MEMORANDUM | September 1, 2015

TO Craig O'Connor, NOAA

FROM Chris Leggett

SUBJECT E1 - Travel Cost Computation

INTRODUCTION

The cost of traveling to each site is calculated as a weighted average of the cost of driving to the site and the cost of flying to the site, where the weights are the probabilities of selecting each mode.[1] Letting c_{iojt} represent the cost to individual i of traveling from origin o to site j in time period t and letting π_{ioj} represent the probability that i will choose to fly to site j from origin o, travel cost is calculated as

$$c_{iojt} = \pi_{ioj} c_{iojt}^{Fly} + (1 - \pi_{ioj}) c_{iojt}^{Drive}$$

The time period, t, is individual specific, corresponding with each respondent's reporting period for trips.[2] This memorandum describes how the cost of driving, the cost of flying, and the probability of flying are calculated.

THE COST OF DRIVING

The cost of driving (one way) from any starting location (a) to any ending location (b) is calculated as a function of the driving distance in miles, the number of hotel nights required, the cost of tolls, and the driving time in hours:[3]

$$c_{it}(a,b) = [(f_{it} + \alpha_t) * distance(a,b) + \gamma_t * nights(a,b) + tolls(a,b)]/\rho + \beta_i * time(a,b),$$

[1] Travel costs are calculated within a series of Stata do files that calculate the cost of driving to each site, the cost of flying to each site, the probability of flying to each site, and the final expected travel cost.

2 Travel cost inputs were available on either an annual, quarterly, or monthly basis. In situations where an individual's reporting period spans more than one input value, a weighted average is calculated, where the weight assigned to the input associated with a particular time period is equal to the proportion of the respondent's reporting period that falls within that time period.

3 General origins and destinations were used in specifying this function (rather than, for example, the cost of driving from the individual's home to site j), as the function is also used to represent the cost of driving to and from airports. Technical Memo E4 - Geocoding Origins and Destinations describes how origins and destinations were geocoded, while Technical Memorandum E6 - Air Travel Data Integration describes how airport locations were geocoded.

where:

f_{it} = Average per-mile fuel cost for respondent i in time period t. This is calculated as the average fuel cost (in dollars per gallon) in time period t associated with the respondent's region of residence (US EIA 2013) divided by the nationwide average fleet fuel economy in time t (in miles per gallon) (Bureau of Transportation Statistics, 2013).

α_t = Average per-mile non-fuel out-of-pocket cost in time period t, including the cost of maintenance, tires, and depreciation (AAA 2012, AAA 2013). The cost of maintenance and tires for an average sedan are obtained directly from the AAA reports.[4] The cost of depreciation is calculated as the average per-mile depreciation implied by 5,000-mile deviations (higher and lower) from AAA's 15,000-mile annual depreciation scenario. For example, AAA reports that in 2012, annual depreciation is $255 lower ($213 higher) for an average sedan that is driven 5,000 miles less (more) than the 15,000-mile scenario. This yields an average per mile depreciation of $0.0468 ($0.0468 = (($255/5,000) + ($213/5,000))/2).

$distance(a, b)$ = One-way driving distance (in miles) between a and b as calculated by PC*Miler.[5]

γ_t = Average cost of a night at a hotel in time period t (D.K. Shifflet & Associates, Ltd., as cited in American Hotel & Lodging Association, 2013 – 2014).

$nights(a, b)$ = One-way driving time (in hours) between a and b as calculated by PC*Miler, divided by 12, then rounded down to the nearest integer.

$tolls(a, b)$ = One-way total tolls between a and b as calculated by PC*Miler.

ρ = Weighted average party size for all trips. The average party size is calculated in two steps. First, a weighted average is calculated for each respondent using the trips for which party size was reported (the "initial loops" trips as described in Technical Memo F4 – National Trip Extraction) and the weights from the valuation survey data. Second, an overall weighted average is calculated across these respondent-specific weighted averages. The respondent-specific weight for this second weighted average is equal to the sum of the weighted trips contributed by the respondent. Thus, this second weight includes contributions from trips where party size is known (i.e., initial loops trips) and from trips where party size is unknown

4 Several recent travel cost studies have used AAA data in calculating out-of-pocket driving costs (see, e.g., Provencher and Bishop 2004, Lew and Larson 2008, and Murdoch 2006).

5 Version 27 of PC*Miler BatchPro was used to calculate all distances and times. PC*Miler is frequently used to calculate travel distances in travel cost studies (see, e.g., Von Haefen and Phaneuf 2003, Murdoch 2006, and Parsons et al. 2009). When running PC*Miler, the default settings were used with the following exceptions: Vehicle Profile = "Full-Size Van", Vehicle Weight = 8,500 pounds, Route Type = "Practical", Route Options = "Borders Open" and "Ovrd Restrictions", Toll Options = "Discount Tolls", Time Settings = "None", Output Options = "Time Estimate", Distance Units = "Miles".

(i.e., gotimes trips; see Technical Memo F4 – National Trip Extraction).

β_i, = Hourly opportunity cost of time for individual i (described in Technical Memo E2 – Value of Travel Time and Income Imputation).

$time(a, b)$ = One-way driving time (in hours) between a and b as calculated by PC*Miler.

Given this driving cost function, the round-trip cost to individual i of driving from origin o to site j in time period t is simply:

$$c_{iojt}^{Drive} = 2 * c_{it}(origin_{io}, site_j)$$

The geographic location associated with $origin_{io}$ may be either (1) the origin assigned by Westat to the respondent's main home, (2) the origin assigned by IEc to the respondent's extended stay location, or (3) the origin assigned by IEc to the respondent's second home. The treatment of extended stay origins and second homes is described in a later section of this memorandum.

Selected driving cost inputs are summarized in Exhibit 1.

EXHIBIT 1. SUMMARY OF SELECTED TRAVEL COST INPUTS

	INPUT	UNITS	2012	2013
A	Fleet fuel economy	mile/gal	23.3	23.3
B	Gas price[a]	$/gal	$3.422	$3.377
C	Out-of-pocket: gas (C=B/A)[a]	$/mile	$0.1469	$0.1449
D	Out-of-pocket: non-gas	$/mile	$0.1015	$0.1094
E	Out-of-pocket: total[a]	$/mile	$0.2484	$0.2543
F	Lodging	$/night	$114	$123
G	Parking (M and L airports)[b]	$/day	$10.09	$10.24
H	Parking (other airports)	$/day	$6.39	$6.48
I	Rental car	$/day	$54.11	$54.90

Note:
[a] Gas prices vary over month and region. For illustration, average gas prices are presented for the Gulf Coast region in 2012 and the first six months of 2013.
[b] M and L stand for medium and large.

THE COST OF FLYING

OVERVIEW

The cost of flying is comprised of five components: (1) the cost of driving to the origin airport from the origin, (2) the cost of parking at the origin airport, (3) the cost of flying from the origin airport to the destination airport near the site (including pre- and post-flight time at the airport), (4) the cost of renting a car, and (5) the cost of driving from the destination airport to the site. The two driving components are calculated using a methodology identical to the methodology used to calculate the overall cost of driving to the site, allowing us to express the overall cost to individual *i* of flying from origin *o* to site *j* in time period *t* conditional on the selection of origin airport *m* and destination airport *n* using the following expression:

$$c_{iojtmn}^{Fly} = 2 * c_{it}(origin_{io}, oairport_{iom}) + c_{tm}^{Parking} + c_{itmn}^{Flight} + c_{t}^{Rental} + 2 * c_{it}(dairport_{jn}, site_{j})$$

where:

$origin_{io}$ = Geographic location of origin *o* for individual *i*.

$oairport_{iom}$ = Location of the *m*th potential origin airport associated with origin *o* for individual *i*.

$c_{tm}^{Parking}$ = The cost of economy parking at the *m*th potential origin airport in time period *t* during the trip. Calculated as average parking cost times the number of parking days, divided by the weighted average party size for all trips. Two different average parking costs were calculated, one for large/medium airports and one for small airports (see Exhibit 1). The number of parking days is calculated as the weighted average door-to-door duration of all flying trips (as reported by survey respondents) minus the total time spent driving to and from the origin airport.

c_{itmn}^{Flight} = The round-trip cost to individual *i* of flying from airport *m* to airport *n* in time period *t* (described in detail below).

c_{t}^{Rental} = The expected cost of renting a car during the trip. Calculated as the average daily cost of a rental car times the number of required rental car days times the weighted average proportion of respondents renting cars on flying trips, divided by the weighted average party size for all trips. The average daily cost of a rental car was obtained from the American Hotel and Lodging Association Lodging Industry Profiles (Exhibit 1; AHLA 2013, 2014). The number of required rental days is calculated as the number of required parking days (see above) minus the round-trip flight time (as described below). If the calculated number of required rental days is less than zero, then required rental days is

assumed to be zero.

$dairport_{jn}$ = Location of the *n*th potential destination airport associated with site *j*.

$site_j$ = Location of site *j*.

For individual *i* traveling to site *j* from origin *o*, four potential origin airports (*m* = 1, 2, 3, or 4) and four potential destination airports (*n* = 1, 2, 3, or 4) were identified, creating 16 potential flying routes to each site for every individual *i* and origin *o*. The cost of flying is then calculated as the minimum flying cost among these sixteen potential flying routes:[6]

$$c_{iojt}^{Fly} = \min_{m,n}\left\{c_{iojtmn}^{Fly}\right\}.$$

THE COST OF FLYING FROM THE ORIGIN AIRPORT TO THE DESTINATION AIRPORT

The round-trip cost to individual *i* of flying from origin airport *m* to destination airport *n* in time period *t* is calculated as:

$$c_{itmn}^{Flight} = \beta_i\left(time^{airport} + time_{tmn}^{flight} + time_{mn}^{layover}\right) + p_{tmn}^{ticket}$$

where:

β_i = The opportunity cost of time, which is described in detail in Technical Memo E2 – Value of Travel Time and Income Imputation.

$time^{airport}$ = Time spent at the origin airport prior to the flight plus time spent at the destination airport after the flight (4 hours total for a round-trip flight).

$time_{tmn}^{flight}$ = Total round-trip flying time between origin airport *m* and destination airport *n* in time period *t*, including all legs of the flight but excluding any layover time. Total flying time is calculated for the itinerary associated with the 30th percentile airfare for a given route in time period *t*. The 30th percentile airfare is identified using DB1B "ticket" data for the appropriate time period (i.e., quarter) and route, while the itinerary associated with that specific airfare is determined using DB1B "market" data. These DB1B datasets are described in detail in Technical Memo E6 – Air Travel Data Integration. The flying time for each leg of the 30th percentile itinerary is calculated as the median scheduled flight time for all direct flights between the leg origin and the leg destination, using Q1 2012 data provided by OAG Aviation (see Technical Memo E6 – Air Travel Data Integration). For legs that do not have flight times in the OAG data, flight times are predicted based on the leg distance. Specifically, a simple regression model is estimated, *MedianTime* = *a* + *b***MedianDistance*, where *MedianTime* is the median scheduled flight time for a given leg in the OAG dataset, and *MedianDistance* is the median passenger-weighted flight distance for direct flights associated with that leg in the DB1B market files (pooling data from all of 2012 and from Q1/Q2 of 2013). The

6 When commercial flights between origin airport m and destination airport n were not available in period t (i.e., there were no flights between m and n in period t within the DB1B dataset), then that particular flying route is omitted and the minimum is calculated across the remaining available flying routes.

estimated regression parameters (a = 42.50 and b = 0.1213) are used to predict flight times using leg distance.[7] Finally, for itineraries that include flight legs *without* direct flight distances in the DB1B market files, total flying time is estimated using the regression parameters as: flying time = (a x number of legs) + (b x total distance flown across all legs).

$time_{mn}^{layover}$ = Total round-trip layover time (if any) between origin airport m and destination airport n. Total layover time is calculated for the specific flight associated with the 30th percentile airfare for a given route. The layover times are based on data provided by Sabre Airline Solutions on median layover times for 513 different possible flight routes (see Technical Memo E6 – Air Travel Data Integration). The layover time for an airport of a given size (small, medium, or large) is calculated as the passenger-weighted median across all routes in the Sabre dataset involving layovers at airports in the same size class. These medians are 80 minutes for small airports, 55 minutes for medium airports, and 70 minutes for large airports.

p_{tmn}^{ticket} = The 30th percentile ticket price between origin airport m and destination airport n in time period t, including all taxes and fees. For all airlines other than Southwest and Jetblue, $50 is added for baggage fees.

THE SELECTION OF ORIGIN AND DESTINATION AIRPORTS

As discussed above, four potential origin airports were identified for each individual and four potential destination airports were identified for each site. Airports were required to have at least 100,000 enplanements per year to be selected as an origin or destination airport. After imposing this restriction, four airports were selected using the following process:

1. The four closest airports were selected (i.e., the four airports with the shortest driving distances, as calculated by PC*Miler).
2. If the four closest airports selected in Step 1 did not include at least one medium/large airport, then the furthest of the four selected airports was replaced with the closest medium/large airport. Airports are considered medium or large if they make up at least 0.25% of all passenger enplanements in the U.S., as determined by the Federal Aviation Administration using 2012 flight data (see Technical Memo E6 – Air Travel Data Integration).

THE PROBABILITY OF FLYING

For each individual and site, the probability of flying was determined using information on actual mode choices reported by similar respondents for trips with similar distances. Specifically, multiple-day trips where the mode choice was known were assigned to 12 mutually exclusive and exhaustive categories based on driving distance (0 - 250 miles, 250 – 500 miles, 500 - 1,000 miles, 1,000 - 1,500 miles, and > 1,500 miles), household

[7] Both parameter estimates are significant at the 1% level; the regression r2 is 0.95.

size (<=2 versus >2 household members), and annual household income (less than or greater than $70,000). The 12 categories are defined in the following table:

	<=2 MEMBERS OF HH			> 2 MEMBERS OF HH	
DISTANCE (MILES)	<= $70,000	> $70,000		<= $70,000	> $70,000
0 - 250	Category 1	Category 1		Category 1	Category 1
250 - 500	Category 1	Category 2		Category 1	Category 1
500 - 1,000	Category 3	Category 4		Category 5	Category 6
1,000 - 1,500	Category 7	Category 8		Category 9	Category 10
>= 1,500	Category 11	Category 12		Category 11	Category 12

Category 1 was assigned a zero probability of flying. The remaining 11 categories were assigned flying probabilities based on the weighted proportion of trips where flying was selected.

SECOND HOMES

For respondents who had second homes and whose reported trips included some that originated from their second homes (question Q107F from the national and local valuation surveys), the expected travel cost to each site (c_{iojt}) was calculated for both the main home origin and the second home origin. The expected travel cost from the main home was used in estimation unless (1) the expected travel cost from the second home to the site was lower and (2) the driving distance from the second home to the site was less than 400 miles. For sites where conditions (1) and (2) held, the expected travel cost from the main home was replaced with the expected travel cost from the second home prior to estimation.

EXTENDED STAY ORIGINS

For respondents who reported trips from extended stay origins, the expected travel cost to each site (c_{iojt}) was calculated for both the main home origin and the extended stay origin. Choice occasions for these respondents were then allocated to either the extended stay origin or the main home origin in proportion to the number of trips reported from each.

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