Travel Model Two: Strategic Supply Design

Technical Paper

Metropolitan Transportation Commission with Parsons Brinckerhoff, Inc.

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1 Overview

The Metropolitan Transportation Commission (MTC) is embarking on an effort to rebuild the representation of supply in our travel model. By "supply", we mean the representation of roadways, transit service, bicycle infrastructure, sidewalks and space. These new representations will serve as the basis for an update to MTC's existing activity-based travel model, known as *Travel Model One*; following the integration of the supply changes with the existing demand representation, the travel model will be referred to as *Travel Model Two*. The purpose of this technical paper is to define a strategic direction from which these new supply representations will be crafted.

The direction outlined in the remainder of this paper was largely determined during a two day meeting held at MTC on May 14th and 15th. The meeting was facilitated and guided by Parsons Brinckerhoff and attended by analytical staff from MTC, Association of Bay Area Governments (ABAG), Santa Clara Valley Transportation Authority (SCVTA), and San Francisco County Transportation Authority (SFCTA).

The new representation of supply is intended to improve the following:

- **Representation of non-motorized travel**. A more refined approach to modeling non-motorized travel, including walking, bicycling, and accessing/egressing transit.
- **GIS integration**. An integration of travel modeling tools with existing tools used by MTC's geographic information systems (GIS) team.
- **Local modeling**. Provide an analytical platform from which MTC's county partners can do county-level modeling at the same spatial fidelity at which the regional model operates.

This document is organized as follows. The next section provides details on the envisioned general design of the *Travel Model Two* system. Then, separate sections are devoted to the discussion of each supply element – specifically space, roadways, transit service, bicycle infrastructure, and sidewalks. Sections on data management and travel model software revisions conclude the paper.

2 Model Design

Travel Model Two will employ a tiered spatial system to allow level-of-service indicators to be computed at a fine or coarser geography, as appropriate. Two spatial systems will be defined: a travel analysis zone (TAZ) system and a micro-analysis zone (MAZ) system. MAZs will nest within TAZs. For travel done at a "micro" scale (in the regional context, meaning less than five miles or so), the MAZ system will be used; for travel done at a larger scale, the TAZ system will be used.

Further, transit travel will be represented as a combination of the following three movements:

- **Access**. An access movement from an MAZ to a so-called transit access point (or TAP), which is a single transit stop or an abstract location representing a collection of bus stops.
- **Line haul**. A line-haul movement from a boarding TAP to an alighting TAP, which can include a transfer (moving from one TAP to another TAP) between services.
- **Egress**. An egress movement from the alighting TAP to the destination MAZ.

The motivation for the MAZ and TAP model design is to more precisely represent neighborhood-level travel while avoiding the steep computational price required to maintain a full set of MAZ-to-MAZ level-of-service matrices. This design concept originated at the San Diego Association of Governments (SANDAG) and is being adopted by planning organizations in the Chicago and Miami regions.

The MAZ and TAP model design requires transit paths be built "on the fly" (i.e. outside the commercial software used by the travel model) by intelligently building and combining the MAZ-to-TAP, TAP-to-TAP, and TAP-to-MAZ trip components into logical, efficient potential paths for evaluation in probabilistic models of mode/transit route choice. The initial design will be to create N "best" MAZ-to-MAZ paths for evaluation by the mode/transit route choice models. Such an approach differs from standard practice, as well as that of MTC's *Travel Model One*, of building single-best-mode-weighted paths (which are typically labeled local bus, light rail, ferry, etc) for evaluation by the mode/transit route choice models.

Table 1 below presents the manner in which level-of-service indicators will be extracted from the model network. Three distinct methods of extracting times from the network will be employed, as follows:

- **Equilibrium assignment**. For automobile travel, congestion effects impact path choice, so a traditional equilibrium assignment will be performed at the TAZ-scale.
- **N best least-cost paths**. For transit movements, we will build, "on the fly", the N best least-cost paths between MAZ pairs. The N best least-cost paths will then be evaluated in the mode/transit route choice model. Transit crowding will not impact route choice in *Travel Model Two*, but we set the stage for implantation by assembling relevant information (e.g., number of stalls at park-and-ride lots).
- **Single best least-cost path**. For close-proximity automobile, bicycle, and walk travel, a single best mode-specific least-cost path will be computed from the MAZ-level all streets network. Because the full MAZ level network will not be assigned due to computational cost, we cannot efficiently measure the impact of congestion on MAZ-level path decisions. As a compromise (for gaining the spatial fidelity offered by the MAZ-level network), we will implicitly assume that automobile, pedestrian, and bicycle congestion have a negligible impact on path choice decisions and assign each MAZ-to-MAZ movement to a single best least-cost path.

Table 1: Approach to Constructing Level-of-Service Information

Level-of-service component	Separation of origin and destination	Geography	Source
Automobile times, distances, and costs	Near (threshold TBD)	MAZ to MAZ	MAZ-level single best least-cost path
Automobile times, distances, and costs	Far	TAZ to TAZ	TAZ-level equilibrium assignment path
Transit line-haul	All	TAP to TAP	N least-cost path determination
Transit walk access and egress	All	MAZ to TAP	N least-cost path determination
Transit bicycle access and egress	All	MAZ to TAP	N least-cost path determination
Transit drive access and egress	All	TAZ to nearest TAP TAZ	TAZ-level equilibrium assignment path
Walk	Near (assume all walk travel is near)	MAZ to MAZ	MAZ-level single best least-cost path
Bicycle	Near (threshold TBD)	MAZ to MAZ	MAZ-level single best least-cost path
Bicycle	Far	TAZ to TAZ	TAZ-level single best least-cost path

3 Space

MTC's existing travel model divides the nine county San Francisco Bay Area into 1,454 travel analysis zones (TAZs)[1], each of which is segmented into no more than three virtual transit access sub-zones. The sub-zone segmentation allows the model to simulate, separately, activity that occurs within a short walk to a transit stop, a long walk to a transit stop, and outside the walk shed of a transit stop.

A primary goal of the current work is to increase the spatial fidelity of the model to more faithfully represent how travelers interact with infrastructure at the neighborhood scale. Three options were explored during the May 14th/15th discussion, as follows:

- **More TAZs**. MTC could keep the same model structure and simply increase the number of travel analysis zones from 1454 to, say, 5000 or more.
- **Parcels**. ABAG is currently developing an UrbanSim[2] model that operates at the parcel level of geography. As such, a travel model could be constructed to work with parcels.
- **Tiered**. As described above, a tiered zone system that deploys both TAZs and MAZs.

The "More TAZs" option is unattractive due to the challenges of managing, storing, and performing calculations with full TAZ-by-TAZ level-of-service matrices, particularly for transit. The motivation for the "Tiered" option is to benefit from the smaller geographies while avoiding the expensive computational overhead of large matrices.

The "Parcels" option will be explored during future model development efforts, but it was not felt, at this time, that the currently 2,000,000+ parcels in the Bay Area were needed for the travel model. Additionally, there is currently a significant amount of variation in the quality of the data set across the parcels. As ABAG further refines UrbanSim and builds data models to maintain and update the regional parcel database, the possibility of moving to parcels in the future increases.

As discussed in *Section 2 Model Design*, the team decided on the Tiered approach, using MAZs, TAZs, and TAPs. As a first pass, we will construct TAZs from Census block groups and MAZs from Census blocks, making boundary adjustments as needed to meet the demands of the travel model. Travel model considerations include the need for homogenous land uses, the identification of non-developable lands, and an awareness of transit stop locations. For the nine-county Bay Area, there are approximately 4,600 block groups and 110,000 blocks. To the extent practical and beneficial, parcel boundaries will also be respected during the construction of MAZs and TAZs. MAZs will nest within TAZs. We anticipate 80,000 to 100,000 MAZs nesting within 4,000 to 6,000 TAZs.

Following the delineation of a draft set of MAZs and TAZs, the project team will meet with staff from each of the Bay Area's nine counties to gather their input. Another round of refinement will follow, the result of which will be a final set of MAZ and TAZ boundaries, centroids, and centroid connectors.

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[1] An interactive map is available here: http://geocommons.com/maps/130037.

[2] Additional information is available here: http://urbansim.org .

4 Roadways

MTC's existing travel model uses a 35,000+ link roadway network that is stored and edited in Citilabs's Cube format. The new roadway network needs to serve four functions, as follows:

- **Space**. The refined representation of space noted above warrants a more detailed representation of transportation infrastructure.
- **Mapping**. The current "stick" network does not represent roadway curves and excludes many roadways, giving maps generated from the network an unprofessional, antiquated look.
- **Updates**. MTC desires a method to efficiently update the network when changing base years. For example, when moving from a 2005 to a 2010 to a 2015 base year, methods are needed to quickly and accurately update our networks.
- **GIS integration**. MTC's GIS team does a variety of network-based analyses that need to be integrated with MTC's travel model team's activities.

During the May 14th/15th meeting, two alternative all-street networks were discussed: TomTom (formerly TeleAtlas) and OpenStreetMap. The advantages of the TomTom network are as follows: (i) already used by MTC's GIS team; (ii) has a good number of attributes useful to the travel model, such as number of lanes, functional class, and posted speed limits; and, (iii) is stored in an ArcGIS geodatabase – a format supported by the Cube software.

The primary advantages of the OpenStreetMap network is its cost (free) and MTC's ability to add value to the open source community by attributing the network.

The project team decided that the TomTom network is the best choice for MTC. The portion of the TomTom network in the nine county Bay Area includes approximately 370,000+ nodes and 450,000+ links in two geodatabase layers. These layers are named **nw**, for network links, and **jc**, for junction nodes. The network links layer has a **F_JNCTID** and a **T_JNCTID** attribute representing the link from junction node and to junction node respectively. Each junction node will be assigned a new MTC node number and reserved numbers will be set aside for the exclusive use of each of MTC's county partners. For example, MTC will use junction nodes 1,000,000 to 2,000,000 (reserving the first 1,000,000 for MAZ centroids, TAZ centroids, and TAPs); San Francisco county will be assigned nodes 2,000,001 to 2,250,000; San Mateo will be assigned nodes 2,250,001 to 2,500,000; etc. Such segmentation should allow each county to make edits to their networks in a way that does not conflict with the edits of other counties, allowing for the potential integration of networks across counties.

Special junction nodes will be added to the network to represent TAZ and MAZ centroids, as well as TAPs. A foreign key (i.e. a cross-reference field) will be maintained to connect the TomTom data to the travel model data. Travel model attributes such as functional class, free flow speed, number of lanes, toll, etc, will be coded to each network link. Special purpose lane links, such as toll booths and high-occupancy vehicle lanes, will be added to the network. In many cases, the original TomTom network will have to be split in a way that breaks the direct connection between the travel model network and the original TomTom network. To ensure that breaking these links does not compromise the resulting network's integrity, a series of tests will be run to ensure the network is routable by mode and produces reasonable level-of-service indicators. These level-of-service indicators will be checked against existing model network level-of-service indicators.

Each link will also be coded with traffic data source IDs, including, but not limited to, Caltrans Performance Monitoring System (PeMS) stations[3], MTC's 511 travel information links, and Highway Performance Measurement System (HPMS) site IDs[4]. This information will be useful when calibrating and validating the demand models.

An attribute will be added to the network links to identify which links to use for MAZ- and TAZ-level automobile assignments. Reducing the set of "assignable" links will allow for a more realistic representation of automobile travel as well as more tractable and efficient searches for equilibrium conditions (i.e. faster traffic assignments).

MAZ and TAZ centroids must be connected to the roadway network. Centroid connectors will be built such that they connect the approximate "activity center of mass" of each zone to the locations where automobiles and persons access the network. A combination of automated and manual coding techniques will be used to accomplish this task.

To facilitate the construction of alternative networks, each network link will have different sets of network attributes, each identified by a project identification number. This will allow for the easy creation of multiple roadway networks built from a single geodatabase.

To streamline the creation of future base year networks, a difference tool will be developed to compare two versions of the TomTom network. The tool will identify both new records and records with changed attributes. Such identification will allow an MTC analyst to efficiently create a new base year network, guided by the changes in the TomTom network.

[3] PeMS site locations available here: http://geocommons.com/maps/139698.

[4] HPMS site locations available here: http://geocommons.com/maps/177959.

5 Transit Service

MTC's existing travel model represents transit service via a series of text files in Citilabs's Cube format. These files include representations of transit routes, access links, egress links, transfer links, "funnel" links, and fares. The management of this data is a bit unwieldy and updating base year information is tedious and time consuming. The new transit network representation needs to serve the following functions, which are similar to the needs of the roadway representation:

- **Space**. The refined representation of space and roadway networks requires a refined transit network as well.
- **Mapping**. The current text-file-based management system does not allow for the efficient creation of useful and compelling maps.
- **Updates**. MTC desires a method to efficiently update the network when changing base years. For example, when moving from a 2005 to a 2010 to a 2015 base year, methods are needed to quickly and accurately update our networks.
- **GIS integration**. MTC's GIS team does a variety of network-based analyses that need to be integrated with MTC's travel model team's activities.
- **Management**. The management of the transit network files needs to be improved, as the text-based system often leads to errors of commission and omission.

The MAZ and TAP model design greatly simplifies the transit network representation because only TAP-to-TAP representations of transit service need to be explicitly maintained. All walk access, egress, and transfer movements will occur on the MAZ level pedestrian network, which will be based on the all streets roadway network. These access, egress and transfer movement links will be automatically generated in the new system. Auto access and egress movements will be based upon the highway network assignable links.

In order to efficiently update our base year data, an external representation of the Bay Area's transit service is needed. During the May 14th/15th meeting, two external data sources were discussed: (a) Google, which collects and distributes data per the Google Transit Service Feed specification; and, (b) MTC's Regional Transit Database (RTD), which is an extraction of data provided by transit agencies to MTC to inform MTC's 511 traveler information system. The advantage of the RTD, relative to Google, is that it covers all transit providers in the nine county Bay Area – Google does not. Further, this information is already collected, cleaned, and processed by MTC's GIS team. Google, which provides the information for free, does have some route shaping points, which is helpful in locating route patterns between transit stops.

The project team selected the RTD as the source of information for base map updates. To build the transit network, the project team will first "snap" each transit stop to the nearest roadway node. The project team will then go through each route, making sure the stops are "snapped" to the correct junction node and that the route pattern between stops is correct. Next, both automated and manual processes will be used to create 4,000 to 6,000 TAPs from the 23,000+ transit stops in the RTD (the RTD ID to TAP ID relationship will be many-to-one). All existing light rail, trolley, BART, commuter rail, Amtrak, and ferry stops will be coded as separate TAPs. TAPs will serve only one line haul mode category (i.e. local bus), such that service of separate character can be kept separate. Each TAP will then be attributed, using the best available data, with variables specific to transit stops, such as: has a parking lot; parking lot capacity; has shelter from the weather (sun, rain); has lighting; has real-time arrival information; has bicycle parking; bicycle parking capacity; etc.

In order to create TAP-to-TAP skims within Cube, TAPs will be treated as virtual TAZs. The process of creating transfers links between TAPs will be automated via scripts, using either simple rules, such as: “transfers are allowed for TAPs within ¾-mile straight-line (as the crow flies) distance from each other”, or more complex rules, such as: “transfers are allowed for TAPs that have a least cost path over the pedestrian network of less than X utils”. Additional transfer connections, as needed, will be introduced via user-defined files.

The project team will adapt the fare information from the current travel model into the new supply representation.

To connect MAZ centroids to TAPs, the following procedures are envisioned:

- The all-streets-based roadway, pedestrian, and bicycle networks will be used to find the single best least-cost path between an MAZ centroid and TAPs within a pre-defined range.
- Using the access/egress-mode-specific least cost path information, connections will be assigned a cost and drawn between each MAZ centroid and some number, N, of TAPs within close proximity to the MAZ.
- Additional centroid connections, as needed, will be introduced via user defined files.

To improve the accuracy and efficiency with which MTC updates our base year transit network, a difference tool will be developed to compare RTD information across database years. Queries will extract differences in stop locations, line information, fare information, and headway tables, revealing differences due to new records and changes to existing records. This information will allow MTC analysts to efficiently update base year networks, moving from, say, a year 2010 base year to a year 2015 base year.

6 Bicycle Infrastructure

The existing MTC travel model assumes bicycles can travel over a segment of roadway network links – specifically, all roads except freeways, with allowances made for freeways that traverse bridges with bicycle lanes. The shortest-path distance is skimmed from this network and converted into an estimate of bicycle travel time by assuming a uniform bicycle speed of 12 miles per hour. The new bicycle network needs to serve the following functions:

- **Fidelity**. To reflect small scale, MAZ-to-MAZ movements, the fidelity of the bicycle network needs to be dramatically improved.
- **Paths**. Store information regarding the quality and type of bicycle infrastructure present on each roadway and dedicated bicycle link.
- **Impedance**. Store other information to allow for the computation of a bicycle-specific impedance calculation to be performed, informing travelers about the difficulty of bicycling between two points.

MTC's GIS team has been collecting information for the past several years as part of the BikeMapper[5] effort, which strives to create a useful bicycle trip mapper application. BikeMapper has collected or is collecting the following attributes across the nine county Bay Area:

- Route class:
  - I – dedicated bicycle facility;
  - II – shared (with automobiles) via striping/marking;
  - III – bicycles allowed on an automobile facility, but no striping/marking
- Grade category

The BikeMapper service allows cities and other local partners to maintain an inventory of bicycle facilities.

The travel model network will start by exporting and then integrating the BikeMapper information to the new roadway network. The grade can be checked using the US Geological Service's elevation web service[6], which has a resolution of 10 to 30 feet, depending on the location. The project team will review any other readily available information, such as OpenStreetMap, that may be important to computing bicycle impedance and add these attributes to the network, as appropriate.

To improve the accuracy and efficiency with which MTC updates our base year bicycle network, a difference tool will be developed to compare BikeMapper information across database years. Queries will extract differences in route class designations or for new dedicated bicycle facilities. This information will allow MTC analysts to efficiently update base year networks, moving from, say, a year 2010 base year to a year 2015 base year.

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[5] http://bicycling.511.org/

[6] http://gisdata.usgs.net/xmlwebservices2/elevation_service.asmx?op=getElevation

7 Sidewalks

Similar to the bicycle network, the existing travel model creates a pedestrian network by assuming pedestrians can traverse the roadway network, sans freeways, with allowances made for freeway bridges with sidewalks (e.g., Golden Gate Bridge). The shortest-path distance is skimmed from this network and converted to an estimate of walk time by assuming a uniform speed of three miles per hour. The new pedestrian network needs to serve the following functions:

- **Fidelity**. To reflect small scale, MAZ-to-MAZ movements, the fidelity of the pedestrian network needs to be dramatically improved.
- **Paths**. Be prepared to store information regarding the quality and type of pedestrian infrastructure on each roadway and dedicated pedestrian link.
- **Impedance**. Store other information to facilitate the computation of pedestrian impedance measures, which describe the difficulty of moving between two points on foot.

The two best available data sources for constructing the pedestrian network are TomTom and OpenStreetMap. TomTom has a "form of way" network attribute in which pedestrian friendly streets are identified. OpenStreetMap has footpath-specific network links. These two data sources will be used to create and attribute a pedestrian network. Other data attributes will be created and populated as readily available data allows; these fields may include: sidewalk width, has trees, and has on-street parking.

We do not expect to be able to construct a robust representation of the pedestrian network with readily available data sources. Rather, we will do our best with existing data sources and set the stage for future data collection efforts.

As with the other networks, a difference tool will be created to quickly assess changes made to the OpenStreetMap pedestrian network. Specifically, two OpenStreetMap networks will be compared, and new records tagged as "footpath" will be identified and changes to relevant attributes on existing links will be extracted. This should allow MTC analysts to more efficiently update base year networks.

8 Data Management

As mentioned in *Section 4 Roadways* and *Section 5 Transit Service*, MTC currently manages our roadway and transit networks via Citilabs Cube binary and text files, respectively. A more efficient and integrated system, in which roadway, transit, bicycle, and pedestrian networks can be managed, is needed.

During the May 14th/15th meeting, three alternative data management options were discussed, as follows:

- San Diego Association of Government's (SANDAG's) ArcGIS solution;
- PTV's VISUM commercial software package;
- Citilabs's Cube commercial software package, using ArcGIS geodatabases.

SANDAG's custom built GIS solution was evaluated because MTC's envisioned supply approach is similar to that of SANDAG. The solution uses ArcGIS geodatabases, but has a custom network editor that allows for modifications outside commercial travel model software packages. As MTC is generally comfortable using Cube's network editor, and plans to maintain Cube as the software used for skimming and assignment, the advantages of the custom software were deemed unworthy of the cost of manipulating and/or generalizing SANDAG's code for MTC's use.

The VISUM software package offers a more comprehensive network data model than Cube, including data objects used to represent transit schedules and "complex" stop (locations where several transit services come together). Further, VISUM offers a modern Python API for scripting. Though these advantages are attractive, they were not enough to outweigh the costs of moving to VISUM, which include: (i) VISUM is not going to be used for skimming and assignment, meaning MTC would have to purchase/maintain/learn two software packages; (ii) VISUM uses a proprietary data format, which makes integration with the MTC GIS unit difficult; and, (iii) the Bay Area's modeling community is not familiar with VISUM.

The project team decided to use the Cube with ArcGIS geodatabases solution for managing the networks. The advantages of this approach are largely familiarity: MTC's GIS team is comfortable and satisfied with ArcGIS tools and MTC's travel model team is comfortable and satisfied with Cube's network editing tools.

The following three types of ArcGIS geodatabase formats are available:

- Microsoft Access MDB, which stores data in a Microsoft Access file;
- ESRI file geodatabase, which stores data in a series of files within a folder;
- ArcSDE database implemented on Microsoft SQL Server, which stores data in relational tables on a database server.

Each of these data formats stores similar data and each can be accessed and manipulated by ESRI's **arcpy** Python API. The project team decided on the ArcSDE with SQL Server strategy primarily because the MTC GIS team already uses this approach. For portability, all data can also be exported to a file geodatabase format which is supported by ArcGIS and Cube. All network manipulation scripts will be written in either Python, Cube, or Java (the code used in the travel model).

While the management of the databases will be managed in Cube via ArcSDE geodatabases, this information will generate data in native Cube network format for model runs. This is done for

two reasons: (i) the Cube network editor does not dynamically validate the database to ensure the multi-modal network is consistent (i.e., routable); and, (ii) Cube scripts operate more efficiently on networks in Cube native format.

The existing MTC practice of periodically creating a new master highway network from which alternatives and derivative networks can be created will be extended to all networks in the new management solution. Here, a separate and new database will be created in the database management system for each new master network.

9 Software Revisions

Following the modification of the representation of supply, MTC and PB will re-build the travel model software to accommodate the changes into an existing representation of demand. Importantly, the travel model will not be re-calibrated. Rather, the model system will be reconstructed so that it is operating as designed. We want to make sure the mechanics work and that all required input files are developed in a logical and rational manner. A subsequent work effort will calibrate the demand models and validate the model system against existing data.

During the May 14th/15th meeting, the project team determined that the SANDAG implementation of PB's coordinated travel regional activity-based model platform (CT-RAMP) would likely be the best source for a donor model, given the similarity of the SANDAG's model structure with the planned model structure as well as the usefulness of the estimated coefficients. Models that were estimated with Bay Area data, such as the automobile ownership model, may be retained.

Other key software modification considerations are as follows:

- **Population synthesizer.** Two options will be explored for transitioning from MTC's current population synthesizer: (a) use the synthetic population created by the UrbanSim model; (b) modify the MTC population synthesizer to operate at the MAZ-, rather than TAZ-level, using TAZ-to-MAZ disaggregation methods.
- **Cube scripts**. The model scripts, written in Cube and Gawk, will be updated and/or replaced with Cube or Python scripts to perform the following tasks: network management, skimming, matrix manipulation, and assignment (both at the TAZ and MAZ-level, though the latter will likely be an all-or-nothing daily assignment).
- **Mode choice**. As noted in *Section* 2 *Model Design*, a modified approach to trip mode choice/transit route choice will be taken. Rather than the traditional creation of mode-weighted paths, the N best paths will be created for each access/egress mode combination – possible access/egress modes include walk, bicycle, and drive. The route choice model will then determine the best of these paths for selection in the simulation.

Following the modification of the implementation software, the project team will do extensive testing to ensure that the model is being applied as intended.