CMAP Transit Modernization Model Project

Final Report

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For the Chicago Metropolitan Agency for Planning (CMAP)

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1. Project Focus and Phasing

1.1. Essence of "Transit Modernization" of the CMAP ABM

The goals of the "Transit Modernization" project were to enhance the transit components of the CMAP Activity-Based Model (ABM) to be sensitive to a wider array of policy and service variables than traditional transit demand models. "Modernization" refers to the fact that traditional transit demand models usually account solely for a limited range of explanatory Level-of-Service (LOS) variables such as travel time, out-of-pocket cost, access time, egress time, and time spent waiting at boarding locations. More "modern" variables added to the traditional variables include reliability, safety, cleanliness, probability of having a seat (crowding level), opportunity to be productive during the ride (productivity), ease of boarding, etc. These modern service variables have components contributed by the stop or station and its surrounding environment, components contributed by the boarding or alighting experience, and components contributed by the transit vehicle itself (on-board experience).

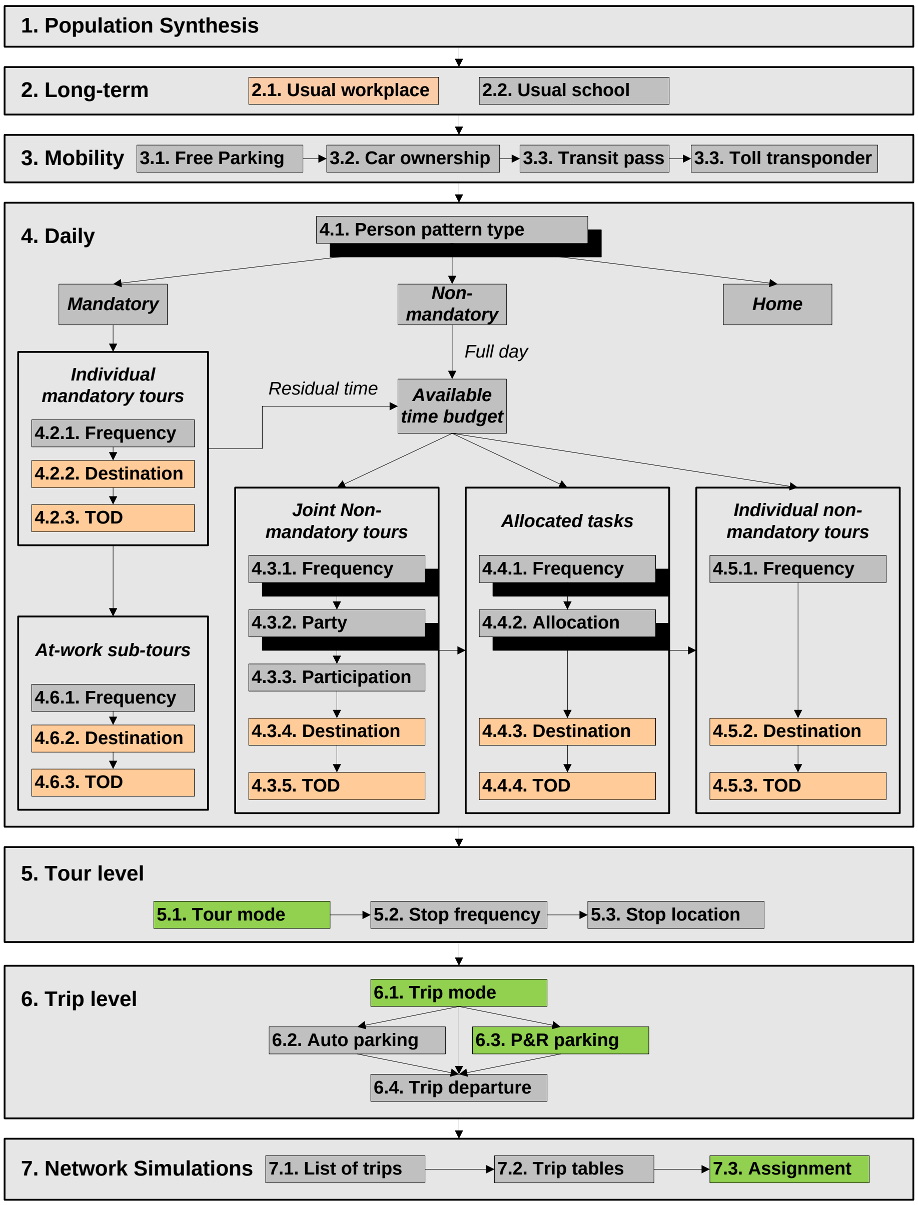
The existing CMAP CT-RAMP ABM represents an advanced microsimulation platform integrated with CMAP socio-economic & land-use data and networks. It has been successfully applied for highway pricing studies. In the current project, the transit side of the CMAP ABM was substantially enhanced and tested. The project objectives included incorporation of the State-of-the-Art & Practice in transit procedures and mode choice with a primary focus on quantifiable measures of premium transit services described above as well as validation of the improved model system against available data on transit ridership. The ABM structure that is based on individual microsimulation represents a very good platform for incorporation of these additional attributes.

The CMAP transit model evolved over the course of the project's two phases to include a sophisticated means of calculating a host of impedance components that enter into transit path-building and transit choice. For example, boarding time in the model is in part a function of the number of persons boarding a vehicle at a given stop. Perceived in-vehicle time is a function of actual in-vehicle time, perceptions of crowding, ability to be productive, vehicle cleanliness, and other factors. The result is a unique model sensitive to a wide variety of public agency investment alternatives, service planning choices, and policy implementations.

1.2. Existing CMAP CT-RAMP ABM

The main CT-RAMP (Coordinated Travel & Regional Activity Modeling Platform) system structure first implemented as the CMAP Pricing ABM is shown in Figure 1 with the sub-models improved in the course transit modernization highlighted in green. Yellow highlights correspond to the components that were previously redeveloped for the Pricing ABM.

Figure 1: CMAP CT-RAMP ABM Structure and Sub-Models in the Focus of Current Project



Overall, the existing CT-RAMP structure remained the same for the transit modernization project since it provides an effective platform for implementation of the planned advanced modeling features. However, the transit modernization significantly affects mode choice models and transit assignment procedures including explicit choice of first boarding and final alighting stations for all transit access sub-modes including Walk to Transit (WT), Park-and Ride (PNR) and Kiss-and-Ride (KNR) trips. The entire model system was restructured to work with an enhanced level of spatial resolution – 16,819 MAZs (Micro-Analysis Zones) nested within the 1,944 TAZs (Traffic Analysis Zones) applied for the Pricing ABM.

1.3. Main Model Improvements in Phase 1 and Phase 2

More specific translation of technical components listed in the previous section into the work plan adopted at the beginning of Phase 1 is presented in **Table 1**. The overall technical approach was to incorporate the major improvements in transit network procedures (and corresponding new transit service attributes) as soon as possible in Phase 1 to create the maximum useful platform for Phase 2. The most principal differences between Phases 1 and 2 are as follows. In Phase 1, the existing zonal system of 1,944 Traffic Analysis Zones (TAZs) is still used through the entire simulation process. In Phase 2, the entire model system was restructured to take advantage of a finer level of spatial resolution that is based on 16,819 Micro Analysis Zones (MAZs). In Phase 1, the mode choice model was implemented in a conventional "labeled" way. In Phase 2, a completely "non-labeled" approach was adopted where instead of mode labels like "conventional" and "premium", a wide set of multimodal transit path parameters and characteristics was used. These parameters were further interacted with individual attributes of transit users where a full advantage of the microsimulation framework was taken. The aggregate transit assignment and skimming procedure implemented in EMME was replaced with the core Transit Virtual Path Building (TVPD) procedure that finds the best Virtual Transit Path (VTP) for each individual from the origin MAZ to destination MAZ. VTP is defined in terms of three segments: 1) access from the origin MAZ to the first-boarding Transit Access Point (TAP), 2) ride from the first-boarding TAP to final-alighting TAP, 3) egress from the final-alighting TAP to destination MAZ.

Table 1: Main Model Improvements for Phases 1 and 2

Model component	Phase 1 (June 2012)	Phase 2 (June 2013)
Individual membership in latent class	Explicit segmentation by 18 travel-person categories: • 2 purposes (commuting vs. other) • 3 income groups (low, medium, high) • 3 age groups (children, younger adults, older adults) Single path type is assigned to each travel-person based on the category and VOT	Linking person characteristics with transit path characteristics: • Individual propensity to walk • Individual class membership with respect to path type preferences
Transit options for each TOD period	27 options (some eliminated): • 3 line haul modes (conventional, premium, mixed) • 3 access modes (walk, PNR, KNR) • 3 path types (streamlined, efficient, convenient)	Individualized choice preferences: • Generic line haul transit mode • 3 access modes (walk, PNR, KNR) • 3 path types (streamlined, walk averse, premium transit preference)
Mode choice	9 modes: • 3 line haul modes (conventional,	3 "non-labeled" modes: • Generic line haul transit

	premium, mixed) • 3 access modes (walk, PNR, KNR)	mode • 3 access modes (walk, PNR, KNR)
Transit assignment and skimming procedures	9 segments for each TOD: • 3 line haul modes (conventional, premium, mixed) • 3 path types (streamlined, efficient, convenient)	3 station-to-station path types (streamlined, walk averse, premium transit preference) combined with individual access and egress preferences
Assigning and skimming PNR & KNR	EMME triple-index calculations with a deterministic station choice for each of 36 segments for each TOD: • 3 line haul modes (conventional, premium, mixed) • 2 access modes (PNR & KNR) and 2 egress modes (reversed PNR & KNR) • 3 path types (streamlined, efficient, convenient)	Replaced with virtual transit path building and station type choice: • 2 access modes (PNR & KNR) and 2 egress modes (reversed PNR & KNR) • 3 path types (streamlined, walk averse, premium transit preference
TOD periods for transit	3 aggregate periods • AM peak • MD (off peak) • (PM is transposed AM)	8 detailed periods as for highway modeling: • AM early (6-7am) • AM peak (7-9am) • AM late (9-10am) • Midday (10am-4pm) • PM early (4-5 pm) • PM peak (5-7pm) • PM late (7-8pm) • Night (8pm-6am)
Spatial resolution	1,944 TAZs	16,819 MAZs with Virtual Transit Path (VTP) building

2. Key Technical Aspects Addressed in Phase 1

2.1. Redefining Transit Modes and Restructuring Mode Choice

The Pricing ABM model included 2 main transit modes (premium and bus) and 2 access sub-modes (walk and drive). The premium mode included the Metra commuter rail and CTA train services while the bus mode included all types of buses (local and express). These definitions correspond to a standard "mode labeling" practice while with the new approach, one of the primary intentions is to replace "labels" with objective and measurable service characteristics. In particular, in Phase 1, our intention was to create a mode choice structure that would be close to the final structure adopted for Phase 2.

With respect to access options, it was decided to extend the mode choice structure to include three access sub-modes (walk, PNR, KNR) that represent very different choice alternatives. It is also beneficial in practical terms, since these three sub-modes, essentially, represent different travel markets.

Changing the approach from using labeled line haul modes to using service (path) types requires some new definitions of path types. These path types are individualized that is a principal advantage of microsimulation. This required several path-preference-specific assignments (user classes) instead of predetermined mode combinations. For each possible trip (first-boarding TAP and final alighting TAP pair) we generate 3 possible paths each of them can include any transit multi-model combination. Each transit user chooses one path based on the probabilistic class-membership model. This choice is intertwined with the choice of access and egress options that are completely individualized (each person has an individual set of preferences based on his/her age, income, travel purpose and other characteristics). The general rules of relationship between (individual) segmentation and mode choices structure is summarized in **Table 2**.

Table 2: Relationship between Individual Segmentation and Mode Choice Structure

Model component	Traditional "mode labeling" approach	New "path type" approach
Segments	Few segments by trip purpose, car ownership, income	Individual preferences organized into population and travel markets (latent classes; i.e. probabilistic individual membership)
Modes considered for each segment	Fixed set of modes with segment-specific utilities	1-2 generic modes per access type (walk, P&R, K&R) corresponding to path types (to keep premium separately)
Route considered for each mode and segment	One path for each mode (normally not segment-specific)	1-2 paths per each segment (class) that follows specific individual preferences

The following summary of main path-building parameters (each related to person classes) was adopted as the main guidance for Phases 1 and 2:

- Included in mode classification in Phase 1 (conventional vs. premium/express):
  - Schedule-based vs. frequent
  - Express vs. all-stop (stop spacing)
  - Reliable vs. unreliable (mixed traffic, no priority)
  - Cost-insensitive (higher VOT) vs. cost-sensitive (lower VOT)
- Included in individual TVPB (MAZ-TAP-TAP-MAZ):
  - Walk propensity (max and weight) as a function of person age, income, etc
  - Convenient waiting (station, plaza/other amenities at stations/information) vs. inconvenient wait (shelter, pole) / awareness & consideration
  - Formal parking lot vs. informal parking lot for PNR
  - Convenient access for KNR
  - Station amenities and commercial activity
  - Station/area safety and cleanliness
- Included in user-class-specific TAP-to-TAP transit path segment (streamlined, walk averse, premium transit preference):
  - Productive seating vs. non-productive seating (on-board amenities)
  - Direct service vs. transfers / age
  - Single transit pass vs. multiple payments
  - Seated vs. standing and impacts on productivity
  - Cleanliness in the vehicles

Application of these main parameters for the specific Chicago Metropolitan Region in Phase 1 resulted in categorization of the transit services into 2 major categories – conventional and premium as summarized in **Table 3**. The original intention was to create the following 3 slots in the mode choice:

- Conventional service,
- Direct premium service with no conventional service involved as a feeder,
- Mixed service including premium and conventional services used for the same trip.

However, the statistical analysis implemented with the available data sources like the recent Household Travel Survey, 2007 in the Chicago Metropolitan Region has shown a negligible share of mixed services. This is an important specific of the Chicago Metropolitan Region that is quite different from such other metropolitan regions as New York and Los Angeles.

The implemented tour mode choice structure on the transit side includes 4 main modes that are defined in a new "non-labeled" way as recommended by FTA and in the related advanced transit research projects like TCRP H-37 "Transit Services that Affect Choice of Mode": 1) Conventional transit with walk access, 2) Premium transit with walk access, 3) Park-and-Ride, 4) Kiss-and-Ride. In Phase 2, where more advanced individualized path building procedures were applied, a single generic walk-to-transit mode was used in mode choice.

Table 3: Generic Transit Mode Definitions and Main Attributes

Attribute	Conventional	Premium
Service type:		
Frequency	Frequent (less than 15 min)	Schedule-based (15 min+)
Stop spacing	All-stop (less than 2 miles)	Express (2 miles+)
Reliability	Dependent on congestion (mixed traffic, no signal priority)	Reliable (right of way, full signal priority)
Vehicle type:		
Seating comfort & convenience	Low, "built to stand", for short trips	High, "built to seat", for long trips temperature control, cleanliness
On-board productivity	Non-productive seating	Productive seating (on-board amenities, Wi-Fi, power outlets, trays)
Station type:		
Size and waiting convenience	Shelter, pole, exposure to weather	Station, plaza (security, proximity to services, cleanliness, closed building)
Information	Limited route information	Real-time arrival/departure information, route information, announcements
Transfer convenience	May require crossing the street and finding the stop	General transfer convenience (the same building)
Cost:	Lower	Higher
Examples in Chicago Region:		
Clear	CTA Local Bus, Pace Local Bus	Metra Commuter Rail
Grey area, adopted for Phase 1	CTA Train	CTA Express Bus

Express services (Metra and CTA Express are identified as premium while local bus and CTA rail are identified as conventional. Pace Express is tentatively identified as premium.

Transit services and fares in the Chicago area represent a continuum of options rather than highly distinct modes or choices. This fact complicates the identification of premium and non-premium modes. The structure that is described in a working memorandum represents one way of distinguishing premium and non-premium services (i.e., premium means "express" with a station spacing greater than 2 miles). As we discussed in the telephone call, this means that CTA rail is somewhat awkward because trains (except the Purple Line) run local with stations that are more closely spaced than Metra (or express bus stops) but more widely spaced than local bus stops. An argument could be made that CTA rail is much more "express" than local bus and ought to be in the premium mode. If the definition of "express" were changed to 1 mile, then CTA rail would be considered "express" rather than local.

Another way we could have defined premium is based on fare. This is a very complex subject since the cost of transfers and the fare impact of multi-operator trips is dependent on the exact fare medium used. Given the fact that the basic CTA monthly pass is useable on all CTA and Pace local bus services and given the fact that Pace express services require payment of a surcharge and Metra is completely separate (and generally more expensive), this suggests that a definition of premium based on fare can be defined that is different from the express-based definition. Under the fare based approach, the definition of transit modes would change slightly so that CTA Express Bus is part of the conventional mode while Pace Express service is part of the premium mode.

The bottom line is that there are at least 3 reasonable ways to distinguish local and premium services:

- Express vs. local with express defined as substantial runs with stop spacing greater than 2 miles. (Current approach). This would break service into local bus/local rail vs. express bus/commuter rail (Note that Metra Electric local trains have a stop spacing under 2 miles but should still be coded as express since express trains are widely available on this line).
- Express vs. local with express defined as substantial runs with a stop spacing generally equal to 1 mile or more. This would break services into local bus vs. express bus/rail rapid transit/commuter rail
- Premium vs. non-premium with difference based on the presence of a premium fare for use of the service. This would break services into local bus/CTA express bus/CTA rail vs. Metra/Pace Express Bus

Advantages and disadvantages exist for all approaches. The current approach offers travelers on each zone-to-zone interchange the best chance of seeing multiple choices. For instance, trips from Evanston, O'Hare or 95th/Dan Ryan to the Loop will have a choice between Metra and CTA rail. Trips from Hyde Park or the North Shore to the Loop will have a choice between CTA rail and CTA Express bus. The downside is that in some places, travelers can choose between CTA rail and CTA bus in the real world and this choice is not preserved in the modeled representation. For the initial model this is probably acceptable and thus we should keep the current structure for now.

In Phase 2, we considered a more advanced concept of how we build paths. FTA is encouraging us to consider the possibility that there is really just one transit choice (for each access mode) but that different travelers weight these choices differently. To make this approach work, travelers need to be grouped according to how they select their paths. Example features of this approach adopted for Phase 2 include:

- Elderly travelers may prefer to walk a short distance even at the price of taking a slower bus with more transfers while young travelers may prefer the opposite.
- Wealthier travelers may prefer an express service at a premium fare while less wealthy travelers prefer the opposite.
- Travelers with higher education (correlated with higher income groups) may rank productivity, i.e. convenience to read or use laptops/tablets on board, as the most desired feature of transit service.

In Phase 1, we restructured the mode choice model to incorporate generic PNR and KNR modes while we still keep two groups of transit modes with walk access (conventional and premium) separately. A substantial transformation of the standard ABM structure (and Utility Expression Calculators, in particular) was required to implement the modified structure as summarized in **Table 4**. Overall, the existing 4 mode "slots" were used but their content was changed significantly.

Table 4: Transformation of Transit Modes and Associated Modifications in CT-RAMP Structure.

Transit modes as previously defined	**Transit modes as defined in the new structure**	**Principal modifications / Phase 1**
Walk to bus (CTA local bus, Pace local bus, CTA express bus)	Walk to conventional transit (CTA local bus, Pace local bus, CTA train)	Change in the subset of modes and corresponding network references, recalibration of mode specific constants for each segment (travel purpose)
Drive to bus (CTA local bus, Pace local bus, CTA express bus)	KNR (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	Change in the subset of modes and corresponding network references, change in the mode availability settings (KNR is available to every person of the age of 8 years or older, and is allowed at any station/stop), recalibration of mode specific constants for each segment (travel purpose)
Walk to premium transit (CTA train, Metra commuter rail)	Walk to premium transit (CTA express bus, Metra commuter rail)	Change in the subset of modes and corresponding network references, recalibration of mode specific constants for each segment (travel purpose)
Drive to premium transit (CTA train, Metra commuter rail)	PNR (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	Change in the subset of modes and corresponding network references, change in the mode availability settings (PNR is available to adults with driver license, households with at least 1 car, and at stations/stops with designated parking capacity), recalibration of mode specific constants for each segment (travel purpose)

2.2. Premium Transit Attributes Affecting Mode Choice

If non-labeled formulation is adopted the difference between such categories as "Conventional transit" and "Premium transit" has to be explained by measurable attributes. Eventually, by using actual service attributes and assuming that this set captures the main transit characteristics perceived by the user, we could completely avoid predetermined mode choice slots and operate with a generic transit service. In order to operationalize this approach the following particular transit service characteristics were considered:

- Premium transit features and corresponding measures:

- On-board/vehicle characteristics such as seating availability, temperature, productivity, etc; these characteristics affect perception of in-vehicle time (findings of the TCRP Project H-37); significant interactions between vehicle type and transit in-vehicle time coefficients were found in the Portland study (LRT in-vehicle time equivalent to approximately 85% of Local Bus in-vehicle time).
- Stop/station design; perceptions of wait time (weight) due to stop characteristics. Stop/station type ("Full amenities", "Shelter\Seat", "Pole") is important for transferring as far as for first boarding, especially for "streamliners" or transfer-averse transit users as was found in the Portland Study. Wait time at "Full amenities" stop proved to be approximately 88% of wait at Pole. Wait time at "Shelter\Seat" proved to be approximately 93% of Pole.
- Service type (reliability, frequency, ease of payment, ease of boarding).
- Total equivalent of all additional premium attributes proved to be significant – 25 min on the average (TCRP H-37).

* Span of the service is naturally accounted in tour-based framework. Less than 60% of commuters commute in AM/PM peak period combination. More than 40% of commuters experience low-frequency transit service at least on one of the commuting legs.
* Pedestrian environment factor – based on number of census blocks per quarter-section (MAZ); it is used to calculate differential walk access/egress weight. It was applied in the Chicago 4-step model developed for the FTA New Start analysis in two ways:
    - Used to compute walk weight as function of pedestrian environment - 1.5 in CBD to 3.0 in exurban areas (mode choice and transit assignment)
    - Used as element of mode choice disutility function. Later model versions applied a direct linear factor separately for the production and attraction zone
* Socio-demographic similarity index (or income incompatibility measure) at a mode or route level was needed to reflect on the fact that the individual decision is influenced by the mix of other passengers. Homogeneous (high-income) OD pairs have a better chance for transit than heterogeneous OD pairs where high-income riders may perceive the other population segments negatively:
    - Average transit mode shares by income group can be used as social feedbacks to individual choices
    - Income mix (presence of low-income riders) can be calculated by transit segments or as and OD skim to use in mode choice and transit assignment for medium and high incomes.
* Mode compatibility with respect to transit pass is important for allowing different modes/services to be used for the same trip, tour, and by the same person. Transit cost structure and free/discount transfer policy is an important factor that has to be taken into account when the transit cost is skimmed.
* Transit cost should be scaled based on the person type and transit pass holding. Transit pass holders as well as person types that have individual discounts (school children, college & university students, retirees) do not experience the entire single-trip cost.

2.3. Transit Network Preparation, Assignment, and Skimming Procedures

Completely new transit assignment procedures in Phase 1 were developed to replace static transit skims used in the Pricing ABM. Transit procedures in EMME fully support the adopted mode choice structure. These procedures incorporated a wide set of non-conventional transit service attributes beyond the standard time and cost components. The following main aspects were considered

- Address 8 TOD periods that are used by the CT-RAMP system; incorporate recent work on TOD transit networks based on Google Transit Feeds (GTFS).
- Apply Strategy Transit Assignment with Variants (5.32) that is a new option available with EMME 3.4 (tested in the Portland Study):
    - Cost attributes can be specified for boarding, in-vehicle, and auxiliary transit time components
    - Perception factor of each time and cost component can be element-specific
    - Time and cost matrices can be saved separately
- Consider the following additional attributes:
    - Station type and amenities:
        - Station, plaza, shelter, pole
        - Real-time info
        - Station/stop security
        - Proximity to services (coffee, shop)
        - Cleanliness
        - Park and Ride capacity and cost (formal vs. informal/street)
    - Vehicle type and amenities dummies:
        - On-board seating comfort
        - On-board temperature control
        - Cleanliness
        - Productivity features (Wi-Fi, power outlets, trays)
        - Seating availability modeled explicitly by crowding functions
- Consider several stations for PNR and KNR. The way it was implemented in the Chicago Area New Starts model is as follows:
    - Parking zone with non-zero off-street park-ride parking and the shortest highway time between the origin and that parking zone is identified and weighted at 1.0.
    - Travel time to all other potential parking zones is weighted at 1.0 times the time to nearest parking zone plus 2.5 times the additional travel time to the other parking zones.
- Some important details for combined transit services in the Chicago metropolitan area should be taken into account:
    - Private bus systems offering feeder connectivity in suburban areas; township-based dial/call-a-ride

- Pace feeder bus service tied to Metra stations and timed to Commuter Rail arrivals (short transfer wait times)

2.4. Adopted Parameters for Transit Path Building

Initial set of parameters and weights adopted for Phase 1 is presented in **Table 5**. In general, initial weights were proposed based on the past experience. Final weights depend on which approaches calibrate best. The weights used to generate shortest paths are passed on to the choice models so that the choice models and the network/path finding models are consistently valuing each component of travel.

The project team also identified a need to update 8 transit vehicle types used in the existing transit network coding, that define (among other things) the unit (bus or train) capacity. Given the way that EMME computes capacity, rail modes should be coded with the train capacity rather than the car capacity. Train capacity should be coded based on the maximum feasible consist length (number of cars per train) rather than the actual consist lengths. In general, rail schedulers provide just enough cars to cover the demand (up to the maximum allowed by the infrastructure). Just because a train is operated with 4 cars today doesn't mean that it is the capacity limit since the train lengths could easily be extended if demand grew to require more cars. These improvements are essential for Phase 2 where capacity constraining and crowding functions are applied.

All transit assignment and network procedures were completely updated to incorporate a large number of additional attributes including vehicle, station, and service characteristics and tested. This procedure is based on the advance features incorporated in the latest version of EMME (3.4.3) that includes "Extended Transit Assignment with Variants". CMAP provided the first set of input variables (station and vehicle characteristics) and the PB/RSG team specified default values for all parameters except for the reliability components.

The skims for transit LOS attributes are fed to the CT-RAMP mode choice model. The skims are calculated based on the new advanced methods that take into account combinations of several transit lines in the optimal strategy as shown schematically below. Some transit LOS components are handled through the combined frequency technique while some other ones through the embedded logit route choice. Each line obtains a share in the optimal strategy that is used to weigh the LOS variables of different lines.

Table 5: Initial Setting of Transit Path Parameters

Path Component	Parameter	Weight
Wait time	Variable "spline function" computing wait time as a function of headway (1/2 of short headway and ¼ (or less) of headways more than 10 minutes. Same curve should be applied for all modes.	2.5 for "pole" stop type. Potential reductions can be tested for other stop types down to 1.5 for stations. This relationship should be tested to determine which weights generate the best assignments and require the smallest mode-specific constants
Boarding time	Node based parameter that reflects both real time required to travel from street to platform (or platform to platform) plus perceived penalty associated with making a transfer. For most bus stops the former quantity is 0 while most stations can be coded with 1 minute. Large Metra terminal stations should be 2 minutes. The initial value for the perceived penalty (on top of the real times) should be 2 minutes. Thus total times are as follows: • Bus stops 2 minutes • Most rail stations or bus transfer facilities 3 minutes • Large terminal stations 4 minutes.	2.5
Boarding Cost	CMAP representation of the station-specific component of fare.	Consistent with initial estimate of value of time in CT-RAMP
In-vehicle time	Weighted representation of in-vehicle time to account for more productive use of time in some modes. Code premium time as 0.85 times actual running time. Conventional time is coded as equal to actual running time.	1.0 (if the new version of emme can weight different modes differently, then the weights can be moved from the parameter column to the weight column)
In-vehicle Cost	CMAP representation of in-vehicle portion of cost	Consistent with initial estimate of value of time in CT-RAMP
Auxiliary Time	Walking time weighted as follows: 1.5 for urban areas with a PEF greater than 50 and 3.0 for a PEF less than 30. The adjustment factor between 30 and 50 is linearly interpolated between 1.5 and 3.0.	1.0 (input time pre-weighted)
Auxiliary Cost		Consistent with initial estimate of value of time in CT-RAMP

An example of the parameters setting for Premium Transit with walk access is shown below. In the same way all details were finalized and coded for the other three transit modes: Conventional Transit with walk access, Park and Ride, and Kiss and Ride. Skimming for Park and Ride and Kiss and Ride modes included matrix convolution process with choice of the boarding transit station to address both auto access and main transit line haul legs of the trip. In the example below, in the left column we present the actual options chosen at each stages of the procedure while in the right column we present the explanation of the option with the other possible choices supported by the current assignment and skimming algorithm. All user defined parameters are set in the control section of the script based on the previous discussions.

Table 6: Example of Transit Path Building for Premium Transit with Walk Access

EMME script command	Comment and other possible choices
5.32	Extended transit assignment
2	1=optimal strategies, 2=strategies with variants
~?q=2	Branching condition
1	1=save volumes as new assignment, 2=add volumes to existing assignment
mf278	Demand matrix
BCPLuvxybcrEQMmwztd	Transit and auxiliary modes used in path building
2	Handle connector-to-connector path: 1=allow (standard), 2=prohibit (assign to another path), 3=prohibit (do not assign)
1	Prohibit connector-to-connector paths: 1=everywhere, 2=based on node attribute
2	Distribute flow between connectors based on: 1=only the best (standard), 2=transit time (logit), 3-5=user-defined proportions
0.2	Scale parameter for logit split between walk access links to first boarding stops
0.05	Truncation/cutoff parameter to eliminate low-probability alternatives
2	Distribute flow between attractive lines at stops by: 1=frequency (standard), 2=frequency and transit time to destination
1	Use frequency and transit time to destination: 1=everywhere, 2=based on node attribute
3	Source for effective headways: 1=actual line heaway, 2=user-defined line attribute, 3=user-defined segment attribute
@hdwef	Effective headway multiplied by the fraction to get wait time, calculated based on the service-specific (non-linear) wait time functions of headway
1	Headway fraction (already accounted in effective headway)
1	Spread factor (multiplied on perception factor)
@wconv	Wait time perception factor by 5 station types

EMME script command	Comment and other possible choices
2	Source for boarding times: 1=same value for entire network, 2=node-specific, 3=line-specific, 4=node and line specific
@timbo	Node attribute containing boarding time (by 5 station types) multiplied by perception factor
1.00	Node boarding time perception factor (included in weighted boarding time)
3	Source for boarding cost: 1=same value for entire network, 2=node-specific, 3=line-specific, 4=node and line specific
ut1	Line attribute containing boarding cost, cents
%r52%	User-defined line boarding cost perception factor (1/VOT, min/cent)
@ivtpf	User-defined In-vehicle time perception factor (mode-vehicle-specific convenience by line)
@zfare	Attribute containing in-vehicle cost (incremental zone fare by segment)
%r52%	In-vehicle cost perception factor (1/VOT, min/cent)
@pefli	Auxiliary transit time perception factor (PEF by link) scaled between 1 (best pedestrian conditions) and 3 (worst pedestrian conditions)
ul1	Attribute containing auxiliary transit cost (transfer discount)
0	Auxiliary transit cost perception factor (transfer discount is not used in path building but can be skimmed)
2	Send reports to printer
6.27	Analysis for extended transit assignment
~/	Section separator for skims that include all conventional modes
1	1=matrix, 2=network, 3=other, 4=user-defined, 5=strategy and transit path details, 6=summary stats, 7=end
1	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
mf245	Matrix to hold total transit impedance for P&R convolution
~+|~?q=1|y|PrWtot|Conv_Prem_Total_Per%2%|y|999	Matrix naming details for total transit impedance
y	More matrix skims to process?

EMME script command	Comment and other possible choices
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
5	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf250	Matrix to hold in-vehicle time (total)
~+|~?q=1|y|PrWivt|Prem_Walk_IVT_Per%2%|y|0	Matrix naming details for total in-vehicle time
y	More matrix skims to process?
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
2	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf394	Matrix to hold total waiting time
~+|~?q=1|y|PrWwai|Prem_Walk_Wait_Per%2%|y|0	Matrix naming details for wait time
y	More matrix skims to process?
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
6	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf395	Matrix to hold auxiliary time
~+|~?q=1|y|PrWwal|Prem_Walk_Walk_Per%2%|y|0	Matrix naming details for walk time
y	More matrix skims to process?
5	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
mf396	Matrix to hold number of boardings
~+|~?q=1|y|PrWboa|Prem_Walk_Boar_Per%2%|y|0	Matrix naming details for number of boardings
y	More matrix skims to process?
3	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
1	1=first boarding cost, 2=total boarding cost, 3=in-vehicle cost, 4=auxiliary transit cost
mf246	Matrix to hold initial boarding fares
~+|~?q=1|y|PrWifa|Prem_Walk_InFa_Per%2%|y|0	Matrix naming details for initial fares
y	More matrix skims to process?
3	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
3	1=first boarding cost, 2=total boarding cost, 3=in-vehicle cost, 4=auxiliary transit cost

EMME script command	Comment and other possible choices
mf247	Matrix to hold in-vehicle cost (incremental zone transit fares)
~+|~?q=1|y|PrWzfa|Prem_Walk_ZoFa_Per%2%|y|0	Matrix naming details for incremental zonal fares
y	More matrix skims to process?
3	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
4	1=first boarding cost, 2=total boarding cost, 3=in-vehicle cost, 4=auxiliary transit cost
mf248	Matrix to hold auxiliary cost (transfer link fare discounts)
~+|~?q=1|y|PrWdis|Prem_Walk_Disc_Per%2%|y|0	Matrix naming details for incremental zonal fares
N	More matrix skims to process?
1	What to skim: 1=actual components, 2=perceived components
*	Active modes to skim
2	Send results to printer
~/	Section separator for skims that include in-vehicle time and number of boarding for bus modes only
1	1=matrix, 2=network, 3=other, 4=user-defined, 5=strategy and transit path details, 6=summary stats, 7=end
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
5	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf251	Matrix to hold in-vehicle time (bus)
~+|~?q=1|y|PrWivb|Prem_Walk_IVTb_Per%2%|y|0	Matrix naming details for bus in-vehicle time
y	More matrix skims to process?
5	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
mf249	Matrix to hold number of bus boardings
~+|~?q=1|y|PrWbob|Prem_Walk_Boab_Per%2%|y|0	Matrix naming details for bus boardings
N	More matrix skims to process?
1	What to skim: 1=actual components, 2=perceived components
BPLEQ	Active modes to skim
2	Send results to printer
~/	Section separator for skims that include in-vehicle time for Premium Transit (Express bus and Metra rail)

EMME script command	**Comment and other possible choices**
1	1=matrix, 2=network, 3=other, 4=user-defined, 5=strategy and transit path details, 6=summary stats, 7=end
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
5	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf391	Matrix to hold in-vehicle time (Premium)
~+|~?q=1|y|PrWivp|Prem_Walk_IVTp_Per%2%|y|0	Matrix naming details for premium in-vehicle time
n	More matrix skims to process?
1	What to skim: 1=actual components, 2=perceived components
MEQ	Active modes to skim
2	Send results to printer
~/	Section separator for skims that include in-vehicle time for Local bus
1	1=matrix, 2=network, 3=other, 4=user-defined, 5=strategy and transit path details, 6=summary stats, 7=end
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings
5	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf392	Matrix to hold in-vehicle time (Local Bus)
~+|~?q=1|y|PrWivb|Prem_Walk_IVTb_Per%2%|y|0	Matrix naming details for local bus in-vehicle time
n	More matrix skims to process?
1	What to skim: 1=actual components, 2=perceived components
BPL	Active modes to skim
2	Send results to printer
~/	Section separator for skims that include in-vehicle time for CTA train
1	1=matrix, 2=network, 3=other, 4=user-defined, 5=strategy and transit path details, 6=summary stats, 7=end
2	1=total transit impedance, 2=time component, 3=cost components, 4=distance, 5=number of boardings

EMME script command	Comment and other possible choices
5	1=first wait, 2=total wait, 3=first boarding time, 4=total boarding time, 5=in-vehicle time, 6=auxiliary time
mf393	Matrix to hold in-vehicle time (CTA)
~+|~?q=1|y|PrWivc|Prem_Walk_IVTc_Per%2%|y|0	Matrix naming details for CTA in-vehicle time
n	More matrix skims to process?
1	What to skim: 1=actual components, 2=perceived components
C	Active modes to skim
2	Send results to printer
Q	Finish the operation

2.5. Specifics of Kiss-and-Ride (KNR) Mode

KNR represents a special transit option that is associated with specific mode choice effects and path choice effects that have to be properly incorporated and distinguished from PNR. That was the primary reason to consider PNR and KNR as separate modes rather than combine them together (that is a prevailing practice). Different from PNR, KNR transit itinerary is frequently asymmetrical because of the difficulty in coordinating return arrival times. Cell phones, however, have significantly improved the ability of coordinating return arrival times, even for children. KNR users will try to obviate a transfer is very appealing if the intra-household pattern supports it; either the drop-off point is along the driver's planned route, the vehicle is committed to another use during the day, or parking at the drop-off point is unavailable. This justifies a separate setting of transfer penalties for KNR compared to WT. This is also behaviorally appealing for PNR.

There are also several path choice effects (i.e. KNR station/stop choice) that have to be taken into account. It was recommended to correlate KNR station choice with stop type as follows:

- Large Rail Terminal and O'Hare: KNR is less likely since auto cannot get conveniently close to the boarding point.
- Rail Station and Bus Plaza: KNR is more likely since design often includes auto pullouts for this purpose; also schedules are typically more reliable at these locations.
- Shelter and Pole: KNR is unlikely since there are little drop-off design accommodation and less predictable schedule advantage.

Additionally, it was recommended to correlate PNR station/stop choice with area type grouped (by color) as shown in Table 7.

Table 7: Area Type Classification for KNR Convenience

1=inside Chicago CBD (2009 subzones 1-47)
2=inside remainder of Chicago central area (2009 subzones 48-80)
3=inside remainder of Chicago (2009 subzones 81-976)
4=inside inner suburbs where Chicago street grid is generally maintained
5=remainder of Illinois portion of the Chicago Urbanized Area
6=Indiana portion of the Chicago Urbanized Area
7=other Urbanized Areas and Urban Clusters within the CMAP Metropolitan Planning area plus other Urbanized Areas in northeastern Illinois
8=other Urbanized Areas and Urban Clusters in northwestern Indiana
9=remainder of CMAP Metropolitan Planning Area
10=remainder of Lake County Indiana (rural)
11=external area
99=points of entry

The PNR convenience and probability relates to the area type as follows:

- 1 = Less likely. Driving in the downtown area is difficult. Associate perceptional penalty is 10 min.
- 2-4 = Likely from the path choice perspective. Rich grid of transit service available. Free parking is scarce. Associate perceptional penalty is 0 min.
- 5-8 = Somewhat likely from the mode choice perspective. In combination with accommodations at stations or plazas. Associate perceptional penalty is 5 min.
- 9 = Less likely. Infrequent service and unsupportive transit amenities. Associate perceptional penalty is 8 min.

With respect to the regulation rules, KNR is not officially prohibited by any of the transit agencies. Local government may restrict drop-offs at specific locations for safety or traffic management, usually through signage and citation. This would require an additional network inventory.

2.6. Hardware and Software Setting for Model Validation & Calibration

The following aspects of hardware and software settings were addressed:

- All mode choice adjustments described above and related linkages to other sub-models were implemented in the core CT-RAMP software.
- All transit procedures (assignments and skimming) were implemented using the Macro script language. For Phase 2 EMME Modeler API were used for all newly developed components.
- The entire set-up including the CT-RAMP core model integrated with EMME transit and highway procedures was delivered to CMAP. Sampling strategy protocol for calibration runs was established (20% to save on run times).

3. Model Validation & Calibration in Phase 1

3.1. Validation & Calibration Targets

The following aspects of model validation and corresponding sources of information were considered:

- Three main levels of geography (CBD, CTA service area, remainder of region) are essential.
- Modes / lines summaries by Premium vs. Conventional services
- For Phase 1 the following main validation dimensions were adopted: Total Boardings by Premium vs. Conventional services (i.e. Rail vs. Bus); Sub-tabulated by interchanges between two services (i.e. transfers) and geography (i.e. cordon).
- 2002 Metra Origin-Destination Survey:
    - 65,000 Metra customers.
    - Used to create the Metra portion of the Year 2000 transit trip tables.
- 2000 Census Transportation Planning Package (CTPP):
    - Used to generate the HBW person trip table.
    - Transit flows are used to prepare non-Metra elements of Year 2000 HBW transit trip table for validation and calibration.
- 2007 Household Travel Survey (HTS):
    - All trip purposes in trip and tour format; rich set of person and household characteristics
    - Relatively small size.
- Future-year forecast for some meaningful scenarios is necessary to evaluate the model in Phase 2.

Transit calibration targets were developed from on-board surveys (CTA and Metra). Missing data on transit ridership were developed from the expanded HTS. Two sets of calibration targets were developed: Linked transit trips/tours for calibration of tour and trip-based mode choice models and unlinked trips for assessment of assignment results.

Linked trips included the same stratifications as used in the mode choice models (i.e., purpose and user segment class). Linked trip analysis converted data that is organized in the surveys as unlinked transit trips (i.e., boardings) into linked transit trips (origin to destination) and tours. Conversion to linked transit trips was done based on the transit trip record to infer the number of boardings incurred during the course of the trip (Metra and CTA surveys contain this information. The surveys did not contain information to exactly convert trip records to tour records but a reasonable approximation was applied dividing home-based linked trips by two and non-home based linked trips by three. This assumption was additionally tested and refined by examining the HTS dataset.

Survey derived linked trip and tour data were organized as a production zone-to-attraction zone trip (or tour) table. This allowed for an easy conversion to district-to-district tables for actual calibration and validation which can evolve over time as early calibration results are reviewed. A zone-to-zone linked trip table has the additional advantage that it can be assigned to the networks to help with QA/QC on the networks and to confirm path building parameters.

Two types of districts were used. A simple set of districts was defined for purposes of developing mode-specific constants:

- CBD
- Urban
- Suburban
- Exurban

These areas were defined based on a quantitative measures (density and CMAP Pedestrian Environment Factor) and generated a 4x4 table, each potentially having its own (but related to its neighbors in a meaningful way) set of mode-specific constants. For validation, a more detailed district structure was used to confirm that the underlying model properly represents regional variations in transit travel. The structure used in the validation process most frequently included 16×16 table defined as follows:

- CBD
- Urban
    - North
    - Northwest
    - West
    - Southwest
    - South
- Suburban
    - North
    - Northwest
    - West
    - Southwest
    - South
- Exurban
    - North
    - Northwest
    - West
    - Southwest
    - South

This table was used to compare modeled trips to survey trips and to identify locations where the model results are significantly at variance from observed totals. Calibration was not performed at this level since 16×16 constants would over-specify the model. Instead, significant discrepancies were studied on a case-by-case basis to determine what, if any, corrective action is warranted. In Phase 1, essentially only the constants for the CBD destination were enabled.

Unlinked transit boardings were also organized to allow assignment results (boardings) to be compared to observed data. Assignment and survey boardings were separately reported for each model segment (purpose, socio-economic group, transit mode, and TOD). This stratification provided helpful information regarding the elements of the model that are or are not working well and will confirm simulated transfer rates for each segment.

The comparison of modeled and observed transit boardings by stratum will be performed in Phase 2 for groups of 5-10 stations ("station groups") and bus routes serving a similar function ("bus route groups"). Transit assignments never accurately estimate route- or station level-ridership and the validation should concentrate on replicating observed ridership at a level of detail that can be realistically achieved.

3.2. Validation & Calibration Results

The new transit procedures were integrated into the CMAP CT-RAMP model system. This included transit assignment and skimming macros implemented in EMME macro scripting language for 4 transit modes (1=conventional transit with walk access, 2=premium transit with walk access, 3=park and ride, 4=kiss and ride) as well all required modifications to the CT-RAMP mode choice models (tour-level and trip-level) and Utility Expression Calculators. The modifications included new matrix references for the extended set of skims and new mode availability rules with respect to set of modes available for Premium and Conventional services as well as generic Park and Ride and Kiss and Ride. All transit assignment and network procedures were completely updated to incorporate a large number of additional attributes including vehicle, station, and service characteristics and tested. This procedure is based on the advance features incorporated in the latest version of EMME (3.4.3) that includes "Extended Transit Assignment with Variants".

The skims for transit LOS attributes are fed to the CT-RAMP mode choice model. The skims are calculated based on the new advanced methods that take into account combinations of several transit lines in the optimal strategy as shown schematically below. Some transit LOS components are handled through the combined frequency technique while some other ones through the embedded logit route choice. Each line obtains a share in the optimal strategy that is used to weigh the LOS variables of different lines. Transit procedures were currently implemented for two representative periods: 3 (AM peak) and 5 (Midday), for testing the new methodology and procedures. The corresponding skims are used to construct level-of-service variables for all periods. For example, the PM peak period is currently using transposed AM peak skims. The improvements to the transit procedures and mode choice model resulted in a much better match to the observed data. Below are examples of comparison of the model output at the tour level to the observed data (targets) by 2 main tour purposes (work and non-work), 4 transit modes (1=conventional transit with walk access, 2=premium transit with walk access, 3=park and ride, 4=kiss and ride), and 25×25 origin and destination districts. As an example in this report, we compare the model output to the expanded Household Travel Survey, 2007 – see **Table 8-Table 15**. Similar comparisons were made to all other available sources (CTPP journey-to-work table as well as Metra, CTA, and PACE on-board surveys)

Table 8: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, Conventional Transit with Walk Access (Phase 1)

TARGETS | WORK | WK CONV | HIS

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	63,172	1,950	-	-	280	2,216	280	709	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68,607
2N	95,466	35,325	1,907	1,598	955	-	1,064	2,668	2,012	-	637	-	-	-	-	-	-	-	-	-	-	-	-	-	-	141,631
2NW	25,354	1,730	1,834	5,886	487	-	-	-	297	-	2,407	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,995
2WNW	7,814	-	1,171	2,122	2,580	-	-	-	-	1,404	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,091
2W	19,301	-	1,314	1,119	1,082	839	856	56	-	-	-	-	-	194	-	-	-	-	-	-	-	-	-	-	-	24,762
2WSW	7,970	1,010	-	-	3,368	5,313	1,831	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,492
2SW	41,193	851	3,188	-	-	-	6,942	2,019	-	546	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54,738
2S	37,561	1,694	745	-	2,322	943	4,232	25,014	-	451	140	175	-	505	745	-	-	-	-	-	-	-	-	-	-	74,527
3N	1,015	71	-	-	-	-	-	-	574	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,732
3NW	92	-	-	-	-	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	164
3WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3W	285	-	-	-	-	-	-	-	-	-	-	-	2,474	-	-	-	-	-	-	-	-	-	-	-	-	2,759
3WSW	142	-	-	-	4,488	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,630
3SW	946	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	946
3S	-	-	-	-	-	-	852	513	-	-	-	-	-	-	1,025	-	-	-	-	-	-	-	-	-	-	2,390
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	186	-	-	-	-	-	-	207	-	-	-	-	-	301	-	-	-	1,674	-	-	-	-	-	-	-	2,368
XIN	-	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	124	-	-	-	-	-	-	197
4NW	153	-	-	87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	240
4N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,317	4,416	-	-	-	-	7,734
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,141	-	-	-	1,141
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	300,648	42,703	10,159	10,813	15,562	9,384	16,057	31,185	2,882	2,473	3,184	175	2,474	1,000	1,770	-	-	1,674	124	3,317	4,416	1,141	-	-	-	461,144

MODEL OUTPUT | WORK | WK CONV

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	24,025	2,065	1,255	445	1,010	1,090	1,285	710	60	40	25	145	25	10	-	-	-	-	-	5	5	-	-	-	-	32,200
2N	57,070	24,815	9,415	1,180	1,265	665	635	935	1,645	355	360	175	10	25	5	-	-	-	-	115	205	-	-	-	-	98,875
2NW	19,030	5,565	12,345	2,150	2,130	685	275	270	665	780	560	205	50	10	5	-	-	-	-	180	100	-	-	-	-	45,005
2WNW	10,085	1,665	4,090	2,395	2,870	810	345	165	190	115	175	335	90	5	-	-	-	-	-	35	25	-	-	-	-	23,395
2W	14,230	865	2,115	1,565	6,265	2,185	680	275	75	45	160	1,200	225	35	-	-	-	-	-	-	35	-	-	-	-	29,955
2WSW	11,370	440	965	570	3,235	3,725	2,055	305	5	25	120	795	255	60	-	-	-	-	-	10	-	-	-	-	-	23,935
2SW	20,020	550	550	320	1,625	2,370	10,000	3,450	35	10	55	240	70	925	55	-	-	5	-	5	5	-	-	-	-	40,290
2S	31,940	1,360	1,100	185	940	1,260	5,995	21,490	25	20	20	200	85	960	580	-	-	150	-	-	-	-	-	-	-	66,310
3N	490	635	285	10	25	-	5	-	560	105	55	-	-	-	-	-	-	-	-	25	110	-	-	-	-	2,305
3NW	135	265	990	40	20	-	5	-	285	1,255	500	45	10	-	-	-	-	-	-	225	75	5	-	-	-	3,855
3WNW	50	20	205	40	20	5	-	-	10	70	330	165	40	-	-	-	-	-	-	-	-	-	-	-	-	955
3W	435	5	110	45	375	80	20	5	5	-	135	1,770	715	-	-	-	-	-	-	-	-	-	-	-	-	3,700
3WSW	35	-	10	5	120	50	5	-	-	10	25	610	1,820	5	-	-	-	-	-	-	-	-	-	10	5	2,710
3SW	1,215	35	-	30	155	155	1,055	645	-	-	-	90	15	1,140	125	-	-	5	-	-	-	-	-	-	-	4,665
3S	375	25	5	-	15	-	75	890	-	-	-	5	10	135	1,080	-	-	15	-	-	-	-	-	-	-	2,630
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	30	-	-	-	-	-	5	100	-	-	-	-	-	15	30	-	-	-	-	-	-	-	-	-	-	180
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4NW	5	10	45	-	-	-	-	-	55	90	5	-	-	-	-	-	-	-	-	695	150	-	-	-	-	1,055
4N	45	25	30	-	-	-	-	-	110	15	-	-	-	-	-	-	-	-	-	365	1,595	-	-	-	-	2,185
4WNW	5	-	55	5	5	-	-	-	15	75	85	5	5	-	-	-	-	-	-	-	-	925	15	-	-	1,195
4W	-	-	-	-	-	-	-	-	-	5	5	-	10	-	-	-	-	-	-	-	-	25	85	50	-	180
4WSW	-	-	-	-	5	-	-	-	-	-	-	45	475	-	-	-	-	-	-	-	-	40	105	1,275	-	1,945
4SW	-	-	-	-	10	10	15	15	-	-	-	55	140	100	5	-	-	-	-	-	-	-	-	-	1,300	1,650
Total	190,590	38,345	33,570	8,985	20,090	13,090	22,455	29,255	3,740	3,015	2,615	6,085	4,050	3,425	1,885	-	-	175	-	1,660	2,305	995	205	1,335	1,305	389,175

Table 9: Comparison of Model Output to the Expanded Household Travel Survey, Non-work tours, Conventional Transit with Walk Access (Phase 1)

TARGETS | **NON-WORK** | **WK CONV** | HIS

Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	57,463	2,147	-	1,425	5,748	346	904	3,328	285	-	-	-	-	-	-	-	-	-	-	6,702	-	-	-	-	-	78,348
2N	27,841	44,996	3,799	652	1,630	-	-	582	582	-	-	81	-	-	-	-	-	-	-	-	-	-	-	-	-	80,163
2NW	11,223	4,516	9,826	14,343	-	-	1,527	239	-	-	-	-	-	-	-	-	-	-	-	1,527	-	-	-	-	-	43,200
2WNW	1,151	197	3,752	3,784	3,881	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,765
2W	13,720	481	298	3,016	14,404	988	522	1,916	-	-	-	662	-	-	-	-	-	-	-	662	-	-	-	-	-	36,670
2WSW	1,963	387	197	-	6,041	26,420	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35,202
2SW	13,087	13,384	-	-	-	14,006	15,389	1,172	-	-	-	-	-	-	-	-	-	140	-	-	-	-	-	-	-	57,178
2S	42,118	701	140	189	7,172	3,112	19,796	113,609	381	446	-	-	-	2,286	139	-	-	-	-	183	-	-	-	381	-	190,652
3N	73	-	-	-	-	-	-	-	1,697	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,770
3NW	1,014	-	-	-	-	-	-	-	-	1,090	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,104
3WNW	-	-	451	-	-	-	-	-	-	141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	592
3W	337	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	612	949
3WSW	-	-	-	-	-	-	-	-	-	-	-	-	870	218	-	-	-	-	-	-	-	-	-	-	-	1,088
3SW	141	-	-	123	-	195	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458
3S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	220	-	-	-	-	-	-	-	-	-	-	220
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
3IN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,450	75	-	-	-	-	-	-	2,525
XIN	2,124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	240	-	-	-	-	-	-	2,364
4NW	139	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,480	878	-	-	-	-	3,498
4N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	278	885	-	-	-	-	1,163
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	545	-	-	-	545
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	218	-	-	218
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	502	-	502
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,698	-	-	-	-	-	-	-	-	-	456	2,154
Total	172,394	66,809	18,462	23,532	38,876	45,068	38,331	120,845	2,945	1,676	-	744	870	2,504	2,057	-	-	2,590	315	11,832	1,763	545	218	883	1,068	554,327

MODEL OUTPUT | **NON-WORK** | **WK CONV**

Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	23,315	8,310	3,320	1,620	2,685	2,520	2,945	4,255	15	5	10	90	5	55	5	-	-	-	-	-	-	-	-	-	-	49,155
2N	32,250	45,055	10,155	1,900	915	345	595	1,430	880	125	65	65	5	45	5	-	-	-	-	30	30	-	-	-	-	93,895
2NW	16,155	12,330	18,955	5,390	2,285	605	395	765	260	480	205	60	20	25	-	-	-	5	-	90	10	-	-	-	-	58,035
2WNW	11,950	3,960	7,480	6,575	4,385	860	495	600	25	30	30	135	10	55	-	-	-	-	-	-	-	-	-	-	-	36,590
2W	17,515	2,275	3,850	4,825	14,150	4,125	1,455	925	25	20	25	890	95	60	10	-	-	-	-	10	-	5	-	-	-	50,260
2WSW	13,085	1,025	1,215	1,165	5,130	9,735	3,390	1,185	20	5	5	300	60	120	10	-	-	-	-	-	-	-	-	-	-	36,450
2SW	14,650	1,140	530	450	1,510	3,300	21,280	10,750	5	5	-	65	20	1,455	50	-	-	5	-	-	-	-	-	-	5	55,220
2S	30,700	3,110	1,170	460	975	1,135	13,415	67,945	25	5	5	60	20	1,375	970	-	-	190	-	-	5	-	-	-	5	121,570
3N	200	770	215	10	20	5	-	15	1,275	155	5	10	-	-	-	-	-	-	-	10	55	-	-	-	-	2,745
3NW	160	215	660	25	25	5	-	10	130	1,115	255	10	-	5	-	-	-	-	-	125	-	15	-	-	-	2,755
3WNW	45	25	100	20	25	5	-	5	5	60	260	140	35	-	-	-	-	-	-	-	-	10	-	-	-	735
3W	195	15	35	50	330	85	20	10	5	-	95	2,465	380	5	-	-	-	-	-	-	-	-	-	-	-	3,690
3WSW	40	-	15	-	30	15	5	5	-	-	-	330	2,150	5	-	-	-	-	-	-	-	-	-	5	100	2,700
3SW	290	65	15	10	45	90	1,255	485	5	5	-	25	-	1,825	125	-	-	-	-	-	-	-	-	-	10	4,250
3S	135	35	-	-	15	5	70	650	-	-	-	5	-	125	1,955	-	-	10	-	-	-	-	-	-	-	3,005
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	35	5	-	-	-	-	5	105	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	170
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4NW	5	30	40	-	-	-	-	-	10	30	-	-	-	-	-	-	-	-	-	1,255	70	-	-	-	-	1,440
4N	35	35	10	-	-	5	5	5	50	-	-	-	-	-	-	-	-	-	-	225	2,360	-	-	-	-	2,730
4WNW	-	5	5	-	-	-	-	-	-	20	5	-	-	-	-	-	-	-	-	-	-	860	10	5	-	910
4W	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	5	95	40	-	145
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	75	-	-	-	-	-	-	-	-	-	50	2,310	-	2,435
4SW	-	-	-	-	-	-	-	-	-	-	-	-	20	5	-	-	-	-	-	-	-	-	-	-	1,855	1,880
Total	160,760	78,405	47,770	22,500	32,525	22,840	45,330	89,145	2,735	2,060	965	4,650	2,900	5,160	3,150	-	-	210	-	1,745	2,530	895	155	2,360	1,975	530,765

Table 10: Comparison of Model Output to the Expanded Household Travel Survey, Work tours, Premium Transit with Walk Access (Phase 1)

TARGETS — WORK — WK PRE — HIS

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	4,683	-	742	-	-	-	-	-	-	-	1,306	-	1,255	-	-	-	-	103	-	-	176	-	-	-	-	8,264
2N	15,303	664	-	-	-	-	-	-	98	-	-	325	-	-	-	-	-	-	-	-	312	-	-	-	-	16,702
2NW	3,970	761	-	-	-	-	-	-	-	325	378	-	-	-	-	-	-	-	-	183	-	-	-	-	-	5,618
2WNW	1,046	-	-	3,603	-	-	-	308	-	-	-	308	224	-	-	-	-	-	-	-	-	-	-	-	-	5,490
2W	1,662	-	-	-	-	-	-	-	-	-	161	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,823
2WSW	7,562	-	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,660
2SW	2,221	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,221
2S	22,928	780	-	-	143	-	-	3,748	-	140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27,738
3N	6,467	381	-	-	-	-	-	2,354	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,202
3NW	3,455	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,455
3WNW	5,104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,104
3W	8,442	2,992	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11,433
3WSW	17,249	456	-	-	-	-	-	-	-	-	282	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,987
3SW	8,412	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,412
3S	2,991	-	-	-	-	-	-	1,226	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,217
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	3,102	-	-	-	-	-	-	-	-	43	-	-	-	-	-	-	-	88	-	-	-	-	-	-	-	3,233
XIN	1,844	-	-	-	-	-	-	227	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	2,089
4NW	6,878	87	-	-	-	-	218	-	-	486	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,669
4N	5,912	-	-	-	-	-	-	-	-	-	740	-	-	-	-	-	-	-	-	-	3,137	-	-	-	-	9,789
4WNW	1,061	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,061
4W	1,129	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,129
4WSW	4,654	-	-	-	-	-	-	83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,738
4SW	7,757	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,757
Total	143,833	6,121	840	3,603	143	-	218	7,946	98	994	2,867	634	1,479	-	-	-	-	191	18	183	3,625	-	-	-	-	172,793

MODEL OUTPUT — WORK — WK PRE

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	530	470	570	125	165	75	65	525	160	140	60	100	180	15	10	-	-	5	-	40	75	10	5	-	5	3,330
2N	20,685	355	300	35	90	40	5	95	145	105	60	20	30	5	-	-	-	-	-	30	190	5	-	-	-	22,195
2NW	10,940	125	370	90	65	20	35	45	75	125	50	10	45	-	-	-	-	-	-	25	65	10	-	-	-	12,095
2WNW	5,860	60	100	85	25	20	20	25	20	25	40	25	10	5	-	-	-	5	-	10	35	-	-	-	-	6,370
2W	4,515	60	100	20	60	25	-	25	30	15	25	20	80	5	-	-	-	-	-	-	25	5	-	-	-	5,010
2WSW	8,160	95	110	35	35	95	55	40	10	20	15	15	65	5	-	-	-	-	-	-	5	-	5	5	-	8,770
2SW	5,590	85	135	50	65	15	40	90	50	10	35	15	55	20	10	-	-	-	-	5	10	5	-	-	-	6,285
2S	40,385	245	550	65	250	185	205	1,280	35	30	15	60	60	80	35	-	-	-	-	15	60	-	-	5	-	43,560
3N	1,645	50	35	-	10	-	-	5	30	-	15	-	-	-	-	-	-	-	-	15	60	-	-	-	-	1,865
3NW	1,205	35	170	20	15	-	5	10	10	75	20	10	5	-	-	-	-	-	-	5	30	-	-	-	-	1,615
3WNW	980	30	45	20	30	5	-	-	5	5	40	5	-	-	-	-	-	-	-	-	10	5	-	-	-	1,180
3W	4,230	55	115	10	115	35	30	25	15	10	55	125	105	-	-	-	-	-	-	5	-	-	-	5	-	4,935
3WSW	9,205	20	95	20	130	110	55	45	5	15	35	70	400	5	-	-	-	-	-	-	-	-	10	5	5	10,230
3SW	5,200	40	25	15	50	50	60	100	5	5	10	25	35	105	15	-	-	-	-	-	-	-	-	-	-	5,740
3S	3,160	30	15	-	15	15	25	100	-	-	-	5	5	5	30	-	-	10	-	-	-	-	-	-	-	3,415
XWI	15	25	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	30	-	-	-	-	100
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	460	5	10	-	5	5	-	20	-	-	-	-	-	10	5	-	-	-	-	-	-	-	-	-	-	520
XIN	50	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	55
4NW	875	80	310	5	10	-	-	-	165	145	70	5	5	-	-	-	-	-	-	235	60	-	-	-	-	1,965
4N	1,310	165	50	-	-	-	5	-	125	35	10	5	5	-	-	-	-	-	-	105	210	5	-	-	-	2,030
4WNW	315	20	35	5	10	-	-	-	5	15	45	40	10	-	-	-	-	-	-	-	20	-	-	-	-	520
4W	325	-	5	10	10	-	-	-	-	-	-	35	10	-	-	-	-	-	-	-	-	-	-	-	-	395
4WSW	665	-	5	-	30	20	15	5	-	-	10	75	100	5	-	-	-	-	-	-	-	-	-	-	-	930
4SW	865	15	-	5	55	50	35	45	-	-	5	35	15	10	-	-	-	-	-	-	-	5	-	-	5	1,145
Total	127,170	2,065	3,155	615	1,240	765	655	2,480	890	775	615	700	1,220	275	110	-	-	20	-	515	885	50	20	20	15	144,255

Table 11: Comparison of Model Output to the Expanded Household Travel Survey, Non-work Tours, Premium Transit with Walk Access (Phase 1)

TARGETS — NON-WORK — WK PRE — HIS

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	1,115	-	-	-	-	-	-	-	-	-	-	-	-	-	280	-	-	-	-	285	-	-	-	-	-	1,680
2N	2,511	458	-	-	-	-	-	-	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,021
2NW	378	-	-	-	-	-	-	-	-	-	-	239	-	-	-	-	-	-	-	-	-	-	-	-	-	617
2WNW	161	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	161
2W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2WSW	702	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	758
2SW	175	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	175
2S	3,844	-	-	-	-	-	-	2,027	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,871
3N	1,645	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	524	-	-	-	-	-	2,265
3NW	257	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	257
3WNW	374	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	374
3W	1,555	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,555
3WSW	1,939	-	-	-	-	-	1,363	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,302
3SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3S	5,390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,390
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	82	63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	218	-	-	-	-	-	-	-	363
XIN	35	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	94
4NW	3,357	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	556	-	-	-	-	-	3,914
4N	1,006	232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,237
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18,388	-	18,388
4SW	1,087	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,087
Total	25,612	905	-	-	-	-	1,363	2,087	52	-	-	239	-	-	280	-	-	218	-	1,366	-	-	-	18,388	-	50,510

MODEL OUTPUT — NON-WORK — WK PRE

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	330	565	590	195	250	295	125	1,325	30	25	35	65	115	20	15	-	-	-	-	45	50	25	20	5	10	4,135
2N	2,765	405	130	25	40	20	25	75	85	30	15	15	35	10	-	10	-	5	-	10	45	5	-	5	-	3,755
2NW	2,895	210	435	70	55	20	35	110	15	25	15	15	20	10	10	5	-	-	-	5	25	-	5	-	10	3,990
2WNW	1,670	50	105	150	60	5	20	80	10	10	20	15	30	25	5	-	-	-	-	5	5	5	-	-	-	2,270
2W	1,395	55	60	55	140	90	20	85	25	15	-	30	55	15	5	-	-	-	-	10	10	15	5	-	-	2,085
2WSW	2,095	55	45	45	65	225	45	105	-	5	-	20	60	15	5	-	-	-	-	10	10	10	-	5	-	2,820
2SW	825	50	55	20	30	30	115	180	15	15	10	10	25	50	15	-	-	-	-	5	10	5	-	5	5	1,475
2S	11,950	305	305	65	125	125	355	3,635	40	25	15	80	90	185	115	-	-	35	-	20	40	-	10	20	25	17,565
3N	285	110	5	5	5	5	5	20	40	-	5	5	5	-	-	-	-	-	-	10	5	-	-	-	-	510
3NW	420	45	65	10	15	5	5	10	-	35	10	5	5	-	-	-	-	-	-	5	5	-	-	-	-	640
3WNW	290	10	25	5	-	5	20	25	-	10	50	5	5	-	-	-	-	-	-	5	-	15	-	-	-	470
3W	665	90	30	25	35	5	-	45	10	5	5	175	45	10	-	-	-	-	-	-	-	-	-	-	-	1,145
3WSW	760	75	30	-	25	45	20	35	-	5	-	25	200	10	-	-	-	5	-	-	5	5	-	10	-	1,255
3SW	320	60	25	-	30	5	65	85	10	5	10	-	5	105	-	-	-	-	-	-	-	10	-	-	10	745
3S	225	5	35	10	25	5	15	70	-	-	-	5	-	-	45	-	-	-	-	-	5	-	-	-	-	445
XWI	55	45	15	5	15	5	-	-	5	-	-	-	5	-	-	-	-	-	-	5	30	-	-	-	-	185
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	120	10	5	-	10	-	15	20	-	-	-	-	-	-	5	-	-	5	-	-	-	-	-	-	-	190
XIN	10	5	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
4NW	615	95	70	15	50	35	15	20	20	20	-	5	10	15	-	-	-	-	-	95	-	-	5	5	10	1,100
4N	735	140	55	25	30	15	5	60	70	5	-	5	-	-	-	-	-	5	-	15	145	-	-	15	-	1,325
4WNW	120	35	-	5	15	-	-	20	5	-	10	5	5	-	-	-	-	5	-	-	-	-	-	-	-	225
4W	100	25	5	-	10	10	5	10	-	-	-	10	-	-	-	-	-	-	-	-	5	-	10	-	-	190
4WSW	160	10	15	-	5	-	10	10	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	225
4SW	190	20	30	-	10	5	10	40	-	-	5	5	5	10	-	-	-	-	-	5	-	-	-	-	20	355
Total	28,995	2,475	2,135	730	1,045	955	935	6,065	380	235	205	500	735	480	220	15	-	60	-	250	395	95	55	70	90	47,120

Table 12: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, KNR (Phase 1)

TARGETS — **WORK** — **KNR** — HIS

Origin Sector	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
	Destination Sector																									
1	1,491	-	-	-	-	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,603
2N	6,622	-	-	-	-	-	-	139	1,278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,039
2NW	3,856	-	186	-	-	-	-	416	-	-	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,778
2WNW	4,306	-	-	-	-	-	-	-	-	-	-	-	224	-	-	-	-	-	-	-	-	-	-	-	-	4,530
2W	2,482	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	708	-	-	-	3,190
2WSW	177	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	177
2SW	5,492	-	-	-	-	-	-	-	678	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,170
2S	5,885	1,726	-	-	-	-	-	619	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,230
3N	560	-	-	-	-	-	-	397	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	957
3NW	4,000	-	-	-	-	-	-	-	-	-	-	89	116	-	-	-	-	-	-	73	-	-	-	-	-	4,278
3WNW	9,304	-	591	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,895
3W	2,676	-	-	-	369	-	-	-	-	-	-	285	1,196	-	-	-	-	-	-	-	-	-	-	-	-	4,527
3WSW	14,744	-	-	-	-	-	-	-	-	-	-	487	-	-	-	-	-	-	-	-	-	-	-	-	-	15,231
3SW	5,540	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,540
3S	2,283	-	-	-	-	-	-	64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,347
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	4,096	-	-	-	-	-	55	87	-	43	-	-	96	-	-	-	-	88	-	-	-	-	-	-	-	4,465
XIN	1,456	-	-	-	-	-	-	-	-	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,504
4NW	8,655	765	73	-	-	-	-	-	185	-	-	-	153	-	-	-	-	-	-	218	-	-	-	-	-	10,049
4N	1,569	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,569
4WNW	509	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	509
4W	1,022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,022
4WSW	3,438	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,438
4SW	5,267	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,267
Total	95,431	2,491	849	-	369	112	55	1,722	2,141	91	320	861	1,784	-	-	-	-	88	-	291	-	708	-	-	-	107,314

MODEL OUTPUT — **WORK** — **KNR**

Origin Sector	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
	Destination Sector																									
1	325	280	305	80	125	240	170	140	10	10	10	20	30	5	-	-	-	-	-	5	5	-	-	-	-	1,760
2N	9,555	1,030	430	85	75	60	35	60	130	35	30	5	5	-	-	-	-	-	-	25	30	-	-	-	-	11,590
2NW	2,795	235	615	110	125	55	20	5	95	55	105	40	15	-	-	-	-	-	-	20	45	-	-	-	-	4,335
2WNW	1,870	140	280	120	155	60	25	10	10	10	35	50	40	5	-	-	-	-	-	5	15	-	-	-	-	2,830
2W	2,570	40	125	45	340	120	65	10	15	20	40	105	50	15	-	-	-	-	-	10	5	-	-	-	-	3,575
2WSW	2,185	40	100	60	260	295	165	35	5	10	35	185	100	30	-	-	-	-	-	5	-	-	-	-	-	3,510
2SW	4,610	25	40	20	170	185	520	230	5	-	15	45	70	55	15	-	-	-	-	-	-	-	-	-	-	6,005
2S	7,405	60	65	15	55	65	380	1,265	-	-	-	15	20	115	75	-	-	15	-	-	-	-	-	-	-	9,550
3N	505	115	135	-	10	-	-	-	125	70	30	-	5	-	-	-	-	-	-	20	65	-	-	-	-	1,080
3NW	315	140	440	15	45	15	5	-	190	610	355	40	90	-	-	-	-	-	-	165	140	10	5	-	-	2,580
3WNW	825	50	515	40	150	45	10	-	115	350	805	260	265	5	-	-	-	-	-	35	25	95	30	-	-	3,620
3W	1,445	25	225	60	230	50	20	-	55	145	290	735	490	10	-	-	-	-	-	10	-	50	25	-	5	3,870
3WSW	2,345	10	125	65	300	140	250	45	25	90	320	925	1,755	95	5	-	-	-	-	-	-	40	10	120	30	6,695
3SW	2,580	35	45	30	200	195	375	315	10	10	25	230	265	500	135	-	-	-	-	-	-	-	-	-	35	4,985
3S	2,735	10	5	-	10	10	110	550	-	-	-	15	15	135	790	-	-	5	-	-	-	-	-	-	15	4,405
XWI	10	5	5	-	-	-	-	-	85	25	10	-	-	-	-	95	-	-	-	455	330	5	-	-	-	1,025
XIL	305	5	30	5	20	20	60	205	5	60	115	125	545	95	490	-	-	5	-	120	-	420	120	525	165	3,440
3IN	2,760	10	10	-	15	20	160	1,275	-	-	-	10	10	100	565	-	-	205	5	-	-	-	-	-	-	5,145
XIN	415	-	-	-	-	-	-	265	-	-	-	-	-	10	295	-	-	90	15	-	-	-	-	-	-	1,090
4NW	140	80	340	-	15	5	-	-	390	610	360	45	30	-	-	25	-	-	-	1,675	680	245	30	15	-	4,685
4N	265	50	80	15	-	-	-	-	210	55	15	-	5	-	-	10	-	-	-	245	405	-	-	-	-	1,355
4WNW	45	10	205	5	15	-	-	-	55	225	255	70	50	-	-	-	-	-	-	100	10	275	20	15	-	1,355
4W	45	-	30	20	10	15	-	-	15	50	75	140	125	-	-	-	-	-	-	15	-	85	60	40	-	725
4WSW	160	5	20	20	30	15	10	5	-	25	80	470	1,115	10	-	-	-	-	-	-	-	25	80	470	35	2,575
4SW	1,605	5	25	20	165	80	150	125	5	20	95	545	1,500	405	200	-	-	5	-	5	-	-	15	140	610	5,720
Total	47,815	2,405	4,195	830	2,520	1,690	2,530	4,540	1,555	2,485	3,100	4,075	6,595	1,590	2,570	130	-	325	20	2,915	1,755	1,250	395	1,325	895	97,505

Table 13: Comparison of Model Output to the Expanded Household Travel Survey, Non-Work Tours, KNR (Phase 1)

TARGETS — NON-WORK — KNR (HIS)

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	1,193	-	-	-	609	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,802
2N	3,114	548	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,663
2NW	197	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	876	-	-	-	-	-	-	-	1,073
2WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2W	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
2WSW	-	-	-	-	1,788	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,788
2SW	-	-	-	-	-	-	286	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	286
2S	415	-	-	-	-	-	-	1,638	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,053
3N	-	-	-	-	-	-	-	-	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55
3NW	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58
3WNW	414	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	414
3W	370	-	-	-	157	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	527
3WSW	1,514	-	-	-	-	-	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,624
3SW	-	-	-	-	-	-	141	-	-	-	-	-	-	-	-	-	-	121	-	-	-	-	-	-	-	262
3S	3,670	-	-	-	-	-	-	-	-	-	-	-	-	-	97	-	-	-	-	-	-	-	-	-	-	3,767
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	70	-	-	-	-	-	-	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	112
XIN	129	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	166
4NW	7,182	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,182
4N	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	-	-	-	71
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	1,700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,700
4SW	403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	507	910
Total	20,713	548	-	-	2,554	-	537	1,694	55	-	-	-	-	-	97	-	-	998	24	-	-	71	-	-	507	27,797

MODEL OUTPUT — NON-WORK — KNR

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	80	215	100	60	100	125	275	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,255
2N	915	755	185	55	15	15	35	20	20	-	-	5	-	-	-	-	-	-	-	-	5	-	-	-	-	2,025
2NW	455	225	410	140	105	20	35	30	30	20	30	10	-	-	-	-	-	-	-	5	5	-	-	-	-	1,520
2WNW	485	105	120	250	110	30	30	30	-	-	-	5	-	-	-	-	-	-	5	5	-	-	-	-	-	1,175
2W	740	25	85	135	340	110	50	35	5	5	5	40	5	5	-	-	-	-	-	-	-	-	-	5	-	1,590
2WSW	560	40	35	70	125	325	130	40	-	5	-	5	60	30	-	-	-	-	-	-	-	-	-	-	-	1,425
2SW	730	10	25	10	65	95	610	290	-	-	-	10	-	40	5	-	-	-	-	-	-	-	-	-	-	1,890
2S	1,205	70	35	15	25	20	340	1,885	-	-	5	5	-	35	55	-	-	15	-	-	-	-	-	-	5	3,715
3N	75	50	75	5	10	-	-	-	40	30	5	10	-	-	-	-	-	-	-	10	30	-	-	-	-	340
3NW	15	25	115	5	25	15	5	-	25	175	60	10	10	-	-	-	-	-	-	35	15	15	-	-	-	550
3WNW	30	15	70	15	45	15	20	5	10	100	155	100	50	5	-	-	-	-	-	15	-	50	5	15	-	720
3W	65	-	30	30	65	5	20	10	-	10	50	250	150	35	-	-	-	-	-	5	-	15	10	10	-	760
3WSW	75	5	5	5	30	65	20	35	5	15	30	150	785	30	5	-	-	-	-	15	-	5	-	50	20	1,350
3SW	60	5	10	5	35	60	155	200	-	-	-	35	70	325	80	-	-	-	-	-	-	-	-	-	10	1,050
3S	140	10	5	-	-	15	45	175	5	-	-	5	10	45	320	-	-	-	-	-	-	-	-	-	15	790
XWI	15	25	5	-	-	-	5	-	-	5	-	-	-	-	-	20	-	-	-	65	30	-	-	-	-	170
XIL	190	15	30	5	5	5	65	165	-	15	35	45	220	30	70	-	-	-	-	40	5	45	25	80	45	1,135
3IN	160	10	10	5	15	5	70	380	-	-	-	5	20	20	150	-	-	70	-	-	-	-	-	-	-	920
XIN	50	55	5	-	-	-	15	65	-	-	-	5	-	5	35	-	-	10	20	-	-	-	-	-	-	265
4NW	70	45	40	5	10	5	5	5	25	60	30	15	25	-	-	5	-	-	-	775	70	75	-	15	-	1,280
4N	90	25	20	-	5	-	5	-	20	15	5	-	5	-	-	-	-	-	-	60	300	-	-	-	-	550
4WNW	10	5	10	-	20	20	-	-	-	15	35	10	25	-	-	-	-	-	-	45	5	110	-	10	-	320
4W	10	10	-	-	-	-	-	-	-	-	40	25	10	-	-	-	-	-	-	5	-	10	35	20	-	165
4WSW	70	-	5	5	15	-	10	5	-	5	10	20	145	5	-	-	-	-	-	-	-	5	15	300	40	655
4SW	200	10	20	5	15	25	65	75	-	-	5	55	135	145	50	-	-	-	-	-	-	5	-	-	410	1,220
Total	6,495	1,755	1,450	825	1,180	975	2,010	3,750	185	475	500	820	1,725	755	770	25	-	95	25	1,080	465	335	90	505	545	26,835

Table 14: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, PNR (Phase 1)

TARGETS — WORK — PNR — HIS

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	429	-	-	-	-	-	-	-	-	224	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	653
2N	6,207	959	-	-	-	-	1,008	-	-	-	-	-	-	-	-	-	-	336	-	-	139	-	-	-	-	8,649
2NW	11,765	-	305	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,070
2WNW	-	-	-	-	-	-	-	-	-	1,404	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,404
2W	4,138	-	-	-	3,768	-	-	-	-	-	-	-	1,842	-	-	-	-	-	-	-	-	-	-	-	-	9,747
2WSW	2,419	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,419
2SW	3,694	-	-	-	-	-	-	-	678	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,372
2S	6,211	1,147	-	-	-	114	560	-	-	-	-	-	-	365	-	-	-	-	-	-	-	-	-	-	-	8,397
3N	277	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	277
3NW	145	-	-	-	-	-	-	-	-	413	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	558
3WNW	569	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	569
3W	4,517	-	-	-	-	-	-	-	-	-	-	674	-	-	-	-	-	-	-	-	-	-	-	-	-	5,192
3WSW	13,317	-	-	-	-	-	-	109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13,426
3SW	1,379	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,379
3S	6,577	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,577
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	281	-	-	-	-	-	-	-	-	48	-	-	96	-	-	-	-	-	-	-	-	-	-	-	-	425
XIN	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60
4NW	1,437	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,437
4N	1,222	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,222
4WNW	2,522	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,522
4W	5,940	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,940
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	73,107	2,106	305	-	3,768	114	1,568	109	678	2,089	-	674	1,938	365	-	-	-	336	-	-	139	-	-	-	-	87,296

MODEL OUTPUT — WORK — PNR

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	555	60	30	-	-	-	-	10	20	5	-	-	5	-	-	-	-	-	-	-	10	-	-	-	-	695
2N	9,640	135	105	10	20	5	-	-	10	-	15	5	5	10	-	-	-	-	-	5	50	5	-	5	-	10,025
2NW	2,180	30	80	10	-	5	5	10	20	15	20	15	-	-	-	-	-	-	-	-	40	-	-	-	-	2,430
2WNW	190	10	15	10	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230
2W	50	20	15	5	-	5	-	10	5	5	10	-	15	-	-	-	-	-	-	-	-	-	-	-	-	140
2WSW	595	10	10	-	-	35	-	10	-	-	-	-	30	-	-	-	-	-	-	5	-	-	-	-	-	695
2SW	995	25	15	5	5	20	20	35	10	-	-	-	10	-	5	-	-	-	-	-	10	-	-	-	-	1,155
2S	6,465	80	60	15	35	30	20	205	-	20	5	15	5	15	5	-	-	-	-	-	15	-	-	-	-	6,990
3N	485	30	15	5	10	5	5	-	5	-	-	5	5	-	-	-	-	-	-	-	35	-	-	-	-	605
3NW	1,140	105	345	10	25	20	5	5	15	75	20	-	10	-	-	-	-	-	-	15	45	5	-	-	-	1,840
3WNW	1,805	75	215	55	60	15	15	10	35	10	55	15	55	-	-	-	-	-	-	5	25	20	10	5	-	2,485
3W	2,755	45	70	50	70	30	25	10	5	20	45	25	115	-	-	-	-	-	-	-	10	25	5	10	-	3,315
3WSW	5,070	50	55	20	140	125	30	40	10	20	95	55	425	25	-	-	-	-	-	5	10	30	5	25	5	6,240
3SW	3,345	25	35	15	100	45	75	125	-	20	10	20	40	70	10	-	-	-	-	5	10	-	-	5	15	3,970
3S	3,300	35	50	10	20	45	35	195	5	-	-	10	5	15	50	-	-	-	-	-	-	-	-	-	10	3,785
XWI	175	90	95	-	-	-	-	-	230	165	65	-	-	-	-	40	-	-	-	485	560	10	-	-	-	1,915
XIL	340	10	85	30	45	10	40	110	40	80	65	430	390	20	5	-	-	-	-	80	35	70	10	65	45	2,005
3IN	8,095	85	65	15	65	40	95	370	-	-	-	-	-	15	30	-	-	20	-	-	5	-	-	-	15	8,915
XIN	2,540	5	-	5	-	15	15	275	-	-	-	-	-	5	40	-	-	40	55	-	-	-	-	-	-	2,995
4NW	1,605	275	865	80	55	5	5	5	415	435	225	65	10	-	-	10	-	-	-	575	360	80	-	-	-	5,070
4N	715	90	65	5	10	-	-	5	110	30	-	-	-	-	-	5	-	-	-	110	100	-	-	-	-	1,245
4WNW	455	55	215	60	35	-	15	5	15	110	120	80	25	-	-	-	-	-	-	15	30	50	5	-	-	1,290
4W	655	-	15	30	100	15	-	-	5	15	50	95	130	-	-	-	-	-	-	-	10	-	-	-	-	1,120
4WSW	1,345	20	40	-	75	45	15	15	5	10	30	235	430	25	5	-	-	-	-	-	-	-	-	35	-	2,330
4SW	3,155	10	50	30	170	120	170	125	5	-	10	145	330	205	40	-	-	5	-	5	-	15	5	5	60	4,660
Total	57,650	1,375	2,610	475	1,040	635	595	1,575	965	1,035	840	1,215	2,040	405	190	55	-	65	55	1,310	1,360	310	40	155	150	76,145

Table 15: Comparison of Model Output to the Expanded Household Travel Survey, Non-Work Tours, PNR (Phase 1)

TARGETS	NON-WORK		PNR	HIS																						
Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	1,807	-	-	-	-	680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,487
2N	1,946	3,342	-	-	-	-	-	-	-	-	-	117	354	-	-	-	-	-	-	-	-	-	-	-	-	5,759
2NW	787	-	269	-	-	-	-	-	-	-	-	-	-	-	-	-	-	876	-	422	-	-	-	-	-	2,355
2WNW	-	-	387	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	387
2W	7,069	885	2,833	-	596	3,974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,357
2WSW	302	-	-	-	1,788	631	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,721
2SW	-	-	-	-	-	-	2,646	451	-	-	-	-	-	-	-	-	-	140	-	-	-	-	-	-	-	3,237
2S	280	-	-	-	-	-	1,764	3,437	-	-	-	-	-	-	278	-	-	-	-	-	-	-	-	-	-	5,759
3N	159	198	-	-	174	-	-	-	620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,150
3NW	2,704	-	-	-	-	-	-	-	-	1,137	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,841
3WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3W	142	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	142
3WSW	1,555	-	-	-	-	-	-	-	-	-	-	-	1,793	-	-	-	-	-	-	1,292	-	-	-	-	2,089	6,730
3SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3S	3,406	-	-	-	-	-	506	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,912
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	18	-	-	-	-	-	-	327	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	345
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	131	-	-	-	-	-	-	-	131
4NW	790	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,619	-	-	-	-	-	10,409
4N	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	3,401	-	-	-	-	-	-	-	-	-	-	-	207	-	-	-	-	-	-	-	-	-	-	294	-	3,901
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	24,414	4,425	3,489	-	2,557	5,284	4,916	4,214	620	1,137	-	117	2,354	-	278	-	-	1,147	-	11,334	-	-	-	294	2,089	68,670

MODEL OUTPUT	NON-WORK		PNR																							
Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	430	75	10	-	5	-	-	145	-	-	-	5	5	-	-	-	-	-	-	-	-	5	-	-	-	680
2N	2,015	440	350	25	45	25	5	20	50	5	-	5	15	5	5	-	-	-	-	10	25	10	-	20	-	3,075
2NW	1,110	5	170	70	20	15	-	55	10	10	30	25	10	15	5	-	-	-	-	15	25	15	-	-	5	1,610
2WNW	215	35	165	115	30	15	5	10	-	-	5	15	15	-	-	-	-	-	-	5	5	-	-	-	-	635
2W	115	15	25	40	15	15	5	15	5	5	-	10	40	-	-	-	-	-	-	5	-	5	-	5	-	320
2WSW	460	10	35	5	-	115	5	15	10	-	-	15	45	-	-	-	-	-	-	-	-	-	-	10	-	725
2SW	165	40	35	35	10	90	125	155	5	20	-	-	20	45	5	-	-	-	-	-	10	25	-	-	5	790
2S	4,530	235	135	20	70	75	145	1,740	15	50	35	25	30	80	60	-	-	10	-	20	25	-	5	5	20	7,330
3N	240	95	40	10	25	-	20	30	35	5	-	-	-	-	-	-	-	-	-	20	35	-	-	-	-	555
3NW	770	130	295	30	20	15	50	90	10	170	10	10	5	10	-	10	-	-	-	30	15	30	5	-	10	1,715
3WNW	790	175	235	40	30	5	10	90	20	20	120	50	70	10	-	-	-	10	-	20	5	115	-	15	-	1,830
3W	685	75	50	70	150	45	45	115	35	30	35	135	95	10	5	-	-	-	-	20	-	35	-	45	-	1,680
3WSW	1,270	200	65	30	80	120	65	120	25	-	15	50	580	55	10	-	-	-	-	15	5	45	20	55	20	2,845
3SW	485	115	70	20	55	60	125	200	5	30	5	15	25	105	20	-	-	-	-	15	10	20	10	5	15	1,410
3S	715	110	95	15	75	40	65	310	5	5	5	15	15	45	220	-	-	-	-	-	20	-	-	5	20	1,780
XWI	1,015	920	515	155	155	80	70	200	125	85	55	65	85	15	-	75	-	5	-	340	225	50	5	5	-	4,245
XIL	1,180	585	735	290	660	355	420	465	90	175	155	515	680	185	50	-	-	10	-	210	100	220	-	55	25	7,160
3IN	2,655	445	340	150	235	95	90	550	45	15	25	70	45	65	100	-	-	140	20	15	55	-	-	10	80	5,245
XIN	1,665	545	230	105	175	135	210	770	20	15	20	30	25	65	65	-	-	20	100	10	10	-	-	5	40	4,260
4NW	2,365	775	930	245	255	175	245	405	170	200	125	65	65	75	5	10	-	-	-	1,015	235	125	-	5	5	7,495
4N	860	325	175	70	50	45	45	80	70	35	20	20	5	-	5	15	-	-	-	135	405	5	-	15	15	2,395
4WNW	600	115	145	85	65	40	60	80	15	55	35	30	35	5	-	-	-	-	-	20	20	95	-	5	10	1,515
4W	495	115	75	65	45	45	50	90	5	-	-	40	50	10	20	-	-	-	-	-	30	-	-	10	-	1,145
4WSW	975	260	130	25	130	100	75	200	25	20	10	65	175	35	10	-	-	-	-	10	-	-	-	145	15	2,405
4SW	785	240	155	100	175	75	185	260	30	20	25	105	150	85	85	-	-	-	-	5	10	10	10	15	235	2,760
Total	26,590	6,080	5,205	1,815	2,575	1,780	2,120	6,210	825	970	730	1,380	2,285	920	670	110	-	195	120	1,935	1,270	810	55	435	520	65,605

4. Key Technical Aspects of Phase 2

4.1. Summary of ABM Improvements in Phase 2

During the implementation work in Phase 1, many additional factors were revealed that were relevant and useful for Phase 2 beyond the previously reported summary from the workshop held at CMAP in February 2012. The list of main model improvements is summarized in **Table 16**.

Table 16: Summary of Main Model Improvements

Model Component	Phase 1	Phase 2
Advanced "non-labeled" mode choice	X	X
Transit access / spatial resolution		X
Station characteristics	X	X
In-vehicle parameters	X	X
Capacity constraints		X
Crowding effects		X
Service reliability		X
Transit frequency / wait time	X	X
Fare / cost structures	X	X
Individualized transit path choice		X

The corresponding detailed analysis of main model improvements is included in the subsequent sub-sections below.

4.2. Non-Labeled Transit Mode Definitions: Further Steps in Phase 2

Non-labeled mode definitions refer to actual transit service characteristics and are based on understanding of traveler perceptions. This approach allows for elimination of proliferation of mode-geography-specific constants that plagued many mode choice models applied in practice. This approach is being promoted by FTA and also represents a conceptual essence of the TCRP Project H-37 "Transit Services that Affect Choice of Mode". In line with this approach, transit user sees generic transit service where different modes and lines can be used. Access modes (Walk, PNR, and KNR) still represent distinct options (modes). The main shift of modeling focus is from proliferation of transit modes (that will never be enough to describe the multitude of trip origins, destination, and user characteristics.) to capturing individual path-building rules (that include the necessary level of details associated with trip origins, destinations, as well as user characteristics). With the non-labeled mode choice approach we have fewer modes in the mode choice set. However, we have a much more elaborate description of the transit path choice that is sensitive to transit attributes and person characteristics. The corresponding transformation of transit mode definitions from the Pricing ABM to Transit Modernization ABM Phase 1 and, finally, to Transit Modernization ABM Phase 2 is summarized in **Table 17**.

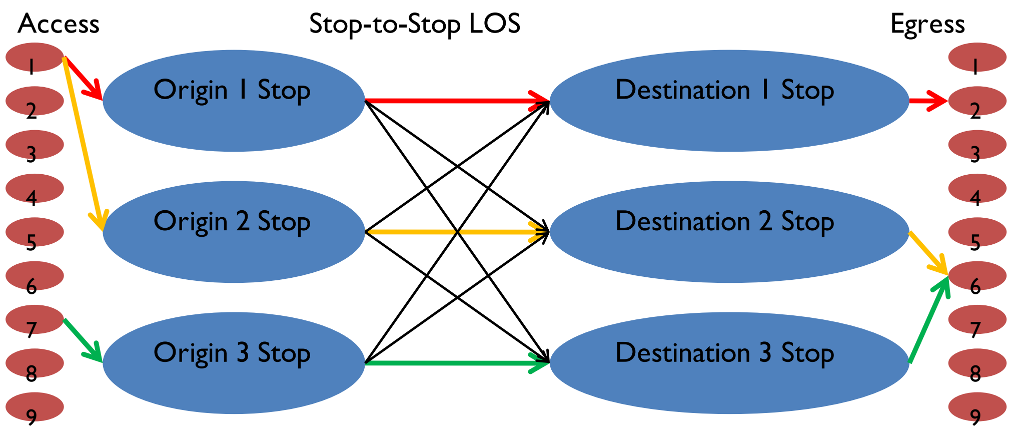
Table 17: Transformation of Transit Mode Definitions

Previous (labeled)	Phase 1	Phase 2
Walk to bus (CTA local bus, Pace local bus, CTA express bus)	**Walk to conventional** transit (CTA local bus, Pace local bus, CTA train)	**Walk to transit** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)
Walk to premium transit (CTA train, Metra commuter rail)	**Walk to premium** transit (CTA express bus, Metra commuter rail)	
Drive to premium transit (CTA train, Metra commuter rail)	**PNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	**PNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)
Drive to bus (CTA local bus, Pace local bus, CTA express bus)	**KNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	**KNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)

4.3. Taking Advantage of Micro Analysis Zones (MAZs)

The overall logic of TVPB is presented in **Figure 2**. Virtual path building represents a convolution of three essential transit pass components: 1) access time/cost pre-calculated for MAZ-to-station matrices using detailed street network, 2) station-to-station time/cost matrices skimmed using EMME transit assignment, and 3) egress time/cost pre-calculated for MAZ-to-station matrices using detailed street network. The entire MAZ-station-station-MAZ path calculated on the fly and cannot be stored in an MAZ-to-MAZ matrix format for two reasons. First, MAZ-to-MAZ matrix would contain roughly one third of a billion cells that is an object that is very inefficient to store and read. Secondly, with the multitude of individual parameters involve in path building (person age, income, trip purpose, etc) one would need to store hundreds of such matrices.

Figure 2: Transit Virtual Path Building (TVPB)



CMAP has established a system of 16,819 MAZs nested within 1,944 TAZs. The following aspects were considered and the following technical steps were made to take a full advantage of a finer level of spatial resolution.

- Use a detailed system of Transit Access Points (TAP). TAP represents a station or group of stops for the same transit mode with insignificant walk between them. TAPs replace TAZs for the purpose of transit assignment and skimming. The connectors between TAPs and stops (nodes) in the transit network are used to represent initial boarding transit fares and station-specific walk times. TAP-to-TAP links used to represent transfer fare additions, walk times, and timed transfers (shorter transfer wait time that would have been calculated based on the headway).
- The MAZ system developed by CMAP (16,819 MAZs) is a significant step forward in terms of spatial resolution but it has its own limitations. In general, having more than one TAP per MAZ is excessive in terms of spatial resolution.
- MAZs can be added if necessary; some of the MAZs in the outer areas are still big. New Starts zone system provides some additional details in Indiana & Wisconsin.
- Chicago has 37,000 total Google transit stops:
    - Pace – 25,000 stops
    - CTA - 12,000 stops
    - Metra – 240 stops
    - NICTD – 20 stops
- Many stops are duplicative, overlapping, or very close to each other. It proved possible to collapse stops to reasonable number, without losing too much accuracy. Application of the TAP building method previously applied for San-Diego and Miami CT-RAMP ABMs resulted in 4,600 aggregate TAPs for Chicago. In the transit assignment and skimming procedures, TAPs are separated by mode (Local Bus, Express Bus, CTA train, Metra rail) for setting mode-specific path building attributes.
- Detailed street network provided by NAVTEQ was used to model transit walk access and egress travel times with actual sidewalk connectivity. MAZ-to-TAP connectors were built to calculate access/egress times by transit access modes (walk, PNR, KNR) with a higher level of accuracy.

4.4. Detailed Transit Network Coding Compatible with MAZ System

The transit network utilizes on-the-fly stop-to-stop path-building approach for transit Level-of-Service (LOS) calculations. This requires a ‘dummy’ zone system (referred to as Transit Access Points, or TAPs) created in a transit-specific EMME databank. Each TAP represents an explicit fixed-guideway transit stop, or one or more aggregated bus stops. Bus stops are only aggregated with other stops of the same mode-type (local with other local or express with other express). Each TAP is connected to the actual transit route stop in the highway network via an auxiliary transit link. Walk and drive connections from Micro Area Zones (MAZs) to TAPs are not coded directly in the network; instead, they are represented in a file or database table that is an output of another program developed as part of the Transit Modernization ABM setup.

Pseudo-code for creating the MAZ system, transit network, TAPs, and associated walk and drive access files are given below.

Pseudo-code:

1) Define MAZ system –
    a. Start with statistical areas
    b. Should be much denser along existing or future planned fixed-guideway stations
    c. 20k – 40k MAZs acceptable
    d. Code MAZ centroids
2) Import transit stops
    a. Metra (~250 TAPS):
        i. Create TAP at every station, with actual XY – either from GTFS or existing emme network; one TAP per station
        ii. Set Metra_Rail = 1 in TAP attributes
        iii. Code parking availability and other attributes
        iv. Generate auxiliary transit link from TAP to highway network transit stop node
    b. CTA Rail (~144 TAPS)
        i. Create TAP at every station, with actual XY – either from GTFS or existing emme network; one TAP per station
        ii. Set CTA_Rail = 1 in TAP attributes
        iii. Code parking availability and other attributes
        iv. Generate auxiliary transit link from TAP to highway network transit stop node
    c. CTA Express bus (? TAPS)
        i. From highest to lowest ridership, by route
            1. For each stop
                a. Find closest link to stop
                b. If no CTA express bus TAP within 1/8 mile on same link
                    i. Code TAP at actual XY
                    ii. If no node on link within 1/8 mile of stop
                        1. Split link at stop location
                    iii. Generate auxiliary transit link from TAP to highway network transit stop node
                c. Else continue to next stop
    d. PACE Express bus (? TAPS)
        i. From highest to lowest ridership, by route
            1. For each stop
                a. Find closest link to stop
                b. If no CTA or PACE express bus TAP within 1/8 mile on same link
                    i. Code TAP at actual XY
                    ii. If no node on link within 1/8 mile of stop
                        1. Split link at stop location
                    iii. Generate auxiliary transit link from TAP to highway network transit stop node
                c. Else continue to next stop

- e. CTA Local bus (? TAPS)
  - i. From highest to lowest ridership, by route
    1. For each stop
       - a. Find closest link to stop
       - b. If no CTA local bus TAP within 1/8 mile on same link
         - i. Code TAP at actual XY
         - ii. If no node on link within 1/8 mile of stop
           1. Split link at stop location
         - iii. Generate auxiliary transit link from TAP to highway network node
       - c. Else continue to next stop
- f. PACE Local bus (? TAPS)
  - i. From highest to lowest ridership, by route
    1. For each stop
       - a. Find closest link to stop
       - b. If no CTA or PACE local bus TAP within 1/8 mile on same link
         - i. Code TAP at actual XY
         - ii. If no node on link within 1/8 mile of stop
           1. Split link at stop location
  - ii. Generate auxiliary transit link from TAP to highway network transit stop node

3) Evaluate the number of stops by mode. If too many, consider revising distance thresholds as described below and re-running procedure.
4) Code transit routes
   - a. Same logic\procedure as currently used; grade-separated fixed-guideway routes are coded over transit-only links while at-grade fixed-guideway and bus routes are coded over the highway network, with stops coded explicitly at nodes (see note 6)
   - b. Average headways should be coded for each time period to be modeled
   - c. Express bus routes should be coded in appropriate direction by time-of-day (for example, inbound in the AM period and outbound in the PM period).
5) Code transfer links.
   - a. Transfer links (auxiliary transit) can be coded between actual highway transit stop nodes within a given distance threshold. (see note 9)
6) Calculate TAP service file
   - a. For each TAP, create list of transit routes that stop at connecting highway node, across all time periods (can create one file for each time period or index by time period)
7) Create MAZ-TAP table
   - a. Determine walk distance threshold from on-board data (see note 10)
   - b. For each MAZ
     - i. For each TAP within walk distance threshold, sorted by distance in ascending order from MAZ to TAP
       1. Check service file for TAP. If TAP provides service to a route that is not already connected to MAZ, create record in MAZ-TAP table

8) Create Formal TAZ – TAP PNR table
    a. Determine formal drive distance threshold from on-board data
    b. For each TAZ
        i. Sort TAPs by distance from TAZ in ascending order
        ii. For each TAP
            1. If within maximum drive distance and Formal PNR Spaces>0, create record in Formal TAZ-TAP PNR table
9) Create Informal TAZ – TAP PNR table
    a. Determine informal drive distance threshold from on-board data, or informal catchment area to select specific TAPs
    b. For each TAZ
        i. Sort TAPs by distance from TAZ in ascending order
        ii. For each TAP
            1. Check service file. If within maximum drive distance and Informal PNR Spaces>0 and TAP provides new service, create record in Formal TAZ-TAP PNR table
10) Create TAZ – TAP KNR table
    a. Determine KNR drive distance threshold from on-board data
    b. For each TAZ
        i. Sort TAPs by distance from TAZ in ascending order
        ii. For each TAP
            1. Check service file. If within maximum drive distance and TAP provides new service, create record in Formal TAZ-TAP PNR table

Additional notes to be taken into account:

1) An emme 'transit' databank needs to be created, where each TAP is represented as a zone.
2) Fixed-guideway rail station TAPs are coded explicitly at actual XY location; routes are coded on transit-only links between stations with actual station-station travel times.
3) Bus TAPs can be aggregated, but only for the same type of service (express with express, local with local).
4) Threshold for combining bus TAPs on a link is 1/8 mile, based upon a maximum walk error of 2.5 minutes. This could be modified based upon the size of MAZs bordering each link. For example, if the average length of the face of each MAZ bordering a link is ½ mile, the TAP distance threshold could be increased to 1/4 mile, so that the variance in walk time between stops is consistent with the variance from any point within the MAZ to the stop.
5) The procedure assumes that stops will be coded on links if there is no stop already coded on that link for the same type of service. So for shorter, downtown links, the stop spacing will be closer than 1/8 mile (Chicago blocks are approximately 350 feet long or 1/16 mile).

6) If TAP is more than 1/8 mile from an existing highway node, a link split is recommended at the stop location in order to minimize error in walking time calculation – this is particularly important if stop is in densely-coded MAZ area.
7) Once TAPs are coded, they can be offset by a small distance to make viewing networks easier.
8) Each TAP is connected to the transit stop highway node via an auxiliary transit link set to a minimal distance (1 foot).
9) Transfer links will be coded with a transfer time penalty and a mode-to-mode specific transfer cost penalty, if appropriate.
10) Walk distances can be set to vary by area type or district, in order to reflect longer relative walk distances in downtown. Walk distances can also be set to vary by mode; with longer walks allowed to stations and transit centers.

The TAP file has one record per TAP, with the following attributes created originally as shown in Table 18. Subsequently, many more attributes are added to the TAP file to represent transit station/stop type and characteristics as well as characteristics of the surrounding area. An example of a full TAP file with characteristics relevant for the TVPB procedure is shown in **Table 19**.

Table 18: TAP File Created Initially

Field Name	Description
TAP_ID	TAP ID
X_Coord	X coordinate or Longitude
Y_Coord	Y coordinate or Latitude
TAZ_ID	Number of TAZ that TAP is in
Metra_Rail	1 if stop is served by Metra Rail, else 0
CTA_Rail	1 if stop is served by CTA Rail, else 0
CTA_Express	1 if stop is served by CTA Express, else 0
Pace_Express	1 if stop is served by Pace Express, else 0
CTA_Local	1 if stop is served by CTA Local, else 0
Pace_Local	1 if stop is served by Pace Local, else 0
Stop_Type	Stop type (1=Pole, 2=Shelter, 3=Platform, 4=Station, 5=Transit center)
Formal_PNR_Spaces	Number of formal PNR spaces (0 if no formal PNR)
Informal_PNR_Spaces	Number of informal PNR spaces (0 if no informal PNR)
Daily_Park_Cost	Parking cost in cents
Elevator_Time	Average time from station location to platform
Lot_Time	Average time from center of PNR lot to station

Table 19: TAP File with a Full Set of Characteristics Used for TVPB

Parameters	Index	Skims generated

Parameters	**Index**	**Skims generated**
Walk-transit-Walk path:		
Walk time weight & walk speed	MAZ-TAP/TAP-MAZ	Walk distance
Auto-transit-walk path:		
Travel time weight	MAZ(TAZ)-TAP(TAZ) /TAP(TAZ)-MAZ(TAZ)	Travel time (total): SOV-non-toll for PNR HOV2-non-toll for KNR
Shortest access/egress time PNR/KNR	MAZ(TAZ)-Closest TAP(TAZ)	“”
Shortest access/egress time PNR/KNR reversed	Closest TAP(TAZ)-MAZ(TAZ)	
Extra travel time weight		Total – Shortest
Travel distance weight (cost per mile/VOT)	MAZ(TAZ)-TAP(TAZ) /TAP(TAZ)-MAZ(TAZ	Travel distance: SOV-non-toll for PNR HOV2-non-toll for KNR
Boarding TAP:		
Station type attraction factor	TAP	Boarding TAP type (1-5)
Real-time information factor	TAP	1=yes, 0=no
Formal parking spaces weight (log)	TAP (PNR only)	# parking spaces
Informal parking spaces weight (log)	TAP (PNR only)	# parking spaces
Daily parking cost weight (1/VOT)	TAP (PNR only)	Daily parking cost
Parking lot time weight	TAP (PNR only)	Parking lot time
KNR convenience factor by category	TAP (KNR only)	KNR convenience category
Buffered area crime rate weight	TAP (MAZ) (WT only)	Buffered crime rate
Buffered retail density weight	TAP (MAZ) (WT only)	Buffered retail density
First boarding fare component weight (1/VOT)	TAP	First boarding fare
Alighting TAP:		
Station type attraction factor	TAP	Boarding TAP type (1-5)
Formal parking spaces weight (log)	TAP (reversed PNR only)	# parking spaces
Informal parking spaces weight (log)	TAP (reversed PNR only)	# parking spaces
Daily parking cost weight (1/VOT)	TAP (reversed PNR only)	Daily parking cost
Parking lot time weight	TAP (reversed PNR only)	Parking lot time
KNR convenience factor by category	TAP (reversed KNR only)	KNR convenience category
Buffered area crime rate weight	TAP (MAZ) (Not for reversed PNR/KNR)	Buffered crime rate
Buffered retail density weight	TAP (MAZ) (Not for reversed PNR/KNR)	Buffered retail density
First boarding fare component weight (1/VOT)	TAP	First boarding fare
EMME TAP-to-TAP:		
Total generalized time weight for user class (default is 1.0)	TAP-TAP	Total generalized time for virtual path building

There is one walk-access MAZ-TAP file that is created by the program that uses the detailed navigation network. It has one record per MAZ-TAP connection, with the following attributes as shown in **Table 20**. Only MAZ-TAP pairs within the maximum allowable walk distance per trip (3 miles) are listed which makes the storage of this table feasible.

Table 20: Walk Access/Egress Connections between MAZs and TAPs

Field Name	Description
MAZ_ID	TAP ID
TAP_ID	TAP Number
Distance	Distance from MAZ centroid to TAP in feet

There are three drive-access files\tables that are created programmatically: one for formal PNR, one for informal PNR, and one for KNR. For PNR and KNR, auto time is used for access rather than walk time. Auto time is currently available only at the TAZ-to-TAZ level since highway assignment is implemented using a standard deterministic user equilibrium algorithm in EMME. Each table has one record per TAZ-TAP connection.

4.5. Estimation of Individualized Transit Path Choice Parameters

One of the main focuses of the current project was to individualize parameters of transit path building by person type such as VOT, propensity to walk, sensitivity to comfort, convenience & productivity while on board or in the station, etc. Ideally, the entire transit path should be individualized that corresponds to the concept of Dynamic Transit Assignment parallel to Dynamic Traffic Assignment with individual microsimulation implementation. However, an efficient Dynamic Transit Assignment procedure is not yet available for a region of the size of Chicago. Thus, the adopted methodology for the current project was a hybrid. The TVPB procedure (finding the best OMAZ-OTAP-DTAP-DMAZ path) was implemented in a completely disaggregate micro-simulation fashion while the middle portion of the path (OTAP-to-DTAP) was aggregated by three user classes. Thus, a wide range of individualized parameters is applied to evaluate the access (OMAZ-to-OTAP) and egress (DTAP-to-DMAZ) parts of the path. The middle part (OTAZ-to-DTAP) is pre-calculated as a set of user-class-specific skims. However, when the class is specified for each user, a probabilistic choice model for class membership is applied that addresses a range of person and household characteristics.

4.6. Transit Path Experimentation

CMAP transit model encodes transit service supply using the seven mode labels listed in **Table 21**. While one overall project objective was to evolve beyond estimating choice models using "named modes" such as "Metra Rail" as major drivers of the model specification, the seven mode distinctions offered granularity useful in encoding fine-grained representations of impedance factors. The "Mode Type", "Bus Type", and "Hierarchy" columns in **Table 21** are relevant to distinctions in such encoding described later.

Table 21: Named Modes Used in CMAP Transit Model

Code	Description	Mode Type	Bus Type	Hierarchy
P	PACE Regional Bus	Local	Local	4
L	PACE Local Bus	Local	Local	4
B	CTA Bus	Local	Local	4
C	CTA Rail (the "El")	Local	n/a	3
E	CTA Express Bus	Premium	Express	2
Q	PACE Express Bus	Premium	Express	2
M	METRA Rail	Premium	n/a	1

The purpose of this task was to evaluate additional service elements for evaluation in the path-building process. We considered questions concerning how much weight travelers attach to IVT's various components and whether those weights varied by traveler characteristics, i.e. Is cleanliness more important than productivity? Do different types of travelers value productivity opportunities differently? One of the resources used to analyze such questions was the findings from--and techniques used to conduct--the Transit Cooperative Research Program H-37 research Characteristics of Premium Transit Services that Affect Choice of Mode.

The H-37 research used revealed and stated preference survey data to inform Max-Diff modeling of user preferences and logit modeling of user choices of transit. One of the surveys was conducted in Chicago, giving the team direct observations on Chicago transit riders' perceptions of assorted impedance factors. For the TCRP H-37 project, RSG also used the revealed preference data describing actual transit paths taken as a means of building transit path-building algorithms that could create small (no more than three choices) sets of path choices per trip with a high probability that one path in the choice set matched the observed path. For easy reference, this document labels the structured process of refining the model path-builder to produce path choices matching actual paths as "path experimentation."

Path Experiment Method

Path experimentation was conducted using observations in the CMAP Travel Tracker Household Travel Survey (HHTS). The model path-builder was modified to employ the five additional factors described below atop the detailed impedance calculations performed in the original transit model (**Table 22**). The boarding penalty factor (XferPen) was applied by adding it to the model's originally-calculated boarding penalty whereas the weight factors were applied as a multiplier to the appropriate impedance total produced by the original model code. For example, the premium in-vehicle-time weight (PmIVTwt) multiplied by the total perceived IVT time from the original model was used as the final IVT time in the path experiment model run.

Table 22: Path Adjustment Factors Applied During Path Experimentation

Path Factor	Description	Range
XferPen	Additive boarding penalty (in minutes) applied to each transit boarding in the path	0-10
PmIVTwt	Multiplicative weight applied only to "premium" mode types	0.5-1
NPbrdPenWt	Multiplicative weight applied to total calculated boarding time only for non-premium mode types	0.5-2
WtTmWt	Multiplicative weight applied to each calculate wait time in the path	1-2
AuxTimWt	Multiplicative weight applied to each calculated access, egress, and transfer time (transfer time is the time spent getting to or between stations and does not include wait time while at the station)	1-3

Initially the CMAP Travel Tracker Household Travel Survey (HHTS) was filtered to those transit person-trip records with complete data on origin & destination location, demographics, trip purpose, and specific transit mode used per trip leg resulting in 2,499 "usable" trip records. Later, a data cleaning exercise was completed that used route identifiers to identify the fully detailed mode code (see **Table 21**) on an additional set of HHTS records resulting in a total of 2,631 usable trip records in the starting data set.

Path Matching to Observed Data

Systematic exercises were conducted matching model-produced paths to surveyed paths in the HHTS data in three general steps:

- Step 1: initial path matching
- Step 2: path matching refined by removing trip records found to be problematic
- Step 3: path matching using refined match criteria and additional path factor combinations
- Step 4: path matching using ordered mode matching applied to the results of groups of three selected path factor combinations

General results in terms of total match rates by access mode and overall appear in **Table 23**. Path factor combinations that produced the match results shown in **Table 23** appear in **Table 24** through **Table 26**.

Table 23: Path Experiment Match Results

Access Type	**Step 1 Results**	**Step 2 Results**	**Step 3 Results**	**Step 4 Results**
Walk	42%	43%	61%	53%
PNR	53%	54%	61%	60%
KNR	43%	43%	57%	52%
All Types	43%	44%	61%	54%
Paths Tested	32	32	57	57
Match Criteria	Ordered Mode	Ordered Mode	Highest Mode	Ordered Mode
Matches Reported	Best paths by access	Best paths by access	Best of chosen 3 paths	Combination of chosen 3 paths
HH Records Tested	2631	2570	2570	2570

The first experiment tested 32 systematically enumerated combinations of the five factors and used "Ordered Mode" matching criteria which considered the modeled path to match the observed path only if the mode for every trip leg matched in the observed order. For example, to match a HHTS trip record where the user walked to board a local CTA bus (B) then transferred to CTA rail (C) to finish their transit trip, the model path-builder would have to return a walk-access B-C path in that order, to produce a match. As shown in the "Step 1 Results" column of **Table 23** the most successful match rate of 53% was obtained for PNR-access trips with other access type match rates around 43%. Several sets of factors by access type produced similar results (see **Table 24**).

Table 24: **Path Factor Combinations that Produced Step 1 Match Results**

Path Success	XferPen	PmIVTwt	NPbrdPenWt	WtTmWt	AuxTimWt
Best Walk	10	1	0.5	1	2
Best Walk	10	1	0.5	2	2
Best PNR	0	1	0.5	1	1
Best PNR	0	1	1.5	1	1
Best PNR	0	1	0.5	2	1
Best PNR	0	1	1.5	2	1
Best KNR	10	1	0.5	1	1
Best KNR	10	1	1.5	1	1
Best KNR	10	1	0.5	2	1
Best KNR	10	1	1.5	2	1

Detailed examination of the Step 1 Results concluded that a small set of HHTS records should be discarded because their paths were such that the model would never successfully match them. After discarding those records the matches were recomputed to produce the "Step 2 Results" in **Table 23**. **Bold** text in **Table 25** indicates new path factor combinations not present in the Step 1 Results in **Table**

24. The new combinations resulting from discarding problematic records occur entirely for walk-access trips

.

Table 25: **Path Factor Combinations that Produced Step 2 Match Results**

Path Success	XferPen	PmIVTwt	NPbrdPenWt	WtTmWt	AuxTimWt
Best Walk	**10**	**0.5**	**0.5**	**1**	**2**
Best Walk	**10**	**1**	**0.5**	**1**	**2**
Best Walk	**10**	**0.5**	**0.5**	**2**	**2**
Best Walk	10	1	0.5	2	2
Best PNR	0	1	0.5	1	1
Best PNR	0	1	1.5	1	1
Best PNR	0	1	0.5	2	1
Best PNR	0	1	1.5	2	1
Best KNR	10	1	0.5	1	1
Best KNR	10	1	1.5	1	1
Best KNR	10	1	0.5	2	1
Best KNR	10	1	1.5	2	1

The entire project team discussed the findings from Steps 1 and 2 and concluded that the "Ordered Mode" matching criteria were too restrictive given the transit-rich Chicago environment and that "Highest Mode" criteria would be more appropriate. The latter criteria first categorize the bus modes by whether they are local or express service (column "Bus Type" in **Table 21**) then establish a mode hierarchy by consolidating local buses into one level, CTA Rail into its own level, express buses into another level, and Metra Rail as its own and highest level (column "Hierarchy" in **Table 21**). To constitute a match under "Highest Mode" the modeled transit path had only to have the same highest mode per the hierarchy as the HHTS transit path. For example, a modeled path where the user walked to CTA Bus (B) then transferred to CTA Rail (C) would match an HHTS record where the user walked directly to CTA Rail and that was the only transit mode used, the user walked to any local bus then transferred to CTA Rail, or where the user walked to CTA Rail then transferred to local bus.

While these discussions were taking place the model was run with additional path factor combinations it had deemed desirable but which had not yet been produced given model run-times. Applying the new "Highest Mode" matching criteria across the new set of 57 combinations of the five impedance adjustment factors produced a marked increase in the best success rates as shown in the "Step 3" column of **Table 23**. The best path combinations from Step 3 based on highest mode matching (plus the desire to have factor combinations that meaningfully differentiated potential traveler classes) were re-matched as a group using ordered mode criteria; those match results appear in the "Step 4" column of **Table 23**. From the Step 4 matching experiment two path factor combinations were selected to carry into final estimation. The 1,395 HHTS records for which the two selected groups of factor combinations obtained matches were tested with multinomial logit choice models. The models were specified to predict the likelihood of a traveler selecting a path built using the selected adjustment factors given trip and traveler characteristics (see next section). Due to the fairly low count of some access types by traveler characteristics in the usable HHTS record-set the access type distinction from path-building was moved to the choice model during the estimation process. The final set of impedance adjustment combinations deemed to have good explanatory power for traveler preferences in path choice appears in **Table 26**; the pathmatch rates by access type for this set appear in the "Step 4" column of **Table 23**.

Table 26: Impedance Factor Combinations that Produced Steps 3 and 4 Match Results

Path Description	XferPen	PmIVTwt	NPbrdPenWt	WtTmWt	AuxTimWt
Premium Service	0	0.5	1.5	1	1
Non Transfer, Non-Premium, Short Walk	10	1	0.5	2	2
Short Walk	0	1	1	1	3

4.7. Demographic Influence on Path Selection (Class Membership Model)

Multinomial logit choice model was used to quantify the significance and direction of effect of traveler, access type, and trip purpose characteristics for HHTS path choices matched by the most successful combinations of impedance factor-adjustments to the model path-builder. Age and income categorical variables used for this modeling were specified as follows. Age was categorized into two groups: 1) Up to and including 35 years, 2) 36 years an older. Income was categorized into four groups: 1) Less than or equal to $35K, 2) $35K-$60K, 3) $60K-$100K, 4) higher than $100K. Work purpose was used as a dummy variable to estimate commute trips effects on path selection.

The first model specifications included separate models by access type and trip purpose. Estimation attempts with those forms indicated that there were too few samples to have separate models. Instead of having separate models by access and trip purpose, we estimated a single model with access type and trip purpose as explanatory variables Initially travelers were also separated into three age groups, two of which were subsequently combined due to low sample counts.

Subsequent estimation iterations used the impedance factor combinations for the 3 path choices: premium service preference, direct, conventional, short-access service preference, and short-access preference regardless of service. If a modeled path based on a particular factor combination matched the surveyed path, then that predicted path was identified as the observed choice. If more than one path factor combination predicted a match or no combination had a match, the record was dropped from the estimation dataset. Final model specification definitions and results appear below.

Coefficients Definitions for the Final Estimated Models:

- $age2$: tendency of people 35 years older towards choosing direct, conventional, short-access service preference
- $hhinc2\_2$: preference of income group 2 ($35K-$60K) towards choosing direct, conventional, short-access service
- $hhinc34\_2$: preference of income group 3 & 4 (>$60K) towards choosing direct, conventional, short-access service
- $acc2\_2$: preference of PNR mode towards choosing direct, conventional, short-access service
- $acc3\_2$: preference of KNR mode towards choosing direct, conventional, short-access service
- $Purp\_2$: preference of work tour towards choosing direct, conventional, short-access service
- $age3$: preference of people 35 years older towards choosing short-access regardless of service
- $hhinc2\_3$: preference of income group 2 ($35K-$60K) towards choosing short-access regardless of service
- $hhinc34\_3$: preference of income group 3 & 4 (>$60K) towards choosing short-access regardless of service
- $acc2\_3$: preference of PNR mode towards choosing short-access regardless of service
- $acc3\_3$: preference of KNR mode towards choosing short-access regardless of service
- $Purp\_3$: preference of work tour towards choosing short-access regardless of service

Variable Definitions for the Final Estimated Models:

- $Age\_Cat2\&3\_dummy$: Dummy variable for people who are 35 years older, 1 if yes, 0 otherwise
- Inc_Cat2_dummy: Dummy variable for those whose household income is between $35K and $60K, 1 if yes, 0 otherwise
- $Inc\_Cat3\&4\_dummy$: Dummy variable for those whose household income is higher than $60K, 1 if yes, 0 otherwise
- $acc2\_dummy$: Dummy variable for PNR access mode, 1 if chosen choice using PNR access mode, 0 otherwise
- $acc3\_dummy$: Dummy variable for KNR access mode, 1 if chosen choice using KNR access mode, 0 otherwise
- $work\_tour\_\mathrm{dummy}$: Dummy variable for work trip, 1 if it is a work trip, 0 otherwise

The models were estimated initially with all variables (**Table 27** and **Table 28**), then with no constants (**Table 29**), and finally with only significant variables (**Table 30**) that corresponds to the final specification implemented in the CMAP ABM.

Utility Expressions for the All-Variables Model:

$U(Path\ factor\ 5 - premium) = 0$

$$U(Path\ factor\ 20 - direct, conventional, short - access\ service\ preference) = ascnone1 + age2 * Age\_Cat3 + hhinc2\_2 * Inc\_Cat2\_dummy + hhinc34\_2 * Inc\_Cat3\&4\_dummy + acc2\_2 * acc2\_dummy + acc3\_2 * acc3\_dummy + Purp\_2 * work\_tour\_dummy$$

$$U(Path\ factor\ 53 - \ short - access\ preference\ regardless\ of\ service) = ascnone2 + age3 * Age\_Cat3 + hhinc2\_3 * Inc\_Cat2\_dummy + hhinc34\_3 * Inc\_Cat3\&4\_dummy + acc2\_3 * acc2\_dummy + acc3\_3 * acc3\_dummy + Purp\_3 * work\_tour\_dummy$$

Table 27: Final Estimation Results for Paths 5, 28, and 53, All Variables Model

Variable	Coeff.	SE	T-Stat	Note
ascnone1 (constant for direct, conventional, short-access service)	0.3384	0.4089	0.828	
ascnone2 (constant for shortest walk service)	1.1	0.353	3.12	On average, shortest walk service is preferred
age2 (tendency of age 35+ towards choosing direct, conventional, short-access service)	-0.2381	0.3701	-0.643	
age3 (tendency of age 35+ towards choosing short-access path regardless of service)	0.05292	0.3136	0.169	
hhinc2_2 (tendency of income group 2 ($35K-$60K) towards choosing non transfer, non-premium service)	0.1939	0.5515	0.352	
hhinc34_2 (tendency of income group 3 & 4 (>$60K) towards choosing direct, conventional, short-access service)	-1.249	0.4449	-2.81	High income less likely choose direct, conventional, short-access path
hhinc2_3 (tendency of income group 2 towards choosing short-access path regardless of service)	0.1429	0.4728	0.302	

Table 28: Final Estimation Results for Paths 5, 28, and 53, All Variables Model

Variable	Coeff.	SE	T-Stat	Note
hhinc34_3 (tendency of income group 3 & 4 towards choosing short-access path regardless of service	-1.249	0.3619	-3.45	High income less likely choose shortest access path
acc2_2 (tendency of PNR mode towards choosing direct, conventional, short-access service)	-0.08808	0.4785	-0.184	
acc3_2 (tendency of KNR mode towards choosing direct, conventional, short-access service	0.3366	0.5992	0.562	
acc2_3 (tendency of PNR mode towards choosing short-access path regardless of service)	-1.851	0.5655	-3.27	PNR less likely choose shortest access path
acc3_3 (tendency of KNR mode towards choosing short-access path regardless of service	-1.623	0.7935	-2.05	KNR less likely choose shortest access path
Purp_2 (tendency of work tour towards choosing direct, conventional, short-access service)	-0.7099	0.3743	-1.9	
Purp_3 (tendency of work tour towards choosing short-access path regardless of service)	-0.6081	0.316	-1.92	Work purpose less likely choose shortest access path
Initial LL:				-328.4
Final LL:				-269.4

Utility expressions for the three path impedance adjustment factor combinations for a No Constant model:

$$U(Path\ 5, premium\ service\ preference) = 0$$

$$U(Path\ 28, direct, conventional, short-access\ service\ preference) = age2 * Age\_Cat2\&3\_dummy + hhinc2\_2 * Inc\_Cat2\_dummy + hhinc34\_2 * Inc\_Cat3\&4\_dummy + acc2\_2 * acc2\_dummy + acc3\_2 * acc3\_dummy + Purp\_2 * work\_tour\_dummy$$

$$U(Path\ 53, short-access\ preference\ regardless\ of\ service) = age3 * Age\_Cat2\&3\_dummy + hhinc2\_3 * Inc\_Cat2\_dummy + hhinc34\_3 * Inc\_Cat3\&4\_dummy + acc2\_3 * acc2\_dummy + acc3\_3 * acc3\_dummy + Purp\_3 * work\_tour\_dummy$$

Table 29: Final Estimation Results for Paths 5, 28, and 53, No Constant Model

Variable	Coeff.	SE	T-Stat	Note
age2 (tendency of age 35+ towards choosing direct, conventional, short-access service)	-0.1486	0.308	-0.482	
age3 (tendency of age 35+ towards choosing short-access path regardless of service)	0.5936	0.2674	2.22	Over 35 persons more likely choose shortest access path
hhinc2_2 (tendency of income group 2 ($35K-$60K) towards choosing direct, conventional, short-access service)	0.4002	0.4678	0.855	
hhinc34_2 (tendency of income group 3 & 4 (>$60K) towards choosing direct, conventional, short-access service)	-1.058	0.375	-2.82	High income less likely choose direct, conventional, short-access service
hhinc2_3 (tendency of income group 2 towards choosing short-access path regardless of service)	0.8474	0.4103	2.07	Medium income more likely choose shortest access path
hhinc34_3 (tendency of income group 3 & 4 towards choosing short-access path regardless of service	-0.7151	0.3176	-2.25	High income less likely choose shortest access path
acc2_2 (tendency of PNR mode towards choosing direct, conventional, short-access service)	-0.06006	0.4768	-0.126	
acc3_2 (tendency of KNR mode towards choosing direct, conventional, short-access service	0.3627	0.5994	0.605	
acc2_3 (tendency of PNR mode towards choosing short-access path regardless of service)	-1.847	0.5622	-3.29	PNR less likely choose shortest access path
acc3_3 (tendency of KNR mode towards choosing short-access path regardless of service	-1.733	0.8028	-2.16	KNR less likely choose shortest access path
Purp_2 (tendency of work tour towards choosing direct, conventional, short-access service)	-0.6271	0.3539	-1.77	
Purp_3 (tendency of work tour towards choosing short-access path regardless of service)	-0.3783	0.3085	-1.23	
Initial LL:				-328.4
Final LL:				-275.1

Utility expressions for the significant-variables-only model:

$$U(Path\ factor\ 5 - premium) = 0$$

$$U(Path\ factor\ 28 - direct, conventional, short - access\ service\ preference) = hhinc34\_2 * Inc\_Cat3\&4\_Dummy + Purp\_2 * work\_tour\_dummy$$

$$U(Path\ factor\ 53 - short - access\ preference\ regardless\ of\ service\ ) = hhinc2\_3 * Inc\_Cat2 + hhinc34\_3 * Inc\_Cat3\&4\_Dummy + acc2\_3 * acc2\_dummy + acc3\_3 * acc3\_dummy + age3 * \text{Aag\_Cat2\&3\_}Dummy + Purp\_3 * work\_tour\_dummy$$

Table 30: **Final Estimation Results for Paths 5, 28, and 53, Significant Variables Model**

Variable	Coeff.	SE	T-Stat	Note
age3 (tendency of age 35+ towards choosing short-access path regardless of service)	0.6501	0.2417	2.69	Over 35 persons more likely choose shortest access path
hhinc34_2 (tendency of income group 3 & 4 (>$60K) towards choosing direct, conventional, short-access service)	-1.189	0.3179	-3.74	High income less likely choose direct, conventional, short-access path
hhinc2_3 (tendency of income group 2 towards choosing short-access path regardless of service)	0.6646	0.3393	1.96	Medium income more likely choose shortest access path
hhinc34_3 (tendency of income group 3 & 4 towards choosing short-access path regardless of service	-0.774	0.3097	-2.5	High income less likely choose shortest access path
acc2_3 (tendency of PNR mode towards choosing short-access path regardless of service)	-1.838	0.5533	-3.32	PNR less likely choose shortest access path
acc3_3 (tendency of KNR mode towards choosing short-access path regardless of service	-1.829	0.7812	-2.34	KNR less likely choose shortest access path
Purp_2	-0.5466	0.3038	-1.8	
Purp_3	-0.349	0.3003	-1.16	
Initial LL:				-328.4
Final LL:				-283.5

The estimation results in **Table 30** are intuitive across several dimensions:

- Older persons tend to choose the shortest access path; this is likely due to people who don't want to walk as far since walk access is the dominant access mode.
- Medium income households tend to choose the shortest access path and higher income households are more likely to choose premium service. This would lead to the assumption that low income households tend to choose direct, conventional service, probably because these services would tend to cost less.

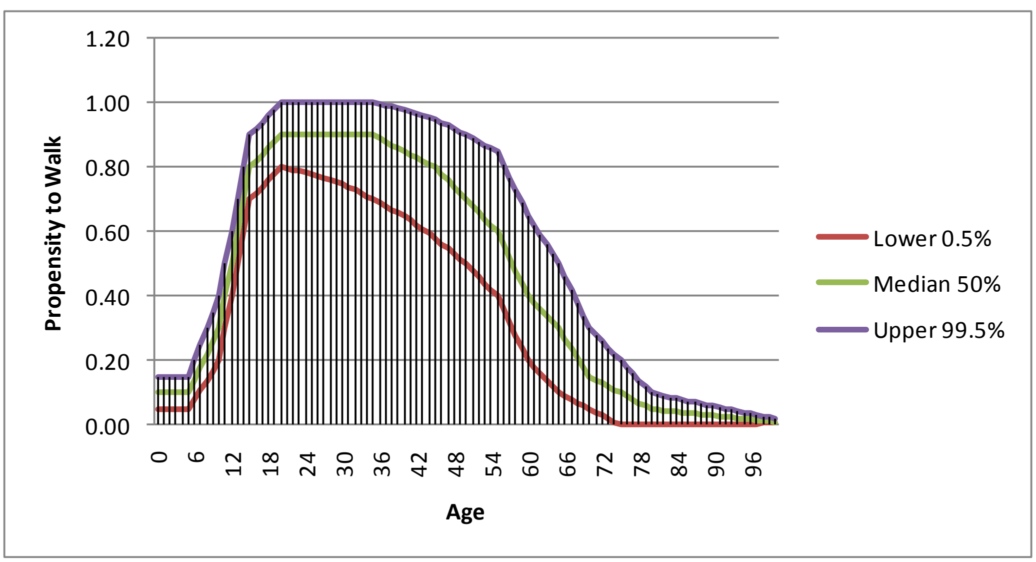
- People who drive to transit (both park-and-ride and kiss-and-ride) are less concerned with short access paths, probably because driving a little further is not very onerous.
- Trip purpose does not have a significant effect on the path choice.

These results were incorporated into the mode choice model estimation work to identify a preferred path choice for each individual traveler.

4.8. Individual Propensity to Walk

In the TVPB procedure, we take a full advantage of individual microsimulation with respect to traveler's propensity to walk and associated path building attributes. This is significant step forward compared to the prevailing modeling practices that operate with crude across-the-board estimated like a 2.5 wait on walk time versus in-vehicle time or 3-mile maximum walk threshold. In the CMAP Transit Modernization ABM, this component is implemented in two steps. First, each person is assigned an individual propensity to walk scaled between zero and one. Zero means minimal propensity to walk while 1 means maximum possible propensity to walk. The model uses three curves: lower, median, and upper bound, for propensity to walk as a function of traveler's age as shown in **Figure 3**. The individual propensity to walk is randomly drawn for each individual using a "stretched" normal distribution scaled to have 0.5%, 50%, and 99.5% percentiles equal to the values defined by the curves.

Figure 3: Propensity to Walk by Person Age



Secondly, individual propensity to walk is translated into three transit path building parameters: base walk time weight, walk speed, and maximum walk threshold (for a single trip) as summarized in **Table 31**. For intermediate values of walk propensity the corresponding parameters are linearly interpolated between the predefined minimum and maximum values for the extreme cases of propensity to walk equal to zero or one. This way, all three path building parameter are logically correlated. For example, a traveler with the maximum propensity to walk (1.0), who must be of age between 16 and 35, the base walk time weight (versus in-vehicle time) would be equal to 1.0, walk time speed would be 4.0 mph, and maximum walk threshold would be 3 miles.

Table 31: Individual Transit Pass Building Parameters as a Function of Walk Propensity

Walk propensity	Base walk time weight	Walk speed, mph	Maximum walk threshold, miles
0.0	3.50	1.00	0.50
0.1	3.25	1.30	0.75
0.2	3.00	1.60	1.00
0.3	2.75	1.90	1.25
0.4	2.50	2.20	1.50
0.5	2.25	2.50	1.75
0.6	2.00	2.80	2.00
0.7	1.75	3.10	2.25
0.8	1.50	3.40	2.50
0.9	1.25	3.70	2.75
1.0	1.00	4.00	3.00

4.9. Classification and Parameterization of Transit Stations & Stops

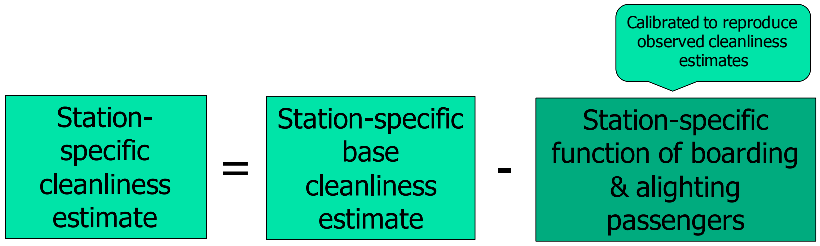
Transit stations/stops play an important role in transit path choices. They primarily affect wait time conditions but can also affect traveler's choice due to considerations of a bundle of station attributes including cleanliness, personal safety, provision of information, presence of amenities and commercial activities, parking conditions (for PNR), etc. The main categorization and initial setting of path building parameters is shown in **Table 32**. Wait convenience factor reflects relative weight of each minute of waiting vs. a minute of in-vehicle time. Real-time information factor is a multiplier that reduces wait time weight (makes waiting less onerous) if the information is available. Boarding/transfer time reflect an estimate of physical time required to traverse the station. It is further multiplied by an individual perceptional factor depending on user class membership discussed above.

Table 32: Classification and Parameterization of Transit Stations & Stops

Station type	Visual association	Wait convenience factor	Real-time information factor	Boarding / transfer time, min	Basic cleanliness estimate
1=Pole		2.50	0.9	0.5	80%
2=Shelter		2.25	0.9	0.5	80%
3=Plaza		2.00	0.9	1.0	85%
4=Station		1.75	0.9	1.5	90%
5=Major station		1.75	0.9	3.5	95%

Station cleanliness is an important characteristic of premium transit service that is normally ignored in travel models. In the CMAP Transit Modernization ABM, station cleanliness is incorporated as a station/stop parameter that affects wait time and boarding time weight. This parameter is also subject to a special policy that improves cleanliness. Station cleanliness calculation involves station-type-specific base estimate shown in **Table 32** that is further multiplied by a station specific factor that depends on the number of boarding and alighting passengers – see **Figure 4**. The marginal impact of each passenger was calibrated to reproduce the available observed cleanliness data. It is currently set to -0.01 multiplied by the log of total (boarding plus alighting) passengers for station types 3, 4, and 5. It is set to zero for station types 1 and 2 since cleanliness of bus stop poles and shelters is indistinguishable from the environment.

Figure 4: Station Cleanliness Calculation



Quality and image of the boarding and alighting stations are important factors in choosing transit service and path by the user. A summary of the station characteristics used in the TVPB procedure is presented in **Table 33**. Station type and cleanliness affects boarding time weight and wait time wait that are used for building the TAP-to-TAP part in transit assignment procedure implemented in EMME.

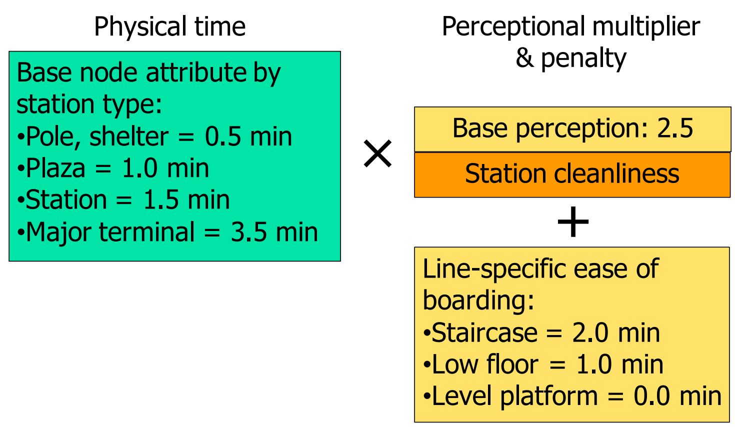
Table 33: Summary of Station Characteristics use in the Virtual Path Building

Characteristic	**Origin TAP (access)**	**TAP-to-TAP**	**Destination TAP (egress)**
Station type	X	X	X
Real-time information	X (out)	X	X (inb)
Formal parking capacity	X (out)		X (inb)
Informal parking capacity	X (out)		X (inb)
Parking cost	X(out)		X (inb)
Parking lot walk time	X(out)		X (inb)
KNR convenience category	X(out)		X (inb)
Buffered area crime rate	X(out)		X (inb)
Buffered retail density	X		X
First boarding fare	X		
Boarding (traversal) time		X	
Ease of boarding		X	
Station cleanliness		X	

4.10. Perceived Boarding Time and Ease

Boarding time in the CMAP Transit Modernization ABM is calculated as a product of the physical time defined by station type and perceptional multiplier – see **Figure 5**. On top of this, line-specific ease of boarding & alighting is accounted as a perceived penalty ranging between 0 (for the most convenient level platform) and 2 min (for the least convenient staircase). The base perceived weight is specified currently as 2.5. Additional weight is associated with station cleanliness.

Figure 5: Perceived Boarding Time and Ease

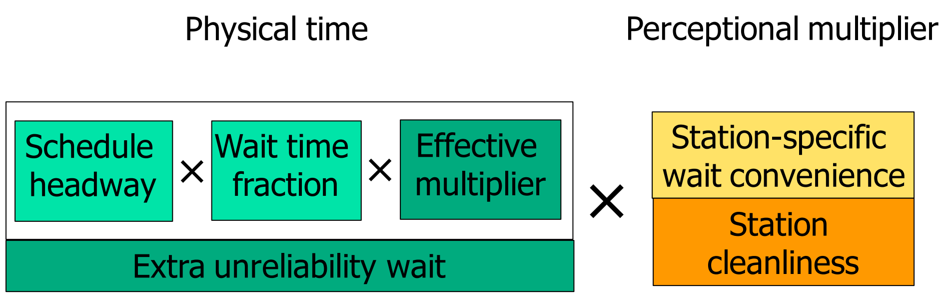


Station cleanliness impact on perception of boarding time is modeled as increased boarding time weight multiplied by the diminished cleanliness. The sensitivity coefficient is currently set to 1.5. This means that if the station cleanliness is, say, 80% (after accounting for the station activity) than the diminished cleanliness will be 1-0.8=0.2 and the additional wait time weight will be 0.2×1.5=0.30.

4.11. Perception and Parameterization of Wait Time

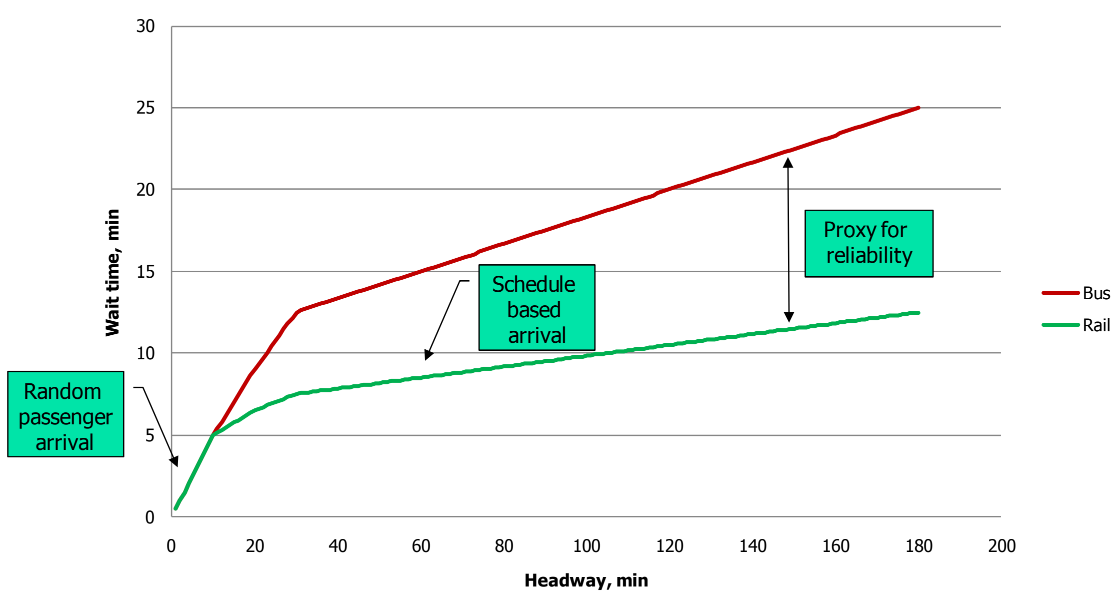
Wait time perceived by the transit users is modeled as a product of physical wait time (in green) and perceptional multiplier (in yellow) that reflects wait conditions that largely relate to the station type described above – see **Figure 6**. The base physical wait is calculated as a product of the line headway (combined for several overlapping lines in the optimal strategy assignment of EMME), fraction used to describe the profile of passenger arrival at the transit stop/station, and effective headway multiplier that is used to constrain line boarding capacity. Average extra wait associated with transit unreliability (currently applied for buses only) is added to the physical time. Perceptional multiplier includes station-specific wait convenience factor described in the section on transit station type and an additional factor that depends on the station cleanliness.

Figure 6: Wait Time Calculation in Transit Path Building



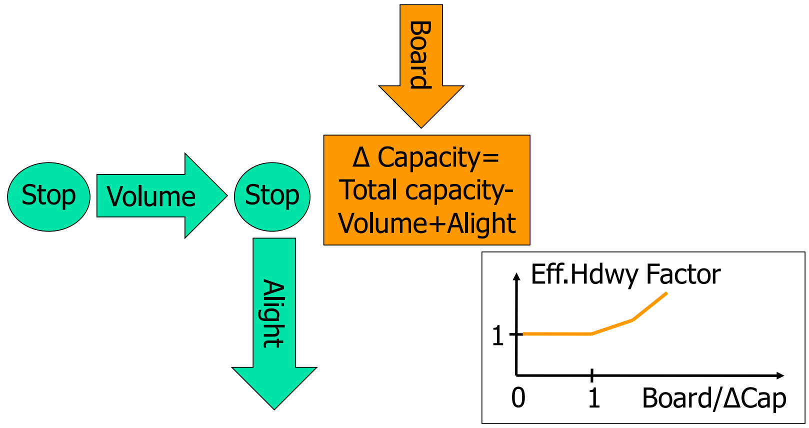
Wait time fraction used to calculate the base wait time as function of the schedule headway is presented in **Figure 7**. For a frequent transit service (headway up to 10 min), we assume that passengers arrive at transit stop randomly; hence the average wait time is calculated as half of the headway. When headway grows, passengers start arriving at stop according to the schedule that is expressed in a concave piece-wise linear function where wait time becomes progressively shorter than half of the headway. The observed pattern shows that with the same frequency, more reliable (rail) service is characterized by relatively shorter wait time (and more specific schedule based passenger arrival at the station) compared to buses.

Figure 7: Wait Time Fraction of Transit Line Headway



Effective headway multiplier is calculated in the process of transit assignment equilibration. It reflects total transit capacity constraints at boarding points as shown in **Figure 8**. Number of barding passengers at each stop is compared to the residual capacity of the vehicle and if the boarding volume exceeds residual capacity, a wait time multiplier is applied. The corresponding function reflects the assumption that if the boarding volume exceed capacity some of the passengers will have to wait for the next vehicle.

Figure 8: Effective Headway Multiplier



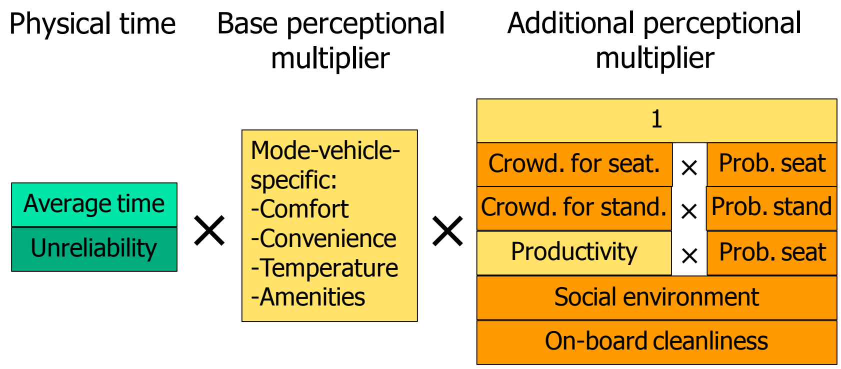
Average extra wait time due to unreliability is another physical wait time component that occurs because of the schedule non-adherence of the transit services (especially buses). This component represents another innovative feature of the Transit Modernization ABM. It is discussed in detail in the corresponding section on reliability.

Station cleanliness impact on perception of wait time is modeled as increased wait time weight multiplied by the diminished cleanliness. The sensitivity coefficient is currently set to 1.2. This means that if the station cleanliness is, say, 80% (after accounting for the station activity) than the diminished cleanliness will be 1-0.8=0.2 and the additional wait time weight will be 0.2×1.2=0.24.

4.12. Perception and Parameterization of In-Vehicle Time

In the Transit Modernization ABM, in-vehicle time conditions are parameterized across a rich set of variables that include seating comfort, productivity (work, sleep, socialize), cleanliness, on-board amenities as well as socio-economic compatibility between riders. Traveler's perception of these characteristics is subject to person type. Since in-vehicle-time is currently handled by EMME aggregate assignment & skimming procedures, the possible multitude of person characteristics (age, income, etc) was encapsulated in three user class groups, where there is a correlation between the class and average income (growing from 1 through 3). The implemented concept of in-vehicle time calculation is presented in **Figure 9**. Physical in-vehicle time (that is shown in green as all physical components) is multiplied by a base (mode-vehicle-type specific) perceptional multiplier and subsequently by an additional multiplier that reflects specific conditions for a particular trip. Perceptional multipliers are distinguished from physical time components by the yellow color. Additional multiplier is a function of the number of passengers using this line segment; thus this component requires internal equilibration of the transit assignment procedure. The darker yellow components specifically indicate on dependence on the number of passengers.

Figure 9: Calculation of In-Vehicle Time for Transit Path Building



Average in-vehicle time is calculated in the network assignment procedure implemented in EMME according to the network coding (Transit Time Function specified for each segment). The unreliability component is currently set to zero, but it can be added in future in a way similar to how extra wait time was added (discussed below in the section on unreliability).

The base in-vehicle time multiplier is currently specified by transit modes as shown in **Table 34**. The coefficient reflects a bundle of characteristics such as comfort, convenience, productivity, temperature, amenities, etc, associated with each mode. In further research it would be interesting to estimate the contribution of each characteristic and make the modeled in-vehicle time perception completely "unlabeled". The base coefficient is further differentiated according to the class-specific perception described above in the section on user class membership.

Table 34: Base In-Vehicle Time Perception Multiplier

Mode-vehicle type	In-vehicle time comfort/convenience factor
Local bus (BPL)	1.00
Express bus (EQ)	0.90
CTA train (C)	0.95
Metra rail (M)	0.85

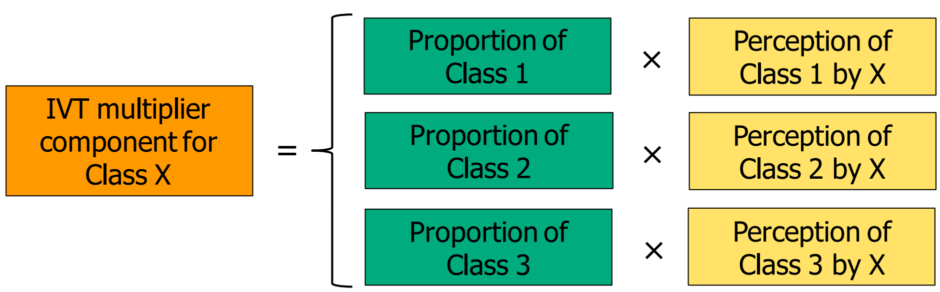
Crowding effects and implemented crowding functions are discussed in detail in the corresponding section below. Productivity bonus is applied to decrease in-vehicle time perceptional weight for seated passengers (seated and standing passengers are separated explicitly in the transit assignment and skimming procedure). It is currently specified by transit mode-vehicle type and differentiated by user class as presented in **Table 35**. Specifically, user class 3 that is associated with higher income and preference for commuter rail (explained in the section on user class membership) has the most substantial productivity bonus.

Table 35: Productivity Bonus for Seated Passengers

Mode -vehicle type	Fixed in-vehicle time productivity bonus as reduction of perceptional multiplier		
	User class 1	User class 2	User class 3
Local bus (BPL)	0.00	0.00	0.00
Express bus (EQ)	-0.05	-0.05	-0.10
CTA train (C)	0.00	0.00	0.00
Metra rail (M)	-0.05	-0.10	-0.25

Social environment in the transit vehicle is usually not modeled explicitly. However, unpleasant social experience is constantly ranked amongst top 5 negative factors diverting travelers from public transit. The secret of commuter rail attractiveness is largely in its social environment, although productivity and reliability play an important role as well. In the Transit Modernization ABM, this effect is modeled explicitly by means of the proportion of different user classes encountered on each transit segment. Presence of other user classes differentially affects the perceived IVT multiplier a shown in **Figure 10**.

Figure 10: Social Environment Component of In-Vehicle Time Perception



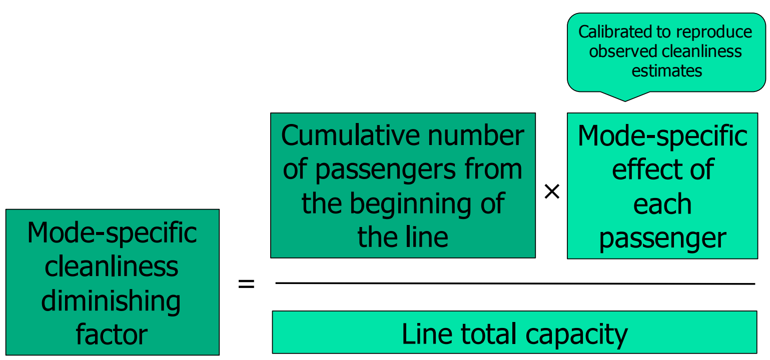
The proportion of each user class on each transit segment is skimmed as the result of equilibrium transit assignment. The cross-class perceptions are specified as a 3×3 matrix in the way shown in **Table 36**. Currently, only two "social frictions" are specified. There is a substantial class 1 aversion assumption made regarding class 3 and somewhat small class 1 aversion assumption for class 2. Since the classes are correlated with income this can be expressed as that higher income travelers (and especially commuter rail users) would try to avoid transit services that are used by low-income travelers.

Table 36: Matrix of Cross-Class Social Perceptions

Modeled passenger	Perception of other passengers as additional IVT weight		
	Class 1	Class 2	Class 3
Class 1	0.00	0.00	0.00
Class 2	0.10	0.00	0.00
Class 3	0.50	0.00	0.00

ON-board cleanliness is another important attribute that is normally ignored in travel models. In the Transit Modernization ABM, a mode-specific cleanliness diminishing factor is calculated for each line segment as shown schematically in **Figure 11**. The calculation is based on the ratio of the cumulative number of passengers from the beginning of the line divided by the line total capacity. This ratio that represents a relative intensity of the line use is multiplied by the marginal effect of one passenger to violate (originally clean) conditions. The one person contribution coefficient was calibrated to replicate the observed statistics on cleanliness percentage (in the range of 70%-95% depending on mode and line).

Figure 11: Calculation of On-Board Cleanliness Factor



The cleanliness diminishing factor represents an extra weight imposed on in-vehicle time to reflect the negative perception that transit users have of unclean vehicles. In the model application, this weight is additionally differentiated by user class. Currently classes 1, 2, and 3 are assigned sensitivity-to-cleanliness attributes of 0.5, 0.75 and 1.00 that are multiplied by the cleanliness diminishing factor.

4.13. Incorporation of Capacity Constraints and Crowding

Most applied travel models still utilize simplified unconstrained transit assignment procedures. This simplification results in two particular problems. First, ridership greater than total line capacity is allowed, that is obviously an unrealistic outcome. Secondly, inconvenience and discomfort in crowded transit vehicles (in particular, standing instead of sitting) is ignored despite that this factor strongly affects transit route choice, mode choice and other travel choices. The current research was intended to incorporate both factors in an operational travel model in a consistent non-duplicative way.

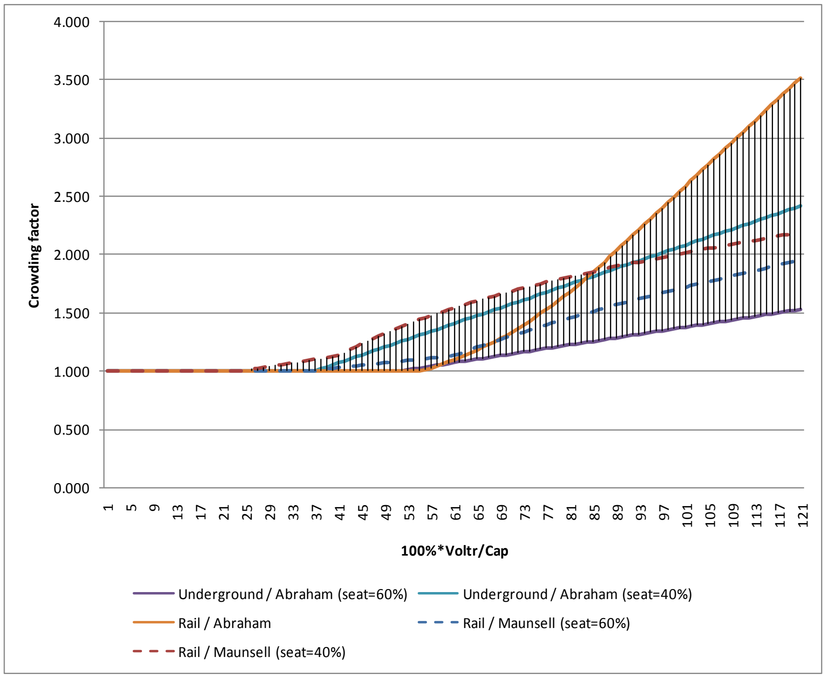
The first related aspect is to ensure feasibility of transit ridership forecast for each line and segment with respect to the *total capacity constraint*. This means that in a case where the transit volume exceeds total segment capacity a penalty should be applied until the feasible solution is reached. A feasible solution might not exist especially if a restricted transit assignment framework with a fixed transit table is employed (i.e. the riders of overcrowded lines can only switch to some other lines). It is normally a better chance to find a feasible solution if a mode choice framework is also employed (i.e. the riders of overcrowded lines can also switch to alternative modes). In terms of behavioral realism, the most appealing method to address infeasible volumes is to increase transit wait times at the corresponding boarding stations, i.e. use effective headways rather than schedule-based headways. This is based on the assumption that the riders will not always be able to board the first-arriving vehicle and will have to wait for the next vehicle. Effective headways is general is difficult to observe in reality. Thus, the form of the effective headway function is derived based on theoretical considerations and evaluated by the aggregate outcome of model application.

The second related aspect is to take into account *crowding in the vehicle* as a negative factor in the user perception of transit service quality. From this standpoint, not only exceeding of the total vehicle capacity but also exceeding the seated capacity (or even approaching it) should be penalized since standing is generally perceived by transit users as a very strong negative factor. Also, in a crowded vehicle, seated passengers experience inconvenience in finding a seat and getting off the vehicle. Crowding, however, should not be penalized in the same way as exceeding the total capacity since it is still a feasible observed situation. In terms of behavioral realism, the probability of having a seat should be reflected in the perceived in-vehicle time weight. This factor was incorporated in the transit assignment and mode choice model. Penalizing in-vehicle-time in crowding vehicles in transit assignment is algorithmically similar to applying volume-delay functions in highway assignment. This perceived weight should be estimated statistically which was one of the main purposes of the current research.

There were successful examples of applying both effective headways and in-vehicle time crowding weights in one model equilibrium framework. We also applied two functions (effective headway and crowding in-vehicle time weight) in parallel.

There is a significant body of literature reporting different forms of crowding functions estimated with either Revealed Preference (RP) or Stated Preference (SP) data or just calibrated based on the comparison of the model outcome to the aggregate ridership data. Some examples of the functions estimated for British Rail and London Underground are shown in **Figure 12**.

Figure 12: Examples of Crowding Functions

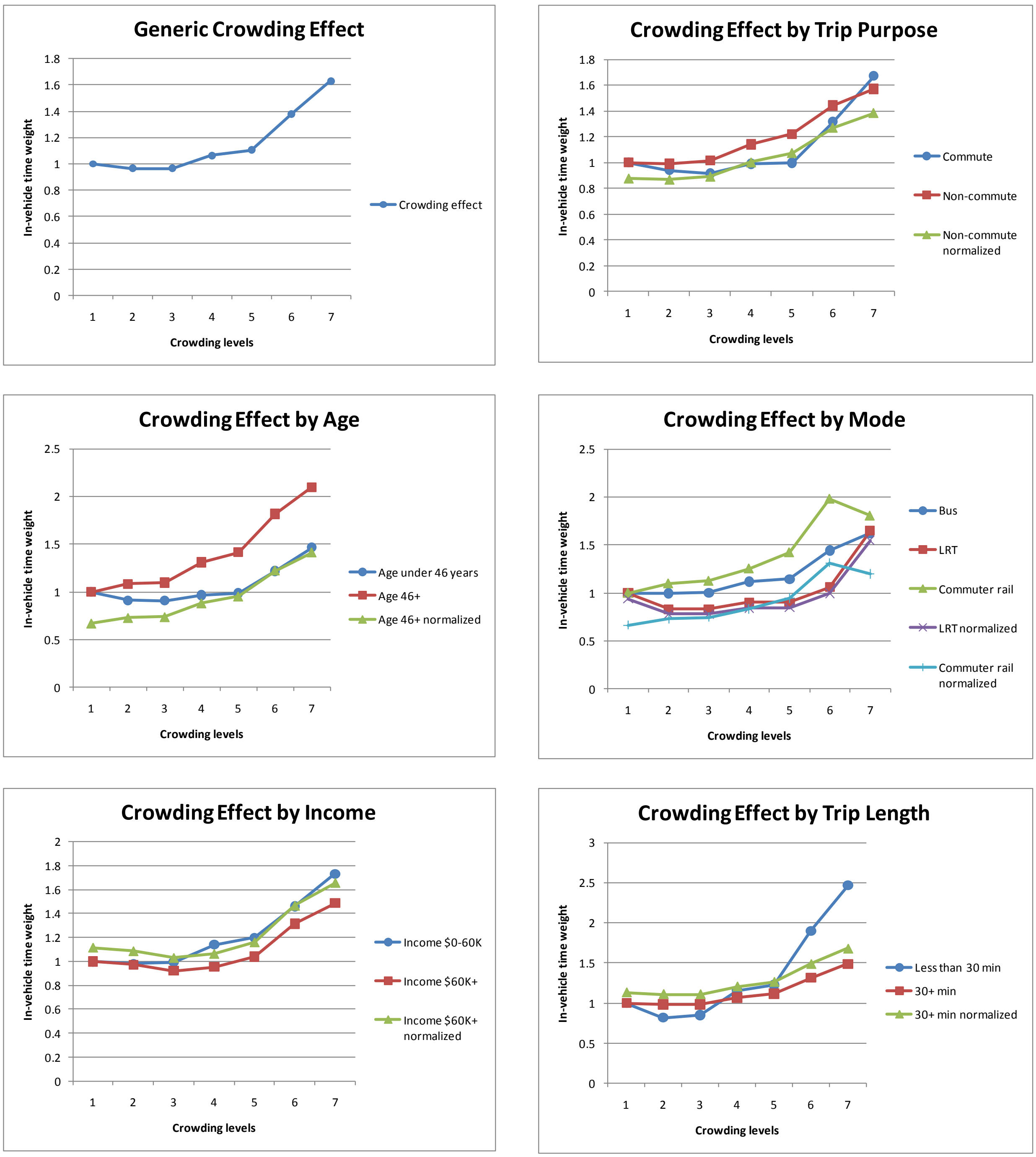


Despite significant differences in functional forms and parameters from study to study there is a clear common denominator that can be summarized in the following way:

- Perceived (inconvenience) weight for in-vehicle time is a monotonically increasing (and most frequently convex) function of the number of passengers in the vehicle. It takes a value of 1.0 (maximum convenience) when the number of passengers is under the seated capacity. It starts increasing when the number of passengers approaches the seated capacity and grows the most when the number of passengers approaches the total capacity.
- It is a strong indication from the previous research that in-vehicle time for a crowded vehicle at maximum capacity should be weighted significantly (1.5 or more).
- Vehicle design and proportion between total and seated capacity affect the crowding function. Typical urban subway and (some) urban bus vehicles are "built to stand". They have a relatively low proportion of seats and consequently many standing passengers but standing itself is less onerous. For these vehicles, the crowding function starts increasing at a relatively low volume but remains relatively flat until the total capacity is reached. Typical commuter rail and express bus vehicles are "built to seat". They allow for only a few standing passengers but the standing itself is very inconvenient. For these vehicles, the crowding function starts increasing only at relatively high volumes but it grows rapidly when the total capacity is approached.
- Crowding function can be further segmented by person age, trip purpose, trip lengths and other person and/or trip characteristics that affect perception of crowding inconvenience, and standing in particular.

In the LACTMA study, 6 model specifications were explored that correspond to 6 crowding-related effects reported previously or hypothesized as possible ways to improve the model. Some of these hypotheses were confirmed by the estimation results while some other ones not. Below we discuss both positive and negative results. In order to facilitate the further analysis we present the crowding weights in a graphical form in Figure 13.

Figure 13: Main Crowding Effects



Non-normalized curved represent crowding weights relative to the minimum crowding level for the same segment (for example, commuting to work and non-work trip weights calculated separately). Normalized curves represent crowding weights relative to the minimum crowding level (for example, commuting to work and non-work trip weight calculated relative to the minimum crowding level for commuting trips).

The first specification used a generic formulation where crowding level used as the only segmentation dimension for in-vehicle time coefficient. Overall, the estimation results confirmed the main hypothesis that crowding is perceived by transit users as an extra weight on in-vehicle time that becomes quite significant (1.62) at the extreme crowding level. This number is somewhat lower than the numbers adopted for extreme crowding levels in some previous studies as discussed above (2.0 and higher). However, it is still very significant and affects transit assignment and mode choice results strongly.

The second specification included a segmentation by trip purpose – commuters to work and college where separated from trip for other (non-work) purposes. The original hypothesis was that crowding would be perceived as somewhat more onerous for commuters due to the frequency of the trip while for less frequent trips the users will be more tolerant to (occasional) crowding. This hypothesis was confirmed although the difference between travel purposes was not striking. The most significant difference corresponds to the highest crowding level that the users are more willing to tolerate on an occasional non-work trip but become very negative when it comes to a daily commuting trip.

The third specification included segmentation by person age. The original hypothesis was that younger users might be relatively tolerant to crowding while older users would be more sensitive and crowding-averse. In particular, having a seat should be essential for older users. The estimation results confirmed certain age-related effects. The most statistically significant results were obtained when the transit users were broken into two broad categories – younger users of age 45 or younger and older users of age 46 or older. There are two particular effects intertwined. One of them can be seen when the relative weights for in-vehicle time are normalized versus the in-vehicle time at the lowest crowding level for the same age group. In this case, older users proved to be more sensitive to higher crowding levels than younger users which is expressed in a greater weight (1.65 versus 1.51). The second interesting effect is that the base in-vehicle time coefficient for the lowest crowding level proved to be significantly lower for the older users. This means that while seated, the older users perceived travel time as a less onerous factor compared to younger users. When the ride becomes less convenient and probability of having a seat decreases the perception of time of older users is approaching the perception of younger users.

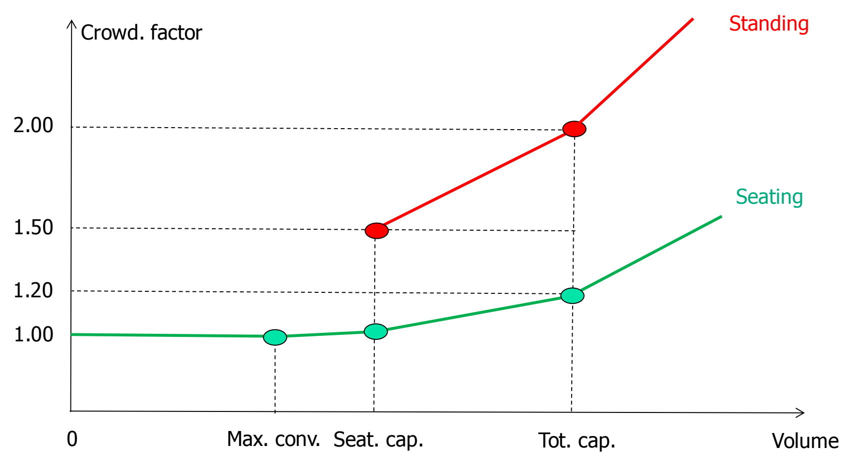
The fourth specification included segmentation by mode. The original hypothesis was that the vehicle design would have a significant impact on the crowding function. Bus curves were hypothesized as relatively flat but starting to “climb up” at relatively low crowding levels since these vehicles are built to make standing convenient. The commuter rail curve was hypothesized to have a longer initial flat part and then a spike at the end when crowding approaches the maximum level since commuter rail cannot accommodate many standing passengers and standing in general is inconvenient. LRT curve was expected to be somewhere between bus and rail. While this initial hypothesis was somewhat confirmed the model estimation results gave some additional insights into the in-vehicle time perception by different transit modes. It proved that there is an overall difference between modes across all crowding levels where more convenient modes like LRT and Commuter Rail are characterized by lower in-vehicle time coefficients than bus. This is an interesting finding that suggests a differentiation of in-vehicle time coefficients by mode that is somewhat contrary to the prevailing practices. Overall, a discounting coefficient of 0.8 for most crowding levels except for very high crowding levels seems reasonable for rail modes compared to bus. When a relative crowding effect is added on top of this, it manifests itself stronger for rail modes although the curve proved to be not as steep as was expected.

The fifth specification included segmentation by household income groups. The original hypothesis was that transit users with higher income would exhibit more sensitivity to comfort and convenience, hence, a more crowding-averse behavior expressed in a steeper crowding function. This can be supported by the fact that higher-income travelers generally have more alternative options available because of the higher car ownership and higher willingness to pay while many low-income transit riders are captives because the auto for them is either not available or prohibitively expensive (for example, because of the parking cost). Multiple attempts were made with different income brackets to capture a systematic effect but neither of them brought a conclusive and statistically significant difference. The specification reported in this paper included two groups: 1=with a yearly income under $60K, and 2=$60K and more. As can be seen, no significant variation of in-vehicle time coefficient by income was found across the entire range of crowding levels. This finding might look counter-intuitive but it can be explained if the entire combination of behavioral parameters is compared across incomes. This is true, that value of time is strongly correlated with income. However, it does not automatically mean that the in-vehicle time coefficient should be lower for low-income users. It is more behaviorally appealing to assume that the lower value of time for low-income users would rather be a consequence of a higher cost coefficient (i.e. higher sensitivity to cost). In the same vein, there is no particular reason why while having an option to choose low-income users would be more tolerant to crowding and standing. When the willingness-to-pay factor is controlled, the user preferences with respect to convenience (traded against in-vehicle time) proved to be similar across all income groups. When the cost coefficient is taken into account, higher-income users are willing to pay more for convenience but this effect is proportional to their willingness to pay more for travel time savings. The expectation that high-income users would have a somewhat special sensitivity to crowding beyond their overall higher willingness to pay was not confirmed by the data.

The sixth specification included segmentation by trip length. The original hypothesis was that trip length would have a strong effect of the steepness of the crowding function. It is logical to expect that transit users would be tolerant to crowding (and standing) when the trip is short while for longer trips that would try to avoid crowded vehicles (and standing). Multiple statistical trials with different functional forms were implemented to capture this effect. However, the results proved to be either statistically insignificant or inconclusive. An example with trip segmentation by in-vehicle time into two categories: 1=under 20 min, and 2=20 min or longer, is shown in the table to illustrate the typical outcome. The crowding weight proved to be roughly equal and independent of the trip length. While, this result looked originally counter-intuitive and disappointing, it can be explained by the underlying choice model structure. In the choice model context, even if the weight is constant, the resulted crowding effect does grow with trip length because the choice probability is defined by the difference in the utilities, and not by their ratio. Consider an in-vehicle time weight of 1.5 for a certain crowding level. With this weight, 10 min in a crowded vehicle would be equivalent to 5 extra min of travel time while 60 min in a crowed vehicle would be equivalent to 30 extra min of travel time. Thus, trip length would manifest itself in stronger crowding-averse behavior for longer trips even if the weight per min is constant.

The function currently adopted for the CMAP Transit Modernization ABM (**Figure 14**) is a modification of the generic function developed for the LACMTA study. In this function, seated and standing passengers are distinguished explicitly. This form is more advanced and better serves the current study since an explicit segmentation by standing and seated passengers is also important for calculation of productivity bonus that should only be applied to seated passengers.

Figure 14: Adopted Crowding Function



4.14. Incorporation of Transit Service Reliability

Our intention is to incorporate transit service reliability in addition to mode-specific wait time curves in a way it was implemented in Los Angeles, CA. PB is currently undergoing an extensive research for the Los Angeles County Metropolitan Transit Authority (LACMTA) funded by FTA with respect to transit service reliability and its incorporation in the travel model. The outcomes of this research are applicable to the CMAP ABM. In general, transit reliability is defined as transit vehicles arriving/departing on schedule. Unreliable service may result in bus bunching, which is when buses deviate from their scheduled arrival intervals (i.e. headways). This deviation in service interval can subsequently increase stop wait time for riders. Currently, the LACTMA demand model (as practically all applied travel models) is insensitive to transit reliability as it assumes buses/trains arrive on schedule and maintain their desired headways. However, this is often not the case in selected areas where buses/trains often arrive late (and sometimes early) due to a variety of reasons, including but not limited to, congestion, incidents, and additional dwell due to passenger demand, bicycles, and wheelchairs.

Without accounting for reliability, the utility (or attractiveness) of transit is overrepresented relative to the utility of other modes such as auto and walk as well as other transit routes that are not crowded. Therefore, the purpose of this work is to incorporate transit service reliability into the travel demand model in a manner that can be forecasted and can be modeled without significant additional data needs. The end result of this work is a simple transit reliability function that is a function of readily available highway and transit level-of-service measures. The resulting function is used within the transit assignment process to generate extra average wait time at stops. The extra average wait time due to reliability is skimmed and included in the utility of bus in the mode choice model.

There are multiple ways to define transit reliability. The simplest definition is that a transit service is unreliable at a stop if it arrives late or leaves early with respect to the schedule. Some more precise definitions of reliability include:

- En route Schedule Adherence (ESA) – percent arrivals within (-1, +5) min scheduled window
- Headway Regularity (HR) – percent actual headway within (150% to 50%) of scheduled headway
- Wait Assessment (WA) – percent headways <= (scheduled headway + 3 minutes)
- Coefficient of Variation in Headways (C_{vh}) – standard deviation of headway deviation / mean scheduled headway
- In-Service On-Time Performance (ISOTP) – same as ESA and currently used by Metro
- Extra Average Wait Time (EAWT) – (actual average wait time – scheduled average wait time) assuming average wait time is half the headway, weighted by scheduled headway interval (see model estimation section for an example)

All of these reliability measures are also measures of on-time performance. Each requires a threshold at which service is deemed on-time. For example, the ESA and ISOTP measure define on-time as a six minute window (from one minute early to five minutes late) around the scheduled arrival time. At Metro, service is currently on-time 77 percent of the time according to ISOTOP. However, the ISOTP on-time window is greater than the headway of some lines such as the Rapid 720, so it isn't always the most useful measure of reliability. The Extra Average Wait Time (EAWT) measure simply calculates the average expected wait time from the schedule and subtracts it from the actual average wait time. A related measure is the ratio of actual average wait time to average expected wait time, which is insensitive to the magnitude of the expected wait time and is easier to compare across locations where the expected average wait times are very different. The EAWT measure is the key reliability measure used in this study since it is does not have any arbitrary bounds and since it a user-centric measure of reliability that can easily be coded into the demand model.

After developing the model estimation data set, some additional data post-processing was done before estimating the model. The main data post-processing step was to calculate stop level (by route and direction) EAWT. This was done as follows:

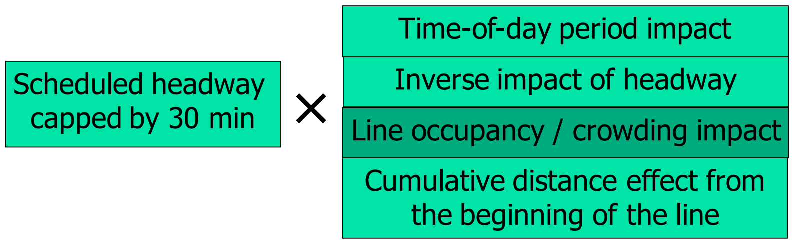
- Calculate the actual headway from the actual arrival times
- Calculate the actual wait time as half the actual headway
- Calculate the weighted actual wait time using the scheduled headway interval as the weight
- Do the same for the scheduled wait time to get the average weighted schedule wait time
- Subtract the weighted actual wait time from the weighted schedule wait time to get the extra average wait time (EAWT)

The following additional measures were created and used in the model estimation as well:

- Accumulated roadway saturation (ARS) = (accumulated miles of average previous road segment LOS) weighted by (road segment VMT)
- Accumulated transit stop activity saturation (ATS) = (accumulated boardings + alightings from the start of run) / (total vehicle capacity for run)

The model was then estimated based on the data provided by bus operators in the Chicago Metropolitan Region that defines EAWT as a function of such variables as accumulated roadway saturation (time-of-day specific parameters), cumulative transit line occupancy, cumulative route length, accumulated number of stops, and average weighted schedule wait time (**Figure 15**). EAWT is proportional to the schedule headway capped by 30 min where all other factors affect the second multiplier. This model was incorporated in the equilibrium transit assignment.

Figure 15: Extra Average Wait Time due to Unreliability of Bus Service



4.15. Incorporation of Fare Structures in Transit Mode & Path Choice

CMAP's Transit Modernization Model includes a representation of the Chicago region's transit fare payment policies that permits the modeler to interpret how out-of-pocket cost might affect a rider's choice of transit path. This includes, to the extent practicable, the cost incentives and discounts offered by the region's three public transit agencies to encourage multiple rides and facilitate transfers.

Discounts for monthly and multi-ride passes, seniors and person with disabilities are not included in this path-choice discussion, but can be incorporated in mode choice on the demand side.

This discussion is presented in three sequential sections to permit the development of algorithms for use in transit path skimming. The fare amounts, as of May 2012, are shown in cents as expected in the model code.

Operator Codes

The following codes are used in network coding to identify the transit operator providing the service on each line. They currently correspond to the fare policy associated with each code. These codes cannot be used to distinguish between types of vehicles or amenities.

- CTA Rail (Mode=**C**)
- CTA Regular Bus (Mode=**B**)
- CTA Express Bus (Mode=**E**)
- Pace Regular (Mode=**P**)
- Pace Local (Mode=**L**)
- Pace Express (Mode=**Q**)
- Metra (mode=**M**)

Single-Line Ride Fares

A single-line ride is the simplest transit path. It consists of a transit rider finding a direct connection between boarding zone and destination zone that can be accomplished without transferring between transit vehicles. Farecards are the preferred media for CTA and Pace. Cash fares are only allowed on buses and are not actively encouraged by the operators. The currently applied prevailing fares and payment types are summarized in **Table 37**.

Table 37: Single Ride Transit Fares in the Chicago Metropolitan Region

Operator code	Transit mode	Fare in cents	Prevailing payment method
C	CTA train	225	Farecard
B	Local bus	225	Cash
B	Local bus	200	Farecard
E	Express bus	225	Cash
E	Express bus	200	Farecard
P	Local bus	175	Farecard or Cash
L	Local bus	175	Farecard or Cash
Q	Express bus	400	Farecard or Cash
M	Metra rail	See table below	

Metra Zonal Fares

Metra fare districts A through M are based on distance from downtown Chicago.   below shows the single line fare charged for a ride to or from district A (central Chicago). To find the fare for non-downtown interchanges, displace the first column of the matrix below by the number of rows needed to move the destination zone to the top of the list and reading the corresponding fare from the origin district row. (e.g. the fare from district F to E is found by moving E to the top along with the rest of the list; i.e. the fare is 300). Outbound fares are symmetrical.

Table 38: Metra Zonal Fares

A	275
B	300
C	425
D	475
E	525
F	575
G	625
H	675
I	725
J	775
K	825
M	925

Intra-Agency Transfers

Following the EMME convention, concatenating the operator codes indicates a trip that uses any (but not necessarily all) of the codes in the list.

CTA (**CBE**) and Pace (**PQL**)   offer fare discounts for customers who transfer between lines during the course of their trip. Up to two additional boardings are permitted at a discounted fare within a two hour period.

CBE

CTA permits riders to alight and re-board the same line at different stops within the two hour period (i.e. it is not necessary to board a different line in order to earn the discount):

- 25 = 1st transfer
- 0 = 2nd transfer

CC (select locations only)

There are several important stations on the CTA rail system (**C**) that allow free transfers between all lines serving the station. These are currently coded with a single node (cross platform) or a walk transfer (pedway or bridge between stations). The latter may involve a 1-2 minute walk and/or 1-2 story vertical change.

0 = unlimited transfer for all lines at the following locations:

- Merchandise Mart (32071): ctr002, ctr008
- Clark/Lake (32170, 32094, 32160): ctr002,ctr003, ctr004, ctr005, ctr008, ctr009, ctr010, ctr051
- State/Lake/Washington (32092, 32161, 32090): ctr002, ctr003, ctr004, ctr005, ctr008, ctr009, ctr010, ctr051
- Adams/Wabash (32164): ctr002, ctr003, ctr004, ctr008, ctr009, ctr010
- Washington/Wells (32073,32169): ctr002, ctr008, ctr009, ctr010
- Jackson/State/VanBuren (32030, 32077, 31650, 31651): ctr001, ctr002, ctr005, ctr008, ctr009, ctr10, ctr051
- Clinton (32096): ctr003, ctr004, ctr010
- Roosevelt (32032, 31750): ctr001, ctr003, ctr004, ctr009
- Howard (32009): ctr001, ctr002, ctr007
- Ashland (32116): ctr003, ctr004, ctr010

PL(Q)

Transfers discounts are only offered to other Pace routes. Transfers can be used for two trips following the initial ride. These trips must be taken within two (2) hours of the beginning of the initial ride. Reverse riding on a P route using a transfer is allowed within the two-hour time limit. Discount does not apply when transferring **to** Q **from** PQ or L:

- 25 = 1st transfer
- 0 = 2nd transfer

LL

Transfers between Local Pace routes are free, and are valid for one hour. Reverse riding is not allowed using free local transfers:

- 0 = 1st transfer

MM

Metra offers no discount for transferring between its own lines.

Inter-Agency Transfers

In general, the current fare policies do not discount transfers in a way that encourages inter-agency transfers.

(CBE)(PL)

No discount is currently offered to transfer between CTA and Pace. This is a temporary condition resulting from budget shortfalls and is expected to be re-introduced shortly. It will likely follow the intra-agency bus transfer policy.

M(CBE)(PL)

Metra Monthly Pass holders can purchase a premium pass for an additional $45 ($30 for Pace only) that permits unlimited free rides on CTA or Pace during peak travel times only. It is primarily oriented toward suburban commuters to downtown that do not work within walking distance of the Metra terminals. This is probably not a significant path choice determinant, but may be useful on the mode choice side.

The described rules in mode-to-mode transfer fare are summarized in **Table 39**. The rules from this table were applied in the transit assignment and skimming procedure implemented in EMME/4 using advance modules 5:32 (Extended Transit Assignment) and 6.27 (Analysis for Extended Transit Assignment).

Table 39: Mode-to-Mode Transfer Rules for Extra Fare Calculation

Mode from	Mode to (transfer fare in cents by number of transfers)						
	C	B	E	P	L	Q	M
C-CTA train	1=25 2=0 selected stations: 1=0	1=25 2=0	1=25 2=0	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Full fare	Full fare for Metra Discounted fare 100 for CTA based on monthly pass extra of $45
B-CTA LB	1=25 2=0	1=25 2=0	1=25 2=0	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Full fare	Full fare Discounted fare 100 for CTA based on monthly pass extra of $45
E-CTA EB	1=25 2=0	1=25 2=0	1=25 2=0	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Full fare	Full fare
P-Pace reg.	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	1=25 2=0	1=25 2=0	Full fare	Full fare Discounted fare 75 for Pace based on monthly pass extra of $45
L-Pace LB	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	1=25 2=0	1=0	Full fare	Full fare Discounted fare 75 for Pace based on monthly pass extra of $45
Q-Pace EB	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	Expected: 1=25 2=0 Currently: Full fare	1=25 2=0	1=25 2=0	Full fare	Full fare
M-Metra	Discounted fare 100 based on monthly pass extra of $45	Discounted fare 100 based on monthly pass extra of $45	Discounted fare 100 based on monthly pass extra of $45	Discounted fare 75 based on monthly pass extra of $30	Discounted fare 75 based on monthly pass extra of $30	Discounted fare 75 based on monthly pass extra of $30	Full fare

4.16. Model System Integration

In summary, the following main improvements were incorporated in the CT-RAMP setup delivered to CMAP:

- All location choices were restructured to take advantage of the MAZ level of spatial resolution (16,819 MAZs).
- Transit Virtual Path Building procedure was implemented to find the best path OMAZ-OTAP-DTAP-DMAZ) with the first boarding station (OTAP) and last alighting station (DTAP) choice for all transit modes. As part of it a special procedure was be developed that calculates access/egress walk times MAZ-to-TAP using a detailed navigation network.
- Two "labeled" walk-to-transit modes ("conventional" and "premium") were replaced with a single generic walk-to-transit sub-mode. Taking into account that PNR and KNR sub-mode were made generic already in Phase 1, the entire model system became "non-labeled".
- Transit assignment, skimming, and TVPB procedures now applied for each of the 8 time-of-day periods as it is was previously implemented for the highway procedures. Mode choice and other models will take advantage of more specific time-of-day choice LOS (instead of transit peak and off-peak LOS applied in Phase 1).

A detailed description of the software components, installation, input and output files can be found in the companion User Guide delivered to CMAP.

5. Model System Validation in Phase 2

5.1. Validation & Calibration Targets

Validation targets for Phase 2 remained the same as for Phase 1

5.2. Validation & Calibration Results

The new transit procedures were integrated into the CMAP CT-RAMP model system. This included transit assignment and skimming macros implemented in EMME macro scripting language for transit with walk access by 3 user classes (1=walk averse 2=transfer averse (“streamlined”), 3=premium transit seekers) as well all required modifications to the CT-RAMP mode choice models (tour-level and trip-level) and Utility Expression Calculators. The modifications included new matrix references for the extended set of skims and new mode availability rules with respect to set of modes available for generic Walk to Transit, Park and Ride and Kiss and Ride. All transit assignment and network procedures were completely updated to incorporate a large number of additional attributes including vehicle, station, and service characteristics and tested. This procedure is based on the advance features incorporated in the latest version of EMME/4 that includes a new version of “Extended Transit Assignment with Variants”.

The TAP-to-TAP skims for transit LOS attributes are fed to the TVPB procedure incorporated in the CT-RAMP mode choice model. Transit procedures were implemented for 8 periods: 1=Night, 2=AM early, 3=AM peak, 4=AM late, 5=Midday, 6=PM early, 7=PM peak, 8=PM late. The corresponding skims are used to construct LOS variables for all periods by adding access and egress components for each transit trip individually. The improvements to the transit procedures and mode choice model resulted in a much better match to the observed data. Below are examples of comparison of the model output at the tour level to the observed data (targets) by 2 main tour purposes (work and non-work), 4 transit modes (1=conventional transit with walk access, 2=premium transit with walk access, 3=park and ride, 4=kiss and ride), and 25×25 origin and destination districts. As an example in this report, we compare the model output to the expanded Household Travel Survey, 2007 – see **Table 40-Table 45**. Similar comparisons were made to all other available sources (CTPP journey-to-work table as well as Metra, CTA, and PACE on-board surveys)

Table 40: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, Transit with Walk Access (Phase 2)

TARGETS | **WORK** | **WK PRE** | HIS

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	32,382	1,702	742	-	280	2,216	280	709	-	-	653	-	1,255	-	-	-	-	103	-	-	176	-	-	-	-	40,498
2N	74,653	16,808	1,319	1,554	407	-	560	1,457	1,602	-	637	325	-	-	-	-	-	-	-	-	312	-	-	-	-	99,634
2NW	17,709	1,676	1,145	3,570	438	-	-	-	148	325	671	-	-	-	-	-	-	-	-	183	-	-	-	-	-	25,865
2WNW	5,218	-	877	4,985	2,580	-	-	308	-	702	-	308	112	-	-	-	-	-	-	-	-	-	-	-	-	15,091
2W	16,058	-	438	1,020	777	452	856	56	-	-	161	-	-	194	-	-	-	-	-	-	-	-	-	-	-	20,013
2WSW	12,941	1,010	98	-	2,307	2,664	1,831	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,851
2SW	12,773	569	3,188	-	-	-	5,818	2,019	-	546	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24,912
2S	44,715	1,394	595	-	1,275	943	3,893	16,797	-	521	70	88	-	365	373	-	-	-	-	-	-	-	-	-	-	71,029
3N	4,779	452	-	-	-	-	-	2,354	393	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,051
3NW	2,879	-	-	-	-	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,951
3WNW	4,648	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,648
3W	3,548	1,496	-	-	-	-	-	-	-	-	-	-	2,474	-	-	-	-	-	-	-	-	-	-	-	-	7,519
3WSW	13,737	456	-	-	1,496	-	-	-	-	-	282	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,971
3SW	7,342	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,342
3S	2,284	-	-	-	-	-	852	768	-	-	-	-	-	-	513	-	-	-	-	-	-	-	-	-	-	4,416
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	2,641	-	-	-	-	-	-	104	-	21	-	-	-	150	-	-	-	1,495	-	-	-	-	-	-	-	4,412
XIN	1,472	73	-	-	-	-	-	114	-	-	-	-	-	-	-	-	-	-	142	-	-	-	-	-	-	1,800
4NW	5,841	87	-	87	-	-	218	-	-	377	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,610
4N	4,017	-	-	-	-	-	-	-	-	-	740	-	-	-	-	-	-	-	-	1,659	5,345	-	-	-	-	11,761
4WNW	1,061	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	347	-	-	-	1,409
4W	914	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	914
4WSW	4,654	-	-	-	-	-	-	83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,738
4SW	5,372	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,372
Total	281,638	25,722	8,402	11,216	9,559	6,347	14,308	24,769	2,143	2,565	3,214	721	3,842	709	885	-	-	1,598	142	1,841	5,833	347	-	-	-	405,804

MODEL OUTPUT | **WORK** | **WK PRE**

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	36,620	680	400	160	280	340	560	120	20	-	20	40	20	-	-	-	-	-	-	40	60	-	-	-	-	39,360
2N	73,520	14,680	2,840	400	300	220	140	260	880	120	120	60	20	-	-	-	-	-	-	120	500	-	-	-	-	94,180
2NW	29,180	2,800	7,540	780	620	240	160	180	80	500	520	80	40	-	-	-	-	-	-	40	340	-	-	-	-	43,100
2WNW	13,860	680	1,780	1,760	1,000	260	120	40	40	20	200	80	40	-	-	-	-	-	-	-	160	-	-	-	-	20,040
2W	20,360	360	580	600	2,500	640	160	80	40	20	60	480	-	20	-	-	-	-	-	-	20	-	-	-	-	25,920
2WSW	17,440	140	240	320	960	2,640	680	80	-	-	20	380	380	60	-	-	-	-	-	-	20	-	-	-	-	23,360
2SW	23,720	300	280	40	380	620	4,480	1,040	40	-	20	40	120	540	20	-	-	-	-	-	20	-	-	-	-	31,660
2S	58,960	560	440	80	140	360	1,760	7,080	40	-	-	80	20	440	200	-	-	360	-	-	-	-	-	-	20	70,540
3N	4,920	620	200	-	-	20	-	-	700	40	20	20	-	-	-	-	-	-	-	80	540	-	-	-	-	7,160
3NW	1,720	160	540	-	40	20	-	-	80	1,520	680	20	-	-	-	-	-	-	-	280	180	40	20	-	-	5,300
3WNW	3,400	20	240	60	60	-	20	-	-	480	1,900	200	80	20	-	-	-	-	-	-	40	680	-	-	-	7,200
3W	5,460	60	60	40	380	20	20	20	20	-	60	2,480	480	20	-	-	-	-	-	-	-	-	20	-	-	9,140
3WSW	7,300	40	40	-	120	120	-	20	-	40	40	400	3,860	60	-	-	-	-	-	-	-	20	40	260	-	12,360
3SW	8,700	60	140	-	40	80	280	540	-	20	-	20	40	2,220	140	-	-	-	-	-	-	-	-	-	160	12,440
3S	6,240	40	20	-	-	20	40	700	-	-	-	20	-	180	1,540	-	-	40	-	-	-	-	-	-	40	8,880
XWI	40	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	120
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	420	-	-	-	-	-	-	60	-	-	-	-	-	-	20	-	-	160	-	-	-	-	-	-	-	660
XIN	40	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	160
4NW	1,860	140	220	-	-	-	-	20	260	340	160	-	-	-	-	-	-	-	-	2,280	1,140	20	-	-	-	6,440
4N	2,540	380	60	-	-	-	20	20	500	100	20	-	-	-	-	40	-	-	-	440	3,540	-	-	-	-	7,660
4WNW	480	-	80	-	40	-	-	-	20	40	180	80	20	20	-	-	-	-	-	60	20	2,580	-	20	-	3,640
4W	540	-	40	-	-	-	-	-	-	40	-	340	20	-	-	-	-	-	-	-	-	60	400	40	-	1,480
4WSW	440	-	20	-	20	20	-	-	-	-	-	40	600	-	-	-	-	-	-	-	-	-	60	2,260	20	3,480
4SW	2,040	-	-	-	-	40	60	80	-	-	-	-	80	360	20	-	-	-	-	-	-	-	-	-	3,480	6,160
Total	319,800	21,720	15,760	4,240	6,880	5,660	8,500	10,360	2,740	3,280	4,020	4,860	5,820	3,940	1,940	40	-	560	100	3,340	6,640	3,400	540	2,580	3,720	440,440

Table 41: Comparison of Model Output to the Expanded Household Travel Survey, Non-Work tours, Transit with Walk Access (Phase 2)

TARGETS — NON WORK — WK PRE — HIS

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	35,361	1,425	-	886	4,327	346	481	3,046	285	-	-	-	-	-	280	-	-	-	-	1,818	-	-	-	-	-	48,255
2N	15,325	23,586	2,963	326	1,630	-	-	291	343	-	-	81	-	-	-	-	-	-	-	-	-	-	-	-	-	44,546
2NW	4,794	2,680	4,108	2,789	-	-	1,527	239	-	-	-	239	-	-	-	-	-	-	-	1,527	-	-	-	-	-	17,903
2WNW	1,312	197	2,000	1,881	2,821	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,211
2W	6,923	481	298	2,084	7,653	392	409	1,105	-	-	-	662	-	-	-	-	-	-	-	662	-	-	-	-	-	20,670
2WSW	2,491	250	197	-	948	6,838	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10,918
2SW	5,543	3,605	-	-	-	1,556	7,987	1,172	-	-	-	-	-	-	-	-	-	70	-	-	-	-	-	-	-	19,933
2S	23,597	701	140	189	1,793	778	6,229	62,194	381	446	-	-	-	1,430	70	-	-	-	-	91	-	-	-	381	-	98,420
3N	667	96	-	-	-	-	-	-	852	-	-	-	-	-	-	-	-	-	-	262	-	-	-	-	-	1,877
3NW	298	-	-	-	-	-	-	-	-	551	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	848
3WNW	330	-	226	-	-	-	-	-	-	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	625
3W	1,503	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	306	1,809
3WSW	539	-	-	-	-	-	227	-	-	-	-	-	870	218	-	-	-	-	-	-	-	-	-	-	-	1,854
3SW	141	-	-	123	-	195	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458
3S	5,219	-	-	-	-	-	-	-	-	-	-	-	-	-	110	-	-	-	-	-	-	-	-	-	-	5,329
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
3IN	41	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,741	75	-	-	-	-	-	-	1,889
XIN	371	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	159	-	-	-	-	-	-	546
4NW	1,144	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,555	351	-	-	-	-	3,051
4N	775	232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	278	591	-	-	-	-	1,876
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	327	-	-	-	327
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	218	-	-	218
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,443	-	3,443
4SW	544	-	-	-	-	-	-	-	-	-	-	-	-	-	849	-	-	-	-	-	-	-	-	-	456	1,848
Total	106,919	33,284	9,932	8,277	19,172	10,106	17,054	68,061	1,861	1,067	-	983	870	1,648	1,309	-	-	1,811	235	6,194	942	327	218	3,824	762	294,854

MODEL OUTPUT — NON WORK — WK PRE

Origin Sector	Destination Sector																								Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	13,060	5,240	1,180	800	1,680	1,420	1,180	2,940	60	20	-	60	60	40	-	-	-	-	-	-	-	-	-	-	20	27,760
2N	15,840	22,960	2,420	340	200	40	120	780	500	60	40	80	-	20	-	-	-	-	-	-	60	20	-	-	-	43,480
2NW	8,300	3,620	8,720	1,420	360	220	100	300	60	300	140	20	-	20	-	-	-	-	-	40	60	-	-	-	-	23,680
2WNW	5,660	1,280	2,300	2,920	1,200	500	100	220	20	-	-	40	20	20	-	-	-	-	-	-	-	-	-	-	-	14,280
2W	7,400	340	740	1,120	6,460	1,180	280	520	20	20	20	400	80	100	-	-	-	-	-	-	-	20	-	-	-	18,700
2WSW	6,440	180	220	260	1,220	6,360	640	280	40	-	-	100	280	100	-	-	-	-	-	-	-	-	-	-	-	16,120
2SW	6,100	340	40	100	260	740	9,560	2,200	20	-	-	-	20	440	-	-	-	-	-	-	-	-	-	-	20	19,840
2S	17,160	840	260	140	160	280	3,580	24,960	40	-	20	20	-	380	600	-	-	80	-	-	60	-	-	-	40	48,620
3N	580	580	240	40	40	-	-	40	2,320	340	-	20	-	-	-	-	-	-	-	20	180	-	-	-	-	4,400
3NW	420	120	500	60	60	20	60	20	80	2,300	400	-	20	-	-	-	-	-	-	60	-	-	-	-	-	4,120
3WNW	400	80	200	40	100	40	40	20	20	440	2,460	240	20	-	-	-	-	-	-	-	-	480	-	-	-	4,580
3W	440	40	60	40	140	60	20	60	-	-	60	3,620	480	-	-	-	-	-	-	20	-	-	-	20	-	5,060
3WSW	720	20	60	-	60	260	40	60	-	-	-	320	5,640	40	-	-	-	-	-	20	-	-	-	20	100	7,360
3SW	440	40	-	20	80	100	800	220	-	-	-	-	100	3,160	260	-	-	-	-	-	-	-	-	-	40	5,260
3S	600	20	-	-	20	-	40	400	-	20	-	-	-	120	3,240	-	-	40	-	-	-	-	-	-	-	4,500
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	80	-	-	-	-	-	-	80	-	-	-	-	-	-	20	-	-	80	-	-	-	-	-	-	-	260
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-	-	200
4NW	340	120	120	20	20	20	-	-	-	40	40	-	-	20	-	-	-	-	-	4,960	160	-	-	-	-	5,860
4N	340	280	40	-	-	-	-	40	80	20	-	-	20	-	-	-	-	-	-	440	5,340	-	-	-	-	6,600
4WNW	80	-	-	20	-	-	-	-	-	-	320	-	-	-	-	-	-	-	-	-	-	3,000	-	-	-	3,420
4W	-	-	-	20	-	-	-	-	-	-	-	40	40	-	-	-	-	-	-	-	-	60	740	-	-	900
4WSW	80	-	-	-	-	-	-	-	-	-	-	-	380	-	-	-	-	-	-	-	-	-	80	3,600	-	4,140
4SW	220	20	-	-	-	-	20	40	-	-	-	-	40	60	20	-	-	-	-	-	-	-	-	-	3,980	4,400
Total	84,700	36,120	17,100	7,360	12,060	11,240	16,580	33,180	3,260	3,560	3,500	4,960	7,200	4,520	4,140	-	-	200	200	5,560	5,860	3,580	820	3,640	4,200	273,540

Table 42: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, KNR (Phase 2)

TARGETS | **WORK** | **KNR** | HIS

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	497	-	-	-	-	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	553
2N	2,825	-	-	-	-	-	-	69	1,194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,088
2NW	2,311	-	186	-	-	-	-	208	-	-	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,865
2WNW	1,623	-	-	-	-	-	-	-	-	-	-	-	112	-	-	-	-	-	-	-	-	-	-	-	-	1,735
2W	1,129	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	177	-	-	-	1,306
2WSW	89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89
2SW	2,395	-	-	-	-	-	-	-	113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,508
2S	2,668	1,726	-	-	-	-	-	585	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,979
3N	457	-	-	-	-	-	-	397	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	854
3NW	2,651	-	-	-	-	-	-	-	-	-	-	44	116	-	-	-	-	-	-	36	-	-	-	-	-	2,847
3WNW	6,125	-	591	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,715
3W	1,526	-	-	-	185	-	-	-	-	-	-	285	598	-	-	-	-	-	-	-	-	-	-	-	-	2,594
3WSW	5,977	-	-	-	-	-	-	-	-	-	-	487	-	-	-	-	-	-	-	-	-	-	-	-	-	6,464
3SW	3,621	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,621
3S	1,547	-	-	-	-	-	-	64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,611
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	2,630	-	-	-	-	-	55	87	-	21	-	-	24	-	-	-	-	44	-	-	-	-	-	-	-	2,861
XIN	698	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	722
4NW	4,010	383	73	-	-	-	-	-	93	-	-	-	153	-	-	-	-	-	-	109	-	-	-	-	-	4,820
4N	780	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	780
4WNW	509	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	509
4W	760	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	760
4WSW	3,331	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,331
4SW	3,564	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,564
Total	51,723	2,109	849	-	185	56	55	1,410	1,400	45	160	817	1,002	-	-	-	-	44	-	145	-	177	-	-	-	60,177

MODEL OUTPUT | **WORK** | **KNR**

Origin Sector	Destination Sector																									
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	440	160	100	40	-	40	60	20	-	-	20	-	-	-	-	-	-	-	-	-	20	-	-	-	-	900
2N	11,780	820	200	-	20	20	-	20	40	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	12,920
2NW	4,880	220	440	40	60	20	-	-	-	20	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	5,720
2WNW	2,340	40	240	60	40	-	20	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,760
2W	3,280	20	-	20	120	60	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	3,520
2WSW	3,140	20	-	20	100	160	-	-	-	-	-	20	60	40	-	-	-	-	-	-	-	-	-	-	-	3,560
2SW	5,020	60	-	-	20	80	320	100	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	5,640
2S	12,500	80	40	-	-	-	180	260	-	-	-	-	-	40	40	-	-	20	-	-	-	-	-	-	-	13,160
3N	840	60	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	980
3NW	640	-	60	-	-	-	20	-	-	180	60	-	-	-	-	-	-	-	-	80	60	-	-	-	-	1,100
3WNW	800	20	-	40	-	-	-	-	-	20	160	-	-	-	-	-	-	-	-	-	-	100	-	-	-	1,140
3W	1,500	-	20	-	-	-	-	-	-	-	-	260	20	-	-	-	-	-	-	-	-	-	-	-	-	1,800
3WSW	1,500	-	-	-	-	20	-	-	-	-	-	-	300	-	-	-	-	-	-	-	-	-	-	80	-	1,900
3SW	2,180	-	-	-	-	-	100	40	-	-	-	-	20	160	20	-	-	-	-	-	-	-	-	-	-	2,520
3S	1,500	20	-	-	-	-	-	60	-	-	-	-	-	20	220	-	-	20	-	-	-	-	-	-	-	1,840
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	40
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	420	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	80	-	-	-	-	-	-	-	520
XIN	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	60
4NW	520	-	-	-	-	-	-	-	20	20	20	-	-	-	-	-	-	-	-	280	120	-	-	-	-	980
4N	480	-	20	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	40	220	-	-	-	-	780
4WNW	180	-	-	20	-	-	-	-	-	20	20	-	-	-	-	-	-	-	-	-	-	260	-	-	-	500
4W	120	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	20	20	-	-	200
4WSW	100	-	-	-	-	-	-	-	-	-	-	-	80	-	-	-	-	-	-	-	-	-	-	100	-	280
4SW	960	-	-	-	-	-	-	-	-	-	-	-	-	20	20	-	-	-	-	-	-	-	-	-	360	1,360
Total	55,140	1,520	1,120	260	360	400	700	500	120	260	300	340	480	320	300	-	-	120	40	400	560	380	20	180	360	64,180

Table 43: Comparison of Model Output to the Expanded Household Travel Survey, Non-Work Tours, KNR (Phase 2)

TARGETS | **NON WORK** | **KNR** | HIS

Origin	Destination Sector																									
Sector	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	699	-	-	-	304	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,004
2N	1,144	183	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,327
2NW	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	219	-	-	-	-	-	-	-	317
2WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2W	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
2WSW	-	-	-	-	199	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	199
2SW	-	-	-	-	-	-	143	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	143
2S	243	-	-	-	-	-	-	390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	633
3N	-	-	-	-	-	-	-	-	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55
3NW	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29
3WNW	207	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	207
3W	93	-	-	-	79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	171
3WSW	1,215	-	-	-	-	-	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,326
3SW	-	-	-	-	-	-	141	-	-	-	-	-	-	-	-	-	-	121	-	-	-	-	-	-	-	262
3S	590	-	-	-	-	-	-	-	-	-	-	-	-	-	97	-	-	-	-	-	-	-	-	-	-	686
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	70	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	91
XIN	129	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	166
4NW	2,728	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,728
4N	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	-	-	-	71
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	567	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	567
4SW	403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	254	657
Total	8,498	183	-	-	582	-	394	425	55	-	-	-	-	-	97	-	-	340	24	-	-	71	-	-	254	10,921

MODEL OUTPUT | **NON WORK** | **KNR**

Origin	Destination Sector																									
Sector	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	80	500	80	-	80	100	80	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,120
2N	1,380	260	40	20	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,720
2NW	520	-	60	20	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	620
2WNW	580	-	20	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	640
2W	760	-	-	20	80	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	880
2WSW	720	-	-	-	20	80	20	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	860
2SW	460	-	-	-	-	20	40	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	600
2S	2,200	20	-	-	-	-	40	340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,600
3N	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40
3NW	-	-	-	-	-	-	-	-	-	20	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40
3WNW	80	-	-	-	-	-	-	-	-	60	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	180
3W	60	-	-	-	-	-	-	-	-	-	40	20	20	-	-	-	-	-	-	-	-	-	-	-	-	140
3WSW	40	-	-	-	-	20	-	-	-	-	20	-	120	-	-	-	-	-	-	-	-	-	-	-	-	200
3SW	20	-	-	-	-	-	-	-	-	-	20	-	-	80	-	-	-	-	-	-	-	-	-	-	-	120
3S	80	-	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	140
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	40	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-	120
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4NW	20	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	100	-	-	-	-	-	180
4N	60	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160	-	-	-	-	240
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160	-	-	-	160
4W	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	40
4WSW	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	20	-	60
4SW	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60
Total	7,200	800	200	100	180	260	180	660	40	160	140	20	160	80	60	-	-	40	-	100	160	160	40	20	-	10,760

Table 44: Comparison of Model Output to the Expanded Household Travel Survey, Work Tours, PNR (Phase 2)

TARGETS | **WORK** | **PNR** | HIS

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	262	-	-	-	-	-	-	-	-	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	373
2N	2,624	313	-	-	-	-	504	-	-	-	-	-	-	-	-	-	-	168	-	-	69	-	-	-	-	3,679
2NW	3,720	-	76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,796
2WNW	-	-	-	-	-	-	-	-	-	702	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	702
2W	1,698	-	-	-	942	-	-	-	-	-	-	-	921	-	-	-	-	-	-	-	-	-	-	-	-	3,561
2WSW	584	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	584
2SW	462	-	-	-	-	-	-	-	113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	575
2S	3,403	574	-	-	-	57	140	-	-	-	-	-	-	182	-	-	-	-	-	-	-	-	-	-	-	4,356
3N	139	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	139
3NW	73	-	-	-	-	-	-	-	-	207	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	279
3WNW	142	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	142
3W	1,862	-	-	-	-	-	-	-	-	-	-	337	-	-	-	-	-	-	-	-	-	-	-	-	-	2,199
3WSW	5,034	-	-	-	-	-	-	109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,143
3SW	690	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	690
3S	1,383	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,383
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	82	-	-	-	-	-	-	-	-	24	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	130
XIN	41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
4NW	263	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	263
4N	611	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	611
4WNW	1,304	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,304
4W	1,485	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,485
4WSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	25,863	887	76	-	942	57	644	109	113	1,044	-	337	945	182	-	-	-	168	-	-	69	-	-	-	-	31,437

MODEL OUTPUT | **WORK** | **PNR**

Origin Sector	Destination Sector: 1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	Total
1	140	40	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	220
2N	3,600	180	20	40	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	3,920
2NW	2,380	120	160	-	20	-	20	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,740
2WNW	1,040	-	100	20	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,180
2W	1,300	-	60	-	20	-	20	-	-	-	-	20	-	-	-	-	-	-	-	-	-	20	-	-	-	1,440
2WSW	1,120	20	-	-	-	100	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	1,260
2SW	2,180	-	-	-	-	20	40	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,280
2S	4,940	-	-	-	-	-	-	200	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	5,160
3N	600	40	-	-	-	20	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	700
3NW	580	-	60	-	-	-	-	-	-	60	20	20	-	-	-	-	-	-	-	40	40	-	-	-	-	820
3WNW	920	-	60	-	-	-	-	-	-	60	140	20	20	-	-	-	-	-	-	-	-	80	-	-	-	1,300
3W	900	-	20	-	-	-	-	-	-	-	20	140	40	-	-	-	-	-	-	-	-	20	-	-	-	1,140
3WSW	1,620	-	-	-	-	60	20	20	-	-	-	100	220	-	-	-	-	-	-	-	-	-	-	20	-	2,060
3SW	2,000	-	-	-	-	-	20	20	-	-	-	-	20	40	20	-	-	-	-	-	-	-	-	-	40	2,160
3S	1,620	-	-	-	-	20	-	20	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	1,700
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	40
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	540	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	120	-	-	-	-	-	-	-	680
XIN	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80	20	-	-	-	-	-	-	220
4NW	660	40	80	-	-	-	-	-	100	160	40	-	-	-	-	-	-	-	-	300	140	60	-	-	-	1,580
4N	280	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	160	-	-	-	-	460
4WNW	120	-	20	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	200	-	-	-	360
4W	80	-	-	-	20	-	-	-	-	-	-	40	40	-	-	-	-	-	-	-	-	40	-	-	-	220
4WSW	260	-	-	-	-	-	-	-	-	-	-	20	60	-	-	-	-	-	-	-	-	-	-	100	-	440
4SW	1,360	-	-	-	20	-	-	20	-	-	-	20	20	120	20	-	-	-	-	-	-	-	-	-	180	1,760
Total	28,360	440	580	60	100	220	160	340	220	320	240	380	440	160	80	-	-	220	20	340	400	420	-	120	220	33,840

Table 45: Comparison of Model Output to the Expanded Household Travel Survey, Non-Work Tours, PNR (Phase 2)

TARGETS | **NON WORK** | **PNR** | HIS

Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	579	-	-	-	-	340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	918
2N	933	1,401	-	-	-	-	-	-	-	-	-	59	354	-	-	-	-	-	-	-	-	-	-	-	-	2,746
2NW	305	-	269	-	-	-	-	-	-	-	-	-	-	-	-	-	-	219	-	211	-	-	-	-	-	1,004
2WNW	-	-	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
2W	1,679	221	177	-	298	662	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,037
2WSW	151	-	-	-	199	158	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	508
2SW	-	-	-	-	-	-	441	113	-	-	-	-	-	-	-	-	-	140	-	-	-	-	-	-	-	694
2S	140	-	-	-	-	-	882	1,094	-	-	-	-	-	-	139	-	-	-	-	-	-	-	-	-	-	2,255
3N	53	49	-	-	87	-	-	-	207	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	396
3NW	541	-	-	-	-	-	-	-	-	465	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,006
3WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3W	142	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	142
3WSW	777	-	-	-	-	-	-	-	-	-	-	-	299	-	-	-	-	-	-	431	-	-	-	-	1,045	2,552
3SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3S	426	-	-	-	-	-	169	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	594
XWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	9	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	74
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65	-	-	-	-	-	-	-	65
4NW	395	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	890	-	-	-	-	-	1,285
4N	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
4WNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4WSW	1,134	-	-	-	-	-	-	-	-	-	-	-	103	-	-	-	-	-	-	-	-	-	-	98	-	1,335
4SW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**7,287**	**1,671**	**640**	**-**	**583**	**1,160**	**1,492**	**1,272**	**207**	**465**	**-**	**59**	**756**	**-**	**139**	**-**	**-**	**424**	**-**	**1,532**	**-**	**-**	**-**	**98**	**1,045**	**18,829**

MODEL OUTPUT | **NON WORK** | **PNR**

Origin Sector	Destination Sector																									Total
	1	2N	2NW	2WNW	2W	2WSW	2SW	2S	3N	3NW	3WNW	3W	3WSW	3SW	3S	XWI	XIL	3IN	XIN	4NW	4N	4WNW	4W	4WSW	4SW	
1	120	40	40	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	260
2N	1,220	380	120	40	40	20	-	100	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	1,940
2NW	880	200	420	80	40	-	-	40	20	20	20	-	-	-	-	-	-	-	-	-	20	-	-	-	-	1,740
2WNW	380	80	40	140	40	-	20	40	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	800
2W	340	40	80	80	120	20	-	-	20	-	20	80	40	-	-	-	-	-	-	-	-	-	-	-	-	840
2WSW	500	20	-	-	160	80	20	20	-	-	-	40	-	-	-	-	-	-	-	20	-	-	-	-	-	860
2SW	720	20	-	40	20	40	180	60	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	1,100
2S	1,680	60	-	-	40	60	180	1,260	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	3,320
3N	80	20	-	-	-	20	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	180
3NW	180	40	60	-	-	-	-	-	-	80	40	-	-	-	-	-	-	-	-	60	-	-	-	-	-	460
3WNW	180	40	20	-	-	-	-	20	-	40	120	-	-	-	-	-	-	-	-	-	20	40	-	-	-	480
3W	100	-	-	40	20	-	-	-	-	-	80	360	160	-	-	-	-	-	-	-	-	-	-	-	-	760
3WSW	260	-	-	-	-	20	-	-	-	-	-	60	540	20	-	-	-	-	-	-	-	-	-	20	-	920
3SW	220	-	-	-	-	20	60	100	-	-	-	20	20	120	20	-	-	-	-	-	-	-	-	-	20	600
3S	140	20	20	20	-	-	20	100	-	-	-	-	-	20	120	-	-	20	-	-	-	40	-	-	20	540
XWI	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	80
XIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3IN	140	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	120	-	20	-	-	-	-	-	300
XIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	40
4NW	240	80	80	-	40	-	-	-	-	100	-	-	-	-	-	-	-	-	-	340	20	20	-	-	-	920
4N	60	20	-	20	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	20	200	-	-	-	-	340
4WNW	40	-	-	-	-	-	20	-	-	20	120	-	-	-	-	-	-	-	-	-	-	140	-	-	-	340
4W	60	-	20	-	20	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	120
4WSW	40	-	-	-	20	-	-	-	-	-	-	20	40	-	-	-	-	-	-	-	-	-	40	80	-	240
4SW	220	-	-	-	-	20	20	-	20	-	-	-	60	60	-	-	-	-	-	-	-	-	-	-	180	580
Total	**7,860**	**1,060**	**900**	**460**	**560**	**300**	**520**	**1,820**	**140**	**260**	**460**	**620**	**860**	**240**	**180**	**-**	**-**	**140**	**40**	**480**	**260**	**240**	**40**	**100**	**220**	**17,760**

6. Conclusions

The developed CMAP Transit Modernization ABM represents a very advanced model system where the core CT-RAMP ABM functionality was greatly enriched on the transit side by incorporation of a large number of premium transit service attributes that are most frequently missing in travel models applied in practice. The project has shown that this extension of the applied modeling techniques is viable and resulted in a fully operational travel model that can be used for transit studies with a wide range of sensitivities to various transit attributed and policies. Amongst the main advanced features and technical improvements incorporated of the developed ABM we can mention:

- Individual transit path choice implemented with a fine level of spatial resolution that tremendously improved the accuracy with which transit access and egress are modeled.
- Advanced "non-labeled" mode choice implementation where the actual parameters that characterize transit path were used instead of multiple mode-specific constants.
- Equilibrium transit assignments with capacity constraints modeled through effective headways and crowding effects modeled through an explicit segmentation by seated and standing passengers.
- Incorporation of impacts of a wide range of station/stop characteristics including station type & size, cleanliness, real-time information, ease of boarding, commercial activity, safety, KNR convenience, etc., in addition to such traditional characteristics as parking capacity.
- Incorporation of impacts of a wide range of in-vehicle parameters including crowding (probability of having a seat), productivity, comfort & convenience, cleanliness, social environment.

The developed model was validated against origin-destination targets developed by expansion of the Chicago Household Travel Survey and ridership data from the On-Board surveys and transit operators. Overall, the new Transit Modernization ABM showed very good validation statistics.

A large number of technical ideas were generated by the project team throughout the course of the project. Some of them were not possible to implement in the current version of the model but they represent very interesting directions for future improvements. In this regard, the following future improvements can be considered:

- Several additional sub-models could be useful. One possibility is to extend the household car ownership model to include transit pass ownership and reserved parking. Person transit pass ownership model as a relevant mobility attribute was already estimated based on the Chicago Household Travel Survey (integrated with household car ownership as joint choice).
- Individual mobility attributes can be driven by modal preferences that could be predicted by a special sub-model. This sub-model could be placed after population synthesis in the model chain. Individual VOT can be correlated with modal preferences although it is also a function of the particular activities and time pressure on the given day.

- Chicago SP survey that was implemented complementary to the Household Travel Survey can be used to estimate VOT distribution using mixed logit (instead of distributions borrowed from the San Francisco ABM).
- Parking capacity restraints at PNR lots are essential. It is necessary to address capacity constraints on key rail sections of Metra and CTA. Parking capacity constraint for PNR lots can be incorporated by using shadow pricing. This should be applied to the total PNR volume of parked cars by station over several relevant time-of-day periods (2-4).
- Currently some coefficients were set to reflect a bundle of characteristics such as comfort, convenience, productivity, temperature, amenities, etc, associated with each mode. In further research it would be interesting to estimate the contribution of each characteristic and make the modeled in-vehicle time and wait perception completely un-labeled.
- Awareness and consideration with regard to transit services can be incorporated as was described in detail in the Phase 1 Interim Report. This sub-model can be integrated with the sub-model for individual modality and mobility attributes.
- More advanced mode choice structure like cross-nested logit model can be applied to describe a differential similarity of auto modes (SOV, HOV) and transit modes (PNR, KNR). In particular, certain similarities between HOV passenger mode and KNR could be taken into account. This was described in detail in the Phase 1 Interim Report.
- In the model validation process, it became clear that non-motorized modes (walk and bicycle) should be modeled with the level of details comparable to transit since they compete for short trips. Many of the details incorporated on the transit side would equally affect non-motorized travel preferences, for example, detailed modeling of walk distances using a navigation network or applying an individual propensity to walk as function of the person age.