Abstract

Improved highway networks result in net benefits to society. A principle benefit of highway improvement is the reduction of user travel time while in the network. Assigning a value to travel (or delay) time is a difficult task since highways are used by a myriad mix of individuals, each of whom values his or her time differently. While the wage rate method of valuing user time is convenient, alternative approaches based on leisure or survival should be considered. Even though users experience benefits once a project is completed, there can be considerable user delay costs for lane closures and/or detouring associated with construction and subsequent maintenance. It is the responsibility of transportation officials to efficiently plan for user delays during these phases and consider the secondary effects to the network. Due to its economic as well as social complexity, alternative measures of user travel time valuation and its network effects need to be considered.

1. Introduction

With respect to user costs associated with transportation facility maintenance, repair, rehabilitation, and replacement, there are three general categories important for consideration. These arise from the delay of traffic associated with the closing of lanes and rerouting of traffic flow, leading to the following situations

1. Increased probability of accidents
2. Increased wear and tear on vehicles
3. Decreased fuel efficiency
4. User delay time

The first three of these have been studied previously and can be fairly easily quantified based on observed data and physical models. The fourth is the subject here.

Improved highway networks result in net benefits to society. To successfully justify transportation improvements, planners conduct a benefit cost analysis (BCA). Considerable research has been done over the past three decades to accurately represent the benefits and costs associated with transportation projects. The leading U.S. authority on highway BCA is the American Association of State Highway and Transportation Officials (AASHTO) with its Redbook (AASHTO, 2003). A principle benefit of highway improvement is the reduction of user
travel time while in the network. Assigning a value to travel (or delay) time is a difficult task since highways are used by a myriad mix of individuals, each of whom values his or her time differently. Current BCA assigns a monetary value to travel time by taking a percentage of the user’s hourly wage rate, the thought being that time delayed traveling is to some degree an alternative to productively working.

While the wage rate method of valuing user time is convenient, alternative measures should be considered. One can argue that if delayed, a user will make up the time and still work a full day, thereby losing leisure time, which can be evaluated through a service industry-based approach. One can also argue that there is a minimum cost rate associated with the essential needs of survival (sustenance and shelter); one way to evaluate the cost of these basic needs is by calibration to the cost of incarceration.

Even though users experience benefits once a project is completed, there can be considerable user delay costs for lane closures and/or detouring associated with construction and subsequent maintenance. It is the responsibility of transportation officials to efficiently plan for user delays during these phases and consider the secondary effects to the network. Detour alternatives that affect the mix of users need to be analyzed to accurately represent the overall user costs. In addition to longer travel times for those users that are forced to detour, the regular users along the detour route are delayed as well. If the wage rate approach to user time is utilized, then detour routes selected to traverse local areas with people in lower income brackets would result in lower overall costs. Similarly, both the benefits and costs for candidate improvement projects would reflect the wage rate mix of users of those projects. The fact that wages vary across a country for the same occupation could be taken to imply that professionals who perform identical tasks, have dissimilar worth. The mix of users for a project probably should be reflected in the benefit cost analysis, whereas regional wage differences for the same occupation probably should not since they are likely due to regional cost-of-living variation. The moral quandary of valuing different people’s time differently is obvious.

2. Value of Time

A primary interest of transportation planners is to reduce user travel time. Because of the wide diversity of transportation users, assigning a value to user time saved is complex. A U.S. Transportation research Board study summarizes these issues as follows; “People value time differently, both on a fundamental basis, and by the purpose and mode of travel. In concept, how people value time spent in travel depends on the mode of travel, the purpose of the travel, the trip component (e.g., waiting versus riding), the total time, socioeconomic characteristics (which are often generally measured by income), and other preferences” (Transportation Research Board, National Research Council, 2002). This is supported also by the American Association of State Highway and Transportation Officials, “The currently accepted practice is that user travel time should bear some relationship to the after-tax wage rate of the traveler, since that is an alternative use of time-especially in a commute travel context” (AASHTO, 2003). A somewhat broader view has been taken by the U.S. Department of Transportation, “Time is valuable to people because they can dedicate it to earning income or use it to engage in leisure activities (United States Department of Transportation, 1997).” The Transit Cooperative Research Program (TCRP) agrees, and comments in its report that, “economists believe the implicit value of all non-work (“leisure”) time is affected by the opportunity to work instead” (TCRP, 2002). The TCRP goes on to summarize that most research suggests that non-commercial travelers generally value their travel time at a substantial fraction of their wage. The TCRP and USDOT both concur that 50% of a traveler’s gross wage rate is an appropriate value for in-vehicle travel time (U.S. Department of Transportation, 1997, and TCRP, 2002). However, The National Cooperative
Highway Research Program (NCHRP) cites several outstanding issues in placing economic value on the time people spend traveling, such as: “the fraction of the wage rate that should be used for work-related travel and personal travel, whether to apply the same time value for very short periods of time saved as for long periods, and how to account for variation of travel time” (Government Accountability Office, 2004).

A more conceptual view of the value of time involves the concept of user willingness to pay (WTP). The GAO looks at this principle by stating that when travel time is reduced, additional time becomes available to spend on some other activity and therefore, people are willing to pay to reduce their travel time. “The value of travel-time savings is an estimate of how much people would be willing to pay for reductions in travel time” (United States Government Accountability Office, 2005). The willingness to pay principle is manipulated by personal perception and is dependent on an individual’s earnings. As the U.S. DOT concludes, “although average wages and hours can be measured with reasonable precision, we cannot observe directly the value an individual places on having more free time or spending time in one way or another” (United States Department of Transportation, 1997). Benefits to travelers from transit improvements come about primarily as the result of reductions in the user’s perceived cost of travel. When a transit user avails himself or herself of the system, that person is making a decision based on the evaluation that the cost of the trip is less than the perceived benefit (Transportation Research Board, National Research Council, 2002).

3. Wage Rate

It seems prudent to refine the current practice of using a single national average for user wage rates. It is clear that the mix of occupants varies considerably across regions, and that the average wage in a rural farming community, for instance, is not comparable to a financial center. While single, universal values are convenient for analysis, they lack a level of rationality which can dissuade confidence in that analysis. It makes sense to adjust for regional variances in wages and to customize the BCA accordingly. It is interesting to also consider the importance of occupation as well.

One can argue that a consistent method to determine benefits is to look at a region’s contributions to the national GDP. With a highway improvement saving users’ time, one can expect that the overall productivity of that region will improve, thereby increasing the region’s GDP contribution. It seems that GDP is a more rational way to see net benefits from a societal standpoint, than wage rate, because it reflects productivity. One needs to realize though that many other factors besides commute time affect productivity, and that people may argue equal value of their time, regardless of the nature of the local economy.

Accounting for regional differences in GDP contribution could be a way to help adjust for the shortcomings of using a single national wage rate. If the labor force of a particular metropolitan area contributes more to the GDP, then their time could be considered to be worth more than that of a labor force that contributes less. Customizing BCA in this way would help to better represent how a specific project would affect its users by accounting for value of time parameters that are distinct from the national average.

One of the reasons for varying wages across regions for the same occupation is the cost of living expense. The correlation is obvious, if it costs more to acquire the basic living essentials in one area than another, then companies have to pay more to attract workers. However, the cost of living adjustment should be neglected from BCA. From a societal standpoint an hour of
productivity from a particular profession is valued universally, regardless of the locale, and consequently, the cost of living.

Current approaches average the wage rate across the country, and then take some percentage of this wage rate as representative of the value of time. Various researchers have justified taking between 20% and 100% of the wage, with 50% the most common value. It is important when performing a BCA to realize that for each individual project the parameters involved with value of time could be optimized to better represent the user population.

4. Service Industry Approach

Another way to assign benefits to time savings resulting from transportation improvements is by recognizing that saving commuters’ travel time is in effect increasing their leisure time. It seems reasonable that people across a wide range of income levels value their leisure time equally, thereby avoiding the wage rate dilemma. This argument stems from the idea that regardless of income, individuals generally work a standard day and then go home and take care of the responsibilities of running a household. Once those responsibilities are fulfilled, the rest of the day is open for leisure activities.

One way to in effect “buy” extra leisure time is to hire professionals to take care of the day-to-day chores of home maintenance and upkeep. Different people will buy widely different amounts of such services, but the hourly value of service should be relatively insensitive to the wage level of the purchaser. According to a United States Department of Labor survey (United States Department of Labor and United States Department of Labor Statistics, 2005), in 2004, the hourly wage for maid service was $8.34 and for grounds keepers and gardeners was $11.66. Averaging these wages and adjusting to current dollars yields $10.62 as the hourly wage. Without any empirical data to show the distribution of how home services are purchased, taking the average of these wages assumes equal distribution. According to this survey, the national average wage in 2004, across all industries, was $18.09 per hour which is $19.20 in current dollars. Comparing the service industry wage to this average shows that the service industry wage is approximately 55% of the national average. While not exact, this service industry analogy to assigning a value to time saved seems to mirror the conventional thinking of using about 50% of the prevailing wage rate.

5. Cost of Survival Approach

Another way to value time in general is to monetize the basic essentials of day-to-day life. The basic motivation for rationalizing the way professionals look at personal value of time is to bring individuals onto a level field of evaluation. Wage rate, while convenient, does not take into account how individuals actually value their own time. Someone might think that his or her time is worth considerably more or less than what that person earns. Someone else might value their time considerably different based on the purpose of travel. Because of all of these unknowns, establishing a single value of time based on wage rates might be impractical. One manner to eliminate some of this variability among people is to monetize the basic needs of subsistence. This is a way to make everyone more similar, and could be considered the di minimis method of time valuation.

The basic living essentials for human beings are shelter, sustenance, and clothing. Conveniently, all of these needs are met by the Federal Bureau of Prisons. Incarcerated individuals have all of their survival needs provided by the prison in which they are confined. Prisons have a budget and keep exacting records of their expenditures. The daily cost of incarceration (and supervision) per
inmate, while in a United States Bureau of Prisons facility, was $63.51 in 2004\(^1\). Adjusting this value to current dollars, and reducing it to an hourly rate, yields $2.76, which is 14% of the average national wage mentioned above. If we add the cost of vehicle ownership and operation (discussed subsequently) this rate increases to 33% of the average national wage. In a way, this is how much an hour of an incarcerated individual’s time is worth because that is how much it costs the supervisory agency to sustain that individual. These two percentages (14% and 33%) are more or less consistent with a study that has recommended using 20% of the wage rate for user travel time value (Calfee and Winston, 1998). While the incarceration information presented here is generalized, it still represents a method for time valuation that is a lower percentage of the national wage rate than is commonly used. Furthermore, this value is representative of the value of time only. The costs of vehicle ownership and operation are not included here. While the cost of survival approach raises many debatable issues, it indicates that one could be justified in utilizing a user time value that is considerably lower than what is commonly accepted.

One could argue that living in prison is not desirable and therefore, equating the cost of prison life to the value of personal time is inappropriate. An alternative means to establish the minimal value of user time is to look at the current national poverty level. The poverty line is the minimum annual income required to sustain an individual or family with the basic needs of living. By looking at the poverty case, an analyst can remove the variability associated with user income. Regardless of what an individual earns, all of the living essentials purchased by that person, for any cost, could in theory be acquired at the poverty level. This approach can separate out a person’s wants from their needs.

According to the U.S. Department of Health and Human Services, in 2004 the poverty threshold for a person in the lower 48 United States was $9,310 per year\(^2\), and in 2006 dollars is $9,740. By considering a forty hour work week for 52 weeks, this value converts to a wage of $4.68 per hour. According to the AASHTO (2003) the total cost for owning and operating a vehicle in 2000 dollars is 41.6 cents per mile, given that the operator drives 15,000 miles per year. This translates to $6240 per year. Inflating this value to 2006 dollars and reducing it to and hourly rate gives a value of approximately $3.56 per hour. Therefore, the subsistence hourly value of time including the costs of owning and operating a vehicle can be represented by the poverty rate plus the ownership rate which is $8.24/hour or roughly 44% of the national average wage. This rate could be considered the minimal value required for an individual to earn in order for that individual to live and utilize a vehicle. If a one were to earn more than this amount then that surplus could be considered a level of luxury and is the superfluous variability that leads to the controversy of time valuation.

6. Construction & Maintenance Considerations

Since the majority of user costs are not borne by the agency conducting a highway project, they are generally neglected from the BCA. If user delay data are entered into the analysis, those data only cover delays due to construction, not any subsequent maintenance delays. While construction delays can be significant, many highway networks can require frequent if not constant maintenance operations, which can reduce capacity. Also, since highway networks experience growing utilization, the number of future users affected by delays due to maintenance could be significant. As evidenced by the AASHTO (2003) user benefit software, user delay considerations are only accounted for during construction. A more accurate portrayal of the stream of highway benefits and costs over time would include the effects of maintenance

\(^1\) http://www.uscourts.gov/ttb/may04ttb/costs/
\(^2\) http://aspe.hhs.gov/poverty/04poverty.shtml
practices over the life of the system. Depending upon the usable life of a highway project, if taken into account initially, the life-cycle delays due to maintenance operations could dominate the BCA and render a project unsuitable.

A possible rational for neglecting maintenance delays from the initial BCA is distinguishing between permanent benefits/costs and temporary benefits/costs. When conducting a BCA the analyst is concerned with the user costs associated with construction. Concurrently, the analyst is concerned with the real benefits reaped by society once the project is completed. Maintenance delays, while burdensome, and potentially drawn out, only constitute a temporary inconvenience to users and currently are not considered to play a role in benefit/cost analysis. However, potentially costly maintenance programs could affect public sentiment toward a new project even if the projected benefits for that project are significant.

Once the presence of future maintenance delays are taken into consideration, the tasks of predicting and appropriately discounting user delay time become important. Predicting the quantity of costs for labor and materials at some future date represents hard costs that can be easily discounted, using the private discount rate, to a present value. However, user delay time is a social cost which does not represent the expenditure of capital and therefore should be discounted separately from labor and material costs at an appropriate social discount rate. Some advocate that the discounting of time preference should mirror the rate used for real money. Intergenerational fairness is an issue that is not addressed by discounting time preference in this way and analysts need to consider that due to economic growth, future generations will likely have greater consumption values than the current one\(^3\). This implies that unlike money, time preference should be discounted at a time varying rate. Therefore, depending on the time when maintenance programs are implemented, the social discount rate should be adjusted accordingly.

The distribution of expected delays throughout a maintenance operation should be taken into account as well. In reality, how the expected delay time is distributed is of great importance. For instance, it can be argued here that one needs to attach greater user cost to a maintenance program that implements one hour of delay, per day, for five days, versus twenty minutes of delay, per day, for fifteen days. This point is emphasized by one of the panelists in the U.S. GAO (2004) report: “Do we see the value of time as linear or nonlinear with respect to the amount of time saved? I do not—I cannot usefully use one minute saved in the same way that I can use 20 minutes saved.” Another consideration for analysts is the discounting of human life. If increased user safety is a forecasted benefit of a project then one needs to discount future lives saved to the present for benefit calculations. Maintenance programs have the potential to not only delay users but to reduce safety and increase the likelihood of fatal accidents. While fatalities during the operation of a completed project are taken into consideration for the BCA, a different accident rate needs to be utilized for fatal accidents expected during maintenance activities.

7. Network Considerations and an Example

Careful consideration of how a maintenance program will affect a transportation network needs to be taken. Depending upon the location of the work, different user costs could be realized for the same activity (e.g., painting and/or paving), based on the variability of the network to alleviate congestion (i.e., longer delays). It is important for transportation planners to realize the effects that maintenance on a specific section of road will have throughout the network. Also, segments that experience heavy volume should be designed to be resilient and not require frequent maintenance, or have supporting surface routes that can be easily accessed if the primary route is

\(^3\) http://www.willamette.edu/~fthompson/pubfin/ABC4.ppt
overburdened or requires detouring. Different maintenance programs can have varying user costs if detouring is required, due to the mix of users involved. In an effort to better represent the actual user costs of a project, it is recommended here that if the wage rate approach to time valuation is implemented, then local wage data be used. Furthermore, when calculating user costs, one must be cognizant of the delays experienced by users that are detoured as well as the collateral costs of regular users of the detour route that are not detoured but experience increased congestion. After considering such circumstances, the project may not prove to be beneficial and appropriate steps such as alternate detour routes and/or off-peak/season work may have to be considered.

A typical design for highway networks around metropolitan centers incorporates an outer beltway with radial interchanges. The logic behind this design is that it routes traffic away from the city center and does not congest a city with highway interchanges. Several U.S. cities such as Indianapolis, Boston, Atlanta, Houston, and Washington D.C. have this design. A drawback from this layout is that all of the highways in this network share a common link, which can compound congestion if one or more of the highway segments experiences delays. Moreover, critical locations such as bridge bottlenecks or segments with reduced capacity due to maintenance can initiate significant traffic delays throughout the entire system.

Washington D.C., for example, experiences significant congestion due to high traffic volumes and insufficient capacity. One critical point in this network is the Woodrow Wilson Bridge, which is part of Interstate 495 and spans the Potomac River. This structure is critical to the point that the states of Maryland and Virginia as well as the District of Columbia have undertaken a project to replace the existing four lane bridge with a twelve lane bridge. This section of I-495 is also considered part of I-95, which is the principle north-south corridor on the East Coast of the U.S. A graphical representation of the Washington beltway is show in figure 1. From a network perspective, this link is important not only from a metropolitan view but from an interstate commerce perspective as well. The decision to replace the Wilson Bridge represents thinking that not only recognizes the obvious need to replace an obsolete structure but also embraces the opportunity to enhance the overall network.

With the current four-lane bridge, commuters and through travelers alike can either choose the considerable delay trying to cross the Wilson Bridge or an alternate route to bypass this crossing. Let us assume that a user traveling north on I-95 wants to cross the city and continue north on the interstate. Assuming that waiting in traffic to cross the bridge will add thirty minutes to the total travel time, two alternate routes are shown in figure 2. The first (route A) involves the user entering the city center via I-395, connect to I-295 and connect back to the beltway near the I-95 exit. While this alternative avoids the bridge crossing it also counteracts the purpose of the beltway to keep through traffic from adding to the local congestion. This alternative may seem preferable to the user but could potentially hinder the network if many travelers decide to take this route. A second option would be to traverse the beltway in a clockwise fashion. While this option seems to be the obvious choice, there is signage on I-95 that instructs a traveler to traverse counter-clockwise on the beltway to rejoin I-95. The reason is that there are more access points to the beltway on the western side and this is the source of most of the commuter volume and the associated delays. While it is uncertain the exact travel times associated with these alternatives it seems clear that no one option is markedly better than the others. The decision to wait in bridge traffic or choose an alternate route is one of personal preference. Transportation officials should realize that users may choose to avoid areas of certain congestion such as notorious bridge crossings, thereby adding congestion to the obvious bypass routes. When replacing a bridge is not an option, renovating the possible bypass options could offer similar benefits.
The following is a hypothetical example of how conducting a Present Discounted Value (PDV) analysis will show that renovating this critical link in the network will benefit the network. We assume that a through traveler will choose one of the three options, previously discussed, for traversing the city. We will examine three time frames: prior to bridge replacement, construction of the bridge, and the finished state. Based on current conditions, we estimate that during the pre-construction phase it will take a vehicle 1.25 hours to travel route C. This travel involves stop and go traffic and low operating speeds, which corresponds to a service level of “F” (Wright, 1996).

During construction of the new bridge delays in this section will increase and through vehicles will choose among options A, B, and C. We assume that due to real-time travel information the travel times for these options will self equalize, and we estimate this will be at 1.5 hours. During the construction phase, these alternate routes that do not typically experienced this high level of use, could potentially be overburdened. Based on peak rush hour traffic volume of 17,000 vehicles with an occupancy rate of 1.5 persons per vehicle, and using 50% of wage rate as a representative value of time, this increase in travel time represents a construction user delay cost of approximately $62,000 for the one hour of rush time per day, and $30,000,000 over the expected 18 months of construction-created delays. This case might also be considered representative of what would happen if the current bridge is left in place and traffic continues to grow.

After the bridge is completed, the traffic bottleneck will be removed and through travelers can be expected to experience a service level range of B (dependent on vehicle density), which corresponds to a free-flow speed of 60 mph for 960 vehicles/lane/hour (Wright, 1996), (speed limit on the beltway is 55 mph but speeds of 70+ mph are common). Route C measures approximately 34 miles, and at a speed of 60 mph translates to a travel time of 34 minutes (41 minutes for 50 mph). From the pre-construction scenario this represents a time savings of 41 minutes, and from the construction scenario a savings of 56 minutes.

Assuming vehicle occupancy is 1.5 persons, traffic growth is 2.5%, value of time growth 1%, and discount rate 6%, a present discounted value (PDV) analysis can be conducted on the user time benefit of the retrofit. Since freeway speed is relatively insensitive to fluctuations in traffic volume, the calculated time saving of 41 minutes will be realized for the first 16 years after the bridge opens despite a constant traffic growth of 2.5%. The following four years will result in a speed reduction to 57 mph due to traffic growth and result in a decrease in time savings to 36 minutes. Applying all of these assumptions yields a present discounted value of benefits due to time savings during the peak hour of travel over 20 years of $326,000,000. It is important to note that this value only reflects the plausible benefits recovered during the peak hour of traffic on this segment. Further benefits would be reaped from some time savings acquired throughout a typical day. Furthermore, this example assumes that all of the traffic is traveling on the I-95 corridor. While not realistic, this assumption is considered acceptable because the time savings assumed here are of similar order to the time savings reasonably expected to be experienced by the rest of the commuter traffic.

It seems apparent that for cities like Washington D.C. measures to relieve congestion for through travelers are important. Where possible, express lanes that have multiple entrances but only exit to the through highway could offer substantial time savings to the through travelers as well as some relief to the local congestion. Overall widening of the beltway seems to be a necessity since the capacity of this system has been surpassed by the daily traffic volume. Hopefully, with the opening of the new Woodrow Wilson Bridge in 2008, not only will regular users of this crossing experience reduced commute times but the overall network will see reduced congestion as well.
Conclusions

Efficient highway asset management cannot be achieved without proper understanding of how maintenance and construction efforts affect the overall network. Of critical importance is rationally monetizing user time (either time saved or delayed) that is expected from network improvements. The system must have the capability to support detours and alleviate delays, since the ability in the future to perform improvements to the system that remove critical areas of delays is important.

References


Figure 1. Washington D.C. Beltway and Major Feeder Routes

Figure 2. Possible Alternative Routes Around Washington, D.C.