Notes on Valuation of Travel Time

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# Notes on Value of Travel Time and Vehicle Automation

## Estimates from

* see "Value Of Travel Time.xlsx" "Type" ,"Purpose", "Type\_Purpose", "High" "Low" "Recommended" "Local" ,"Personal" ,"Local Personal", 14.30, 8.40, 12.00 "Local" ,"Business" ,"Local Business", 27.50, 18.30, 22.90 "Local" ,"All Purposes", "Local All Purposes", 14.90 8.90 12.50 "Intercity", "Personal Intercity Personal" 21.50 14.30 16.70 "Intercity", "Business", "Intercity Business", 27.50, 18.30, 22.90 "Intercity", "All Purposes", "Intercity All Purposes", 22.80, 15.20, 18.00 , ,"Truck Drivers", ,"Truck Drivers", 29.60, 19.80, 24.70 , ,"Bus Drivers", "Bus Drivers", 29.40, 19.60, 24.50 , ,"Walk access waiting transfer" ,"Walk access waiting transfer", 28.70, 19.10, 23.90

"Type , Purpose, Type\_Purpose, High Low Recommended  
Local , Personal, Local\_Personal, 14.30, 8.40, 12.00   
Local , Business, Local\_Business, 27.50, 18.30, 22.90   
Local , AllPurposes, Local\_AllPurposes, 14.90 8.90 12.50   
Intercity, Personal, Intercity\_Personal, 21.50 14.30 16.70   
Intercity, Business, Intercity\_Business, 27.50, 18.30, 22.90   
Intercity, AllPurposes, Intercity\_AllPurposes, 22.80, 15.20, 18.00   
 , , TruckDrivers, TruckDrivers, 29.60, 19.80, 24.70   
 , , BusDrivers, BusDrivers, 29.40, 19.60, 24.50   
 , , Walk\_access\_waiting\_transfer, Walk\_access\_waiting\_transfer, 28.70, 19.10, 23.90"

## [1] "Type\t, Purpose,\t Type\_Purpose,\tHigh\tLow\tRecommended\nLocal\t, Personal, Local\_Personal,\t14.30, \t8.40, \t12.00 \nLocal\t, Business, Local\_Business,\t27.50, \t18.30, \t22.90 \nLocal\t, AllPurposes, \tLocal\_AllPurposes, \t14.90 \t8.90 \t12.50 \nIntercity, Personal,\t Intercity\_Personal,\t21.50 \t14.30 \t16.70 \nIntercity, Business,\t Intercity\_Business,\t27.50, \t18.30, \t22.90 \nIntercity, AllPurposes, \tIntercity\_AllPurposes, \t22.80, \t15.20, \t18.00 \n , , TruckDrivers,\tTruckDrivers,\t29.60, \t19.80, \t24.70 \n , , BusDrivers,\t BusDrivers,\t29.40, \t19.60, \t24.50 \n , , Walk\_access\_waiting\_transfer, Walk\_access\_waiting\_transfer,\t28.70, \t19.10, \t23.90"

# Source: US DOT: “Plausible Ranges for Hourly Values of Travel Time Savings” (2009 U.S. $ per person-hour)

## Valuation of Travel Time

Well-surveyed by Small (2012)

* Small, Kenneth A. (2012). Valuation of travel time. Economics of Transportation, 1(1-2), 2-14. <doi:10.1016/j.ecotra.2012.09.002>

### Definition of the value of travel time

* The value of travel time (VTT, or ) is defined as the"tradeoff between time and cost leaving utility constant" (Lave 1969, Small 2012), i.e. the marginal rate of substitution between time and monetary cost. This may be computed as or marginal (conditional, indirect) utility of travel time divided by the marginal utility of income (or cost/dollars)
* For example, if conditional indirect utility for a transportation mode is linear in cost and travel time: where *C* is cost, is travel time, and *w* is wage rate, then VTT is .
* **Note:** One important effect of CAV technology is to change the marginal utility of travel time for any level of travel, presumably increasing it.

### Begin with the Utility Maximization Problem of the Traveler

We follow the standard Becker (1965) model of time allocation across work, leisure and travel, as elaborated by DeSerpa (1971), to account for multiple activities with being the time allocated to travel and the time allocated to work, and the income from labor plus unearned income *Y* is used to purchase goods *G*. There are constraints on budget (where ), total time expenditure, and constraints indicating the minimum allowable time to be spent on each activity:

With the Lagrangian:

The optimality conditions, at maximizing point are:

For being the maximal (indirect) Utility for given constraint levels and wage , the sensitivity theorem says that the Lagrange multipliers provide the marginal variation in indirect utility with constraint RHS values:

Here the Lagrange variables are all defined with the following signs,

Combining these relationships we can find an expression for the marginal (indirect) utility of travel time at the optimum (this exposition follows Small and Verhoef 2007 Chapter 2):

and

so

which leads to an expression for the Value of Travel Time VTT

Thus the value of travel time is equal to the wage, adjusted by a term that accounts for the difference between the marginal utility (direct consumption benefit) of work time and the marginal utility of travel time (with the marginal utility difference converted to dollars by the marginal utility of (unearned) income, ). Note that this expression accounts for both the opportunity cost of travel time in terms of foregone wage () and the relative consumption benefit of work time versus travel time.

In general, most forms of travel time are evidently more pleasant than work time, because the estimated value of travel time is typically below the wage indicating that the second adjustment term is negative.

Or (alt derivation)???

## Applications and Extensions of Value of Travel-Time Theory to Travel in CAVs

* **Changing marginal utility of travel time** The theories for the value of travel time exposed in Small 2012 have the common feature that they all rely on travel time displacing other activities, i.e. other types of time use, through the time budget constraint $. Except for referring to the risk-burden/effort associated with congested travel time, they do not speak of the *quality* of time spent while traveling. So quality of travel-time must be embedded in the marginal utility of travel time .
* **Multiple types or components of travel time** Need to disaggregate travel time by mode (car, transit, foot/bike) and component (congested travel, recreational travel, local vs. highway or long-distance travel) or purpose (commute, shopping/errand, etc.) Small (2012) and others document the heterogeneity of travel time, and CAV technology may affect the value of time in each of these activities differentially
* **Non-linearity of Travel Time Cost** There is some evidence that the utility of travel time is not linear in trip length. How can this be included in the theory, and can we then consider the implications of connectivity/automation?
* Small notes that Ben-Akiva and Lerman (1985) use a piece-wise linear specification for travel demand, and conclude that the first 20 minutes of a commute trip have little or no cost, presumable due to a high consumption benefit associated with spending a short time commuting.
* **Travel Time Reliability**

## Useful References

* Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. Transportation Research Part C: Emerging Technologies, 67, 1-14. <doi:10.1016/j.trc.2016.01.019>
* Ben-Akiva, M., Lerman, S.R., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT Press, Cambridge, MA.
* Cervero, Robert, 2001. "Induced Demand: An Urban and Metropolitan Perspective."" Prepared for Policy Forum: Working Together to Address Induced Demand. Berkeley, CA. <http://www.uctc.net/research/papers/648.pdf>
  + Published as: "Induced Demand: An Urban and Metropolitan Perspective," in *Working Together to Address Induced Demand*, Washington, D.C., Eno Transportation Foundation, 2002, pp. 55-73.
  + Surveys 30 years of literature on Induced demand, which mostly focused on the elasticity of VMT to highway improvements or expansions (lane miles)
    - Of course there are problems with using lane-miles as a measure of highway capacity expansion
    - Since CAVs would reduce congestion and increase traffic through-put, their effect may be similar to an expansion of highway lanes. One important difference is that their effect can apply anywhere in the system, rather being localized to one highway segment like a roadway improvement.
    - Also, since the microeconomic theory indicates that road improvements alter travel demand through altering the intermediate variable of "Generalized Travel Cost" (by altering time and safety), in that sense, CAVs are similar to roadway improvements. (NHTSA has known this for decades).
    - Cervero writes that the theory is:
      * travel demand (number of trips) is a function of generalized cost and other control variables ,
      * generalized cost is a function of road supply and other control variables ,
      * elasticity of travel demand with respect to generalized cost:
    - Cervero (2001:10) reports that virtually all empirical studies to date fail to properly represent these nested relationships between road improvements and induced travel. They either omit the intermediate causal step of road capacity altering generalized cost, or "fail to weigh the relative role of road improvements in bringing about travel-time safings and to guage how in turn this induces travel."
  + some/many induced demand effects are actually shifts in route or timing of the trips, rather than new trips (latent trips, mode shifts, longer trips).
    - Cervero finds "Most consistent across studies is the position that improved roads trigger shifts [in travel time] from the off-peak to the peak."
* Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. Transportation Research Part A: Policy and Practice, 77, 167-181. <doi:10.1016/j.tra.2015.04.003>
  + Also published as Eno paper in 2013, <https://www.enotrans.org/wp-content/uploads/2015/09/AV-paper.pdf>
* Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transportation Research Part C: Emerging Technologies, 40, 1-13. <doi:10.1016/j.trc.2013.12.001>
* Gucwa, Michael, 2014. [Mobility and Energy Impacts of Automated Cars](https://higherlogicdownload.s3.amazonaws.com/AUVSI/c2a3ac12-b178-4f9c-a654-78576a33e081/UploadedImages/documents/pdfs/7-16-14%20AVS%20presentations/Michael%20Gucwa.pdf). Presentation to the Automated Vehicles Symposium. Burlingame, CA, July 16.
* Gu?riau, M., Billot, R., El Faouzi, N. E., Monteil, J., Armetta, F., & Hassas, S. (2016). How to assess the benefits of connected vehicles? A simulation framework for the design of cooperative traffic management strategies. Transportation Research Part C: Emerging Technologies, 67, 266-279. <doi:10.1016/j.trc.2016.01.020>
* Hess, S., Bierlaire, M., & Polak, J. W. (2005). Estimation of value of travel-time savings using mixed logit models. Transportation Research Part A: Policy and Practice, 39(2-3 SPEC. ISS.), 221-236. <doi:10.1016/j.tra.2004.09.007>
* Jamson, A. H., Merat, N., Carsten, O. M. J., & Lai, F. C. H. (2013). Behavioural changes in drivers experiencing highly-automated vehicle control in varying traffic conditions. Transportation Research Part C: Emerging Technologies, 30, 116-125. <doi:10.1016/j.trc.2013.02.008>
* Le Vine, S., Zolfaghari, A., & Polak, J. (2015). Autonomous cars: The tension between occupant experience and intersection capacity. Transportation Research Part C: Emerging Technologies, 52, 1-14. <doi:10.1016/j.trc.2015.01.002>
  + Non-drivers can engage in other activities, but experience discomfort at lower levels of acceleration than drivers. Authors "found that restricting the dynamics of autonomous cars to the acceleration/deceleration characteristics of both rail systems [to improve ride quality leads to reductions in a signalized intersection's vehicle-processing capacity and increases in delay. The impacts were found to be larger when constraining the autonomous cars' dynamics to the more-restrictive acceleration/deceleration profile of high-speed rail."
* Lyons, G., & Urry, J. (2005). Travel time use in the information age. Transportation Research Part A: Policy and Practice, 39(2-3 SPEC. ISS.), 257-276. <doi:10.1016/j.tra.2004.09.004>
  + In transport scheme appraisal, savings in travel time typically represent a substantial proportion of the benefits of a scheme.... Such benefits are founded on the assumption that travel time is unproductive, wasted time in-between "real" activities .... Travel demand analysis treats travel time and activity time as separate, albeit acknowledging an interdependency. The paper challenges these approaches by exploring how travel time can be, and is, being used 'productively' as activity time, .... Such undermining of the division between activities and travelling, and between activity time and travel time, may have major implications for future levels of mobility, for the modal distribution of travel, for the validity of current transport appraisal methodology ....
* Mersky, A. C., & Samaras, C. (2016). Fuel economy testing of autonomous vehicles. Transportation Research Part C: Emerging Technologies, 65, 31-48. <doi:10.1016/j.trc.2016.01.001>
* Mokhtarian, P. L. (2005). Travel as a desired end, not just a means. Transportation Research Part A: Policy and Practice, 39(2-3 SPEC. ISS.), 93-96. <doi:10.1016/j.tra.2004.09.005>
* Ory, D. T., & Mokhtarian, P. L. (2005). When is getting there half the fun? Modeling the liking for travel. Transportation Research Part A: Policy and Practice, 39(2-3 SPEC. ISS.), 97-123. <doi:10.1016/j.tra.2004.09.006>
  + explores the notion of "directionless travel," i.e. travel for its own sake
  + eight models of short-distance Travel Liking and five models of long-distance
  + studied "Travel Liking"
* Pawlak, J., Polak, J. W., & Sivakumar, A. (2015). Towards a microeconomic framework for modelling the joint choice of activity-travel behaviour and ICT use. Transportation Research Part A: Policy and Practice, 76, 92-112. <doi:10.1016/j.tra.2014.10.013>
* Pickrell, D. (2001). Induced demand- its definition, measurement and significance. In Eno Transportation Foundation Policy Forum. Retrieved from <http://ntl.bts.gov/lib/51000/51100/51199/InducedDemand.pdf>
* Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. Transportation Research Part A: Policy and Practice, 39(2-3 SPEC. ISS.), 147-162. <doi:10.1016/j.tra.2004.07.001>
  + This paper reports results of two questionnaire studies aimed at examining various motives for car use. ... As proposed by Dittmar's (1992) [The social psychology of material possessions: to have is to be.] model on the meaning of material possessions, results from both studies revealed that car use not only fulfils instrumental functions, but also important symbolic and affective functions. Second, it was studied to what extent these different motives are related to the level of car use. ... it appeared that commuter car use was most strongly related to symbolic and affective motives, and not to instrumental motives. ... These results suggest that policy makers should not exclusively focus on instrumental motives for car use, but they should consider the many social and affective motives as well.
* Wardman, M., & Lyons, G. (2015). The digital revolution and worthwhile use of travel time: implications for appraisal and forecasting. Transportation, 507-530. <doi:10.1007/s11116-015-9587-0>

## VMT Implications of Congestion

* Fagnant and Kockelman (2015) estimate the induced VMT effects of automated vehicles, accounting for two factors: additional unoccupied travel of shared AVs when traveling to pick up riders, and VMT induced by reduced costs and congestion. They estimate the former at approximately 10% for a mature/high-CAV-penetration market, based on simulations with their own agent-based model for the Austin, Texas market. For the effects of congestion-reduction, they apply Cervero's (2001) survey and meta-analysis results for

## Quo Vado?

# commented code  
x = rnorm(1000)