, \\[2ex] \max\{b_i x_i + f_{i+1}(s_i - w_i x_i)\,|\,0 \ \leq\ x_i \ \leq\ \dfrac{s_i}{w_i},\ x_i \text{ is integer}\}, & \text{if } i < n, \end{cases} \qquad 4\text{-}2$$

where $s_i = 0, 1, \dots, W$ for $i=2, \dots, n$ and $s_1 = W$. The problem is solved using backward recursion to compute $f_1(W)$. Similar ideas are used to solve the resource allocation problem, which is a multiple choice version of the knapsack problem.

Incremental Rate of Return Analysis

Incremental rate of return (IRR) analysis is a standard engineering economic method for comparing multiple mutually exclusive investment alternatives. In this method, one compares the rate of return on just the incremental increase in investment between the two compared investment alternatives to the specified minimum attractive rate of return (MARR). If the rate of return from just the additional amount of investment being considered is greater than the MARR, then the additional investment is worthwhile, and the second alternative including the additional investment is preferred. Otherwise, if the rate of return is less than MARR, the first alternative is more attractive. In this project, the incremental rate of return analysis process is incorporated to allow comparison of alternative early acquisition budget levels and in so doing to determine the optimal budget for early right-of-way acquisition.

THE DYNAMIC PROGRAMMING APPROACH: FORMULATION AND EXAMPLE

The following notation is used:

N = the total number of projects considered;
i = index representing the project number, $i=1, \dots, N$;
S_i = the set number of considered early acquisition scenarios for project i;
j = index used for the scenarios, $j \in S_i$;
c_{ij} = the cost of project i under scenario j;
s_{ij} = the savings for project i under scenario j;
b = a lower bound on the budget for early right-of-way acquisition (the default value is 0); and
B = the total available budget.

If the binary variable is denoted by x_{ij}, such that $x_{ij}=1$ if the j-th scenario of project i is selected and $x_{ij}=0$, otherwise, then the multiple choice knapsack model can be formulated as the following integer program (IP):

$$maximize \sum_{i=1}^{N} \sum_{j \in S_i} s_{ij} \, x_{ij} \qquad\qquad 4\text{-}3$$

so that $\qquad \sum_{i=1}^{N} \sum_{j \in S_i} c_{ij} \, x_{ij} \leq B,$

$x_{ij} \in \{0,1\}.$

Similarly with the DP approach for the knapsack problem outlined above, the stages will correspond to projects, and the state b_i at stage i will represent the budget available for projects $1,$ $...,$ i (note that unlike in the knapsack example, forward recursion is used instead of backward, however, the basic concept is identical). The recursive function $v_i(b_i)$ at stage i expresses the maximum savings resulting from allocating the budget given by b_i among the options available for projects $1,$ $...,$ i. The decision at stage i is which of the options in S_i, if any, should be chosen so that the optimal savings of $v_i(b_i)$ is achieved at stage i. Next the recursive relation is defined that will be used to compute the values of $v_i(b_i)$. To simplify the formulation, an artificial stage 0 is introduced, which corresponds to having no projects. It is also assumed that the first early acquisition scenario in each S_i corresponds to not picking project i, i.e., $c_{i1} = s_{i1} = 0$. Another important assumption is that only a discrete set of possible budget levels b_i is considered. Notation $b_i = b,$ $...,$ B will mean that b_i takes on all possible budget levels (according to the corresponding discretization) between the minimum considered budget b and the maximum considered budget B. This provides the following recursive relation for each $b_i = 0,$ $...,$ B:

$$v_i(b_i) = \begin{cases} 0, & if\ i = 0, \\ \max\{s_{ij} + v_{i\text{-}1}(b_i\text{-}c_{ij}) \mid j \in S_i\}, & if\ 0 < i \leq n. \end{cases} \qquad 4\text{-}5$$

By solving this recursion for all projects starting from the first project to the last, the computational results for $v_n(b_n),$ $b_n = b, ..., B,$ will represent the optimal solution for all the considered budget increments. Next, the DP algorithm is illustrated with a simple small example.

A Simple Example

Assume that the following cost and savings data are given for three projects, each of which has three possible scenarios as shown in Table 16 and Table 17, respectively.

Table 16. Example Cost Data.

Case	Scenario 1	Scenario 2	Scenario 3
Project 1	0	900	1700
Project 2	0	1280	2050
Project 3	0	2200	3950

Table 17. Example Savings Data.

Case	Scenario 1	Scenario 2	Scenario 3
Project 1	0	650	980
Project 2	0	510	1150
Project 3	0	1100	2200

The computational results for the range of budget of $1,000 to $8,000 are demonstrated below. The values in parentheses at the end of each line represent the corresponding optimal decision, given by the number of the selected scenario.

$$v_1(b_1): \begin{cases} v_1(1000) = Max\{0,650\} = 650 \ (2) \\ v_1(2000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(3000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(4000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(5000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(6000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(7000) = Max\{0,650,980\} = 980 \ (3) \\ v_1(8000) = Max\{0,650,980\} = 980 \ (3) \end{cases}$$

$$v_2(b_2): \begin{cases} v_2(1000) = Max\{0 + 650\} = 650 \ (1) \\ v_2(2000) = Max\{0 + 980, \ 510 + 0\} = 980 \ (1) \\ v_2(3000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 650\} = 1800 \ (3) \\ v_2(4000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 980\} = 2130 \ (3) \\ v_2(5000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 980\} = 2130 \ (3) \\ v_2(6000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 980\} = 2130 \ (3) \\ v_2(7000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 980\} = 2130 \ (3) \\ v_2(8000) = Max\{0 + 980, \ 510 + 980, \ 1150 + 980\} = 2130 \ (3) \end{cases}$$

$$v_3(b_3): \begin{cases} v_3(1000) = Max\{0 + 650\} = 650 \ (1) \\ v_3(2000) = Max\{0 + 980\} = 980 \ (1) \\ v_3(3000) = Max\{0 + 1800, \ 1100 + 0\} = 1800 \ (1) \\ v_3(4000) = Max\{0 + 2130, \ 1100 + 980, \ 2200\} = 2200 \ (3) \\ v_3(5000) = Max\{0 + 2130, \ 1100 + 980, \ 2200 + 650\} = 2850 \ (3) \\ v_3(6000) = Max\{0 + 2130, \ 1100 + 2130, \ 2200 + 980\} = 3230 \ (3) \\ v_3(7000) = Max\{0 + 2130, \ 1100 + 2130, \ 2200 + 1800\} = 4000 \ (3) \\ v_3(8000) = Max\{0 + 2130, \ 1100 + 2130, \ 2200 + 2130\} = 4330 \ (3) \end{cases}$$

To determine the scenarios selected in the optimal solution, track back the scenarios listed in the parentheses at the end of each line above. For example, if B = $5,000, then the optimal solution is to pick scenario 3 for project 3, which leaves a budget of $5,000-$3,950 = $1,050 for projects 1 and 2. Since the selected budget increment is $1,000, look at the solution corresponding to $v_2(1000)$ above, which is to pick scenario 1 for project 2. Finally, the solution for $v_1(1000)$ is to pick scenario 2 for project 1. Table 18 summarizes the computational results. "Not Selected" is shown whenever the first scenario is picked. In addition to budget, cost figures, and savings figures, the corresponding incremental rate of return is also one of the outputs.

Table 18. Summary of EROW Results.

Budget Option ($)	Resulting Expenditures ($)	Resulting Savings ($)	Rate of Return (%)	Project 1	Project 2	Project 3
1000	900	650	72.22	Scenario 2	Not Selected	Not Selected
2000	1700	980	57.65	Scenario 3	Not Selected	Not Selected
3000	2950	1800	61.02	Scenario 2	Scenario 3	Not Selected
4000	3950	2200	55.70	Not Selected	Not Selected	Scenario 3
5000	4850	2850	58.76	Scenario 2	Not Selected	Scenario 3
6000	5950	3230	54.29	Scenario 3	Scenario 3	Scenario 2
7000	6900	4000	57.97	Scenario 2	Scenario 3	Scenario 3
8000	7700	4330	56.23	Scenario 3	Scenario 3	Scenario 3

It should be noted that when budget increments greater than 1 are involved, it can be thought of as if the increment represents one monetary unit. So, instead of using 1 dollar or 1 cent, the value may be considered to be $1,000 or $10,000. As a result, the computed values are optimal only with respect to the selected increment value, and one could easily build a "pathological" example where the "real" optimal solution with an integer unit represented by $1 is very different from the solution that is computed. However, such pathological cases are extremely unlikely with real life data. Moreover, the resulting error of the model can be neglected due to the nature of data input, which includes data obtained from simulation and therefore is not exact.

INPUT DATA REQUIRED

While the methodology described in this chapter is general in nature and can be used to determine optimal resource allocation decisions in many diverse applications, this discussion will concentrate on decision-making for early right-of-way acquisition. In the right-of-way context, one may have different pieces of information that can be used to forecast future land parcel prices, and the optimization approach can be effectively combined with the forecasted figures to determine the optimal resource allocation strategies, assuming that the forecasted figures are reasonable. The forecast data obtained from TAMSIM output for expected costs and savings for the early acquisition scenarios of interest will be used. This section describes the specific input parameters needed for EROW and the format of input data.

Costs and Savings Data Files

Recall that TAMSIM allows a user to select particular parcels within a given project that are subject to early acquisition and then provides estimates of the right-of-way cost for the project both with and without selected early acquisitions occurring. These values are used to compute the potential savings due to early right-of-way acquisition. By selecting different numbers of parcels for early acquisition, different early acquisition scenarios for each project are obtained. For each such scenario, two of the values generated by TAMSIM will be used: the expected cost of the project under the considered early acquisition scenario and the expected savings resulting from selecting the given early acquisition scenario. These two EROW inputs will be stored in two different EROW text files. To be congruent with TAMSIM output

nomenclature, these files will be named `Costs.txt` and `Savings.txt`, respectively, paralleling files `Cost.out` and `Save.out` generated by TAMSIM as described in the previous chapter. Note that one run of TAMSIM is performed for each early acquisition scenario. Therefore, if S_p different early acquisition scenarios are considered for a given project p, the resulting files `Cost.out` and `Save.out` will contain S_p numbers each (with S_p rows and one number per row). All S_p numbers from file `Cost.out` will be recorded in the p-th row of file `costs.txt`, with a space separating two consecutive figures. For example, if `Cost.out` for project p is given by

   35000

   32000

   48000

then the p-th row of the corresponding `costs.txt` file will be given by

   0   35000   32000   48000

Note that 0 is shown as the first element of each row to represent the case when the project is not selected. The p-th row of the file `savings.txt` is obtained from the corresponding `Save.out` file in exactly the same fashion. Thus, if a total of P potential right-of-way projects are considered in the budget analysis, with S_p early acquisition scenarios for each project p, where $p=1,\ldots, P$, then the resulting files `costs.txt` and `savings.txt` will each contain P rows, with the p-th row containing S_p numerical values. Note that different numbers of entries may occur in different rows of the same file. However, it is crucial that the number of entries in the p-th row of `costs.txt` is exactly the same as the number of entries in the p-th row of file `savings.txt`.

EROW: A SOFTWARE IMPLEMENTATION OF THE PROPOSED APPROACH

The DP algorithm with incremental analysis described above has been implemented in C# programming language. The user interface of EROW consists of two screens, PROJECT INPUTS and RESULTS.

Project Inputs Screen

Figure 20 shows a snapshot of the project inputs screen. The input parameters that need to be specified in the PROJECT INPUTS screen include the maximum and minimum considered early acquisition budgets and the budget increment size (the interval between budgets to be considered between the maximum and minimum values). These inputs have a crucial impact on program run time. The run time decreases with an increase in the value of budget increment, however the tradeoff is that the model's precision decreases in that situation. One could begin the analysis by considering a relatively large budget range and a relatively large budget increment. From the results output, identify promising smaller budget ranges, and then pursue the smaller range or ranges with a smaller budget increment value.

Figure 20. EROW Project Data Entry Screen.

The other data inputs are the costs and savings files (the example in Figure 20 uses the input files `costs.txt` and `savings.txt` included with the EROW distribution). The RESULTS OPTIONS box allows the user to select whether or not the project scenarios providing the best rate of returns for each possible budget solution will be displayed on the RESULTS tab. A second check box is offered to require EROW to perform an IRR and compare

each resulting value to the specified MARR. When an IRR for a considered early acquisition budget does not exceed the MARR value, that budget amount is removed from solution consideration. The STATUS window displays the most recent important actions performed.

Pressing the SOLVE button at the bottom of the screen causes the program to run in the manner specified, and the RESULTS screen is automatically displayed at the conclusion of the program run.

Results Screen

Figure 21 displays the RESULTS screen from the Figure 20 input data.
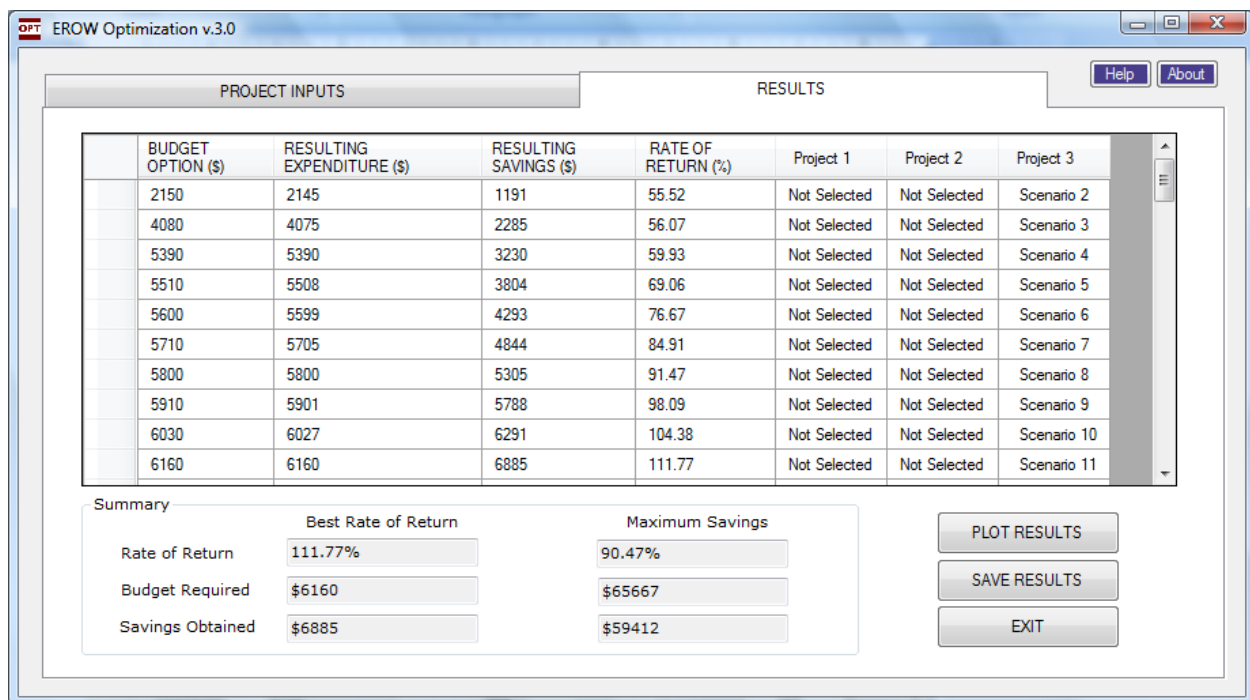
Figure 21. EROW Results Screen.

The table in this screen shows the optimal solutions corresponding to different early acquisition budget alternatives. The columns in this table have exactly the same notations and meaning as those in Table 18. The Summary box shows the rate of return, budget required, and total savings values for budget solutions corresponding to the best rate of return and the maximum savings possible within the specified budget range. Finally, the user can save the results in a text file by pressing the SAVE RESULTS button. The results can also be viewed graphically through the PLOT RESULTS button.

Plots for Rate of Return and Savings versus Budget

Figure 22 shows graphically displayed results from the data in Figure 21.
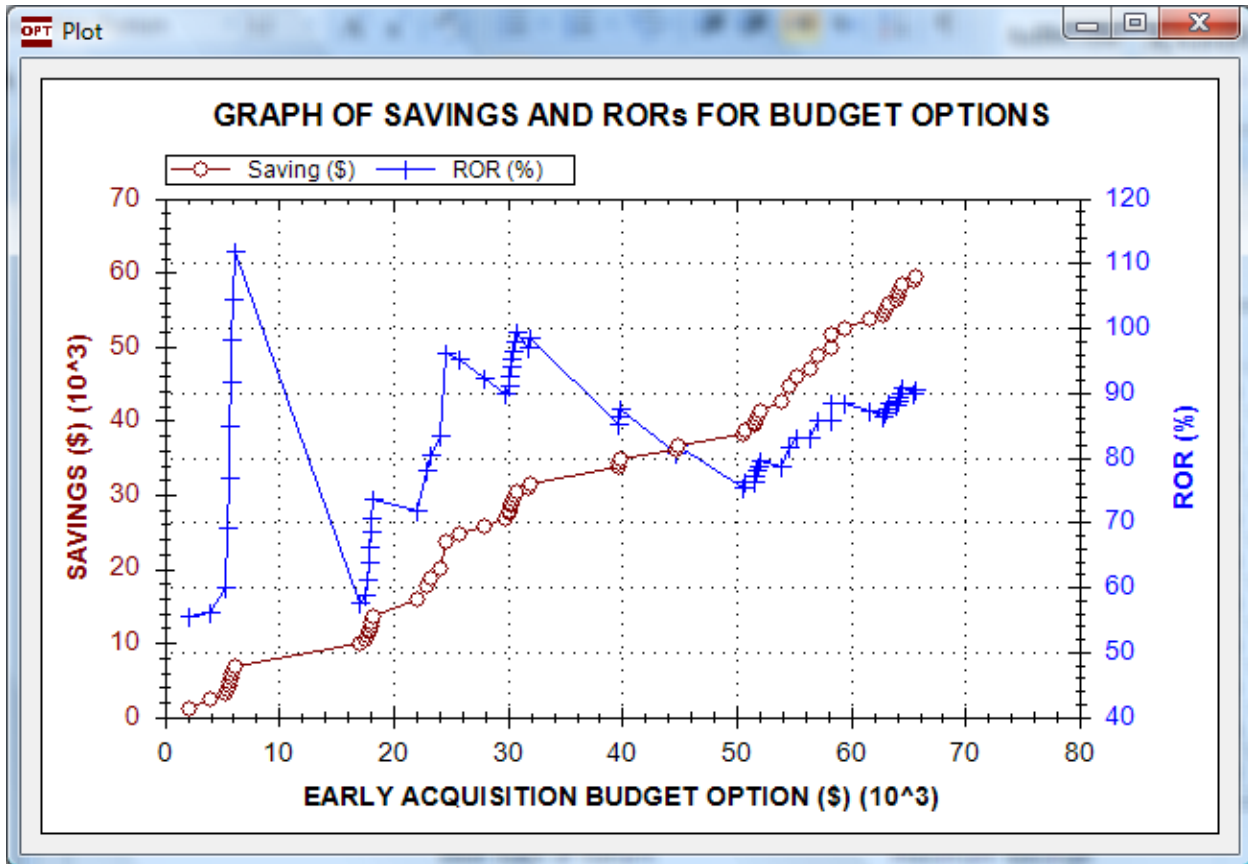
Figure 22. EROW Output Plot Example.

As can be seen from this figure, there are several budget intervals with peaks that the user may want to analyze in greater detail by decreasing the uncertainty interval for the budget and decreasing the budget increment value. Peaks indicate favored budget solutions from a rate of return standpoint. As noted in Figure 22, the highest rate of return may occur at a budget solution rather low in the allowable budget range for the analysis. When this occurs, it is more likely that the user will prefer a somewhat lower rate of return at a considerably higher early acquisition budget considering the increased total savings that can be obtained as well as the time duration benefits of acquiring a greater number of parcels for the group of projects being analyzed. Wherever the peaks occur, the represented budget options offer rate of return advantages over the budgets represented by valleys in the chart.

Help Information

  EROW contains a Help section to provide the user with additional information and facilitate use of this tool. The Help information explains user options, necessary data entries, and the displays of results obtained from an EROW run. EROW also contains an About button, displaying appropriate tool identification and credit information. Information provided under Help is included in Appendix C.

CHAPTER 6:
DECISION-SUPPORT TOOLS IN OTHER AREAS OF TXDOT RESOURCE ALLOCATION DECISION MAKING

Simulation and optimization business science methods have been found suitable for the development of decision-support tools regarding resource allocation. The research team was requested to explore the potential of applying a similar approach to that developed for right-of-way acquisition budget decisions to assist TxDOT in optimizing fleet-level equipment replacement decision-making.

THE FLEET-LEVEL EQUIPMENT REPLACEMENT ISSUE

The problem of designing an optimal strategy for replacing old equipment with new often arises in practice. In fact, it is one of the most important aspects of fleet management, which is a process focused on reducing overall costs associated with operation of an organization's vehicle fleet. In addition to cost savings, having effective equipment replacement policies is important for determining adequate funding levels, especially in governmental organizations. For example, funding below the optimal level may result in higher maintenance costs due to greater use of aged equipment. There were also previous research projects conducted for TxDOT to develop an automated fleet level equipment replacement methodology. A brief summary of optimization techniques for designing optimal equipment replacement policies and the previous TxDOT research projects in this area follows.

OPTIMIZATION TECHNIQUES FOR DESIGNING OPTIMAL EQUIPMENT REPLACEMENT POLICIES

As with many other decision-making problems, optimization techniques can be applied for designing adequate equipment replacement policies. Of course, in order to use the powerful optimization techniques effectively for this purpose, one needs to have appropriate information about the factors that influence the asset's lifecycle and the corresponding costs associated with the lifecycle. Even though some of these factors may be difficult to predict due to uncertainties associated with demand variability and technological change, in many cases the corresponding

probability distributions can be estimated based on historical data for a particular type of equipment.

Brief Overview of Existing Optimization Techniques

Due to the time-dependent nature of the problem, dynamic programming has come to the forefront as the most popular optimization technique for decision-making on equipment replacement. The DP methodology was developed in the 1950s by Richard Bellman to deal with optimization problems that can be broken into smaller sub-problems, which can then be solved recursively so that the solution to the last sub-problem solved yields an optimal solution to the original problem. The first basic DP approach to the equipment replacement problem was proposed by Bellman in 1955. This approach assumes that the machine's operating characteristics, output and maintenance cost as a function of time; the trade-in value as a function of time; and the purchase price are given. Then, simple DP equations can be written to determine a replacement policy maximizing the overall return from a machine over a given time horizon. The model allows for an easy incorporation of technological improvement considerations. Even though this model is very simple and does not make allowances for the uncertainties involved, its basic principle can be applied to develop much more realistic models. In fact, the models proposed in multiple publications that followed the seminal Bellman paper can be viewed as extensions of the basic Bellman model (Hartman 2004; Hartman and Murphy 2006). In particular, Hartman (2004) proposed a stochastic DP approach that assumes variable asset utilization and stochastic demand. On the other hand, if the funding is limited, one needs to adjust the equipment replacement strategy to operate under the capital budgeting constraints (Karabakal et al. 1994).

In another interesting recent paper, Hritonenko and Yatsenko (2008) study the impact of technological change on the optimal asset lifetime and show that a more intensive technological change may result in both an increase and decrease of the optimal lifetime of assets. Rajagopalan (1998) proposes a unified model for optimal capacity expansion and equipment replacement. He shows that even though the general problem is computationally hard, efficient algorithms are possible under certain assumptions.

Automated Fleet Level Equipment Replacement Methodology (TxDOT Report 4941-2)

This research was conducted by the University of Texas in San Antonio. Report 4941-2, published in 2003, describes the methodology and summarizes researcher findings (Weissmann and Weissman 2003). Comments about the methodology developed under TxDOT research Project 0-4941 follow.

Optimization Criterion

Assume that the optimization criterion is to be the total discounted expected cost over an infinite time horizon. For this purpose $\alpha < 0$ will be the discount factor; that is, α is the present value of \$1 a year from now.

Optimal Replacement Time for One Vehicle

Before considering the fleet, first determine how to obtain the optimal replacement time when considering only one vehicle. The assumption is that a fleet vehicle was purchased one or more years ago. When it is replaced, it will be with a new vehicle that is probably not equal to the current vehicle due to improvements in vehicles. However, because of the uncertainty of the future, it is assumed that the replacement vehicle will eventually be replaced by another equivalent vehicle ad infinitum.

Optimal Replacement Time for a New Vehicle

Let $f(n)$ denote the present value of the expected life-cycle cost for the vehicle that is purchased in year zero and sold at the end of year n. Thus,

$$f(n) = PC + \sum_{i=1}^{n} \alpha^i AC_n - \alpha^n RS \qquad \text{5-1}$$

where PC is the purchase price, RS is the expected resale value, and ACi is the expected annual cost for year i that includes repair costs, operational costs, indirect costs, and costs of downtime. The equivalent uniform annual life-cycle cost is given by

$$EUAC_n = f(n) \frac{1-\alpha}{\alpha(1-\alpha^n)} \qquad\qquad 5\text{-}2$$

The optimal replacement time is found by obtaining the value of n that minimizes Eq. (5-2). Another equivalent method of writing the optimal replacement time is to minimize the following total discounted cost given by

$$f(n) + \alpha^n f(n) + \alpha^{2n} f(n) + \dots$$

since this represents always replacing the vehicle with an identical vehicle. Thus, the optimal replacement age is to find the value of n that minimizes the following objective function

$$F(n) = \frac{f(n)}{1-\alpha^n} \qquad\qquad 5\text{-}3$$

Optimal Replacement Time for a Currently Operating Vehicle

There are two major differences between a new vehicle and a currently used vehicle that is being considered for replacement: 1) the purchase price of the currently used vehicle is a sunk cost and therefore irrelevant, and 2) its replacement may have different characteristics. Let us assume that the replacement vehicle has been analyzed, its optimal replacement time, if purchased now, is given by n,* and the total discounted cost is given by $F_{new}(n^*)$. Thus, the optimal replacement time for the existing vehicle is the value of n that minimizes

$$F_{old}(n) = \sum_{i=1}^{n} \alpha^i AC_n - \alpha^n RS + \alpha^n F_{new}(n^*) \qquad\qquad 5\text{-}4$$

where AC_n and RS refer to the annual cost and resale value of the current vehicle. Eq. (5-4) gives the objective function for one vehicle, so for a fleet, similar equations for each vehicle within the fleet are combined.

Comments

a. Report 0-4941-2 uses Eq. (5-2) to identify the optimal age assuming that "Ideally, any equipment should be replaced right before the point where the EUALCC equals the purchase cost of a new unit." The question is why to recommend waiting beyond the optimal replacing age? If budget limitations cause delay in vehicle replacement, then the approach of report 0-4941-2 of choosing based on which vehicle is furthest beyond the optimal age seems reasonable; however, if budget causes the delay in optimal age purchasing, it is ultimately causing increased costs.

b. It is easy to see that Eq. (5-2) and Eq. (5-3) yield the same optimal age, but it is not obvious that Eqs. (5-2) and (5-4) would yield the same age if the annual costs and resale value of the new and old vehicle were the same. Since it may be difficult to estimate the cost of the replacement vehicle, using Eq. (5-2) may be a reasonable approach. However, if it is possible to estimate the new vehicle's expected costs, then using Eq. (5-4) would be better.

c. The trend score approach in report 0-4941-2 (Eq. (4.9) on p. 38) is not particularly robust as it will stay negative beyond the optimal age of replacement. Since the report indicates that a negative trend score implies a low priority for replacement, a vehicle would never be replaced at its optimal age. However, again, if the budget limits replacement purchases, this approach may be reasonable.

d. Statistical analysis is desired to predict future costs based on historical costs. In other words, since maintenance costs are likely correlated, it may be possible to continually update the predictions of future costs.

e. The "Statistical Analysis of Attributes' Contribution to Replacement Priority" gives clear directions on establishing appropriate weights. If weights are a good idea, then more advice needs to be given on the selection of these weights. It makes sense for managers to adjust the weights, but they should start with initial weights based on an analysis of optimal replacement decisions.

FLEET ASSET MANAGEMENT RECOMMENDATIONS

Several recommendations are offered.

a. It would be extremely beneficial to have a simulation of fleet operating characteristics and costs to validate or refine fleet replacement policies.

b. Optimization techniques, deterministic and stochastic, are very common in fleet management in general and in equipment replacement in particular, and using stochastic dynamic programming for this purpose seems to be especially natural and appealing.

c. Because of the size of the problem, it is likely that some form of heuristic or approximation method will be necessary to use in conjunction with the stochastic dynamic programming approach.

CHAPTER 7:
IMPLEMENTATION PLAN

APPLICATIONS FOR TAMSIM AND EROW

Beneficial tool applications are anticipated at the statewide budgeting level, at the district project planning level, and at the project level concerning desirable right-of-way acquisition timing for individual parcels of property. The TAMSIM and EROW tools are also envisioned for use in estimating potential statewide right-of-way cost savings under various legislative decision scenarios.

Statewide Planning

As TAMSIM is designed as a project-level tool, development of statewide planning information will require use of TAMSIM at the project and district levels, then aggregating collected information. In some cases, use of a statewide representative set of generic projects may be used for statewide planning purposes.

Legislative Data Applications

TAMSIM and EROW have the capability of estimating cost savings to the State of Texas should legislation of various types be passed to allow broadened use of early acquisition of right-of-way parcels. To facilitate these estimations, it is suggested that a test pool of representative projects be developed from the entire group of projects currently in planning, statewide, which involve right-of-way purchasing. The test pool should include a known percentage of the statewide population of projects. All regions and population variables should be included in the project pool. In this manner, a reasonable estimation will be obtainable while limiting the efforts involved in making the cost-saving estimations.

Statewide Budget Planning Applications

TAMSIM and EROW will provide input to decision-makers determining the amount of budget that should be allocated for early acquisition of right of way, whether new legislation expands the use of this practice or not. Use of these tools for this purpose involves district-level tool application on all projects in each district which have probability of providing cost savings through utilization of early acquisition. The district-level information can then be aggregated at

the headquarters level for determining both the statewide budget for early right-of-way acquisition and the allocation of this budget among the districts.

District-Level Planning

Once an early right-of-way acquisition budget has been established for a district, that district can use TAMSIM and EROW to assist them in determining which projects and parcels should be pursued for early acquisition to obtain the greatest rate of return from their early right-of-way acquisition budget.

Other District-Level Uses

It is likely that additional beneficial uses of particularly the TAMSIM tool will be identified when these tools are demonstrated and training is provided to district right of way and project planning personnel. One such potential additional use is to use TAMSIM to develop initial right-of-way cost estimates needed by project planners very early in the project planning process.

FIRST USE AND TRAINING

One of the most effective methods of tool training is hands-on use in cooperation with an experienced individual. The implementation plan for TAMSIM and EROW includes the selection of one district from each of TxDOT's four regions. District planning and right-of-way section personnel from these districts will each be walked through the use of these tools by the research team. Actual project and right-of-way parcels will be used, thereby achieving the dual goals of training district personnel in use of tools and providing these districts beneficial information as they move to actual parcel acquisitioning. Workshops will then be held in each region to train TxDOT personnel from other districts in the regions. It is anticipated that insight will be obtained from these four tool applications into potential statewide cost savings if new legislation allows broadened use of early right-of-way acquisition.

WORK PLAN

The recommended implementation plan includes the following four tasks:

Task 1. Cooperative Initial Use of TAMSIM and EROW. Four districts will be selected and contacted in consultation with the implementation project director and the ROW Division to become initial users of the newly developed tools. A district will be selected to represent each

TxDOT region. Preference will be given to urban and metropolitan districts with a history of rapid escalation in right-of-way parcel costs due to speculative purchasing and/or property improvements by landowners.

The research team will make a presentation to each selected district to:

- explain the purposes for which TAMSIM and EROW were developed,

- explain simulation and optimization business science tool basics,

- describe data input needs to use the tools,

- facilitate selection of several local projects or a small corridor to be evaluated using these tools,

- plan and schedule cooperative gathering of needed project and parcel information, and to, if possible,

- tentatively establish a date for the regional workshop to be hosted by the district.

The research team will then work with district planners and right-of-way section staff in each district to collect necessary project-level and parcel-level information. Any information available in ROWIS will be collected first by the research team, working through the ROW Division and/or district office to obtain appropriate ROWIS data files.

Upon completion of gathering project and parcel data and statistics from ROWIS and district files, the research team will schedule a visit to the district for the purpose of photographing parcels and obtaining the district's assessment of likelihood that each parcel may experience property improvements prior to department acquisition. An assessment will also be obtained from district right-of-way section staff of likelihood of other speculative activities. The participation of local right-of-way section specialists in these assessments is absolutely essential to successful use of the software tools being implemented.

The research team will input gathered information and will demonstrate use of TAMSIM and EROW to each district participating in initial tool use, thereby providing tool output for district consideration as planning for the selected projects or short corridor moves forward.

Task 2. TAMSIM and EROW Regional Workshops. Up to four regional workshops will be planned and delivered by the research team. Workshops will be held during the summer of 2010. The objective of these workshops is to provide training in use of TAMSIM and EROW to other districts in each TxDOT region. The host district for which the tools were initially utilized will have the opportunity to participate in presenting regional workshop information. It is

anticipated that the analysis performed earlier in the year for the host district will be used to demonstrate use of the tools during each workshop.

Workshops will be approximately four hours in length. As a minimum, the agenda will include:

- explanation of the purposes for which TAMSIM and EROW were developed,
- explanation of simulation and optimization business science tool basics,
- description of data input needs to use the tools, and a
- demonstration of each tool.

Each district attending a regional workshop will be provided a CD-ROM containing TAMSIM, EROW, and a User's Guide for each.

Task 3. Tool Calibration Adjustments. It is anticipated that use of these tools in the four districts may allow minor adjustments in tool calibrations. If this is the case, these adjustments will be described in the implementation report. Major adjustments and enhancements to the tools will not be possible during this implementation project.

Task 4. Implementation Report Preparation. An implementation report describing project activities will be submitted at the end of this implementation project.

CHAPTER 8:
CONCLUSIONS AND RECOMMENDATIONS

Minimizing the cost of right-of-way acquisition and speeding construction completion time are high-priority objectives of TxDOT. The acquisition of right of way for a highway construction project can impact a project through both time and cost. Potential benefits from advantageous early right-of-way acquisitions are believed to be quite substantial in terms of both tax dollar savings and construction project predictability and completion time. While quantifying these benefits in monetary terms is a challenging task, obtaining a much better estimate and understanding of the potential impact that early right-of-way acquisition would have on project costs is needed.

Researchers developed two right-of-way acquisition decision-support tools in this project: a simulation tool and an optimization tool. These tools rely on models developed from historical data stored in ROWIS and interviews conducted with TxDOT right-of-way personnel.

TOOLS AND POTENTIAL TXDOT USERS

TAMSIM is designed to provide statistical measures of the impacts that right-of-way acquisition timing can have on a project. It simulates right-of-way related activities and costs for a project during the Plan Authority and Develop Authority phases of project development, both with and without use of early acquisition. These costs include not only the purchase of the right of way itself, but also cost estimates associated with the possible delay in construction start time due to lack of right-of-way availability. TAMSIM also estimates right-of-way acquisition time durations, taking into account the randomness inherent in the acquisition process, such as the possibility of condemnation proceedings, the length of time for negotiations, and the costs involved in taking possession of the parcels.

EROW is the optimization tool designed for estimating the most desirable right-of-way dollar-value to be allocated for early purchase of right-of-way parcels. It enhances TAMSIM capabilities. Additional uses of EROW are likely as the level of experience with this tool grows. It may become possible for experienced users to determine on a statewide basis the projects that offer the best return on investments within certain budget restrictions.

TAMSIM is designed for use by knowledgeable right-of-way professionals at the district level to determine the likely results on a specific project if some of its parcels were acquired

early. It can also be used as a policy supporting tool at the state level to compare the potential effects on project costs of various proposed policies regarding early acquisition of right of way. Outputs produced by TAMSIM can be compiled into a pair of files including information on each project investment scenario included in the analysis. EROW can use these files at the district or the state levels to determine how much money would optimally be allocated to early right-of-way acquisition and which projects should receive funding for early acquisition. For a state level application, inputs from right-of-way administrators at the district level are critical in order to generate dependable estimated cost information for each right-of-way project investment scenario.

The tools developed during phase two of this project, TAMSIM and EROW, are included on a CD-ROM in a jacket inside the cover of this report.

CONCLUSIONS

1. Simulation and optimization business science methods have been found suitable for the development of decision-support tools regarding early acquisition of right-of-way parcels.

2. Two tools were developed in this project: TAMSIM and EROW. These tools can assist decision makers at the district and state levels in the funding allocation process for early right-of-way acquisition.

3. TAMSIM and EROW can support the following activities:

   a. Determination of the probability of significant savings from early acquisition on a single project and estimating the magnitude of that savings.

   b. Determination of the number of parcels within a given project which should be considered for early acquisition.

   c. Determination of which projects within a district offer the most potential for significant savings from early acquisition.

   d. Determination on a statewide basis an optimal number of parcels or projects or right-of-way dollar-value to be allocated for early acquisition of right of way.

4. Based on TAMSIM sensitivity testing, TAMSIM provides cost saving results in correct relative magnitude sequence. Earlier times for speculation to begin result in greater

savings potential from early acquisition. The greatest cost savings occur when speculation activities begin immediately after the schematics become available.

5. Findings from the TAMSIM sensitivity analysis performed to consider speculation beginning when the schematics become available are shown in Table 19. The highest expected savings in terms of dollars are in the Dallas project while the highest time reduction to procure needed right of way is anticipated by TAMSIM to occur in the Tarrant project.

Table 19. Costs, Savings, and Time Durations for Speculation Scenario Providing Greatest Benefits

County Type	Speculation-Begin Scenario Providing Greatest Early Acquisition Benefits	Total Right-of-Way Cost without Early Acquisitions ($1,000)	Total Right-of-Way Cost with Early Acquisitions ($1,000)	Total Expected Savings from Early Acquisitions ($1,000)	Cost Savings Ratio	Time Duration without Early Acquisition (months)	Time Duration with Early Acquisition (months)	Time Reduction Ratio
Metro	Schematics Available (time 0)	$147,320	$25,355	$121,965	0.83	102.6	36.1	0.648
Urban	Schematics Available (time 0)	$11,817	$4,440	$7,377	0.62	76.8	22.8	0.703
Rural	Schematics Available (time 0)	$1,967	$1,435	$532	0.27	65.1	17.4	0.733
Dallas	Schematics Available (time 0)	$88,764	$13,498	$75,266	0.85	83.1	26.1	0.686
Harris	Schematics Available (time 0)	$381,424	$89,884	$291,540	0.76	78.5	23.5	0.701
Tarrant	Schematics Available (time 0)	$138,718	$55,774	$82,944	0.60	60.3	14.5	0.760

6. The use of asset management practices for right-of-way early acquisition can be technically justified, but there may be limitations to implementation potential. Availability of funds for purchase of right of way is a concern in Texas. Parcels which are identified as beneficial for early acquisition may not be within TxDOT budgeting ability to purchase early.

7. To maximize benefits possible through early acquisition, laws and policies will need to be modified to allow early acquisition with less restriction than is currently allowable. Asset management tools used for estimating the benefits of right-of-way early

acquisition, when applicable, will assist in improving communication with legislators if legislative changes are considered in the future.

RECOMMENDATIONS

1. TxDOT should implement TAMSIM and EROW on a statewide basis for the initial purpose of assisting in selection of right-of-way parcels for early acquisition within the current limitations of state legislation.

2. Initial results provided to TxDOT by TAMSIM and EROW during the implementation period should be analyzed by TxDOT right-of-way professionals to allow model adjustments as may be found desirable.

3. A pool of representative projects should be assembled for use in estimating potential cost savings for the State of Texas should various new allowances be provided through future legislation.

4. In the opinion of TxDOT personnel with experience in right of way, the following are general recommendations for applying asset management principles to right-of-way early acquisition:

    a. Projects should be studied case-by-case to determine if early acquisition will be beneficial.

    b. Protective buying can save money if: 1) parcels are located in an area where cost can increase rapidly, 2) a significant number of parcels are purchased, and 3) parcels are acquired early enough to avoid speculation and/or improvements being added to the properties.

    c. Buy parcels when they are vacant. It is not recommended to wait for improvements in the parcels. Any improvement will cause the cost to increase.

    d. Speculation, improvements to the property, and damages to the remainder of the property are considered to be the major factors causing significantly increased land cost.

    e. Right-of-way early acquisition may foster smoother negotiations, saving time and human resources.

f.   Good communication with cities and counties will help to identify areas where right-of-way cost can increase significantly from initial estimates. This will allow districts to take action to minimize the impact of potential cost escalation.

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APPENDIX A – FILTERED ROWIS DATA SETS

A CD-ROM containing filtered right-of-way acquisition data sets used to establish simulation data attributes is enclosed in a jacket inside the cover of this report.

APPENDIX B – TAMSIM HELP INFORMATION

About TAMSIM

TAMSIM is a simulation program for developing total right-of-way (ROW) cost estimate information during early project planning activities. It is designed for use by experienced Texas Department of Transportation (TxDOT) project planners and ROW acquisition personnel. This tool allows users to determine the potential for achieving significant cost savings under various ROW acquisition timing strategies.

TAMSIM utilizes embedded statistics developed from historical department ROW acquisition records together with user-provided project and parcel information to generate total cost estimate information in present value dollars. The range of outcomes as well as the most likely outcome is determined through simulated occurrences of ROW acquisition for the parcels within the analyzed project. TAMSIM defines time zero of the acquisition time line as the point in planning when the initial schematics indicating the parcels to be obtained become available.

TAMSIM was created for TxDOT by the Texas Transportation Institute (TTI) of the Texas A&M University System under TxDOT Research Project 0-5534. TAMSIM was designed and developed by:

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Alignments

An alignment refers to a collection of parcels that will be accepted or rejected as a unit during the environmental clearance process. Because TAMSIM is designed to be used before the environmental clearance has been obtained, there is a possibility that some of the parcels listed will not be included in the final corridor and those parcels that are accepted or rejected together form an alignment.   The designation of which parcel belongs to specific alignments is made on the Parcel Data Screen.

Alignments are organized into groups such that one, and only one, alignment from the group will be accepted for the final approved corridor. Alignments within one group must always be listed consecutively within the Alignments Screen with the first alignment of each group being identified by a check box.

The Alignments Screen

The Alignments Screen allows for input or modification of alignment specific data. It also contains four menus: the File Menu, which is the same as the "Quit" Button; the View Menu used to view and/or modify data; the Run Menu, which is the same as the "Continue" Button to execute the simulation model; and the Help Menu for accessing the help system. The list of shortcut keys can also be accessed from the Help Menu. Two of the three buttons on the screen are redundant and are placed on the screen for ease of use. Clicking the "Continue" Button will continue the simulation to the Basic Data Screen and is equivalent to using the Run Option (or the *F5* key); clicking the "Quit" Button is equivalent to using the Exit Option (or *<ctrl>+X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data, and no warning message is given asking if you want to save your data. The "Add Rows" button is used to add additional parcels to the project. To view this screen after other screens have been accessed, use the View Menu from any of the other screens or use the *<ctrl> + L* keys.

If a project has only one alignment specified on the Parcel Generator Screen, then all identified parcels will be included in the final corridor, and the Alignments Screen is unnecessary and will not appear.

The sum of the likelihoods associated with all alignments within one group must equal 1.0 because there must be one (and only one) alignment from a group that is selected for the final approved corridor. The "Check Likelihood" button on the screen will automatically adjust that likelihood associated with the final alignment of each group so that the total sums to 1.0.

The data entered through the Alignments Screen are stored in the Access Database containing the project's data within the "Alignments" Table. Each row of the table represents one alignment. Once the number of alignments are given in the Parcel Generator Screen, no further alignments can be added. The data fields for the alignments are as follows:

1. *Alignment Description (Num and ID).* The two fields represent descriptive data for the alignment. The first field is automatic and cannot be modified. (Only the first field

cannot be changed; all other fields on this screen are editable.) The second field is available so that parcels can easily be identified.

2. *Start New Group*. Alignments form groups so that one and only one alignment within a group will be selected for a project. Alignments associated with one group must be listed together and the first alignment the starts a new group is indicated with a check mark in this column.

3. *Likelihood of Inclusion*. The simulation model is designed to be run towards the end of the Feasibility Phase or the Plan Authority Phase of a project before it is known with certainty what the final approved corridor will be; thus, it is possible that an alignment (i.e., a set of parcels) identified during the feasibility phase as possibly being within the required corridor may not end up within the final corridor as approved during environmental clearance. If it is known with certainty that an alignment will be included in the final approved corridor, then 1.0 should be entered for the "Likelihood of Inclusion"; otherwise, a value less than 1.0 should be entered. If 0 is entered, then that alignment will never be included within the final corridor, which is equivalent to deleting that alignment (and any associated parcels) from the project.

4. *Permit Cost*. If there is a permit cost associated with an alignment, it is entered in the final column of data.

The Basic Data Screen

The Basic Data Screen allows for input or modification of project-level data. It also contains four menus: the File Menu used to save data, the View Menu used to view and/or modify data, the Run Menu used to execute the simulation model, and the Help Menu for accessing the help system. The list of shortcut keys can also be accessed from the Help Menu. The two buttons on the screen are redundant and are placed on the screen for ease of use. Clicking the Simulate Button is equivalent to using the Run Option (or the *F5* key) and clicking the Quit Button is equivalent to using the Exit Option (or *<ctrl>+X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data and no warning message is given asking if you want to save your data.

The data entered through the Basic Data Screen are stored in the "TitlePage" Table of the Access database containing the project's data. The "TitlePage" Table also contains the date of the latest simulation run of the data and the CPU time required of the run. Once the Run Menu is used, data can no longer be modified without clicking the Reset Data Button. The Basic Data Screen provides data entries for six categories of required information:

1. *Project Description*. The project description and author entries are provided for your convenience so that it will be easy to identify a specific set of data when viewing the Access database created by the project. (Note that the database associated with a project contains both input and output data.)

2. *Environmental Clearance*. The simulation model is designed to be run toward the end of the Feasibility Phase or toward the start of the Plan Authority Phase of a project with the purpose of estimating the eventual cost of ROW; therefore, a key component is the

estimate of the time at which the environmental clearance will occur. (Time is measured in months and represents the duration from the availability of the design schematics to obtaining environmental clearance.) There are three parameters that will be used in generating this time: the minimum possible time, the most likely time, and the maximum possible time.

3. *ROW Release Date*. After the environmental clearance has been obtained, it is necessary to obtain the release to begin the ROW acquisition process. The length of time required for this depends on the priority of the project as well as the paperwork processing time. Time is measure in months and again there are three parameters needed (minimum, most likely, and maximum) for describing the probability distribution for the duration of time from obtaining environmental clearance to obtaining the ROW Release. In other words, the duration of time measured in months from the availability of the design schematics to permission to begin the acquisition is the sum of generated times based on the data entered that describe the probability laws governing the environmental clearance and the ROW release date.

4. *Number of Replications*. A simulation model is designed to be an experiment based on the probability laws entered into the model so it is necessary to make several replications of a model run. The final analysis of output depends on a statistical sample, the size of which is equal to the parameter identified as the Number of Replications.

5. *Inflation Rate*. The total cost for ROW acquisition will be expressed in terms of current-day dollars (i.e., the present value) based on the input value of the nominal annual inflation rate. It will be assumed that the nominal rate is compounded daily. (Note that the inflation rate is not the rate at which land appreciates which may be more than the general inflation rate.)

6. *Early or Late Finish Time*. It is possible that the acquisition of ROW takes longer than expected thus forcing a delay in the start of construction, or it is possible that the acquisition of ROW takes a shorter time than expected thus allowing an early start of construction. To quantify the costs or benefits associated with the start of construction, there are three required parameters: a target date (the number of months between the point in time that the design schematics or available to the start of the Construct Authority Phase), the penalty cost for each day late, and the cost savings for each day early. The number of days late or early is determined by comparing the time of possession for the final parcel required to the target completion date. Some studies have suggested that a cost savings of 25–30% per year of the total project cost is a reasonable value for finishing a project early.

7. *Factors Related to Land Value Appreciation*. The final three data types (namely, the additional property cost increase, the event causing the additional increase, and the offset) refer to cost increases in property values that are in addition to normal inflation (but not caused by additional improvements to the property). Based on several interviews, it appears the most common reason attributed to the cost increase is due to land purchased by speculators. It is not always clear when speculative activity begins and whether or not early acquisitions would cause the land value to increase; therefore, under the heading "Speculation begins" a choice must be made as to what causes the land value increase to begin. For example, assume that for a particular project the analyst feels that speculation will likely begin 2 months after the ROW Release is obtained, then the option "ROW

Release Obtained" would be selected using the drop-down menu for "Speculation begins", and "2 months" would be chosen using the drop-down menu for "Offset for Speculation."

Data Input Screens

There are four data input screens: the Alignments Screen, the Basic Data Screen, the Parcel Data Screen, and the Parcel Possession/Cost Data Screen, which allows for data changes. The initial data values are stored in an Access database; therefore, data may be changed within the program through a data screen or it may be changed outside the program by accessing the database directly, although this can be risky.

Data Screens

TAMSIM uses data screens to display information and allow for the input and modification of data. There are eight different screens associated with the program. These are:

1. The Start-up Screen is to begin a new project or to continue with a saved project. To begin a new project, either use the menu or use the *<ctrl>+N* shortcut keys. To open an existing project, either use the menu or use the *<ctrl>+O* shortcut keys.

2. The Parcel Generator Screen appears whenever the user chooses to begin a new project. A few counties (namely, Dallas, Harris, and Tarrant) had a sufficiently large number of projects to allow reasonable statistics to be obtained; thus, a user may choose one of those counties or a category of counties. Based on the input from this screen, a project with the specified number of parcels is established; however, data regarding the parcels may be modified on later data screens, including the number of parcels that may be purchased early.

3. The Alignments Screen appears if there is more than one alignment under consideration and enables the user to provide the likelihoods of each alignment being included in the final approved corridor and allows permit costs to be entered if relevant.

4. The Basic Data Screen allows for input verification or modification of project-level data.

5. The Parcel Data Screen allows for input verification or modification of some of the parcel level data including data related to impacts of future improvements and early acquisition.

6. The Parcel Possession/Cost Data Screen allows verification or modification of parcel possession time and cost data. Possession time refers to the number of months from the ROW release to the actual possession of the parcel. The cost refers to the final purchase price of the parcel including the cost of land, cost of improvements, cost of damages, and any court costs or outsourcing costs, if relevant. It does **not** include the cost of any improvements that are projected to be made during Plan Authority or Develop Authority phases of the project. The only data that can be changed on this screen are the mean values, standard deviation values, and multipliers. The other values listed on the screen are for information purposes only. Once the Parcel Possession Data Screen is accessed, some data can no longer be changed including parcel names, nor can parcels be added or deleted.

7. The Detailed Results Screen appears at the conclusion of the simulation run and contains the detailed output from each replication of the simulated project.

8. The Summary Statistics Screen contains a statistical summary of the results from the simulated project.

In addition, two text files are also created to allow communication between TAMSIM and EROW (an optimization program). The first file created is called `Cost.out` and contains the average value over all replications of the amount of purchase cost spent for early acquisitions. The second file created is called `Save.out` and contains the average amount of reduction in total ROW costs due to early acquisition; thus, a negative number in the `Save.out` file refers to an increase in average total cost. Each run of TAMSIM will produce one number to each file as a separate row. If no files with these names are in the folder containing TAMSIM.exe, they will be created.

The Detailed Results Screen

The Detailed Results Screen can be accessed only after the simulation has been executed. Accessing this screen is either through the View Menu or the use of the *F6* key. The Detailed Results Screen contains: the File Menu used to save data, the View Menu used to view data, and the Help Menu for accessing the help system. The button on the screen is redundant and is placed on the screen for ease of use. Clicking the Quit Button is equivalent to using the Exit Option (or *<ctrl> + X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data, and no warning message is given asking if you want to save your data.

A simulation involves a random experiment with several replications, the number of replications being determined from the Basic Data Screen. Each replication involves generating times according to various probability distributions as defined by the data input screens for the time of environmental clearance, the time of ROW release, and the times of possession for each parcel. Costs are also generated according to probability distributions for acquisition of each parcel. Each replication will produce different times and costs due to the random nature of a simulation. The specific times and costs generated by each replication can be viewed on the Detailed Results Screen using the drop down menu immediately below the title. The drop down menu for the different replications also allows you to view the mean times averaged across all replications and the standard deviation of those times. Other descriptive statistics can be viewed on the Summary Statistics Screen through the use of View Menu (or the *F7* key). Also, the summary of the costs and savings for early acquisition as needed by EROW (the optimizer used to determine the optimal early ROW budget) is contained in two text files and are not viewed on this screen.

Each replication will have a cost savings or additional cost expense depending on whether or not the replication produced times that resulted in an early completion of the acquisition process or a late completion of the acquisition process. This cost savings or cost increase is displayed in the bottom right-hand corner of the screen. (The data for these costs were taken from the Basic Data Screen).

There are three types of data displayed in the grid for each parcel on the screen:

1. *Parcel Description (Num, Name).* The first two fields represent descriptive data for the task or parcel. Asterisks before the name of a parcel indicate that the parcel was purchased through eminent domain for that replication. The number in parentheses after the parcel's name is the alignment that contains the parcel as specified on the Parcel Data Screen.

2. *Task Duration (Duration, End).* The first row in the grid always refers to the time for obtaining the environmental clearance, and the second row refers to the time for obtaining the release to begin the right-of-way acquisition process. Each row after that until the final row refers to the task of obtaining possession of a specific parcel. The value of the times is always measured in the number of months after the design schematics are available. The value for the ending time in the final (or "Stop") row of the grid is the maximum ending parcel possession time. There are two ending times presented; these times refer to the time to purchase the property if no early acquisitions are made, and the second ending times are the values obtained by the simulation under the early acquisition scenario.

3. *Costs (Present Value Cost, Present Value Cost with Early Acquisition).* The final two columns refer to the predicted cost of the parcel with and without early acquisition. Red numbers indicate which parcels (if any) were purchased early. The value of the costs is always in terms of present value, i.e., costs in terms of dollars at time 0 (namely, when the design schematics become available). The cost of improvements made on the parcel after time 0 is based on data entered on the Parcel Data Screen. Cost is based on the probability that an improvement will actually occur as well as the timing and amount of improvement that occurred. Since we assume that the parcel acquisition costs are always input in terms of present day dollars, normal inflation will not affect costs but any appreciation in property value that is above the inflation costs will cause an increase in present day dollar cost of the parcel depending on the time at which the appreciation starts as specified on the Basic Data Screen.

In addition to the parcel related data, the cost increase due to late completion or a cost savings due to early completion is also given. These costs are determined based on the cost data given on the Basic Data Screen.

The "Reset Data" button allows a new simulation to be run with new data.

The File Menu -- Data Screens

The File Menu allows for saves and exits. The "Save" option is enabled only if there are new data to be saved. If you have entered new data but the "Save" option is not enabled, use the *TAB* key to insure that the data has been recorded.

1. *Save.* The "Save" Option is used if you want to save data from the various data screens. The "Save" Option overwrites the old data file, so if you want to save the old date, use the "Make Backup" Option before the "Save" Option. If none of the screens contain new

data, the "Save" Option will not be enabled. You can use the *<ctrl> + S* keys as a shortcut for the "Save" Option.

2. *Make Backup*. The "Make Backup" Option copies the original file into a second file. When using the "Make Backup" Option, a dialog box will appear that requires you to name the second file. If data in the original file have been changed by a previous save operation, this option is not enabled (i.e., the "Make Backup" Option is only available if it is still possible to make a backup of the original data). You can use the *F12* key as a shortcut for the "Make Backup" Option.

3. *Exit*. The "Exit" Option quits the program. If any data have been changed, you will be given the option of saving it. You can use the *<ctrl> + X* key (or the Quit Button) as a shortcut for the "Exit" Option. If you want to skip the dialog box reminding you about unsaved data, use the close box (the "x" in the upper right corner) for the screen.

The File Menu -- Startup Screen

There are three main options available from the File Menu on the Startup Screen:

1. *New*. The "New" Option (or *<ctrl>+N*) is used when you want to simulate a project for which no data have yet been stored. When this option is chosen, a Parcel Generator Screen appears in which you identify the number of parcels within the project and the county or category of county in which the project is being planned. Parcels are then generated with parameters according to historical data. After the parcels are generated, the Basic Data Screen appears if only one alignment is used. If more than one alignment is under consideration, then the Alignments Screen appears. After the Alignments Screen the Basic Data Screen appears when the "Continue" button is used. Parcel specific data can be changed by accessing the Parcel Data Screen through the View Menu on the Basic Data Screen.

2. *Open*. The "Open" Option (or *<ctrl>+O*) is used if you want to simulate a project for which you have already saved some data. After identifying the data file containing the data, the Basic Data Screen. You can then modify any of the previously stored data before executing the simulation.

3. *Exit*. The "Exit" Option (or *<ctrl>+X*) is used to quit this application. The "Cancel" button is the same as the Exit Option.

Getting Started

TAMSIM is a simulation program that can be used to estimate the cost of ROW acquisition for a specified project. All data needed for running the simulation are stored in an Access Database. All data, both input and output, are displayed on various Data Screens within TAMSIM. The data can be entered into the database and later modified using TAMSIM. The minimum requirements to run the simulation is the Microsoft .NET Framework 2.0, and a folder containing three files: TAMSIM.exe (the compiled version of the simulation program), _db.tmp (a hidden file that is the database containing all parameters of the code), and tamsim.chm (the compiled HTML help file). Note that it is important for these three files to be in the same folder. The program works with both Windows XP and Vista; however, it does not work using

a 64-bit operating system. When in doubt, the F1 key can be used to access the Help System, which also includes a list of shortcut keys for the various menu options.

To run TAMSIM, there are five types of data needed:

1. Project level data entered on the Basic Data Screen.
2. Alignment level data entered on the Alignment Screen.
3. Parcel level data entered on the Parcel Data Screen.
4. Possession time data (referring to the time span beginning with ROW release and ending with the obtaining possession of the parcel) entered on the Parcel Possession/Cost Data Screen.
5. Cost data, which is the total purchase price of a parcel including the value of the land, improvements, and damages, also entered on the Parcel Possession/Cost Data Screen.

The steps needed for using this simulation program are as follows:

1. Create or identify the database file containing the data for this run using one of the options under the File Menu (or use *<ctrl>+N,* or *<ctrl>+O* keys) of the Start-up Screen.
    a. Choose the "New" option on the File Menu (or *<ctrl>+N*) to create a new project for which parcel data will be automatically generated. (Modification of the automatically generated data is possible later through the various data input screens. All data input screens can be accessed through the View Menu that is on all data screens.) When the "New" option (*<ctrl>+N*) is chosen, the Parcel Generator Screen will appear. The number of parcels of land needed to satisfy the ROW requirements for the project is entered on this screen. If only one alignment is to be used for the project, the next screen to appear will be the Basic Data Screen; otherwise, the Alignments Screen will appear next. After the Alignments Screen, the next screen to appear will be the Basic Data Screen.
    b. Choose the "Open" option on the File Menu (or *<ctrl>+O*) to open an existing project. You can verify the parcel data after the Basic Data Screen appears.

    Enter, verify, or modify the project level data on the Basic Data Screen. Project level data refer to those data that are not associated with individual parcels.

    Verify and/or modify the parcel level data using the Parcel Data Screen that is displayed through an option on the View Menu or by the *F3* key.

    Verify and/or modify the possession time (i.e., the time from ROW release to parcel possession) and cost data using the Parcel Possession/Cost Data Screen that is displayed through an option on the View Menu or by the *F4* key. Once the Parcel Possession Data Screen has been accessed, parcels can no longer be added or deleted.

    Save data that have been modified by choosing an option on the File Menu. Because the save operation overwrites the old data, you may want to make a backup of the original data again through the use of the File Menu or by using the *F12* key. Once the Save Option has been used, a backup is no longer possible since the original data are no longer available.

Choose the "Run Simulation" option on the Run Menu (or the *F5* key) to execute the simulation. After the simulation is complete, the Summary Statistics Screen will be displayed.

After the run, there are two output screens. Data for each replication of the simulation is contained in the Detailed Results Screen, and a summary of the results is contained in the Summary Statistics Screen. Again, you may choose to save the output or not save it.

Two text files are also created to allow communication between TAMSIM and EROW (an optimization program). The first file created is called `Cost.out` and contains the average value over all replications of the amount of purchase cost spent for early acquisitions. The second file created is call `Save.out` and contains the average amount of reduction in total ROW costs due to early acquisition; thus, a negative number in the `Save.out` file refers to an increase in average total cost. Each run of TAMSIM will produce one number to each file as a separate row. If no files with these names are in the folder containing `TAMSIM.exe`, they will be created.

The Parcel Data Screen

The Parcel Data Screen allows for input or modification of parcel specific data. It also contains four menus: the File Menu used to save data, the View Menu used to view and/or modify data, the Run Menu used to execute the simulation model, and the Help Menu for accessing the help system. The list of shortcut keys can also be accessed from the Help Menu. Two of the three buttons on the screen are redundant and are placed on the screen for ease of use. Clicking the Simulate Button is equivalent to using the Run Option (or the *F5* key) and clicking the Quit Button is equivalent to using the Exit Option (or *<ctrl>+X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data and no warning message is given asking if you want to save your data. The "Add Rows" button is used to add additional parcels to the project. To view this screen, use the View Menu from any of the other screens or use the *F3* key.

The data entered through the Parcel Data Screen are stored in the Access Database containing the project's data within the "ParcelList" Table. Each row of the table represents one parcel and during the editing phase, it is possible to add rows as well as change individual data items within a row. A parcel is added using the "Add Rows" button, and a parcel is effectively deleted by entering zero in the third column (namely, set the "Likelihood of Inclusion" to zero for the parcel to be deleted). Once the Run Menu is used, data can no longer be modified without resetting the simulation. The data fields for the parcels are as follows:

1. *Parcel Description (Num and ID)*. The two fields represent descriptive data for the parcel. The first field is automatic and cannot be modified. (Only the first field cannot be changed; all other fields on this screen are editable.) The second field is available so that parcels can easily be identified.

2. *Associated Alignment*. The simulation model is designed to be run toward the end of the Feasibility Phase or the Plan Authority Phase of a project before it is known with certainty what the final approved corridor will be; thus, it is possible that parcels identified during the feasibility phase as possibly being within the required corridor may not end up within the final corridor as approved during environmental clearance. Parcels

that are accepted or rejected as a unit are associated with an alignment and such an alignment is identified in the third column. The probability that an alignment will be included in the final approval is given on the Alignments Screen. If all parcels identified in the project are to be included in the final corridor, then only one alignment will be used and the Alignment Screen never appears; in this case, all parcels should be associated with alignment #1.

3. *Likelihood of Outsourcing*. Some districts use outside contractors for the accessing and acquiring of parcels. The data related to possession time differs depending on whether the parcel is being processed through an outside contractor or by district employees. If it is known with certainty that a parcel will be acquired through an outside contractor, then 1.0 should be entered here; if it is know for certain that district employees will be used to access and acquire the parcel, then 0.0 should be entered. Otherwise, a value between 0.0 and 1.0 should be entered.

4. *Likelihood of Condemnation*. The likelihood that condemnation proceedings will be necessary to acquire the parcel should be entered. This field requires a value less than or equal to 1.0 and greater than or equal to 0.0. Both the time to acquire the parcel and the final cost required to purchase the parcel are affected if condemnation proceedings are necessary.

5. *Likelihood of Improvements*. The usual reason that early acquisition is economically beneficial is the likelihood that improvements will be made on the parcel under consideration. This input requires a number between zero and one (inclusive) representing the probability that improvements will be made. If no improvements are expected, this probability would be set to zero and early acquisition would be unlikely. When this entry is zero, the remaining entries for that parcel are ignored. However, if improvements are a possibility, then a positive value would be entered here and it is important to fill in the remaining data entries.

6. *Time Duration over which Improvement Will Likely Occur*. The next four entries refer to establishing a probability law that will reflect the timing over which the improvements will be made.

7. *Cost multiplier for Improvements*. During the simulation, a random value based on a probability law defined through the next screen will be generated that will represent the cost of each parcel. If improvements are made on the parcel, then this random value will be multiplied by the value (any number greater than one) entered here to determine the total cost of the parcel.

8. *Indicator for Early Acquisition*. If there is a check mark under this entry, then the parcel will be acquired early. During the simulation, total project ROW costs and the time at which all parcels are purchased will be computed without any early acquisition and with early acquisition of those parcels that have been checked.

The Parcel Generator Screen

The Parcel Generator Screen is the first screen to appear whenever the "New" Option is used from the File Menu on the Startup Screen. This screen is used so that you can indicate how many parcels are to be included in project, how many parcels are expected to have future improvements, how many of those parcels will be purchased early, and how many alignments will be used in the project. (Future improvements refer to the possibility of improvements on the

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parcel after the schematic diagrams have been developed. This is important because, in general, these are the parcels for which early acquisition would likely prove beneficial.) The screen also indicates the data set to be used; that is, if a specific county, class of counties, are state-wide values are to be used.

The data for a Metropolitan area were obtained by averaging over all counties with population size large than 400,000. The Urban Area is for counties with a population between 50,000 and 400,000, and the Rural Area is those counties less than 50,000.

After entering the requested data on this screen, click on the "Continue" button or use the *F5* key. If only one alignment is entered for the project, the next screen to appear after the continuing is the Basic Data Screen. If more than one alignment is entered on this screen, then the Alignments Screen will be the next screen to appear. After continuing, you may correct any of the numbers entered by adding or deleting individual parcels through the Parcel Data Screen. However, if you want to change either the selection of the county or the data set used to generate the data (i.e., the choice of metropolitan, urban, or rural) or the number of alignments used for the project, it will be necessary to start over.

The Parcel Possession/Cost Data Screen

The Parcel Possession Data Screen displays possession time and possession cost distributional data for each parcel. Possession time refers to the number of months from the ROW release to the actual possession of the parcel. The cost refers to the final purchase price of the parcel including the cost of land, cost of improvements, cost of damages, and any court costs or outsourcing costs, if relevant. It does **not** include the cost of any improvements that are projected to be made during Plan Authority or Develop Authority phases of the project. If improvements are made on the parcel during the Plan Authority or Develop Authority phases, these will be according to the probability laws specified on the Parcel Data Screen. The only data that can be changed on this screen are the mean values, standard deviation values, and multipliers. The other values listed on the screen are for information purposes only. Once the Parcel Possession/Cost Data Screen is accessed, the parcel name cannot be changed nor can parcels be added or deleted.

The Parcel Possession Data Screen contains four menus: the File Menu used to save data, the View Menu used to view and/or modify data, the Run Menu used to execute the simulation model, and the Help Menu for accessing the help system. The "Simulate" and "Quit" buttons on the screen are redundant and are placed on the screen for ease of use. Clicking the Simulate Button is equivalent to using the Run Option (or the *F5* key) and clicking the Quit Button is equivalent to using the Exit Option (or *ctrl-X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data, and no warning message is given asking if you want to save your data. Once the simulation has been executed, input data may no longer be changed.

Within a single project, parcels are not independent of each other. That is, if one parcel tends to be relatively expensive, other parcels will more likely be expensive as well. The probability law governing both duration and costs is a lognormal distribution, which is a distribution that is

skewed to the right. For these distributions, the mean and standard deviation can be modified, which will automatically change the minimum, median, and maximum values. The minimum, median, and maximum values are displayed so that a better intuitive understanding of the distribution can be obtained. The displayed values for the mean and variance indicate the project mean and variance. The individual parcels are then generated around the lognormally generated project mean. However, if the user changes a specific mean and variance, those numbers will refer to the specific parcel and that parcel's data will be generated independently according to the new values.

Note: The first row (numbered zero) of data on this screen refers to the project values that are averaged over all parcels in the project and does not refer to any one specific parcel. Changing a value in this first row will change the values of all parcels.

The Run Menu – Input Data Screens

The Run Menu is used to execute the program. The "Run Simulation" Option causes an execution of the model by simulating the project a number of time according to the "Number of Replications" parameter specified on the Basic Data Screen. The next screen to appear will be the Summary Statistics Screen. You can use the *F5* key as a shortcut.

The Run Menu – Parcel Possession Screen

The Run Menu has only one option, the "Run Simulation" option, and it is used to finish the execution of the program, namely, it will run the simulation portion of the program. You can use the *F5* key as a shortcut.

Shortcut Keys

Key	Function
<ctrl> + L	View and/or modify data on the Alignments Screen
<ctrl> + N	Create a new project. Only available from the File Menu of the Input Screen
<ctrl> + O	Open an existing project data file. Only available from the File Menu of the Input Screen
<ctrl> + S	Save data from the various screens
<ctrl> + X	Exit the program
F1	View help
F2	View and/or modify data on the Basic Data Screen
F3	View and/or modify data on the Parcel Data Screen
F4	View and/or modify data on the Parcel Possession Data Screen
F5	Run simulation if used on a Data Entry Screen, or continue with data entry if used on the Parcel Generator Screen
F6	View the Detailed Output Data Screen

F7	View output on the [Summary Statistics Data Screen](#).
F12	Copy existing data file to a backup data file

The Summary Statistics Screen

The Summary Statistics Screen will automatically display at the conclusion of a simulation run. This screen contains three menus: the [File Menu](#) used to save data, the [View Menu](#) used to view data, and the Help Menu for accessing the help system. The button on the screen is redundant and is placed on the screen for ease of use. Clicking the Quit Button is equivalent to using the Exit Option (or *<ctrl> + X*). You can also quit the application by clicking the "x" in the upper right corner of the screen; however, using the close box on the screen will cause you to lose any unsaved data, and no warning message is given asking if you want to save your data.

The summary of the costs and savings for early acquisition as needed by EROW (the optimizer used to determine the optimal early ROW budget) is contained in two [text files](#) and are not viewed on this screen.

A simulation involves a random experiment with several replications, the number of replications being determined from the [Basic Data Screen](#). Each replication involves generating times according to various probability distributions as defined by the [data input screens](#) for the time of environmental clearance, the time of ROW release, and the times of possession for each parcel. Costs are also generated according to probability distributions for acquisition of each parcel. Each replication will produce different times and costs due to the random nature of a simulation. The specific times and costs generated by each replication can be viewed on the [Detailed Results Screen](#) (which can be viewed using the *F6* key) and a statistical summary of the results is viewed on this screen (the Summary Statistics Screen).

The summary includes mean values, standard deviation, and the 10, 50, and 90 percentile values. If the cost differences shown under the "Impact of Early Acquisition" portion of the screen are negative, then early acquisition reduces costs.

There are two types of data displayed in the grid on the screen:

1. *Project Duration*. Time is the number of months from the availability of the design schematics to the time at which possession has been achieved for all parcels. The estimates for the mean and standard deviation also include 95% confidence intervals based on the t-statistic for the means and the chi-squared statistic for the standard deviations. The statistics are based on a sample size equal to the number of replications as given in the [Basic Data Screen](#).
2. *Costs*. The cost values are in terms of "present day" dollars, where the present day refers to the point in time at which the design schematics first become available. The cost for the project is the sum of the personnel costs for the possession tasks, the right-of-way acquisition costs including improvements (if any), and the cost savings or cost increase obtained by comparing the final parcel possession time to the target date as given on the [Basic Data Screen](#).

The "Reset Data" button allows a new simulation to be run with new data.

Text File Output

Output from TAMSIM is used as input data to EROW, an optimizer used for determining the budget in the early acquisition of right of way. Specifically, EROW needs from TAMSIM estimates for the total dollar value for early acquisition purchases and the resultant savings in total cost. In order to facilitate the easy transfer of information from TAMSIM to EROW, two text files are created containing this information.

After execution of the simulation, a text file named `Cost.out` will contain the average value for the total costs of all parcels purchased early, and a text file named `Save.out` will contain the average value of the total savings in cost due to the early acquisition. (Note that a positive value in the `Save.out` file implies a reduction in total costs, and a negative value implies and increase in total cost due to early acquisition.) The following are some properties associated with these files:

1. The files will be located in the same folder that contains TAMSIM.exe.
2. If the files do not exist, they will be created.
3. If the files already exist, the data from the simulation run will be appended to the already existing data.
4. Each run of TAMSIM will produce one number for each file.

The View Menu – Input Data Screens

The View Menu is used to switch among the various data screens to verify and possibly modify your data.

1. *Alignment Data.* The "Alignment Data" Option (not visible from the Alignment Screen) is used to bring forward the Alignment Screen. The Alignment Screen can be used to change alignment level data; however, alignments cannot be added. (Alignments can be deleted by setting their likelihood of inclusion equal to zero.) You can use the $<ctrl> + L$ keys as a shortcut.

2. *Basic Data.* The "Basic Project Level Data" Option is used to bring forward the Basic Data Screen. The Basic Data Screen displays project level data, which are data not related to specific parcels. You can use the *F2* key as a shortcut.

3. *Parcel Data.* The "Parcel Related Data" Option is used to bring forward the Parcel Data Screen. The Parcel Data Screen displays parcel specific data. You can use the *F3* key as a shortcut.

4. *Possession Time/Cost Data.* The "Possession Time/Cost Data" Option is used to bring forward the Parcel Possession/Cost Data Screen. This screen displays possession time and possession cost distributional data for each parcel. Possession time refers to the number of months from the ROW release to the actual possession of the parcel. The cost refers to the final purchase price of the parcel including the cost of land, cost of improvements, cost of damages, and any court costs or outsourcing costs, if relevant. It

does **not** include the cost of any improvements that are projected to be made during Plan Authority or Develop Authority phases of the project. The only data that can be changed on this screen are the mean values, standard deviation values, and multipliers. The other values listed on the screen are for information purposes only. Once the Parcel Possession Data Screen is accessed, the parcel name cannot be changed nor can parcels be added or deleted. You can use the *F4* key as a shortcut.

5. *Detailed Results*. The "Detailed Output Data" Option is used to bring forward the Detailed Results Screen. The purpose of TAMSIM is to simulate several replications of the right-of-way acquisition process. Each replication involves generating times, costs, and possession method according to the probability distributions given by the input data. The results of each replication are displayed on the Detailed Results Screen. (The various replications are viewed by use of the drop down menu located just under the heading.) You can use the *F6* key as a shortcut.

6. *Summarized Results*. The "Summarized Output Data" Option is used to bring forward the Summary Statistics Screen. The results from the simulation run are summarized in the Summary Statistics Screen. You can use the *F7* key as a shortcut.

The View Menu – Output Data Screens

The View Menu is used to switch among the various data screens to verify your data. (Since the simulation has already been run, no input data can be modified.) Thus, the purpose of this menu is to allow you to review and/or confirm the data used as input to the project.

1. *Alignment Data.* The "Alignment Data" Option (not visible from the Alignment Screen) is used to bring forward the Alignment Screen. The Alignment Screen can be used to change alignment level data; however, alignments cannot be added. (Alignments can be deleted by setting their likelihood of inclusion equal to zero.) You can use the *<ctrl> + L* keys as a shortcut.

2. *Basic Data*. The "Basic Project Level Data" Option is used to bring forward the Basic Data Screen. The Basic Data Screen displays project level data, which are data not related to specific parcels. You can use the *F2* keys as a shortcut.

3. *Parcel Data*. The "Parcel Related Data" Option is used to bring forward the Parcel Data Screen. The Parcel Data Screen displays parcel specific data. You can use the *F3* key as a shortcut.

4. *Parcel Possession Data*. The "Parcel Possession Data" Option is used to bring forward the Parcel Possession Data Screen for each individual parcel. You can use the *F4* key as a shortcut.

5. *Detailed Results*. The "Detailed Output Data" Option is used to bring forward the Detailed Results Screen. The purpose of TAMSIM is to simulate several replications of the right-of-way acquisition process. Each replication involves generating times, costs, and possession method according to the probability distributions given by the input data. The results of each replication are displayed on the Detailed Results Screen. (The various replications are viewed by use of the drop down menu located just under the heading.) You can use the *F6* key as a shortcut.

6. *Summarized Results*. The "Summarized Output Data" Option is used to bring forward the Summary Statistics Screen. The results from the simulation run are summarized in the Summary Statistics Screen. You can use the *F7* key as a shortcut.

The View Menu – Possession Times Data

The View Menu is used to switch among the various data screens to verify your data. Once the Parcel Possession/Cost Data Screen has been accessed, it is not longer possible to add or delete parcels. Thus returning to the Parcel Data Screen allows the user to view or modify all data except for the name; however, some of the data on the Basic Data Screen cannot be modified after accessing the Parcel Possession/Cost Data Screen.

1. *Alignment Data.* The "Alignment Data" Option (not visible from the Alignment Screen) is used to bring forward the Alignment Screen. The Alignment Screen can be used to change alignment level data; however, alignments cannot be added. (Alignments can be deleted by setting their likelihood of inclusion equal to zero.) You can use the *<ctrl> + L* keys as a shortcut.

2. *Basic Data*. The "Basic Project Level Data" Option is used to bring forward the Basic Data Screen. The Basic Data Screen displays project level data, which are data not related to specific parcels. You can use the *<ctrl> + B* keys as a shortcut.

3. *Parcel Data*. The "Parcel Related Data" Option is used to bring forward the Parcel Data Screen. The Parcel Data Screen displays parcel specific data. You can use the *F2* key as a shortcut.

4. *Detailed Results*. The "Detailed Output Data" Option is used to bring forward the Detailed Results Screen. The purpose of TAMSIM is to simulate several replications of the right-of-way acquisition process. Each replication involves generating times, costs, and possession method according to the probability distributions given by the input data. The results of each replication are displayed on the Detailed Results Screen. (The various replications are viewed by use of the drop down menu located just under the heading.) You can use the *F6* key as a shortcut.

5. *Summarized Results*. The "Summarized Output Data" Option is used to bring forward the Summary Statistics Screen. The results from the simulation run are summarized in the Summary Statistics Screen. You can use the *F7* key as a shortcut.

APPENDIX C – EROW HELP INFORMATION

EARLY RIGHT OF WAY (EROW) BUDGET OPTIMIZATION TOOL

This optimization tool solves for optimal budget allocation among a set of projects for which each is considered under a series of early acquisition scenarios (versions) for a range of possible early acquisition total budgets. The application requires the input from two text files created by TAMSIM, one containing all associated cost data and the other containing all associated savings data for the set of projects being considered. The results provided by EROW give guidance for selecting a budget allocation for early right-of-way acquisition.

PROJECT INPUT TAB

• Budget Data

Enter values to define the range for the allowable early acquisition budget solution: the minimum allowable early acquisition budget, the maximum allowable early acquisition budget, and the increment size to be considered between these limits. Currently, the program will handle up to 10,000 increments. Guidance is provided for the user below the increment data entry field to assist in selecting an increment meeting this limitation.

• Results Options

The results options box contains two checkboxes for selecting information to be displayed under the results tab.

If the first box is checked, the results to be displayed will include the selected version for each project in addition to the savings to be obtained from each early acquisition budget level being considered.

If the second box is checked, EROW will estimate the rate of return to be realized from each increase in budget from the prior budget option analyzed. The rate of return realized from this additional budget amount is then compared to the minimal attractive rate of return (MARR) specified by the user. When the rate of return realized from the amount of budget increase does not exceed the MARR, this incremental budget is eliminated as a possible total budget solution.

• Cost Data

The user can browse files to select a text file containing cost data. The rows in the text file correspond to different scenarios for each project. This text file is normally created by TAMSIM and saved for use in an EROW budget analysis.

• Savings Data

The user can browse files to select a text file containing savings data. The rows in the text file correspond to different scenarios for each project. This text file is normally created by TAMSIM and saved for use in an EROW budget analysis.

EXAMPLE INPUT DATA FORMATS

Maximum Budget: 100000

Minimum Budget: 10000

Increments: 1000

If nine early acquisition versions for project 1, six early acquisition versions for project 2, and 11 early acquisition versions for project 3 are considered, the input data will be in the format shown below. The first column of zeros reflects costs and savings involved if a project is not selected for a given solution.

Costs:

0	12115	17061	20604	20989	22078	22861	23241	24067		
0	12856	21831	26125	27195	28204					
0	2145	4075	5390	5508	5599	5705	5800	5901	6027	6160

Savings:

0	6536	9830	12966	13894	15862	18708	20040	23603		
0	5189	8579	11073	13957	16561					
0	1191	2285	3230	3804	4293	4844	5305	5788	6291	6885

RESULTS TAB

The results tab displays the total savings estimated from optimal use of each early acquisition budget being considered, starting with the minimum allowable budget solution and continuing in increments up to the maximum allowable budget solution.

If the first box is checked in the results options box, the results to be displayed for each total early acquisition budget being considered includes the selected version for each project that will result in the displayed optimal savings.

If the second box is checked in the results options box, the results being displayed only include early acquisition budgets for which the incremental budget increase met the specified MARR criteria.

A Summary box at the bottom of the results screen displays two of the numerous possible early acquisition budget solutions, the first being the budget solution providing the highest rate of return and the second being the budget solution providing the maximum amount of savings achievable consistent with the budget limitations and the MARR if one is specified by the user.

The computational results can be plotted by clicking on the "Plot Results" button. Peaks in the rate of return plot indicate more favorable early acquisition budget options. The computational results can be saved in a simple tabular format by clicking on the "Save Results" button.