VALUE OF TIME SAVED FOR USE IN CORPS PLANNING STUDIES

A REVIEW OF THE LITERATURE AND RECOMMENDATIONS

by

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Executive Summary

The value of time saved is an important component in water resources planning studies. It is used for evaluating benefits of projects that reduce the travel time between origins and destinations. Conversely, it is also used to calculate additional National Economic Development (NED) costs that construction of a project may incur, via increasing travel time through traffic delays.

Public use of the value of time in transportation studies dates back to the early part of the twentieth century when a constant value per hour was administratively set for simplicity. Since that period, research attempting to estimate the value of time intensified with the growing use of both the automobile and with economic analysis as a tool in the project decision making process. Many methodologies and corresponding values were derived, both in the U.S. and the U.K., resulting in as many estimates as studies. Some methods derive a constant unit value of time to be multiplied by the time differential, while others have developed values dependent on the magnitude of time differential involved, the purpose of trip, or income levels. This lack of cohesion in methods and values has caused confusion as to how to evaluate time in travel, what value to assess it at, and in what direction should future research take. Furthermore, the lack of precision in evaluating the value of time "saved" or "lost" creates miscalculations in benefits or costs, respectively, which ultimately are used in deciding the worthiness of a proposed project.

This paper provides a review of past research, and assesses the methodologies used based on their comprehensiveness, economic soundness, and conduciveness for Corps

planning procedures. The review provides insight into the diversity of methods employed and variance of corresponding results. However, it also illuminates the underlying similarity in the conceptual frameworks of the models.

The Thomas and Thompson model and results, based on the criteria given, was judged to be the most comprehensive, logical and applicable to Corps purposes. The study provides results whose values depend on the consumer's income, purpose of trip, and trip duration. Additionally, the conclusion reached in this review corresponds with the previous endorsement of the model and results by the American Association of State Highway Officials (ASSHO). The results from Thomas and Thompson are updated for price changes and are recommended for use in Corps studies that require evaluation of automobile traffic delays.

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I. INTRODUCTION

The value of time saved is frequently used in water resources planning studies for evaluating the benefits of projects that reduce the travel time between origins and destinations. For projects with outdoor recreation as an output, the value of time saved is an integral part of the evaluation when the travel cost method (TCM) of benefit evaluation is used. In addition, flood control projects can reduce the incidence or duration of transportation disruptions, particularly for the journey to work. By preventing flooding to the shortest route, a project creates a savings in travel time and, therefore, produces a benefit to the project. Projects that require the modification of bridges may incur traffic delays during construction. This results in an addition to travel time and in an additional National Economic Development (NED) cost of the project.

Realization of the importance of the value of time saved was established in the early part of the twentieth century by the Bureau of Public Roads. Primarily resulting from Henry Ford and the assembly line process, the number of automobiles in the U.S. exceeded one million by 1913. In response to the resulting increased demand for highways and road improvements state and local governments increased their expenditures on these public goods. By 1917, these expenditures reached $68 million per year. By the mid 1920's, due to the increasing costs associated with this continued growth in the number of automobiles, economic analysis began to be used as a valuable tool in making decisions on which projects to build. The amount of time saved was recognized as a major justification for public expenditures on highways. In order to be used in economic analysis, a unit of an hour's savings of time had to be converted into a numerical dollar value. In 1925, this value was set for the average vehicle. This value held as the official standard until 1960 when a report by the American Association of State Highway Officials (AASHO) recommended a value of $1.55 per hour per car ($0.86 per person per hour multiplied by 1.8 persons per car) be used as a "representative value of current opinion for a logical and practical estimate" (AASHO 1960).

Since 1960, the importance of the calculation has expanded directly with the amount of expenditure. As Bishop and Heberlein (1979) pointed out in their study comparing TCM with contingent value method (CVM) results, for TCM "total consumer surplus is nearly four times as large when time costs are added at half the income rate, as when time costs are set at zero." This implies that failure to account for the value of time saved could understate economic benefits by as much as 75%. Clearly, the accuracy of the value of time is important to assure accurate and unbiased estimates of project benefits. Yet, the precision and conformity of the research in the field has not progressed as fast nor as decisively as the need. The range of different methodologies and subsequent derived values varies as widely as the number of studies themselves. This creates ambiguity in selection of the proper methodology to use and the appropriate value to assess time. An incorrect or highly biased value of time will lead to either an overestimation or underestimation of the benefits, depending on whether the value of time is biased upward or downward, respectively. Consequently, miscalculation could have adverse effects on the efficiency of the provision of a publicly produced good, by either overproducing a good when time is overvalued, or underproducing a good when time is undervalued.

In the following sections a number of studies that attempt to measure the value of time are reviewed. The methodologies, results, and applicability to Corps planning are used as the criteria for evaluation. The final section recommends a value of time, based on a theoretically sound approach, for use in Corps planning studies. Lastly, Appendix B provides an example application of the recommended time values.

II. INDIRECT METHODS

The majority of the studies reviewed derive the value of time through indirect means. In these models, the value of time is inferred from observing consumers who reveal their money-time tradeoff based on individual preferences. However, different models use variations in consumer choices to express this exchange. For instance, some studies use faster, more expensive private transport versus slower, cheaper public transport, while others observe the consumer choice between faster toll routes and slower free roads. Nonetheless, the basic premise is that consumers reveal their preferences by choosing an alternative, and in doing so, disclose their true perceived money value of time saved at that moment.

a. Journey to Recreation Sites

One of the most important uses of the value of time is in the application of TCM in recreation studies. This method was designed to measure the benefit to consumers of the recreational facilities they used. The method uses variations in the distance to recreation sites of different users and their frequency of visitation to estimate the unobserved economic value of the recreation site. The method has developed some consistency in its assumptions over the years based on the general acceptance in the conclusions of previous work. For instance, time in transit should be considered as a separate independent variable. This time multiplied by the value of time represents part of the cost of visiting a recreational site and should be added to the other costs of visitation. A project that reduces this time provides a benefit in the form of reduced costs of the recreational experience. Furthermore, the greater the value of time, the larger the calculated benefit resulting from taking a given number of trips. Thus, to have a more precise estimation of the benefit derived from a particular recreational site, it is important to develop travel costs inclusive of the value of time.

An important advance in the theoretical basis for the value of time saved in recreation trips was presented by Wilman (1980). She examines the role of time in both on-site costs and travel costs. In this approach, the total time spent on an activity is costly, and the appropriate way to value this time is to segment it, respectively, between opportunity and scarcity costs corresponding to whether the time is spent in travel or in on-site recreation. In her approach two demand curves are considered; one for the recreational experience, which includes the travel experience, and another for the site itself. She makes the normal assumption that travel cost is viewed as a barrier to entry, and develops the prescribed utility function, time and income constraints. The innovation in her model is that the number of trips are constrained to a one-to-one correspondence with the number of visits. From the use of these assumptions, Wilman's model found the marginal (dis)utility of travel time, or what others have termed as the "commodity value of time" to be equal to the term :

$$U_{Z_t} * 1/a_t \qquad (1)$$

where Z_t is the number of round-trips to the site, U_{zt} is the marginal utility of round trips to the site, and a_t is the time requirement per round-trip. The value of time saved is derived by subtracting the commodity value of time from the scarcity value of time. The scarcity value of time, or on-site value of time, is given by the Lagrangian multiplier of the time constraint, cited as γ. The Wilman specification of the value of travel time saved(VTTS) is shown in equation (2):

$$VTTS = \gamma - U_{z_t} * 1/a_t \qquad (2)$$

This formulation is advantageous over others in that it can be used to consider a variety of influences on the value of time saved. Although the value is based on some fixed parameters for a given consumer in a given area, changes in the appropriate variables can be utilized to separate the marginal utility of a trip of a certain length U_{zt}, from the marginal cost of that particular trip. It is then possible to show that variation in some parameters such as a_t, b_t, and Z_t affect the marginal utility of a trip, where b_t is the market good requirement, or out-of-pocket costs, per round trip Z_t. Thus, the marginal utility of a trip and, therefore, the value of time saved, may be said to depend upon the given trip's length. Furthermore, Wilamn assumes that the marginal utility of the trip, U_{zt}, is only a function of the time requirement per round trip and the number of round trips, a_t and Z_t, and that the marginal utility of the recreational experience, U_{zv}, depends only on Z_v, the number of visits of a given length at a given site. It is then possible to assert "how great an increase in the money cost of a trip at a given distance the traveler would be willing to pay to reduce travel time" while maintaining the same level of trips.

Wilman, under these very restrictive assumptions and circumstances, then concludes that on-site time should not be ignored in the travel cost approach. However, if on-site time is included it should not necessarily be valued at the same rate as travel time. On-site time is to be evaluated by the scarcity value of time, whereas the value of time saved is the correct rate for travel time when the marginal utility of travel is non-zero.

McConnell and Strand (1981) provide important insights into the use of the indirect method to determine the value of time in recreational travel. In this study the authors conclude that the opportunity cost of time, or value of time, is some proportion of the individual's market wage rate or income per hour, and that this ratio can be derived from sample data. A closer examination of the modeling framework employed is instructive. Their model assumes the consumer to be a utility maximizer, subject to both time and budget constraints in choosing r, the number of recreational trips. The mathematical representation of this formulation is:

$$\text{MAX } U \equiv U(x,r) \tag{3}$$

respectively subject to:

$$T = ar + w \tag{4}$$

$$[\ F(w) + E\ ] \cdot (1-t) = px + cr \tag{5}$$

where:

- x = a composite bundle of all other goods,
- r = number of recreational trips per T,
- w = the amount of work time,
- F(w) = is income earned from w units of work
- E = is fixed income,
- t = is proportionate income tax rate,
- p = is price of composite bundle of goods (x),
- c = is the out-of-pocket costs per trip, such as gasoline or food,
- T = is the total time available, and
- a = is the amount of travel time per recreational trip.

Equation (5) is the budget constraint indicating that the total after-tax work plus non-work income is spent on market goods and travel, and equation (4) is the time constraint. Maximizing equation (3) subject to constraints (4) and (5), and assuming that price, p, does not vary across individuals yields the demand for recreational trips, r, to be:

$$r = f\ [\ c + a\ (1-t)\ F'(w)\ ] \tag{6}$$

Defining average income as v = [F(w) + E] / w , McConnell and Strand show that if:

(a) the tax rate t is zero;
(b) marginal earnings are constant so that F'(w) = F(w) / w which can be viewed as the wage rate; and
(c) non-work income E is zero;

then the marginal opportunity cost of time is equal to v.

Considering the likelihood of all these conditions being met simultaneously, McConnell and Strand essentially prove that it is improbable that the opportunity cost of time is equal to the average income. Instead, they hypothesize that the opportunity cost of time may be some proportion, k, of average income. The demand function may be restated as:

$$r_i = f(c_i + k a_i v_i) \quad \text{where} \quad 0 < k < 1 \tag{7}$$

Because the authors did not know the exact value for k, and did not want to simply set it equal to some ratio as other studies had done, McConnell and Strand decided to run an ordinary least squares regression on a linear form of the demand equation, written as:

$$r_i = \beta_o + \beta_1(c_i + k a_i v_i) + \beta_3 Z_i + e_i \tag{8}$$

where Z_i is a vector of exogenous variables including a wealth proxy, and e_i is the error term. Rearranging terms, equation (7) can be rewritten as:

$$r_i = \beta_o + \beta_1 c_i + \beta_2 a_i v_i + \beta_3 Z_i + e_i \tag{9}$$

where $\beta_2 = k\beta_1$.

By estimating the values of the parameters in equation (7), k can now be determined as the ratio:

$$k = \frac{\beta_2}{\beta_1} \tag{10}$$

McConnell and Strand tested the model by studying fisherman in the Chesapeake Bay area. Through the derivation of the recreational demand for annual fishing trips per angler, the value of k was estimated to be .612 . This indicated that the anglers' self perceived opportunity cost of time was approximately 61.2% of their average hourly income.

The McConnell-Strand model provides a simple way of estimating the value of time through the cost of travel approach and establishes a theoretical link between the value of time and the hourly income or wage. However, the authors note several shortcomings. The model cannot explain why the opportunity cost of time is related to income for individuals working on a fixed number of hours, such as forty hours a week. Secondly, the model requires the ratio of the opportunity cost of time to income per unit to remain constant for all sample observations. An improvement would be to allow this ratio to vary as a function of the length of trip.

b. Journey to Work

Travel mode choice is frequently studied using the indirect method to infer the value of time saved in non-recreational trips. In these models researchers attempt to infer values from observed actions of consumers as they choose between modes of travel. Typically, consumers are observed choosing between modes that display distinctive characteristics from which the time-money tradeoff is readily observable. One of the first of these studies was performed by Beesley (1965), in which the value of time was estimated for commuting civil servants in London. He hypothesized that there was a single correct estimate for the value of time saved, expressed in terms of x cents per unit. He stated that the correct modal choice occurred when it was not possible to either pay less than x cents to save a unit of time, or to save more than one unit of time while spending x cents, when choosing an alternate mode. He observed two samples of urban commuters choosing between driving to work by private auto versus taking the public bus or train transportation. His results estimated the value of time to vary in an increasing proportion to wage rate, stating that as the wage rate increased, depending on the subject, so did the value of time. The actual numerical estimate of an hour of time was valued between 31% to 49% of the wage rate.

In a similar study, Quarmby (1967) attempted to measure precisely the same tradeoff between the same modes as Beesley had done two years earlier. However, there were significant differences between the studies. Quarmby gathered his data in Leeds, U.K. rather than London, and used discriminant analysis in lieu of minimization of incorrect choices. Quarmby's results suggest that the value of time is lower than Beesley's estimate, representing only 20% to 25% of the average wage rate. He also concluded that the value of time was a constant proportion of the hourly income.

Peter R. Stopher (1968) also reported on a study of commuters' choice of transportation mode in London. Specifically, he observed consumer choice between public train and private automobile. His sample was thus limited to automobile owners. Using regression analysis, he estimated the value of travel time saved as the ratio of coefficients when choosing one mode while regressing it against the time and monetary costs of the other mode. This determines the change in time difference between modes against the specified change in cost difference for the same change in the proportion of commuters using that mode. The resulting value of time saved was found to be 42% of the wage for a high income sample. He tested the model again after segmenting the sample into income brackets, resulting in estimates ranging from 21% to 32% of the wage, with the proportion decreasing with increases in income, and thus contradicting the results by Beesley.

The British studies using the indirect approach to estimate the value of time saved establish a value of time saved between 20% and 49% of the wage rate. In addition, one study indicated that this proportion may not be constant but varies inversely with income levels. Other studies, many of them more recent, are based on cost of travel in the U.S. and provide additional insight into the value of time saved.

One of the most significant U.S. studies was by Lisco (1967). He used the modal choice decision to investigate consumer choice between private automobile versus public train in the Chicago area. Using multiple probit analysis, and including mode time and cost differences as explanatory variables, Lisco estimated the value of time to be 40% to 50% of the wage rate for the observed sample. He found that in relation to income the value of travel time saved decreased proportionally, although the relationship was not statistically significant. In addition, Lisco estimated that the value of time saved for out-of-vehicle time was three times as high as that for in-vehicle time.

Talvitie (1972) reanalyzed Lisco's data using logit, probit, and discriminant analyses. He found that the three different methods of analysis yielded nearly the same estimates for the value of travel time savings at approximately 62% of the sample's average wage rate. However, he noted that when time was segmented into in-vehicle and out-of-vehicle time, the value of in-vehicle time saved was drastically smaller. The value of in-vehicle time saved was estimated to be only 12% to 14% of the average wage rate, while out-of-vehicle time was valued at a much higher rate, approximately seven times as much as the in-vehicle value. These studies suggest that, at least for the journey to work, the value of a project that reduces the amount of in-vehicle time would be overstated by using an average value of time saved.

This result may be misleading, however, since it was based on the transportation choice between public versus private mode. Typically this choice is complicated by issues other than just time saving, especially modal transfer time which may occur in distasteful surroundings. The modal choice approach, generally, has only limited application to the typical water resources planning problem which results in travel time change for a single mode (i.e. personal auto).

Land and housing studies represent another form of the indirect methodology. In these studies, the value of travel-time savings is estimated from the relationship between land or housing prices and the distance to a specified point. The validity of this whole approach rests upon the assumptions of the urban spatial models by Kain (1962) and Muth (1969). The underlying assumption is that people are willing to pay higher prices for more accessible residential locations that reduce their travel time for the journey to work implying a positive cost of using time for travel. These costs are defined in both monetary terms and the value of travel time saved. The first significant study of this kind was done by Mohring and Harwitz (1962). They observed the change in land prices in suburban Seattle due to the construction of a new bridge that significantly reduced travel time from the suburban residential areas to the urban business areas. It was assumed that the price change was due to the capitalization of the reduction in travel time. They estimated the value of travel time saved from the observed change in land prices to be 30 to 65 cents per hour. This value, at 1949 wage levels, represented an estimate of 22% to 43% of the average wage rate.

Pendalton (1963), upon reviewing the Mohring and Harwitz paper, showed that the study was flawed because the increases in land prices used, included the capitalization of a reduction in monetary costs of travel. Noting this, but using the same method as the Seattle study, Pendalton estimated the relationship between housing prices and travel time in the

Washington, D.C. area. He found that the difference in housing prices did not even cover the capitalized savings in vehicle operating costs. This implied that the value of travel time saved was either zero or negative. This result must be questioned and suggests the obvious conclusion, that factors other than just the distance to work influence the market value of real estate.

Upon reviewing both the Mohring and Harwitz and Pendalton studies, Nelson (1977) argued that both the Mohring and Harwitz and Pendalton studies were incorrect. He states that their estimates are biased downward due to the failure to detect any capitalization of time savings in real estate prices. He identifies three possible causes of bias:

1. Oversimplification of the measure of accessibility.
2. Omission of relevant explanatory variables.
3. Use of incorrect data, such as discount rates, trip frequencies, or operating costs.

Nelson, using a different model, the Hedonic Price Model, estimated the value of travel time saved after adjusting for the capitalization of money cost savings. His estimate ranged from 23% to 45% of the average wage rate depending on assumptions involving trip frequency and the discount rates in the capitalization process.

Recently, Deacon and Sonstelie (1985) examined the value of time saved based on consumer choice of waiting versus paying a higher price for gasoline. Although their results are not specifically for the journey to work, they are relevant to the issue of constancy of the value of time saved, regardless of the method of saving. In the spring of 1980, a number of Chevron gasoline stations in Southern California were forced to lower their prices by $0.16 to $0.21 a gallon due to price controls. As a result, long lines formed at these stations, while other service stations within the vicinity operated normally under unconstrained prices.

Therefore, consumers were observed making a choice of trading the reduced cost of gasoline for the increased time in the queue.

Construction of the model assumed that the consumer would purchase gasoline in order to minimize total costs. Total costs were expressed as price of gasoline purchased multiplied by the mean purchase amount added to the amount of time spent multiplied by the value of time for the consumer. Acceptance of this formulation and the use of the means as constants allowed the value of time to vary depending on the individual consumer. The two total cost equations are represented as:

$$TC_0 = p_0 \, y_i + t_0 \, v_i \qquad (11)$$

$$TC_1 = p_1 \, y_i + t_1 \, v_i \qquad (12)$$

where:

TC_0 = total cost of purchasing gasoline at an uncontrolled station,
TC_1 = total cost of purchasing gasoline at the controlled Chevron station,
p_0 = is the price of gasoline at the uncontrolled stations,
y_i = is the quantity purchased,
v_i = is the value of time,
t_0 = is the amount of time spent at the uncontrolled stations,
p_1 = is the price of gasoline at the Chevron stations, and
t_1 = is the amount of time spent at the Chevron stations.

The data were collected in two fashions. Indirectly, data concerning the waiting time, price per gallon paid, and number of gallons purchased were observed from the consumers actions. Directly, each subject was asked to complete a categorized survey, which inquired into their before tax income, occupation, age, martial status, and employment status. The large yield of socio-economic data, from direct survey of the sample population, allowed for greater precision in the estimation procedure. The value of time was allowed to vary according to income and employment groups placed into specified brackets. The range of the value of time per hour was estimated for each bracket, bounded by upper and lower limits. Grades of gasoline were considered uniform and the price differential between the control and Chevron stations was established at $0.185 per gallon. Using the mean values of waiting time per customer of 14.6 minutes at the Chevron stations and the mean purchase amount of 10.5 gallons in their estimated equation yielded the values shown in Table 1. Note that the amounts shown in Table 1 apply only to vehicles with no additional passengers. According to Deacon and Sonstelie, each additional passenger raises the estimated bounds for the value of time by 53.4%. Additionally, for those fully employed, the value of time is 100% or more of the after-tax wage rate even using lower bounds, except for the $20,001 to $30,000 range. This is a much higher percentage than that found in most other studies. This result could have been influenced by several factors including the fact that those entering the end of the line do not have perfect foresight of the time they would have to wait. Once in the line, there exists a certain inertia to continue to wait even when the total time cost of waiting exceeds the monetary gains from the lowered gasoline cost.

Analysis of the estimated model, concerning the difference of the estimated coefficients for income, demonstrated that the choice of station was not highly sensitive to income. This conclusion is economically justifiable due to the relatively inelastic demand characteristics of gasoline to automobile owners. This shades the validity of the experiment to some degree, suggesting that the results may be structurally biased. It questions the use of the value of time, price, and waiting time as perceived consumer decision making criteria for this particular good. However, in contrast, the results also indicated that income could not be rejected, with 95% confidence, as a significant variable, except for students, housewives, and part time workers. This confirms the conclusions of some of the British studies. That is, the

Table 1: Estimates of the Value of Time (Dollars per hour)

	Lower Bound	Upper Bound	After-Tax Wage
Part-time workers	3.52	5.39	N.A.
Students	7.15	10.96	N.A.
Housewives	6.32	9.70	N.A.
Unemployed:*			
$0-$15,000	6.30	9.67	N.A.
Over $15,000	5.12	7.86	N.A.
Fully Employed:#			
$0-$10,000	9.94	15.25	2.71
$10,001-$20,000	7.47	11.46	4.82
$20,001-$30,000	6.51	9.44	7.55
$30,001-$40,000	8.93	13.70	8.89
Over $40,000	11.26	17.26	11.12

*Income classes refer to family income.
#Income classes refer to individual income.
Source: Deacon and Sonstelie (1985), p. 640.

value of time saved may not be a constant proportion of income.

One of the most comprehensive attempts to estimate the value of time saved in the journey to work was by Thomas (1968). He used a method similar to that by Lisco but used route choice rather than modal choice as the basis for inferring the value of time saved. The foundation of this model rests upon the establishment of a situation where motorists are given a choice of two roads, a faster toll road versus a slower free road. This specification of the problem is more representative of the choice faced by the commuter affected by investments such as bridge modifications or reductions in the flooding of highways.

Thomas first hypothesized a model assuming that individuals had already chosen an equilibrium route choice on the value of the toll and the time saved. The problem was then to estimate the coefficients of this model, controlling for other variations in individual characteristics such as income. Using the logit model, Thomas specified that the probability of choosing the free road was a function of route characteristics and the characteristics of the individuals so that

$$p(x) = \frac{f(x)}{1 + e^{f(x)}} \tag{13}$$

where:

$p(x) = f\,(a_0 + a_1\, \Delta\text{cost} + a_2\, \Delta\text{travel time} + a_3\, \Delta\text{traffic impedances} + \sum a_i\, Y_i)$

$p(x)$ = the probability of choosing the free road,

Δ cost = difference in out-of-pocket travel costs between routes,

Δ travel time = difference in travel times between routes,

Δ traffic impedances = difference in traffic impedances between routes, and

Y_i = individual motorist characteristics.

Essentially, this function demonstrates that both route and individual motorists' characteristics influence the choice of route. The value of the coefficients specify the relative importance of each variable in the motorist's consumption decision. In the estimation process the value of time was defined as the ratio a_2 / a_1 , and the value of traffic impedances was valued as a_3 / a_1.

Two sources of data were utilized; readings from a test vehicle, and interviews with motorists. The test vehicle was specially built with a fifth wheel recording descriptive route characteristics such as mileage, velocity, acceleration periods, type of road, and traffic flow. These were processed and recorded by an on-board computer with magnetic disk storage capabilities. The interviews with motorists provided information about their perceived trip expenditures, principal and alternative routes, and personal characteristics. Eight different commuting sectors in the U.S. were selected for the study. Groups of commuters who worked at approximately the same location and had overlapping routes were chosen as the subjects. Although these restrictions eliminated the possibility of a random sample, they were justified due to requirements of the test vehicle and the sheer statistical weight accompanying the number of variables that would otherwise arise. In all, 812 commute trips were analyzed, and 37 different models were developed. Two criteria were established to judge the best particular model. First, the coefficients of income of the driver, toll per person, and all route characteristic variables had to be significant at the 95% confidence interval when compared to their standard errors. Secondly, the higher the percentage of correct prediction, given the first criterion, the better the model.

The best model, based on test vehicle data, estimated the value of time for the median motorist to be $1.82 per person per hour, being 95% confident between the interval of $1.04 to $2.60. The value of time based on the best model using the motorists data covering the same route was estimated to be $3.84 per person per hour with 95% confidence within the range of $2.82 to $4.86. Neither the test nor the interview data gave a precise estimate of the actual value of travel time at the point of route choice decision. Interview data was found to be biased because motorists, in retrospect, made the road appear better than its actual value would have suggested. However, the measured data may not be appropriate, since it does not necessarily correspond with the motorists subjective perception at the point of decision. Thomas decided that a simple, effective way to solve the discrepancy would be to take the average of the two estimates. The result was that the value of time was estimated at $2.82 per person per hour.

An obvious difficulty with the Thomas results is the question of its applicability to passengers. Although the cost of travel explanatory variable is toll per person, this may result in a bias in the value of time when applied to drivers as compared to passengers. Presumably the driver makes the determination of which route to choose based on his own value of time saved. When passengers are present they may also have some value of time saved.

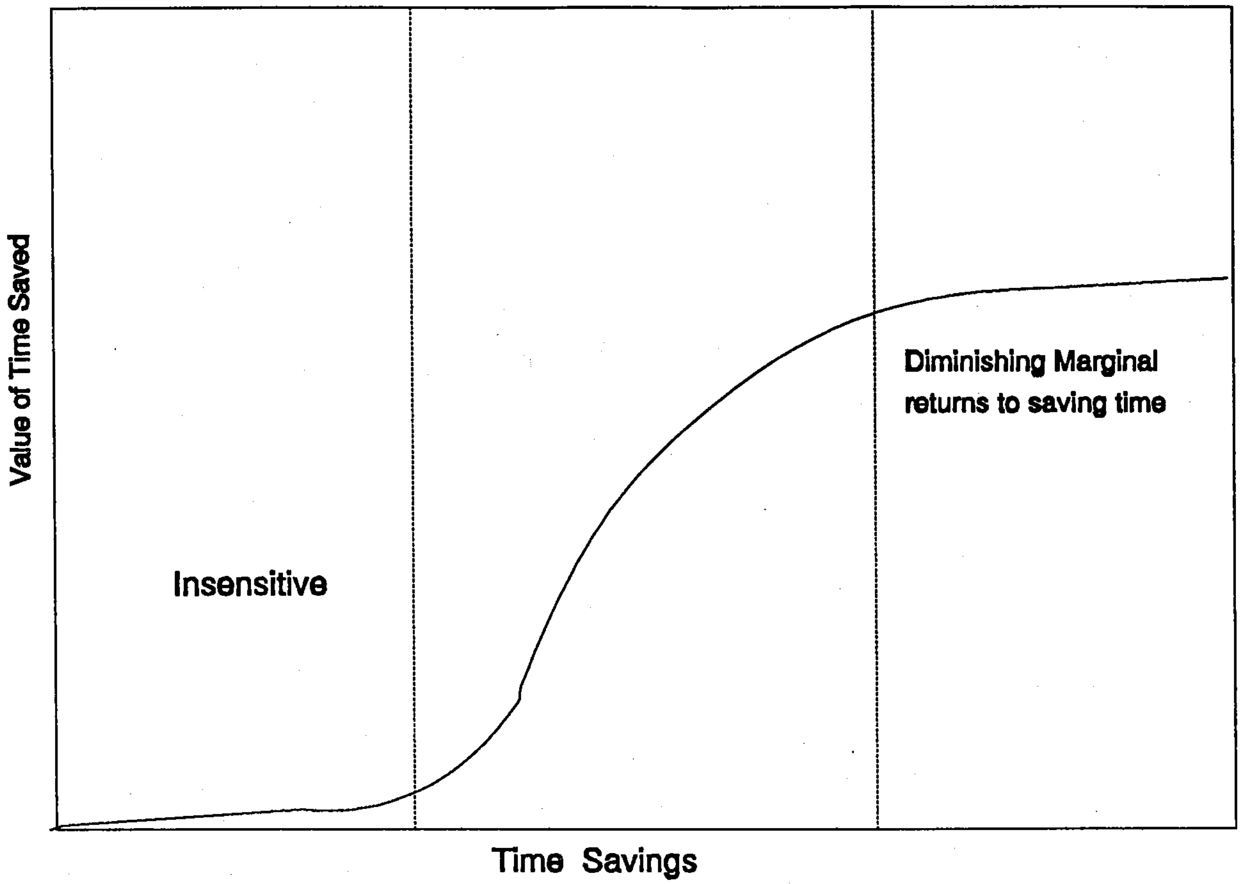
Although Thomas suggests using a fixed per hour value of time saved, he cautions that this may not be appropriate when the total amount of time saved is either very small or very large. He hypothesizes that the hourly equivalent value of time saved is an "S-shaped" function of the amount of time saved such as shown in Figure 1.

Thomas and Thompson (1971) expanded the scope of value of time saved studies beyond the journey to work to encompass other types of trips. In doing so, the value of time saved was hypothesized to differ across various trip purposes. Data for the logit model estimation was collected using a mail-back questionnaire of motorists faced with a choice between a faster toll road and a slower free road.[1] The survey generated 2688 valid responses from toll road users and 1480 free road users.

The route choice function and probability equations using logit analysis from Thomas's exclusive journey to work study were retained to analyze other trip purposes with an expanded data base. The value, or benefit, of time saved through this estimation appears not to be a linear function, and cannot be found by simply multiplying a constant for the value of time by the amount saved. The results indicate that the value of time varies

[1]Thomas and Thompson provide no information on how the population to be sampled was chosen, the sampling procedures, nor the questionnaire used. Sites in the states of Florida, Texas, Oklahoma, Maine, New Jersey, Pennsylvania, Virginia, Kentucky, Kansas, and Illinois were identified as survey sites. Apparently questionnaires were distributed to motorists at these sites.

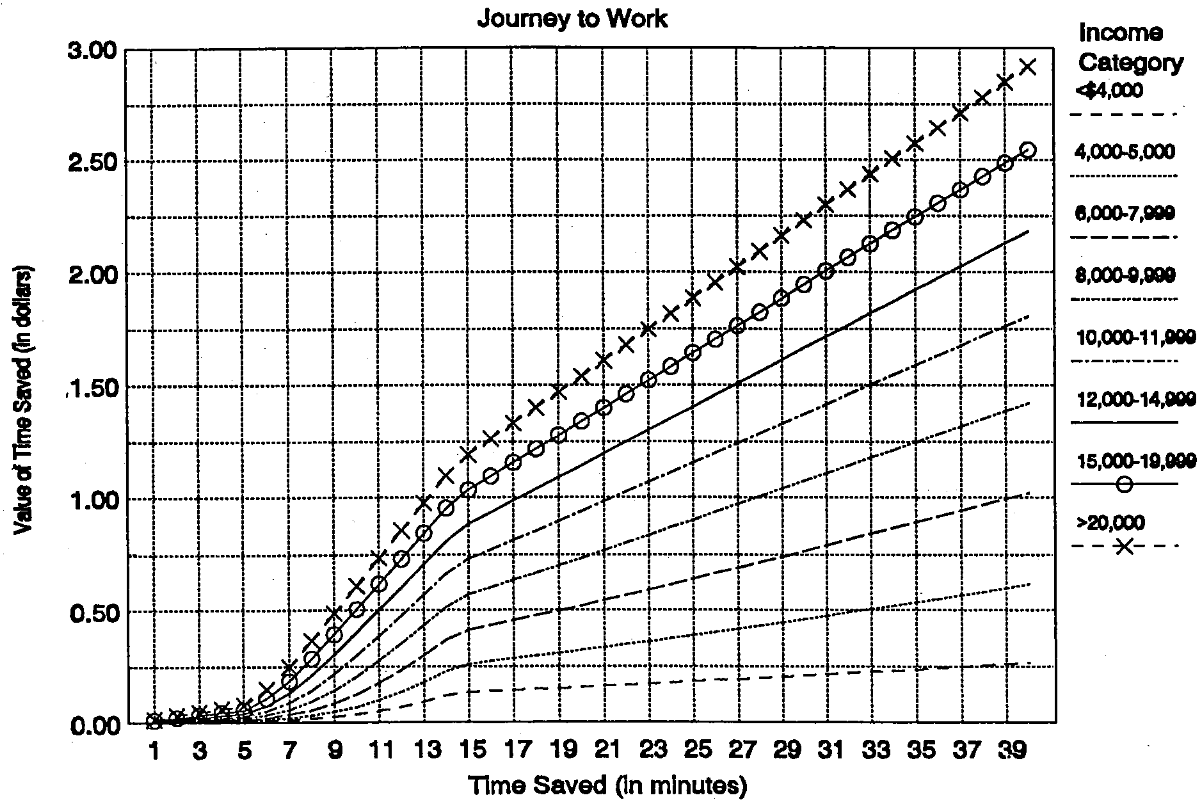
Figure 1: Thomas's Hypothesized Value of Time Saved Function



depending on the length of trip, trip purpose, and the motorist income. The estimates for the value of time saved by purpose and amount of time saved are shown in Figure 2 for the journey to work and Figure 3 for social/recreational trips.

Despite the results shown, Thomas and Thompson recommended maximums of $1.00 for saving 40 minutes in a work trip, $2.00 for saving 40 minutes in personal business or vacation trips, and $2.00 for saving 20 minutes in social-recreation or school trips. These limitations result in an approximation of Thomas's S-shaped curve representing the value of time saved as a function of quantity of time saved. The basic rationale, however, is that any larger amounts fall beyond the range of the data used to derive the value of time savings.

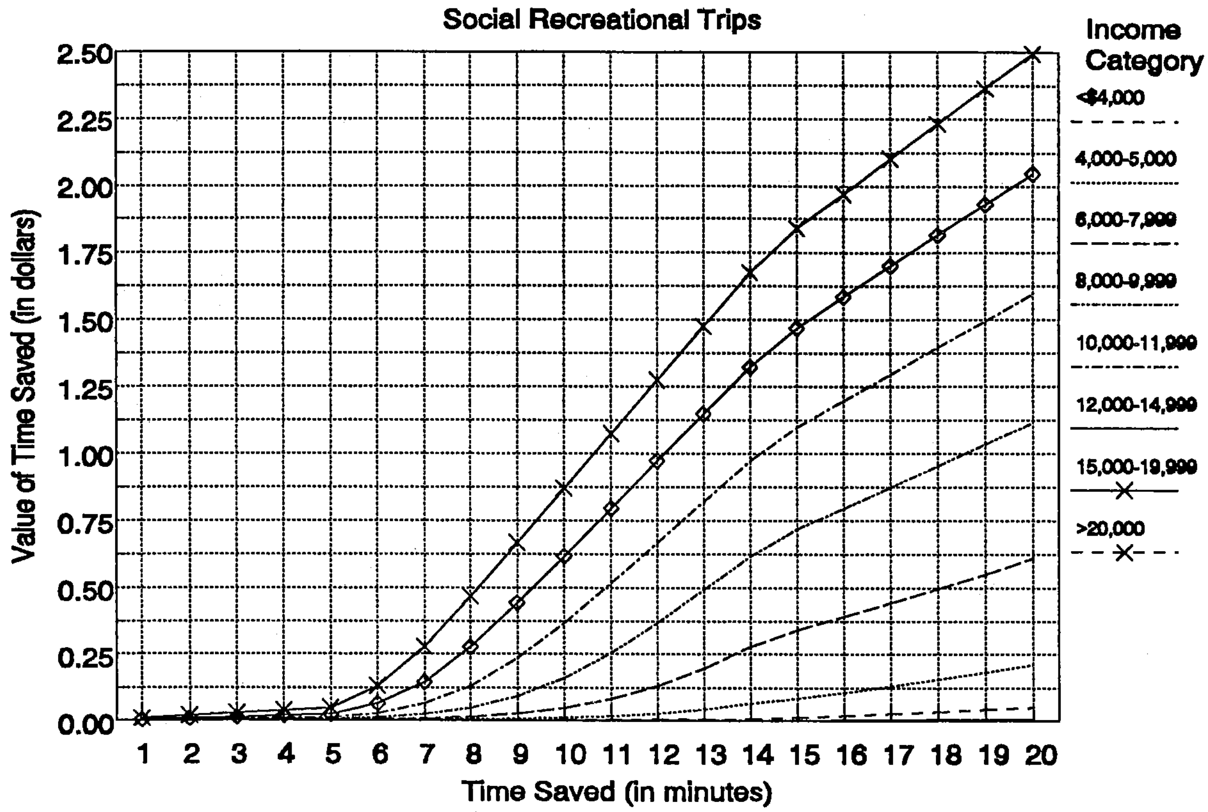
Figure 2: Value of Time Saved in Work Trip



SOURCE: Thomas and Thompson (1971), p. 110.

The American Association of State Highway Officials (AASHO 1977) recommended the Thomas and Thompson approach and revised their results to 1975 income levels. In addition, AASHO calculated the value of time saved as a proportion of income for Thomas and Thompson's median income category. Using the median family income for 1988, the Thomas and Thompson results are updated and presented in Figure 4. Table 2 follows the AASHO (1977) recommendation of classifying time saving into three categories. Notice that the value of time saved as a percentage of the wage for "high time savings" for

Figure 3: Value of Time Saved in Social/Recreation Trip



SOURCE: Thomas and Thompson (1971), p. 111.

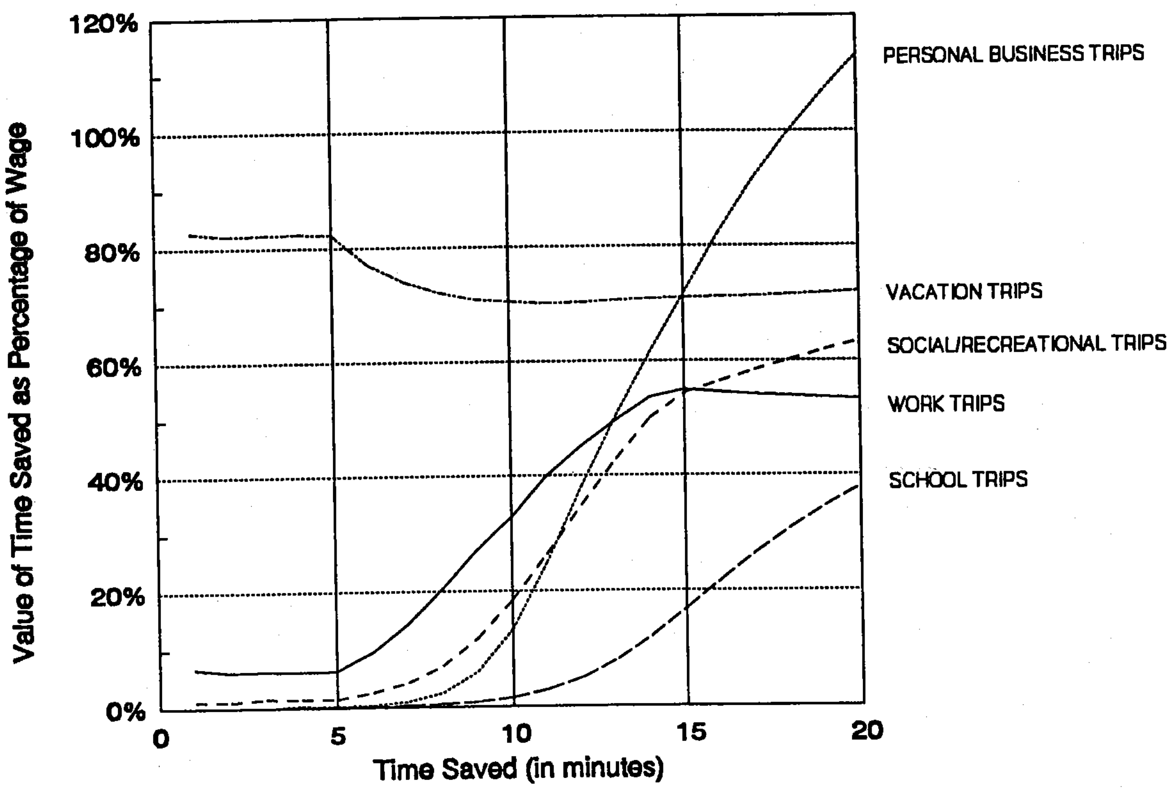
social/recreational trips is nearly identical to that found by McConnell and Strand (1981). In addition, these percentages generally fall within the range found by many of the studies summarized in the Appendix A.

III. CONCLUSIONS AND RECOMMENDATIONS

The current review has found no other studies as comprehensive or that have been endorsed for use in estimating the value of time saved from transportation investments as that by Thomas and Thompson. Therefore, it is recommended that the values shown in Table 2 be used for the value of time saved in Corps planning studies. Thus, the value of time saved will be different depending on the purpose of the trip and the amount of time saved on each trip. The percentages shown in column (3) can be applied after the before-tax family income of drivers in the study area is estimated. The dollar values shown in column (2) are based on $32,191, the median family income for the U.S. in 1988 (U.S. Bureau of the Census).

Following Thomas and Thompson, the value of time savings for work trips is on a per vehicle-occupant basis. Therefore, to calculate the total value of time saved per vehicle requires multiplication by the adults per vehicle. For social/recreation, vacation, and other trips, the value of time saved is on a per vehicle basis. The value of time saved for these trip purposes should not be adjusted for the number of passengers.

Figure 4: Value of Time Saved as Percentage of Driver's Family Income



Based on using Thomas and Thompson (1971) median income category.
Value of time saved adjusted to hourly basis

Table 2: Recommended Value of Time Saved by Trip Length and Purpose

	Value of time saved adjusted to hourly basis $/hour (2)	Value of time saved adjusted to hourly basis % of hourly family income of driver (3)
For low time savings (0-5 minutes)		
Work Trips	$0.99	6.4%
Social/Recreation Trips	0.20	1.3%
Other Trips	0.01	0.1%
For medium time savings (5-15 minutes)		
Work Trips	4.99	32.2%
Social/Recreation Trips	3.58	23.1%
Other Trips	2.24	14.5%
For high time savings (over 15 minutes)		
Work Trips	8.33	53.8%
Social/Recreation Trips	9.29	60.0%
Other Trips	9.98	64.5%
Vacation		
All time savings	11.63	75.1%

NOTE: Work trip is on per person basis while all other trip purposes are on a per vehicle basis

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APPENDICES

APPENDIX A

Summarization Table

Author(s)	Location/Year	Method	Characteristics of estimated VTTS
AASHO (American Association of State Highway Officials)	/ 1960		Recommendation of $1.55 per hour per car, or $0.86 person per hour.
Mohring and Harwitz	Seattle / 1962	Observed land price changes due the capitalization of reduced travel time.	30-65 cents per hour, representing 22%-43% of 1949 wage level.
Pendalton	Washington D.C. / 1963	Observed land price changes due the capitalization of reduced travel time.	VTTS was either zero or negative.
Beesley	London / 1965	Modal choice between private car and public train or bus for urban commuters, using a minimization of error analysis.	VTTS was increasing in proportion to income, evaluated range was 31% to 49% of wage rate.
Quarmby	Leeds / 1967	Modal choice between private car and public train or bus for urban commuters, using discriminant analysis.	Proportional to wage, 20%-25% of the average wage rate.
Lisco	Chicago / 1967	Modal choice between private car and public train, using multiple probit analysis.	Decreasing in proportion to wage, 40%-50% of wage rate.
Thomas	8 Commuting Corridors in the U.S. / 1967	Route choice using survey questionnaire and test vehicle evaluated by Logit analysis	$2.82 per person per hour

Author(s)	Location/Year	Method	Characteristics of estimated VTTS
Stopher	London / 1968	Modal choice between private car and public train, using regression analysis.	Decreasing in proportion to wage, 21%-42% of the wage rate.
Thomas and Thompson	8 Commuting Corridors in the U.S. / 1968-71	Route choice using survey questionnaire and test vehicle evaluated by Logit analysis, covering a broader range of travel activities other than going to work.	Variable results depending on the amount of time saved, thus value of time is a non-linear function of amount of time saved. See text and Figures 2 and 3.
Talvitie	Chicago / 1972	Using Lisco's data, performed same study but used logit, probit, and discriminant analysis.	For each of the three different modes of analysis found time to be approx. the same, 62% of average wage rate.
Wilson	Singapore / Data collected in 1975.	Discrete model of joint travel mode/ work start time choice using survey data.	Using six different models the value of time was estimated at approximately 40% of the hourly wage rate.
Nelson	/ 1977	Hedonic Price Model	23%-45% of the average wage rate.
AASHO (American Association of State Highway Officials)	/ 1977	Updated Thomas and Thompson results from route choice survey.	See Figure 4.
Wilman	/ 1980	Cost of Travel Model	None calculated.
McConnell and Strand	Cheaspeake Bay / 1981	Cost of Travel Model	Value of time calculated at 61.2% of the mean hourly wage.

Author(s)	Location/Year	Method	Characteristics of estimated VTTS
Hensher and Troung	Five Australian cities / 1982	Stated preference through survey of differential trip situations regarding travel to work, rating choices on a scale of 0-10.	Average value of in-vehicle time savings is 16.3 cents per person per minute,
Deacon and Sonstelie	Ventura, CA / 1985	Observed consumer choice between low price/ high time intensive good vs. higher price lower time intensive good, and use of survey data.	Variable depending on income level.

APPENDIX B

Example: How to Use the Recommended Values

The following example will present a hypothetical scenario in which the recommended values of time will be utilized in calculating the benefit of time saved resulting from a proposed project.

The Situation

In Unispan, Illinois there exists a river that runs through the center of town. For all purposes of this example, it is assumed that the river partitions the town into a residential district and a business district, labeled Areas R and B, respectively. The bridge (labeled 1) spanning the river, thus allowing traffic to flow between the two areas, is an old bridge and very low to the river surface. Periodically, due to rainfall or other factors, the river rises and floods. On these occasions the bridge becomes impassable. The traffic that would normally use bridge 1 must travel down river to the next bridge (labeled 2). Bridge 2 is a new bridge that is high above the river, and for simplicity in this hypothetical situation, it is assumed that it is never impassable at the same time as bridge 1. The diverted traffic can then cross the river using bridge 2 where it will travel back upriver to Area B. This is an inconvenience to the businesses and population of Unispan. It costs those who normally use the bridge 1 extra time, money, and opportunity when it is closed. Lately, the people of the town have been discussing the problem and possible solutions. The U.S. Army Corps of Engineers has been authorized to conduct a feasibility study which will determine whether the benefits of a project, such as a channel widening or deepening operation, would exceed the costs. One of the benefits to a project keeping bridge 1 open would be the value of time saved to those people whom normally use the bridge.

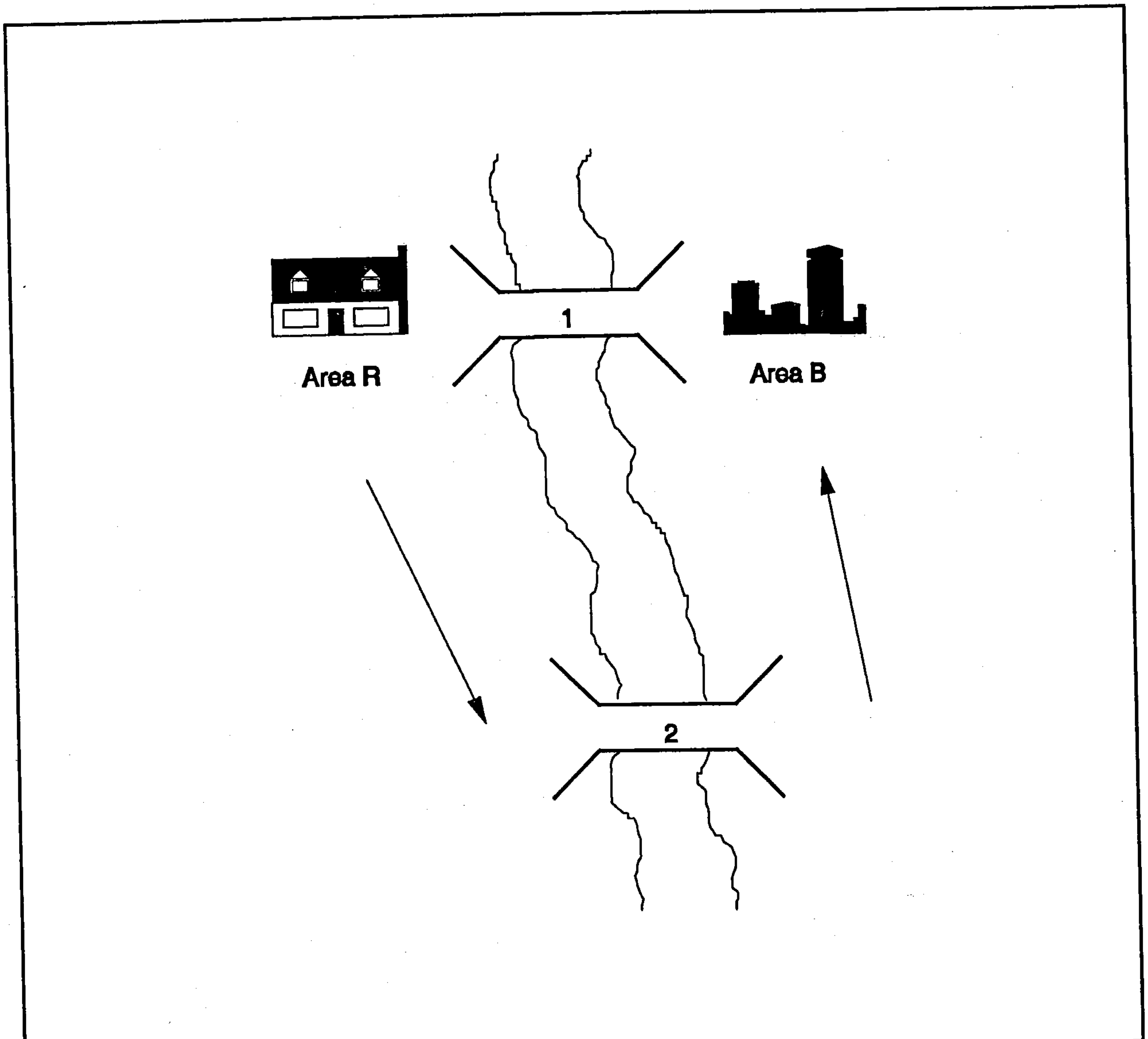

Figure B-1: Diagram of Hypothetical Situation

Calculating the Value of Time Saved

The calculation of the value of time saved is a complex problem which is best handled by segmenting it into a series of smaller problems.

Step 1: Calculation of Median Family Hourly Income

The conclusion of the literature review in the main report recommends estimating the value of time saved as a percentage of the hourly family income of the driver (Table 2, p23). However, the median family hourly income is not always readily available for a given segment of the population. In this example, the following process was used. The median family income for the United States in 1988, found in the Statistical Abstract of the United States: 1990, was selected as the base since it was the most recent value available. It is assumed that a person, working 8 hours a day, 260 days per year, will work 2080 hours per year. The median family hourly income is the quotient of the median yearly family income divided by the number of hours worked per year.

Table B-1 Calculation of Median Family Hourly Income

Median Family Income (1988)	32,191
Number of hours worked per year Assuming 8 hours/day * 260 days/year	2,080
Median Hourly Family Income (1988)	15.48

For a project in a given local area, it is recommended that income data corresponding more closely to the population of the project area be utilized. In doing this, the value of time saved will more closely reflect the diversion cost to the people of the area, who potentially could be cost sharing in the project's construction. Subsequently, a more accurate benefit-cost ratio will be provided. One available reference source is the County and City Data Book, published by the Bureau of the Census. This reference book lists the median income for all the counties and cities in the United States. The U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (CERL) located in Champaign, Illinois is another source of pertinent local data for regions of the U.S. CERL has produced excellent computer information systems such as Environmental Technical Information System (ETIS) and Economic Impact Forecast System (EFIS). To access these systems, call 1-800-USA-CERL to obtain an account number.

Step 2: Determination of the Average Number of Vehicles by Day and Purpose

This step determines the scope, or magnitude of the situation. For purposes of this example, the average number of vehicles using the bridge was assumed to be 5000 per weekday and 1000 per weekend day. Weekdays and weekend days are separated due to the assumption that Saturdays and Sundays have both different levels of traffic flow and different percentages of traffic by trip purpose as compared to the rest of the week. More clearly stated, the number of people going to work on Sunday is assumed to be significantly different than the number of people going to work on Monday, or those vacationing on Sunday as compared to those on Wednesday. Acquiring real data for this step entails the following:

1. Contact the local government and state Department of Transportation (DOT) to see if such data already exists for the given location. If not, one could also ask for assistance in obtaining or collecting this data.

2. Set up a vehicle counting station. Count the number of vehicles crossing the bridge for a given number of days; the more days sampled, the better. Sum the totals for each day, then divide by the number of days to calculate the average daily count.

3. Set up an intercept survey. Stop the cars crossing the bridge and ask the driver to chose among four possible trip purposes that most accurately describes his/her reason for traveling. The choices should resemble the following trip purposes:

a. Work
b. Social/Recreation
c. Other, including Personal Business
d. Vacation

Calculate the number of trips for each purpose as a percentage of the total number of vehicles surveyed. Conceptually steps 2 and 3 could be performed at the same time. Also, remember that data for weekdays must be kept separate from that of weekend days.

Table B-2 Weekday [MTWRF] Traffic Count

Trip Purpose	(1) Percentage of Average Daily Traffic Count	(2) Derived Number of Vehicles
a. Work	75%	3750
b. Personal Business	15%	750
c. Social/Recreation	10%	500
d. Vacation	0%	0

Table B-3 Weekend Day [SS] Traffic Count		
Trip Purpose	(1) Percentage of Average Daily Traffic Count	(2) Derived Number of Vehicles
a. Work	10%	100
b. Personal Business	25%	250
c. Social/Recreation	50%	500
d. Vacation	15%	150

NOTE: Weekday Average Daily Traffic Count is 5000 vehicles. Weekend Average Daily Traffic Count is 1000 vehicles.

Legend for Columns in Tables B-2 and B-3

(1) Percentage(%) of Average Daily Traffic Count by Trip Purpose.
(2) Number of Vehicles by Trip Purpose per day, derived by multiplying average daily count by Column (1).

Step 3: Calculating the Dollar Value of Delay by Trip Purpose and per Day

First, it is necessary to find the average difference in the amount of travel time, i.e. delay, when the bridge 1 is closed compared to when it is open for each trip purpose. Second, the average number of passengers per vehicle is needed for calculating the value of time saved for work trips. Collection of this data may entail the following:

1. Again check with the local government and the corresponding state DOT for the data and/or possible assistance in its collection. Most likely the average delay by purpose will be unavailable, but the average number of passengers per vehicle is the type of statistic that the DOT may have.

2. The data might also be collected when performing the traffic count and/or intercept survey mentioned in Step 2. To calculate the average number of passengers per

vehicle, count passengers and vehicles (again, the more the better) and divide the total number of passengers by the total number of vehicles. For the average delay, when using the intercept survey, simply ask the driver how much longer the trip takes when their primary route is obstructed. Total the minutes of delay for all drivers of each purpose separately, then divide by the number of drivers questioned for average delay according to trip purpose. Conceivably, the data could be collected in such a fashion as to differentiate between weekdays and weekends for average delay by trip purpose and passengers per vehicle, although in this example that approach is not taken.

3. The use of a test vehicle and driver could be utilized in making various trips for selected purposes during different times of the day, for a given length of time, measuring the delay in minutes.

4. Theoretically, assuming no traffic congestion, the extra time taken in a trip could also be calculated by measuring the distances of the two trips (the primary and diverted) and noting the posted speed limits at their given intervals.

In the example, the average delay by trip purpose was assumed to be the same regardless of whether it was a weekday or weekend. The values per purpose were assumed to be one-half hour for work trips, and one-quarter hour for all other trips. The average number passengers per vehicle was established at 1.8 persons per vehicle following an ASSHO recommendation.

The average delay in minutes by trip purpose is used to select the appropriate percentage of hourly income from Table 2. The dollar value per hour by purpose is then calculated by multiplying that percentage by the median family hourly income calculated in Table B-1. Taking this value and multiplying it by the average delay in hours yields the dollar value of the average delay for each purpose. Entering these values into Tables B-5 and B-6, and multiplying them by the corresponding number of vehicles per purpose and type of day yields the total value of the average delay per purpose. However, work trips must proceed one calculation further by multiplying that value by the number of passengers per vehicle, since their delay is calculated on a per person basis. The summation of these values for each day derives the total value of the bridge closing per weekday and weekend day.

Table B-4 Calculating the Dollar Value of Delay by Purpose

Purpose of Trip	(1) Avg. Delay [Min]	(2) Avg. Delay [Hours]	(3) Percent of Hourly Income	(4) Dollar Value of Time per Hour	(5) Value of Avg. Delay per Vehicle
a. work	30	0.50	53.8%	8.32	4.16
b. personal business	15	0.25	14.5%	2.24	0.56
c. social/recreation	15	0.25	23.1%	3.57	0.89
d. vacation	15	0.25	75.1%	11.63	2.91

NOTE: Personal business, for percentage of hourly income purposes, is classified as "other" types of trips on Table 2: Recommended Value of Time Saved by Trip Length and Purpose.

Legend for Table B-4

(1) The average change in travel time, i.e. delay, from origin to destination in minutes, due to the closing of bridge 1.
(2) This column converts column (1)'s values to hours, since calculation of the value of time is done on an hourly basis.
(3) Percentage of Median Hourly Family Income of driver to be used in time calculation, based on trip purpose and length of average delay. See Table 2: Recommended Value of Time Saved by Trip Length and Purpose.
(4) Value of Time per hour. Median Hourly Family Income ($15.48 from Table B-1) multiplied by the Recommended Percentage (Column 3).

(5) Cost of Average Delay in Dollars per Purpose per Vehicle. Calculated by multiplying the value of time per hour (Column 4) by the average delay in hours (Column 2).

Table B-5 Weekday [MTWRF] Cost of Delay

Purpose of Trip	(1) Dollar Value of Avg. Delay per Vehicle	(2) Avg. Number of Vehicles	(3) * Avg. Pasngr. Vehicle	(4) Total Value of Avg. Delay (In Dollars)
a. work	4.16	3750	1.8	28107.81
b. personal business	0.56	750		420.86
c. social/recreation	0.89	500		446.99
d. vacation	2.90	0		0
Total Time Cost of Delay per Weekday				28975.66

Table B-6 Weekend Day [SS] Cost of Delay

Purpose of Trip	(1) Dollar Value of Avg. Delay per Vehicle	(2) Avg. Number of Vehicles	(3) * Avg. Pasngr. Vehicle	(4) Total Value of Avg. Delay (In Dollars)
a. work	4.16	100	1.8	749.54
b. personal business	0.56	250		140.29
c. social/recreation	0.89	500		446.99
d. vacation	2.90	150		435.95
Total Time Cost of Delay per Weekend (day)				1772.77

<u>Legend for Tables B-5 and B-6</u>

(1) Time Cost of Average Delay per Vehicle by Purpose, from Table B-4, Column (5).
(2) Number of Vehicles per Purpose respectively from Tables B-2 and B-3, Column (2).
(3) Average Number of Passengers per Vehicle, used only in the calculation for work trips, since all other trips are on per vehicle basis, while work trips are on a passenger basis.
(4) Total Time Cost of Delay per Purpose, derived by multiplying Time Cost of Delay per Vehicle by Purpose, Column (1), by the number of vehicles per purpose Column (2). * For Work Trips, follow the same process but also multiply the value by the Average Number of Passengers per Vehicle, Column (3).

Step 4 Calculating the Expected Value of Time Saved

A flood that closes bridge 1 could start on any given day, and last for any given duration. This presents a problem since the value of a weekend day, Saturday or Sunday, is different from that of a weekday. The solution is to calculate the value of all the possible outcomes and then to take the expected value of a particular event occurring. Assume that the flood is to have a duration of nine days, during which time the bridge is impassable.[1] The flood could start on any day, but since there are only seven days in a week this limits the possibilities to seven. Count, from the day the flood starts, the number of weekdays and weekend days for each of the seven possibilities. To compute the value of each possibility, multiply the number of weekdays by the value per weekday and multiply the number of weekend days by the value per weekend day. Next, sum the products. This summation is the expected value of avoiding bridge closure from this particular event.

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[1]For this example, the 9 day closing represents the effect of a 1% (100 year) exceedance flood. Both larger and smaller floods and corresponding longer and shorter closing durations need to be evaluated to calculate expected annual delay costs and project benefits.

Table B-7 Calculating the Value of Time Saved for Each Possibility			
(1) Possible Events	(2) 9 Day Sequence	(3) # of Weekend Days and # of Weekdays	(4) Value of Event (In Dollars)
1	M T W R F S S M T	2 and 7	206,375
2	T W R F S S M T W	2 and 7	206,375
3	W R F S S M T W R	2 and 7	206,375
4	R F S S M T W R F	2 and 7	206,375
5	F S S M T W R F S	3 and 6	179,172
6	S S M T W R F S S	4 and 5	151,969
7	S M T W R F S S M	3 and 6	179,172

Legend for Table B-7

(1) Assigns a number to a possible event. Note that there are only seven possibilities.
(2) Chronological listing of the nine day period for which the bridge would be closed due to the flood.
(3) Counts the number of weekend days and weekdays in each possibility. Note that for each possibility the sum of weekdays and weekend days must equal nine for this particular flood.
(4) Calculates the value of time associated with each possibility. This is equal to the sum of the product of the number of weekend days by the value per weekend day (See Table B-6) and the product of the number weekdays by the value per weekday (See Table B-5).

Table B-8 Calculating the Expected Value of Time Saved for the Event			
(1) Aggregation of Possible Events	(2) Probability of Occurrence	(3) Corresponding Value (In Dollars)	(4) Expected Value of Possibility (In Dollars)
V1 [1,2,3,4]	4/7 = 0.571429	206,375	117,929
V2 [5,7]	2/7 = 0.285714	179,172	51,192
V3 [6]	1/7 = 0.142857	151,969	21,710
Expected Value of Time Saved for the 9 Day Flood			190,831

Legend for Table B-8

(1) Analyzing the values in Table B-7, column (4) one can determine that many of the original seven possible events are of the same value; these can be grouped.
(2) This calculates the probability of occurrence of a given outcome value. For example, V1 is the outcome value of the possibilities 1, 2, 3, and 4, i.e., $206,375. Since this value has the possibility of occurring 4 times out of the 7 total possibilities, its probability of occurring is 4/7 or 0.571429. Note that the sum of the probabilities of the aggregate possibilities equals 1.
(3) This is simply the corresponding value to the possibilities from Table B-7, Column 4.
(4) The expected value of each possibility is the product of the value of the possibility by the probability of occurrence. The expected value of the event is the sum of the expected values of the possibilities.

Overview

The example presented here, simplified for demonstrational purposes, describes a logical way to use the recommended values. In the field many other factors influencing the calculation of the value of time saved will likely appear, making the problem much more difficult. The collection of accurate data is sure to be one of these problems. In this situation the value of time was calculated as a benefit, thus termed "saved". As stated earlier this situation could be reversed, suppose that in a different situation construction of certain projects caused a delay in traffic. The value of time would then be a cost, and correspondingly termed the value of time "lost".