SPR 760 Task 2 Deliverables [Draft]

**Methods for Market Basket Definitions and Transportation Costs Calculation**

# I. Transportation Market Basket Identification

In order to construct a transportation “market basket”, we need to identify a basket of travel locations for households for different trip purposes, such as employment, entertainment, shopping and other activities. For each origin (TAZ *k* within Reiff and Gregor’s model-based approach or household *h* within the individual-level model-based approach), a transportation market basket is defined for each trip purpose *p* and income group *i.* In order to balance the tradeoffs between computational complexities and data requirements for any given metropolitan area, we propose several alternative methodologies to establish transportation market baskets (TMBs) using both model-based and cluster-based approaches.

### (A) Reiff and Gregor’s model-based approach

Reiff and Gregor’s (2005) original approach to market basket definition relies on data and models in traditional 4-step travel demand model. The advantage of their approach is that the data for market definition are readily available and the computation for TAZ level travel market baskets differentiated by trip purpose and income group is very straightforward. Although Reiff and Gregor tested methods of defining reference travel market baskets (varying by income group and trip purpose) via identifying a reference TAZ, as an analog to a reference market basket of goods and services used by the CPI measure, they abandoned the idea due to idiosyncrasy and variation in the sizes of the identified market baskets (Reiff and Gregor, 2005, pp. 41–42). Instead they identified a “travel market area” for each TAZ and for each income group and trip purpose. Even though such an approach would resemble the actual travel cost for each combination more closely, it deviates from the market basket definition used by CPI, which inspires the original idea of creating TCI.

According to Reiff and Gregor’s (2005) original approach, defining the market basket for TAZ *k* for income group *i* and trip purpose *p* follows these steps:

**Step 1 Determine size terms**. The size terms of the destination choice model utilities measure the perceived attractiveness of TAZs to trips of different types. They are functions primarily of the numbers of jobs and households in a TAZ, but may include other factors. For example, the size term for home-based recreation trips is calculated with this equation:

(1)

where

emp = number of employees of TAZ *k;*  
hhs = number of households;   
parks = park land in acres.

**Step 2 Identify the potential market area of TAZ *k***for income group *i* and trip purpose *p*. Reiff and Gregor used a threshold to identify the set of TAZs that is to be included in the market area of the focus TAZ. They tested two different methods: the first method bases the threshold on percentage of the total trips attracted to each TAZ from TAZ *k*, as shown in Equation (2); the second method establishes a log sum threshold as in Equation (3):

(2)

(3)

where

*T* = the set of all TAZs in the model area;  
cutoff = chosen threshold for defining the market area;  
trips*pikj* = the number of trips by income group *i* for purpose *p* between TAZ *k* and TAZ *j*;  
logsum*pikj* = the log sum of the access utilities for travel by income group *i* for purpose *p* between TAZ *k* and TAZ *j.*

Several percentage cutoffs were tested, in particular 75% and 50%. The log sum threshold in Equation (3) was chosen by examining ordered plots of log sum values for all TAZs and each trip purpose. For the Medford data, the value of 1 was chosen as the threshold for determining the market area, because the average log sum trends for all zones have inflection points of 1, as log sums increase rapidly to the left of the inflection points and decline gradually to the right (Reiff and Gregor, 2005, page 40, Figure 4.2).

Because of the difficulty in describing a market basket defined by using a threshold log sum value in common sense terms, a 50% trip percentage cutoff in Equation (2) was used in the Medford case study (Reiff and Gregor, 2005, page 42).

**Step 3 Create market baskets for each TAZ by income group and by trip purpose.** Once a market area has been identified for TAZ *k* income group *i* and trip purpose *p*, the market basket can be calculated by adding up the size terms for all the TAZs in the market area.

(4)

where

MB*pik* = market basket for TAZ *k* for income group *i* and trip purpose *p*;

J*pik* = market area for TAZ *k* for income group *i* and trip purpose *p*, as defined in Equation (2) or (3);

size*j* = the size term for TAZ *j*.

**Step 4 Identify a reference TAZ and reference market baskets.** The purpose of identifying a reference TAZ is two-folded: 1.) Through a reference TAZ, reference market baskets (one for each income and trip purpose combination) can be identified as the market area of the reference TAZ; 2.) Once travel market baskets are identified and travel cost aggregated, aggregated travel cost by TAZ are compared with travel cost of the reference TAZ for the same income group and trip purpose (page 50, Equation 4-16).

Identifying the reference TAZ begins with calculating a score for each TAZ:

(5)

where

MB*pik* = market basket for TAZ *k* for income group *i* and trip purpose *p*, as defined in Equation (4).

The reference TAZ is the TAZ with highest score in scorek.

Reiff and Gregor tested different methods for identifying market areas (Equation 2 and 3) and subsequently identified the reference TAZ. They found the two methods defining market areas resulted in two very different reference TAZs and reference travel market baskets with varying sizes and concluded that there is a practical limitation with this approach of identifying reference travel market baskets, as the market basket for the reference TAZ can be very idiosyncratic. They thus abandoned the idea of identifying reference travel market baskets via the reference TAZ and used the reference TAZ only in indexing the aggregated travel cost.

### (B) Individual-level model-based approach

This approach is similar to Reiff and Gregor’s travel market area approach in that they both rely on models, but this approach works at the individual level and can incorporate detailed socio-economic and demographic characteristics of individual households as well as spatial and travel information at fine resolution. With trip generation model and destination choice model, the approach can theoretically approximate the travel needs, thus travel market basket, of any individual household. The disadvantage of this approach is that it has much higher data requirement and is more computation intensive.

Another theoretical limitation is that this individual-level approach relies on first estimating travel behavior models for individual households, as these models may not be readily available in traditional travel demand model system, and then applying the estimated model specification to simulate travel needs for individual households. Besides the land use and accessibility information used in Reiff and Gregor’s approach, model estimation requires individual household level observations, such as Household Activity Survey data, while model application needs synthesized population (households) data, usually from a population synthesizer.

**Step 1 Determine trip rates for households by trip purpose with trip generation models**. Various models have been used to determine the trip rates for households. Cross-classification analysis and linear regression model are commonly used in 4-step travel demand model (Martin et al., 1998). In a linear regression model, trip rates for household *n* are modeled with:

(6)

Where

tripsn = trip rates for a select trip purpose for household *n*;

Xn = socio-economic and demographic characteristics of household n, including household size, income, number of vehicles, etc;

α, β = parameters in the model to be estimated.

Once the model parameters are estimated from observed data, the model can be applied to predict trip rates for any household for which we have information. The advantage of an individual-level approach is that households don’t need to be segmented by income, like in the Reiff and Gregor’s approach, or other variables.

Alternative methods include count model and discrete choice model (references).

**Step 2 Simulate trip destinations for household by trip purpose**. Destination choice model is a commonly used method in determining trip destination. Take HBW trips as an example, the destination of HBW trips can be modeled with a workplace location choice model (Wang et al., 2011). Let the probability that worker *n* chooses workplace location *i* from the set Cn of potential workplace locations, conditional on variables including personal characteristics and locational attributes *Xni*, be given by the following multinomial logit form:

(7)

where

*Xni* is a vector of variables associated with workplace location  for individual *n*, including socio-economic and demographic characteristics of household n (interacting with origin and/or destination attributes), attributes of origin and destination (choice), as well as accessibility between origin and destination.

β is a parameter vector to be estimated.

Once the model parameters are estimated from observed data, Equation (7) can be applied to simulate trip destination for any household. It is possible to predict the probabilities of a household choosing any destination in alternative set Cn or predict a single destination for a trip via a Monte Carlo process. Either method should produce similar results when examined at aggregated level (by TAZ or by income group etc.). For simplicity, a single destination will be predicted.

Step 1 and 2 together identifies travel market baskets of a given trip purpose for any household by predicting its trip frequency and destination. Coupling with a mode choice model and using skims data from travel demand model, it is possible to calculate trip-level transportation cost for the household, which can be aggregated to total transportation costs by household or further to any summary information useful, such as average transportation costs by TAZ or by household income group.

### (C) Cluster-based approaches

In order to balance the tradeoffs between computational complexities, data requirements and accurately capturing activity centers (i.e. for employment, recreation and shopping), the following cluster-based approaches present alternatives to the identification of trip destinations that form transportation market baskets. These cluster-based approaches can potentially identify sets of travel destinations with moderate data requirements, and can also be used in conjunction with one of the model-based approaches.

1. **Center Business District (CBD):** For this methodology, we assume a mono-centric CBD (or TAZ which contains the CBD) where all employment opportunities and entertainment or shopping options are clustered ((Anas et al., 1998), describes this standard urban spatial structure based on the bid-rent theory). The data requirements for this method are low, and may accurately describe very small cities where most businesses are concentrated on a small geographical scale.

Helsley and Sullivan (1991) and Chen (1996) theorize that the diseconomies of transportation and congestion as CBDs experience growth combined with technological advances in transportation (which lower transportation costs) may lead to more polycentric urban spatial trends. In addition, Giuliano and Small (1991), Giuliano et al. (2007), McDonald and McMillen (2000) and Greene (2008) have empirically documented the existence of multiple employment centers within US metropolitan areas. For most modern metropolitans, assuming a central CBD may be unrealistic and over-simplistic for the purposes of calculating a transportation cost index. However, the mono-centric CBD approach provides a straightforward baseline for a minimalist transportation cost index calculation. Therefore, we propose additional methodologies that take this complexity into account.

1. **Spatial employment center identification**:

This type of spatial analysis can take on multiple forms for implementation. Although most of the research examines employment centers specifically, the methodology is applicable for other types of travel destinations such as recreation or shopping.

* Spatial cluster analysis – This methodology has been used mainly in identifying crime hotspots within metropolitan areas, and is built into many geographical information system (GIS) packages.
* Employment density thresholds – McDonald (1989) and Giuliano and Small (1993) agree that “employment, not population, is the key to understanding the formation of urban centers; and that a center is best identified by finding a zone for which gross employment density exceeds that of its neighbors” (Giuliano and Small, 1993). Empirically, Giuliano and Small (1993) and Giuliano et al. (2007) identify urban centers by employing “a density cutoff of 10 employees per acre, and a minimum total employment of 10,000” in their analysis. Redfearn (2007) expands upon this idea by mapping employment densities, identifying peaks in the densities, and testing these peaks for significance.
* Nonparametric identification – McMillen (2001) utilizes a two-stage non-parametric procedure to identify employment centers. In the first step, a nonparametric locally weight regression (LWR or also known as geographically weighted regression) is conducted to smooth employment densities over space to create a benchmark. Next, actual employment densities are compared to the estimated (smoothed) densities to identify candidates for subcenters. McMillen also clusters nearby significant residuals together (within a 3 mile radius) to avoid counting nearby sites as multiple candidates for employment centers. A semiparametric regression is conducted during the second stage to identify which candidates subcenters display “signiﬁcant local effects on the overall employment density”.

Data sources required to implement the above methodologies may include:

* Census Transportation Planning Package (CTPP) – Estimations of jobs by TAZs or census tracts using commuting data (Giuliano et al., 2012)
* Longitudinal Employer-Household Dynamics (LEHD) – Employment statistics by industry for local geographies on census block level
* Oregon Household Activity Survey (OHAS)

# II. Transportation Cost Methodology

Through a literature review process, we determined that *conditional* transportation costs are the appropriate costs to include within a transportation cost index calculation. These costs include costs that are explicitly charged to the users of transportation, such as operating, maintenance and ownership costs of various transportation modes and the cost of travel/wait/delay time. Research by Bhat (2000, 1998a, 1998b, 1995), Hensher (1994), Anas (2007, 1981), Kahn et al. (1981), Train and McFadden (1978), Train (1980), Gillen (1977), Louviere (1988), Louviere and Hensher (1982), Zhao et al. (2013) and Pinjari et al. (2011) has shown that these costs are the primary determinants of transportation choice. The transportation cost calculation methodologies and potential data sources for automobile, public transportation and non-motorized modes (walking and cycling) are detailed below.

### (A) Automobiles

For travel by private automobiles, the transportation cost is characterized by operating costs (fuel cost and tire usage), ownership costs (maintenance, repair, etc.), parking costs and the value of travel time. The cost of automobile travel for a trip between a TAZ or a household location and a travel destination is defined as follows:

(8)

where

D = distance between origin and destination (miles);

fauto = per mile fuel and tire costs;

Oauto= per mile ownership costs including maintenance and repair;

Parking = parking cost for trip (and/or toll costs);

w = value of travel time per hour;

TTauto = estimated travel time for trip.

#### Potential Data Sources

**1. Fuel and tire costs (fauto) –** Permile fuel costs are calculated as the price per gallon of gasoline divided by fuel economy of vehicles (miles per gallon). Although American Automobile Association's (AAA) reports average per mile driving cost for the entire country, it is preferable to obtain regional fuel prices and regional vehicle fleet fuel economy data because both of these components may vary significantly depending on the region or state.

Estimated city and highway fuel economies can be obtained from Environmental Protection Agency's (EPA) fuel economy data. Alternatively, if regional or state-level Department of Transportation maintains more detailed data on fleet composition, more accurate average fuel economy may be estimated. Per mile fuel cost data may be obtained from AAA's Fuel Gauge Report on average fuel prices or the Energy Information Administration’s (EIA) regional gasoline price series.

Fortires, AAA estimates the cost to be $0.01 per mile based on tires of similar quality as those that came with the car. IntelliChoice (IntelliChoice, 2002) also estimates tire costs based on an estimated lifetime of 45,000 miles for each set of tires, without the assumption that car owners continue to purchase the same tires as the original set.

**2. Ownership costs (Oauto) -** Assuming vehicles are driven for 15,000 of miles per year and maintained at manufacturer’s recommended maintenance schedule, AAA estimates a maintenance average cost per mile of $0.497 which is consistent with the average maintenance cost of $0.54 found by Polzin, Chu & Roman (2008). AAA estimates average maintenance cost for small, medium, and larger sedans while Polzin, Chu & Roman (2008) estimated averages for both older and newer cars. Since vehicle age is the main determinant of maintenance and required repairs, the costs estimated by Polzin, Chu & Roman (2008) may be more applicable for our purposes.

Following Barnes & Langworthy (2004), we will utilize estimated repair costs from IntelliChoice (2002). Similarly, we will also assume that 50% of 5-year repair costs occur in the first 4 years, 50% occurs in the 5th year, and the same amount of repair (as the 5th year) occurs for every year thereafter. Marginal per mile depreciation costs can be estimated using data from the National Automobile Dealers Association, Edmunds or Kelley Blue Book.

**3. Parking -** Direct parking cost for commute and non-commute purposes in different destinations would be estimated using parking meter rates and annual commute and non-commute mileages. Other fixed costs such as tolls will also be considered within this category.

**4. Value of travel time (**- ODOT (2012) estimates the value of travel time associated with both business and personal travel by vehicle type following guidelines from USDOT. The most recent estimated weighted average value of travel time on automobile and passenger trucks is equal to $23.68 per hour.

Ozbay et al. (2001) use a regression-based approach to estimating marginal costs associated with vehicles. The authors separate user costs into two categories: self-vehicle operating costs (“car ownership, fuel and oil consumption, regular or unexpected maintenance, and so forth”) and user interaction costs (“accident- and congestion-related costs”). For the purposes of estimating the transportation cost index, we are particularly interested in the estimated self-vehicle operating costs (Copr), formulated as a function of depreciation, gas cost, oil cost, tire cost, maintenance cost, insurance cost and parking fees and tolls. Ozbay et al. (2001) estimate the marginal vehicle operating cost per mile as

(9)

where *a* is equal to the vehicle age (years). When necessary regional data associated with vehicle operation and ownership is unavailable, this methodology represents a reasonable alternative. In this case, the cost of automobile travel for a trip between a TAZ or a household location and a travel destination is defined as:

(10)

where

D = distance between origin and destination (miles);

MCopr = per mile cost of vehicle operation (including gas, oil, maintenance, etc.);

w = value of travel time per hour;

TTauto = estimated travel time for trip.

### **(B)** Public **transportation**

Costs for travel via public transit include transit user fares and value of travel/wait time. Specific data for the study area would be obtained from the appropriate source. Transit fares would be obtained from the regional public transit agency while transit travel time would be based on… The cost of travelling on public transportation for a trip between a TAZ or a household location and a travel destination is defined as follows:

(11)

where

fare= transit fares;

w = value of travel time per hour;

TTpublic = estimated travel time (including wait time) for trip.

#### Potential Data Sources

**1. Transit fares** For the Portland Metro area, we use the formula in the Metro’s travel demand model for estimates of transit fares, which are based on the average fares charged by the region’s transit providers (Metro Research Center and Transportation Research and Modeling Services, 2013). The average fares for all transit providers providing a transit pass option were estimated at 73% of the cash fare price, which is the 2010 ratio for TriMet.

**2. Transit travel time** Transit travel time including accessing and transferring can be retrieved from travel skims when they are available. When travel skims are not available, it may be possible to approximate travel time from transit network (Krizek et al., 2007),network with GTFS (Gandavarapu, 2012), or query transit travel time from online APIs like Google Maps.

### (C) Non-motorized modes (bicycle and walking)

**Bicycle** - Litman (2009) estimates the annual cost per mile of a bicycle to range between $0.47 to $0.56, including ownership, maintenance, value of travel time and parking cost estimations, depending on urban/rural travel and peak/off-peak hours. .

(12)

where

D = distance between origin and destination (miles);

fbicycle = per mile cost of bicycling.

**Walking** – Walking is estimated to cost $1.37 per mile (Litman, 2009). This cost is primarily consists of the value of travel time, particularly because walking usually incurs very little out-of-pocket costs.

(13)

where

D = distance between origin and destination (miles);

fwalk = per mile cost of walking.

#### Potential Data Sources

**1. Biking and Walking Distance** MPOs including the Metro have started to incorporate biking and walking into their travel demand models, and thus the distance matrices may be available from travel model skims. When such skims are not available, it may be possible to approximate travel time from bicycle and pedestrian network (Krizek et al., 2007) or via online APIs like Google Maps.

# III. Transportation Market Basket (TMB) Cost Aggregation

Once transportation market baskets are defined for an urban area and transportation costs have been identified for both motorized and non-motorized modes for each TAZ or household location to destinations within a market basket, the total cost of a TMB can be calculated.

* The total cost of a TMB can be calculated as a weighted average cost, weighted by the proportion of trips conducted by each travel mode and by trip purpose.
* As an alternative, we may only consider the travel mode that yields the lowest cost between the point of origin and the identified destination (i.e, employment, entertainment or shopping).
* Another choice may be to estimate probabilities of each travel mode and each destination within the TMB. Then, the probabilities would be utilized as weights to aggregate the overall costs within a market basket.

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