A Dynamic Programming Optimization Approach for Budget Allocation to Early Right-of-Way Acquisitions

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Maximizing potential savings when purchasing right-of-way within a limited budget is a challenge currently faced by state departments of transportation (DOTs) across the nation. Early right-of-way acquisitions promote smoother negotiations and are aimed to save money, time, and human resources. This paper describes an optimization approach based on dynamic programming developed for the Texas Department of Transportation (TxDOT) to identify projects with candidate parcels for early right-of-way acquisition in order to achieve the highest potential savings. Each candidate parcel must be subjected to a preliminary environmental analysis to ensure that each comply with the National Environmental Policy Act (NEPA) standards.

INTRODUCTION

Early right-of-way acquisitions promote smoother negotiations and are aimed at saving money, time, and human resources. Property improvements, speculation, and damages to remainders of properties are some of the major factors that increase the cost of right-of-way acquisitions. The Texas Department of Transportation (TxDOT) found that property costs double, triple, or more after property improvements, speculation, and damages to remainders of properties occurs. Some of the methods used to increase the cost of the properties include the subdivision of the property to sell more units at higher per unit cost and the development of the property to add more value to it (TxDOT 2009).

Early right-of-way acquisitions are intended to improve project efficiency and promote smooth negotiations; although sometimes condemnation cannot be avoided to acquire the land, causing a delay in the project and rougher negotiations with the owners. However, condemnation rates can be decreased by improving the valuation and negotiation processes (Caldas et al. 2011). Early right-of-way is an option to consider due to anticipated property cost increases; however, its use is constrained by laws and policies. Not all parcels are candidates for early right-of-way acquisition and each candidate parcel must be subjected to a preliminary environmental analysis to ensure compliance with the National Environmental Policy Act (NEPA) standards.

Purchase of right-of-way transportation projects must consider the environmental, social, economic, and political aspects of each project. This paper provides an insight into the parcel selection process to start early negotiations in order to maximize DOTs savings. A dynamic programming optimization method was applied to optimize the selection of the best candidate parcels with the highest rate of returns from early acquisition. A software called Early Right-of-Way (EROW) is the decision tool used to support this concept. EROW analyzes the optimal projects needed to be purchased in early right-of-way acquisition in a given scenario. The model used by EROW has the ability to input the project's costs, expected savings, and available budget for early right-of-way acquisitions. Savings are defined as the difference in budget between the early right-of-way scenario and the traditional right-of-way acquisition process. Each parcel included in the candidate list for early right-of-way acquisition must comply with NEPA's standards; this should be analyzed by performing a preliminary environmental analysis prior to the selection of candidate projects. The model identifies the parcels that may lead to higher savings; the final selection of projects should always be performed by the decision maker based on the individual characteristics of each project.

BACKGROUND

The process of acquiring right-of-way for a construction project can considerably impact the project's completion time and overall cost. The degree of impact to these important considerations fluctuates due to the number of variables associated with the project and individual parcel characteristics. One of the ways to reduce potential negative impact on time and cost from the right-of-way acquisition portion of the project is to acquire portions of the right-of-way early. U.S. DOTs have limited authority to acquire right-of-way prior to completion and approval of the 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 (TxDOT 2009). In addition to the challenges associated with limited ability to purchasing parcels early in the project planning process, no systematic analytical approach is available to decide when to allocate funds for early right-of-way acquisition. However, 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 costs. TxDOT research project 0-5534 (2009) documented some examples of increase in land costs:

- Example 1: 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.
- Example 2: A parcel cost increased from \$0.17/sq-foot up to \$0.23/sq-foot in three years.
- Example 3: A parcel cost for pasture land went from \$7,000 per acre to \$22,000 per acre in three years.
- Example 4: Total parcel costs for a group of parcels went from an estimated \$5.4 million to \$10 million when not acquired early.
- Example 5: Total parcel costs for a group of parcels went from an estimated \$5 million to \$15 million (Krugler et al. 2010).

It was concluded that property improvements, speculation, and damages to remainders of properties are some of the major factors that contribute to increases in land costs (TxDOT 2009). For this reason, the valuations of properties and the negotiations with property owners are two important aspects in the right-of-way acquisition process for transportation projects. If the valuation and negotiation processes are improved, the overall project delivery efficiency can increase due to a decrease in condemnation rates (Caldas et al. 2011).

LITERATURE REVIEW

Efficient allocation of resources is a critical component of successful transportation asset management practice. Since optimization is a mathematical approach that minimizes cost or maximizes benefit while satisfying pre-given constraints, it is adopted for many transportation problems including, the capital budgeting allocation problem. There are some publications on funding allocation, but none regarding the application of dynamic programming to right-of-way acquisitions. Armstrong and Cook (1979) developed a model for a single-year planning period. In this model, the objective was to maximize the total benefit from the highway subjected to fixed budget constraints. Later it was expanded to consider multiple planning years by using a financial planning model and a goal programming approach (Cook 1984). In contrast to maximizing benefit, another approach is to seek a solution minimizing total project costs. Davis and Van Dine (1988) developed a computer model to minimize user costs subject to budget and production capacity constraints for optimizing maintenance and reconstruction activities. They used linear programming formulation as an optimization technique. More recently, advanced computing power allows optimization techniques to solve more realistic and sophisticated pavement management problems, which is a part of a larger decision-support system. Ferreira et al. (2002) formulated a mixed integer optimization model for network-level Pavement Management Systems (PMS). They used genetic-algorithm heuristics to solve the optimization problem, minimizing the expected total discounted costs of pavement maintenance and rehabilitation actions over a planning period. Heuristic methods are used in optimization problems in order to provide an approximate answer to the problem when the optimal solution is very difficult to find. A Genetic Algorithm (GA) is an adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. The GA exploits historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution, especially those that follow the principles first laid down by Charles Darwin of "survival of the fittest," i.e. optimal answers. Wang et al. (2003) also used genetic-algorithm heuristics to solve the zero-one integer programming formulation, which is a special optimization case where the problem's solution is required to be 0 or 1.

As described before, resource allocation problems are among the classical applications of optimization techniques. However, the complexity of real-world problems associated with resource allocation in right-of-way acquisitions limits the applicability of classical methods. Few research efforts were found for right-of-way acquisition. A research report published by the Minnesota Department of Transportation addresses the question of whether there are financial benefits to acquiring transportation right-of-way far in advance of when the improvement will be done (MNDOT 2005). The main findings of this report suggest that early acquisition is recommended under the following conditions:

- Developed land that is in danger of being redeveloped to a higher value
- Developed land that is being offered for sale voluntarily
- Undeveloped land that is near developing areas or in desirable recreation areas and may appreciate rapidly enough to justify early acquisition
- Undeveloped land that is expected to be developed
- Land along major transportation corridors that may appreciate more rapidly than land in general in the vicinity

Hedonic price models to estimate the cost of right-of-way acquisition were proposed in Texas taking into consideration data from several corridors and commercial sales transactions in the state's largest regions. The findings showed that the value of improvements were more important to costs than the size of the parcels, and that utility costs were highly variable (Heiner and Kockelman 2005). Furthermore, an electronic appraisal methodology for right-of-way acquisition in highway projects has been suggested in order to improve the appraisal process and reduce the likelihood of inconsistent appraisal values (Caldas et al. 2012). Before any appraisal valuation takes place, DOTs must select the parcels that will be considered in the right-of-way acquisition process. Due to limited funding for ROW acquisition of transportation projects, decision makers must ensure that the projects selected for early right-of-way acquisition are the most cost efficient projects, represented by higher rate of return.

No optimization techniques for early right-of way allocation are mentioned in these reports. A dynamic programming optimization approach to optimize right-of-way acquisitions to maximize savings is presented in this paper. Dynamic programming is a method to solve complex problems by breaking them down into simpler interrelated sub-problems that affect the overall decision making process. The approach is based on a comparison of anticipated rates of returns from acquiring right-of-way at a certain time to a rate of return expected from other potential uses of the evaluated budgetary amount.

BUDGET ALLOCATION FOR EARLY RIGHT-OF-WAY ACQUISITION

Early acquisition of right-of-way is defined as the purchase of parcels before the approval of the environmental study. Early right-of-way acquisitions foster smoother negotiations, and save money, time, and human resources (TxDOT 2009). Projects considered in the early acquisition must not represent a hard case in environmental approval; this can be analyzed by performing a preliminary environmental analysis of the candidate projects under the National Environmental Policy Act (NEPA) regulations. It ensures that federal agencies consider the effect of their actions on the quality of the human environment and sets standards that must be met by these agencies in order to receive federal funding (NEPA 2012). In the process of early acquisition, because no environmental approval has been made, federal funding cannot be used to buy these properties. Therefore, the state DOT must provide its own money to buy the parcels selected in early acquisition and must wait for the environmental approval in order to receive federal reimbursement. All projects bought during the early or normal right-of-way acquisition must comply with NEPA's standards prior to receiving federal funding or reimbursement. Early right-of-way acquisitions are performed only under the following cases: to alleviate a particular hardship to the property owner, to prevent imminent parcel development, and as donations. Early acquisition does not avoid the environmental review of a project, influence a decision regarding the need to construct the project, or the selection of a specific location (TxDOT 2011).

A significant amount of cost savings are expected when parcels are purchased early in the right-of-way acquisition process. If a good property valuation and a good negotiation with the property owner take place during the early right-of-way acquisition, the likelihood of taking the parcel by condemnation or of delaying the project will be reduced due to the successful purchase (Hakimi and Kockelman 2005). Experiences of TxDOT show that cost savings could easily double the funds invested in purchasing selected parcels earlier when compared with the normal procurement process (Krugler et al. 2010).

Expected costs and savings resulting from early acquisition of a specified number of parcels included in a given right-of-way project is usually estimated by experienced personnel in the state DOTs. Knowledge of the characteristics associated with each individual parcel is essential for a good estimate. Among these characteristics are: location of the parcel, type of right-of-way acquisition process (either through negotiation or condemnation), time at which the parcel is acquired, ownership of the parcel, and likelihood of future improvements made on the parcel before acquisition. The cost estimation process is quite difficult due to the complex interaction among the factors that affect acquisition of the parcels, especially when parcel cost increases could be driven up by land speculation, a fairly common situation where transportation improvements are planned. These factors were considered in the study and included when calculating costs and potential savings.

When funds available for projects are constrained, senior managers in state DOTs face a difficult situation, making hard decisions on where and how to invest the limited budget. The levels of expertise of managers as well as tools available to conduct funding allocation are crucial to stretch the budget. In this situation, optimization methods can assist managers in selecting the set of projects with the highest rate of return. The rate of return (ROR) of an investment is the interest rate at which the net present value (NPV) of costs, i.e., negative cash flows, equals the NPV of the benefits, i.e., positive cash flows in the investment. In this case study, ROR was calculated as the ratio between the expected savings to the expected costs of a given project.

Numerous projects and parcel options are taken into consideration from a statewide perspective, and to obtain a broader based optimal solution, all possible scenarios must be included in a system-level optimization model, to ensure that at most only one of the scenarios corresponding to each critical project will be selected. The problem becomes more complex when the number of projects is large and budget constraints are taken into account. In fact, the resulting combinatorial optimization problem is known as NP-hard, meaning that the problem is computationally intractable in theory. Despite this discouraging theoretical property, the problem can be solved in practice by using pseudo-polynomial dynamic programming (DP) algorithms to output cost savings for all possible budget scenarios. Dynamic programming is a method to solve complex problems by breaking them down into simpler sub problems. It solves different parts of the problems, called sub problems, and then combines the solutions of the sub problems to get an overall solution. Furthermore, the use of pseudo-polynomial algorithms simplifies the problem even more by only storing and calculating the values that meet all the criteria, reducing running time.

DYNAMIC PROGRAMMING OPTIMIZATION FOR EARLY RIGHT-OF-WAY ACQUISITION

Dynamic programming (DP) is a methodology used to solve a large-scale problem by breaking it down into a number of smaller problems, which can then be solved in a recursive fashion. The nature of the early right-of-way acquisition process fits very well with the use of DP algorithms, which share the following common characteristics:

- The early right-of-way acquisition problem can be subdivided into separate stages.
- There are a number of states and possible early right-of-way scenarios associated with each stage. The division of sequence of an optimization problem into various subparts is called stages. A state is a measurable condition of the system; in this problem, a state represents the budget available for project funding.
- At each stage of the right-of-way acquisition process, a decision is made to move from the current to the following stage.
- An optimal decision at each state does not depend on the previous decisions or states since the right-of-way acquisition process is unique and depends on each individual parcel characteristics as discussed before (principle of optimality).
- There is a recursive relationship representing the optimal decision for each state of the right-of-way acquisition process at stage i in terms of previously computed optimal decisions for states at subsequent stages *i+1*, *i+2*, … (for backward recursion). Backward recursion is used to determine the list of optimal actions needed to solve the problem using a backwards sequence. It considers the last time a decision is made and computes its possible outcomes; then, it analyzes the second-to-last decision in the same manner. This process continues until every possible scenario is analyzed.

The resource allocation problem being dealt with in right-of-way funding allocation can be viewed as a modified version of the knapsack problem, in which a given set of N items, in our case projects, can be placed in a knapsack of a certain budget capacity *B*. Each project *i* is characterized by its cost c_i and its savings s_i. Savings is defined as the monetary value that the agency might save if a given parcel is bought during early right-of-way as compared with a scenario where no early right-of-way parcels are bought. Savings is an input that must be given to the EROW software. It can be calculated based on expert judgment, simulations, or any other method.

The dynamic programming optimization model was a result of a four-year study sponsored by TxDOT and validated through a one-year implementation project with reasonable results, demonstrating its applicability for early right-of-way acquisition decisions. The objective of the dynamic programming problem is to find the parcels from each project to maximize savings while staying within the budget constraint, while total acquisition costs of selected project scenarios must be less than or equal to the total available budget. The problem is formalized as follows:

(1) Maximize $\sum_{i=1}^{N} \sum_{j \in S_i} s_{ij} x_{ij}$

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

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

where:

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 $x_{ij}=0$ if the j-th scenario of project i is not selected. The DP stages correspond to projects, and the state b_i at stage i will represent the budget available for projects $1\dots i$ using forward recursion. Forward recursion is the method to solve a problem that is decomposed into a series of n stages and analyzes the problem starting with the first stage in the sequence, working forward until the last stage is analyzed. 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 $1, \dots, i$.

Incremental rate of return (IRR) analysis is used to compare investment alternatives to the specified minimum attractive rate of return (MARR). The MARR is the minimum rate of return on a project a manager or company is willing to accept before selecting a project, taking into account the risk and the opportunity cost of not accepting other projects. In this case study, MARR was determined by calculating the average ratio of annual benefits to initial investment of various projects. In order to illustrate this concept, consider an example with two alternatives: Alternative 1 and Alternative 2. Alternative 1 has a base list of given ROW projects and Alternative 2 shows the same list of projects plus some extra projects that might be bought if additional funds were allocated. 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. The incremental rate of return analysis allows comparison of alternative early right-of-way acquisition funding scenarios to determine the optimal budget. Optimal budget is given by the total amount of money needed to buy the ROW projects that will maximize the incremental rate of return.

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 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; therefore, discretization is used to transfer the model from continuous to discrete equations to make the model easier to analyze. Notation $b_i = b,\dots, B$ will mean that b_i takes on all possible funding 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 $b_i = 0,\dots, B$:

$$(2) \qquad v_i(b_i) = \begin{cases} 0, & if\ i = 0 \\ max\{s_{ij} + v_{i-1}(b_i - c_{ij}) \mid j \in S_i\}, & if\ 0 < i \le n \end{cases}$$

By solving this recursion for all projects starting from the first project to the last, the computational results for $v_n(b_n), b_n = b, \ldots, B$ will represent the optimal solution for all the considered budget increments. This dynamic optimization model was used to develop a software tool for Early-Right-of-Way Acquisition (EROW). EROW was developed at Texas A&M University to assist TxDOT in selecting projects under different right-of-way acquisition scenarios.

USING EROW TO IDENTIFY EARLY RIGHT-OF-WAY ACQUISITION PROJECTS

EROW input parameters include the maximum and minimum possible early right-of-way acquisition budgets and the budget increment size (interval between the maximum and minimum budgets). The costs and savings for each project scenario are also entered as well as the minimum attractive rate of return. A project scenario is defined by certain number of parcels acquired early.

A one-year implementation project was conducted with the participation of right-of-way personnel in each of the four TxDOT regions. The project objective was to apply EROW to analyze three construction projects with candidate parcels for early right-of-way acquisition. Project 1 is located in a metropolitan county in Houston and contains 28 parcels. Project 2 is located in an urban county in Austin and contains 20 parcels. Project 3 is located in an urban county in Dallas and contains 10 parcels.

EROW was used to compare the three construction projects under 10 possible parcel acquisition scenarios. In this example, only the 10 parcels with the highest rate of return per project were considered. Table 1 shows the costs and savings under each scenario for all three projects. Scenario 1 is when one parcel was acquired early. Scenarios 2 through 10 correspond to two to 10 parcels acquired early—one additional parcel acquired per scenario. Table 1 shows the costs of each scenario, which are merely the sum of the parcels that were considered. The savings shown is the difference in the budget produced by early right-of-way as compared to the case where no early right-of-way is used. Savings are calculated using historical data of previous acquisitions and based on expert feedback. Table 1 shows very high potential savings in the projects of Houston and Dallas because these parcels were mainly commercial and had a high likelihood of improvement and speculation.

Table 1: Data Inputs for Project Costs and Savings Under Different Right-of-Way Acquisition Scenarios

	Number of Parcels Acquired	Project 1-Houston		Project 2-Austin		Project 3-Dallas	
		Cost ($)	Savings ($)	Cost ($)	Savings ($)	Cost ($)	Savings ($)
Scenario 1	1	183,821	171,683	1,539	1,051	16,781	44,653
Scenario 2	2	450,444	418,850	5,292	2,604	108,594	286,675
Scenario 3	3	8,576,594	7,600,182	11,585	4,629	115,371	296,380
Scenario 4	4	9,123,858	8,043,000	16,327	6,029	119,868	302,611
Scenario 5	5	9,573,150	8,405,204	598,716	154,593	132,756	320,446
Scenario 6	6	9,737,632	8,532,623	622,080	161,031	144,755	336,302
Scenario 7	7	9,952,620	8,679,954	635,515	165,187	196,087	395,963
Scenario 8	8	10,120,755	8,792,406	674,702	175,171	197,086	398,280
Scenario 9	9	10,250,046	8,878,657	675,761	175,593	263,432	440,842
Scenario 10	10	11,100,703	9,413,069	1,099,439	270,938	327,902	568,036

Therefore, if acquired early, these parcels would produce more savings as compared with the case where no parcels are bought during early right-of-way acquisition.

Optimal Solutions

Further analysis was conducted to find optimal solutions corresponding to different early right-of-way acquisition budget alternatives. The total budget available was $1,000,000 and the lower bound on the budget was $100,000. The MARR was set by TxDOT at 20% based on the results from a study that concludes that the rate of return for transportation projects is around this range based on the new direct and indirect jobs created and the aggregate annual income increase due to the highway construction and indirect jobs created (Governor's Business Council 2006). EROW performs an IRR analysis to 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. In this analysis, the project scenarios providing the best rate of returns for each possible budget solution are identified. Using the input costs and savings from Table 1, the EROW software was run under the given budget and MARR constraints in order to maximize the IRR. Table 2 shows the rate of return, budget required, and total savings values for budget solutions corresponding to each optimal solution given by the EROW software.

Table 2: Summary of Optimal Solutions at Different Funding Levels

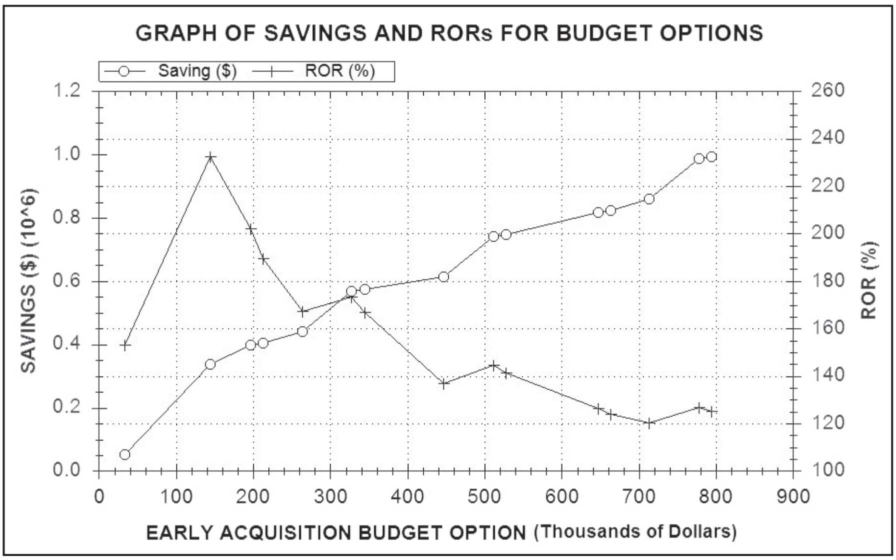
Funding Level ($)	Total Resulting Expenditure ($)	Total Resulting Savings ($)	Rate of Return (%)	Project 1 Houston	Project 2 Austin	Project 3 Dallas
100,000	33,108	50,682	153.08	-	Scenario 4	Scenario 1
150,000	144,755	336,302	232.32	-	-	Scenario 6
200,000	197,086	398,280	202.08	-	-	Scenario 8
250,000	213,413	404,309	189.45	-	Scenario 4	Scenario 8
300,000	263,432	440,842	167.35	-	-	Scenario 9
350,000	327,902	568,036	173.23	-	-	Scenario 10
400,000	344,229	574,065	166.77	-	Scenario 4	Scenario 10
500,000	447,253	612,525	136.95	Scenario 1	-	Scenario 9
550,000	511,723	739,719	144.55	Scenario 1	-	Scenario 10
650,000	528,050	745,748	141.23	Scenario 1	Scenario 4	Scenario 10
700,000	647,530	817,130	126.19	Scenario 2	-	Scenario 8
750,000	663,857	823,159	124.00	Scenario 2	Scenario 4	Scenario 8
800,000	713,876	859,692	120.43	Scenario 2	-	Scenario 9
850,000	778,346	986,886	126.79	Scenario 2	-	Scenario 10
900,000	794,673	992,915	124.95	Scenario 2	Scenario 4	Scenario 10

Table 2 shows the budget required to buy the parcels indicated in each project, i.e., the budget required is the sum of all the scenarios needed in all three projects to obtain the given rate of return under the given funding scenario. Total resulting savings indicates the money that will be saved due to the early acquisition of the parcels indicated in each scenario. Table 2 also shows the rate of return of the investment, which is merely the ratio of total savings to total expenditures of each case. For example, if the funding level is $550,000 then the total expenditure needed to maximize the rate of return is $511,723 and the resulting savings of this purchase is $739,719, which produces a rate of return of 144.55%. In order to have this rate of return, it is needed to buy the parcels on Scenario 1 from Houston and the parcels on Scenario 10 from Dallas.

From Table 2, it is observed that the best rate of return is given by Project 3, Scenario 6 with 232.32%. This rate of return occurs when the funding scenario is $150,000. This means that funding should be allocated primarily to six parcels in the Dallas project. The rates of returns shown are very high because the parcels chosen under each budget scenario were primarily commercial with a high likelihood of improvement and speculation. The budget estimates and funding recommendations based on EROWs were consistent with expert opinions from TxDOT's ROW personnel, including appraisers and planning staff.

Figure 1 shows 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.

Figure 1: EROW Output Plot Example



Peaks indicate favored budget solutions from a rate of return standpoint. Wherever the peaks occur, the represented funding scenario offers rate of return advantages over the budgets represented by valleys in the chart. It is observed that the highest rate of return may occur at a funding scenario rather low in the allowable budget range for the analysis. When this occurs, the user may prefer a lower rate of return at a considerably higher early right-of-way acquisition budget. Parcels with rates of return lower than MARR for a parcel should not be considered for early right-of-way acquisition. MARR is determined by the agency based on its own experience, and for TxDOT, the expected MARR is between 20%-25%. The outcome of the analysis is not sensitive to MARR since the IRR for all funding levels is several multiples higher than 20%.

CONCLUDING REMARKS

Efficient allocation of resources is critical for state DOTs, even more when budget limitations are experienced. Early right-of-way acquisition is considered a valid option to obtain substantial cost savings when buying parcels. However, the complexity and variability surrounding the acquisition of right-of-way parcels made this type of analysis extremely difficult and not all projects are qualified to use the early right-of-way acquisition process. In order to qualify for this process, a preliminary environmental analysis of the candidate projects under the NEPA regulations must be performed. Candidate parcels considered for early right-of way acquisition must show compliance with NEPA's standards. Furthermore, early right-of-way parcels must only be bought to alleviate a particular hardship to the property owner, to prevent imminent parcel development, and as donations. Early right-of-way acquisitions are intended to improve project efficiency and negotiations and avoid the condemnation process if possible. The use of a dynamic programming optimization approach allows comparing different right-of-way acquisition scenarios, to optimally allocate funds among candidate projects for a given funding scenario. The dynamic programming optimization model was a result of a four-year study sponsored by TxDOT and validated through a one-year implementation project with reasonable results, demonstrating its applicability for early right-of-way acquisition decisions.

Given the planning time horizon and the right-of-way sites to be acquired, the optimal solutions generated by the model for different budget levels can assist state DOTs make more efficient right-of-way acquisitions decisions through:

- Determination of which right-of-way projects within a district offer the greater potential for substantial savings.
- Determination on a statewide basis of candidate projects and their optimal number of parcels for early right-of-way acquisition.
- A sensitivity analysis varying the input parameters to analyze multiple right-of-way acquisition funding scenarios for different sets of projects providing managers with a broader perspective, and making explicit the previously hidden factors affecting cost savings.
- When selecting which parcels were going to be acquired early, the size of the parcel, the owner (private, public, military, government), project location (metropolitan, urban, rural county), and likelihood of improvements become relevant factors.

The model identifies the candidate parcels that may lead to potential higher savings; such parcels must meet the criteria of early right-of-way acquisitions to be considered in the analysis. A preliminary environmental study must be performed on the candidate parcels before considering them for early right-of-way acquisition. The final selection of projects should always be performed by the decision maker based on the individual characteristics of each project.

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