THE GREATER TORONTO AREA TRAVEL DEMAND MODELLING SYSTEM VERSION 2.0 VOLUME I: MODEL OVERVIEW

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CHAPTER 1

INTRODUCTION

This is the first in a three-volume report series documenting Version 2.0 of the Greater Toronto Area Travel Demand Modelling System. This volume presents a brief and largely non-technical overview of the "GTAModel" (as it will hereafter be referred to) which provides the reader with a basic understanding of what the model does, the key assumptions upon which the model is built, and the major strengths and weaknesses of the current modelling system. It is primarily intended to provide non-modellers with a general understanding of the GTAModel's characteristics and capabilities, although it also provides a useful starting point for modellers who wish to familarize themselves with the system.

This presentation of GTAModel proceeds in three parts. Chapter 2 provides a brief overview discussion of the standard four-stage modelling process which defines the conceptual starting point for development of GTAModel. Chapter 3 then presents most of the major definitions and assumptions embedded within GTAModel. Finally, Chapter 4 provides an overview of the modelling methods employed in GTAModel calculations.

Far more detailed technical discussions of the model are presented in the other two volumes of the report series. Detailed documentation of the modelling system is provided in Volume II (*Model Documentation*), which includes complete descriptions of the model procedures, the model parameter statistical estimation results, and 1996 validation results. Volume III (*User's Manual*) provides detailed instructions concerning how to prepare and execute a model run.

CHAPTER 2

OVERVIEW OF THE FOUR-STAGE MODELLING PROCESS FOR MODELLING URBAN TRAVEL DEMAND[1]

The starting point for the development of GTAModel is the adoption of the standard *four-stage* approach to modelling urban travel demand, which has been developed over the last forty-plus years (i.e., its origins trace back to the pioneering urban transportation planning studies in the 1950s and 1960s in Detroit, Chicago and elsewhere, including Toronto), and which to this day remains the dominant operational approach to this very complex and challenging problem. The four-stage process has been severely criticized for almost as long as it has been in existence. Many travel demand modellers believe that we are on the verge of a "paradigm shift" which will see radically new modelling methods being implemented within the next decade or so. Despite both the criticism of the four-stage approach and the considerable optimism concerning alternate methods, the four-stage process is currently the most practical operational approach to modelling urban travel demand for regional planning agencies within the GTA. The challenge, therefore, is to develop as sound a modelling procedure as is possible within this basic four-stage paradigm.

Four very basic features are fundamental to the four-stage modelling process. The first is the definition of the basic unit of travel demand: the *trip*. **A trip is defined as the movement of an individual from a single origin to a single destination for a single purpose.** The journey from home to work is an example of a single trip. If the traveller stops at an intermediate point (say to drop a child at daycare), given this definition, the journey now consists of two trips: the trip from home to the daycare centre (with purpose "serve passenger", or some similar designation), and the trip from the daycare centre to the workplace. The four-stage process concerns itself with modelling the trips made by individuals within an urban area, with these trips being divided into a set of trip purpose categories (home-to-work, home-to-school, etc.) which collectively include all possible trips.

The second fundamental characteristic of the four-stage process is its treatment of time. Although trips are actually made over the course of the day, with trip-making behaviour varying by time of day, day of the week and by season, the four-stage approach attempts to model trip-making within specified time periods for a "typical" or "average" weekday (usually corresponding to either a fall or spring weekday), with all trips being made within a given time period (morning peak period, midday, etc.) being treated as essentially occurring at the same point in time. That is, the temporal distribution of trips within a given time period is ignored.

The third fundamental characteristic of the four-stage process is its treatment of physical

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[1] For more detailed discussion of the four-stage modelling process see, among others, Meyer and Miller [2001] or Ortuzar and Willumsen [1994].

space. The urban area is divided into a set of mutually exclusive, collectively exhaustive *zones*. Each zone contains a point within it which is designated the *zone centroid*. For modelling purposes it is assumed that all trips originating from and destined to a given zone have the zone centroid as their origin and destination point.

The fourth fundamental characteristic of the four-stage process is its representation of the transportation system. This involves the use of computer representations of road and transit networks as a connected set of *links* and *nodes*. Typically only "major" roads such as freeways and arterials are explicitly represented in these computerized networks. Zone centroids are connected to the road and transit networks by means of *centroid connectors*, which are surrogates for the local street system which provides trip-makers within the zone with access to the arterial/freeway system. The accuracy of the overall modelling system depends in no small way on the quality of the network "coding" performed in constructing these computerized network representations.

The four-stage approach derives its name from the fact that it breaks the demand forecasting problem down into four sequential stages or sub-models, each one of which deals with one key dimension of travel demand. These four stages are:

1. *Trip Generation*. This stage predicts the total number of trips which originate in or are destined for each zone in the urban area (by trip purpose and time of day).

2. *Trip Distribution*. This stage "links" the "trip ends" computed in the trip generation phase into *flows* of trips from origin zones to destination zones.

3. *Mode Split*. This stage takes the origin-destination (O-D) flows computed in the trip distribution phase and "splits" them into O-D flows by mode (auto, transit, etc.).

4. *Trip Assignment*. This stage takes the O-D flows for a given mode (e.g., auto) and "assigns" them to specific paths from origin to destination, thereby generating estimates of the *link flows* on each link (e.g., road segment) in the transport network.

Figure 2.1 depicts this four-stage process, both in terms of a simple flowchart which illustrates the way outputs from one stage become the inputs to the next stage), and a schematic which illustrates the way in which the detailed representation of urban trip-making is sequentially built up within the process). As shown in Figure 2.1(a), the major inputs to the four-stage process are:

1. "activity system" or "land use" forecasts, which in practice consist of forecasts of the spatial (zonal) distributions of population, employed labour force, employment, etc.; and

2. detailed computer representations of the road and transit networks (and their performance characteristics).

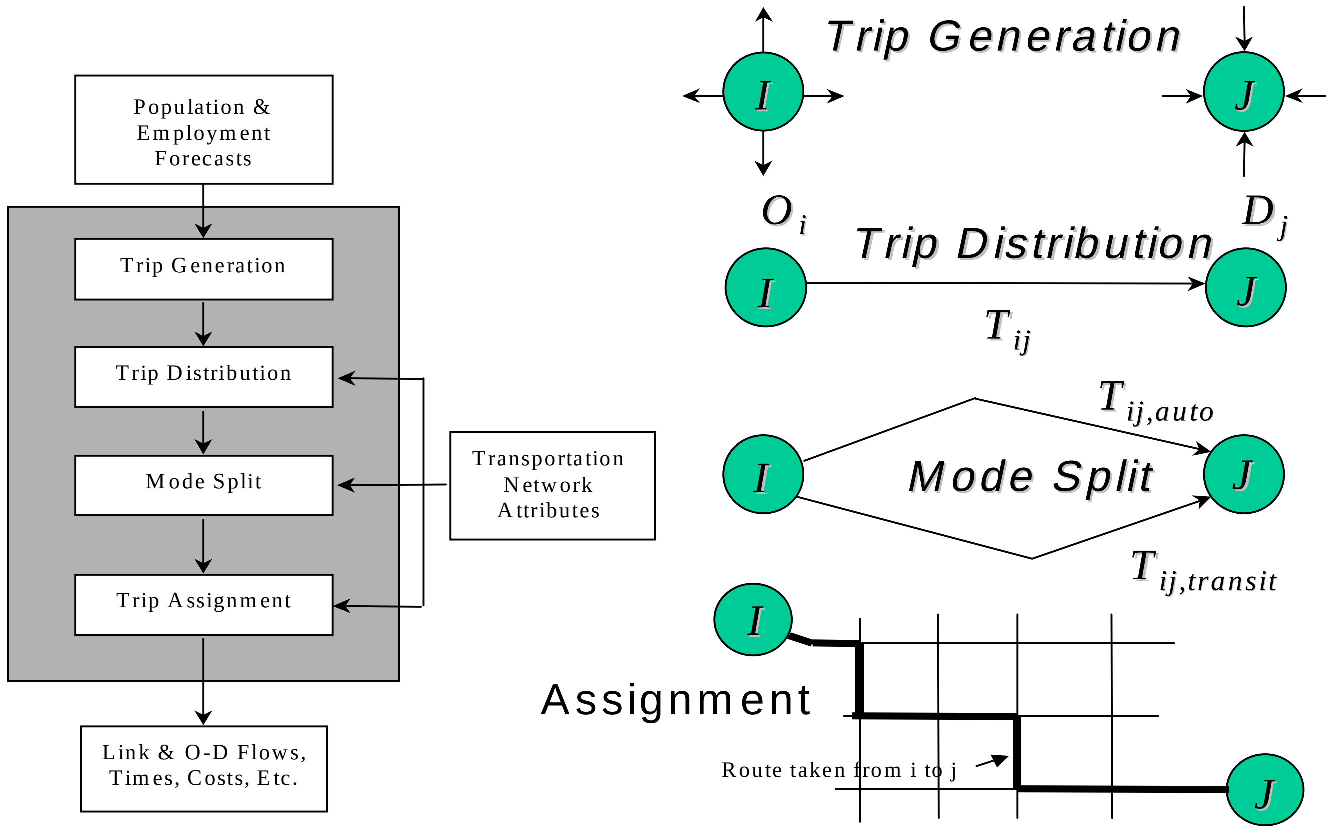

Figure 2.1
The Four-Stage Urban Transportation Modelling System
Source: Meyer and Miller [2001]

Two important points should be noted concerning the way these inputs enter the four-stage process. First, as indicated in Figure 2.1(a), transportation system characteristics are used as explanatory variables in the trip distribution, mode choice and trip assignment stages, but they do <u>not</u> affect trip generation. Thus, the <u>number</u> of trips originating from or destined to each zone is <u>not</u> affected by the level of transportation service being supplied to these zones. Second, although the "activity system" forecasts of population and employment distributions are shown as inputs to the trip generation stage, characteristics of trip-makers can and, in fact, do enter as explanatory variables within other stages of the process, in particular, mode split, within which variables such as age, occupation, possession of a driver's licence, and number of household vehicles play important roles in determining trip-makers' modal choices.

As is also indicated in Figure 2.1(a) the major outputs of the process are estimates of network link flows by mode (i.e., auto and transit), as well as associated link flow related variables such as:

1. average link travel times and speeds;

2. link volume-to-capacity ratios;

3. link operating costs by mode;

4. various transit ridership characteristics such as boardings and alightings by transit line; and

5. other variables which can be calculated as a function of links times, speeds and/or volumes (e.g., vehicle emissions or energy consumption using simple average-speed-based models).

Two additional points should be noted concerning the four-stage process. First, the first three stages of this process (generation, distribution and mode split) must be separately applied to each trip purpose and time of day combination of interest in the analysis, since trip-making behaviour varies considerably from one trip purpose to another and since the transport network factors affecting this behaviour (e.g., travel times and costs) vary dramatically from one time period to another (e.g., peak versus off-peak). Thus, in practice a four-stage modelling system consists of a set of parallel models for each trip purpose being modelled, with the results of these models being brought together at the trip assignment stage wherein the O-D flows for a given mode (e.g., auto) are summed over the trip purposes being modelled to yield total O-D flows for the mode. These total flows are then assigned to the mode's network (e.g., the road network). If more than one time period is being modelled, then this process needs to be repeated for each additional time period.

Second, flowcharts such as Figure 2.1 imply a linear, sequential, "top to bottom" movement through the four-stage process. The dependence of the trip distribution and mode split stages on auto travel times, however, requires an iterative computation strategy. That is, auto travel times must first be estimated based on an assumed set of auto O-D flows. Trip distributions and modal splits are then computed based on these travel times, and a new road assignment is performed given the new estimates of auto O-D flows. This process then continues until the travel times and O-D flow estimates reach "equilibrium". That is, a classic "supply-demand" interaction exists in which the auto O-D flows depend on the travel times among O-D pairs, while the O-D travel times depend on the level of congestion (i.e., the auto O-D flows) on the routes connecting the O-D pairs.

CHAPTER 3

GTAModel CHARACTERISTICS

3.1 INTRODUCTION

This chapter briefly describes most of the key characteristics and assumptions of GTAModel. Section 3.2 describes the traffic zone system used in the model. Section 3.3 describes the network modelling software package (EMME/2) within which the model is implemented. Section 3.4 describes the base year database used for model development, the 1996 Transportation Tomorrow Survey (TTS) database. Section 3.5 then discusses fundamental model definitions and assumptions, including choice of analysis time period, definition of trip purposes to be modelled, definition of travel modes, and the assumptions underlying travel cost calculations within the model.

3.2 GTA ZONE SYSTEM

GTAModel is based on an 1677 zone system covering the entire Greater Toronto Area (GTA), consisting of the regional municipalities of Metropolitan Toronto, Durham, York, Peel, Halton and Hamilton-Wentworth. This zone system is the standard 1996 TTS zone system developed and maintained by the Data Management Group, Joint Program in Transportation for use by regional planning agencies. In addition, 26 "external" zones are used to represent travel between the GTA and adjacent regions outside the GTA.

Other zone systems, consisting of aggregations of the 1996 GTA zone system are also used within GTAModel for a variety of analysis and display purposes. The most important of these are the 46-zone "Planning District" zone system (consisting of the 16 major planning districts within the City of Toronto and the 30 local municipalities within the remainder of the GTA), and a 10-zone "super zone" system used to summarize model results.[2]

3.3 THE EMME/2 NETWORK MODELLING SYSTEM

GTAModel is implemented within a large, commercial transportation network modelling software package called EMME/2. EMME/2 enables the analyst to develop very detailed computerized representations of road and transit networks, and provides the software "environment" within which the entire four-stage modelling system can be implemented. Indeed, as is discussed in Volume III, GTAModel consists of a combination of EMME/2 "macros" (i.e., programs) which, in

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[2] Volume III presents detailed definitions of these aggregate zone systems.

combination with a set of Fortran programs, perform all the calculations required to generate a full forecast of morning peak period travel demand within the GTA.

Key features of EMME/2 include the following.[3]

1. It provides extensive interactive colour computer graphics for network display, analysis and editing purposes.

2. It provides extensive network and matrix (i.e., zonal) data analysis and manipulation capabilities.

3. It provides best state-of-practice road and transit network assignment procedures. These are used to load predicted auto and transit flows onto their respective networks. In so doing, the procedures also generate the travel times (and, for the road network, the travel costs) which are required by the travel demand models (see Section 4.4 for further discussion of the assignment procedures).

EMME/2 supports the development of a single "scenario" which contains both the road and transit networks defined over a common set of links and nodes. To use GTAModel to generate travel demand forecasts for a given future year, the analyst must first define the "scenario" which specifies the road and transit networks to be tested for the forecast year.

EMME/2 runs on a Sun workstation operated by the Data Management Group, University of Toronto Joint Program in Transportation. It is used by virtually all transportation planning agencies within the GTA for their travel demand modelling work, including the Ministry of Transportation of Ontario (MTO), City of Toronto, most regional municipalities within the GTA.

3.4 THE 1996 TRANSPORTATION TOMORROW SURVEY DATABASE

The base year for development of Version 2.0 of GTAModel is 1996, which represents the most recent year for which extensive travel behaviour data for the GTA are available from the 1996 Transportation Tomorrow Survey (TTS). The 1996 TTS consisted of a 5% sample of all households within the GTA and its surrounding areas (115,193 households in total) and gathered detailed household characteristics and trip records for all members of the surveyed households for one 24-hour weekday period during the Fall of 1996. The survey data are maintained by the Data Management Group, University of Toronto within a relational database management system which provides convenient and comprehensive access to the data for a wide range of modelling and planning purposes. 35
For detailed documentation of the 1996 TTS database, see DMG [1997].

[3] For a complete description of EMME/2, see Inro Consultants [1999].

As is discussed in considerable detail in Volume II, all sub-models within GTAModel were developed using 1996 TTS data, and the overall model was validated in terms of its performance in replicating the observed 1996 GTA travel patterns.

3.5 MODEL DEFINITIONS AND ASSUMPTIONS

This section deals with a variety of operational definitions embedded within GTAModel. These include definitions of the time period, trip purposes and modes being modelled (sub-sections 3.5.1, 3.5.2 and 3.5.3), along with the calculation of travel cost terms within the model (sub-section 3.5.4).

3.5.1 Time Period

GTAModel models only one travel time period: the weekday morning peak period, defined as consisting of all trips which begin between 6:00 and 8:59 a.m. inclusive.[4] This corresponds to typical Canadian practice, in which it is assumed that the morning peak-period is the primary period of analysis for most regional transportation planning purposes. It also recognizes the fact that morning peak-period travel is by far the easiest type of travel to model, given its dominance by the journey to work (and, to a much lesser extent, the journey to school), which is a relatively well understood behavioural process.

In order to assign vehicle flows to the road network, peak-<u>period</u> auto-drive trips must be factored down to representative peak-<u>hour</u> values. A GTA-wide average peak-hour to peak-period conversion factor of 0.405 is used for this purpose. This factor simply represents the proportion of total GTA trips starting during the morning peak period which yields the highest hourly total number of trips. Limited experimentation to date with more detailed, spatially differentiated peak-hour factors has not yielded significantly improved model results. [IBI Group, 1991]

3.5.2 Trip Purposes

Within the morning peak-period, three trip purposes are explicitly modelled:

1. *home-to-work (HW) trips*, in which the trip origin zone contains the worker's home and the trip destination zone contains the worker's place of employment;

2. *home-to-school (HS) trips*, in which the trip origin zone contains the student's home and the trip destination zone contains the student's school; and

3. *non-work/school (NWS) trips*, which consist of all other trips made during the morning peak-

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[4] This definition of the morning peak-period is based on an analysis in Miller, *et al*. [1990] of trip start times reported in the 1986 TTS database. It is the definition of the morning peak period used in most, if not all, travel demand models currently used by planning agencies within the GTA.

period.

Table 3.1 summarizes the 1996 breakdown of morning peak-period interzonal[5] trips by these three purposes, from which it is seen that home-to-work trips dominate morning peak-period travel within the GTA, representing 51.5% of all within-GTA morning peak-period trips. Home-to-school trips represent 33.9% of total within-GTA trips, so that together, work-based and school-based travel accounts for 85.4% of all morning peak-period travel. The remaining 14.6% of trips consist of a wide variety of trip purposes (shopping, personal business, etc.), but by far the largest non-work/school trip purpose is "facilitate passenger" (i.e., picking up or dropping off passengers).

In addition to within-GTA trips (i.e., trips whose origin and destination both lie within the six regional municipalities of the GTA), trips to/from the GTA from/to adjacent regions external to the GTA are also estimated within GTAModel. In this case, total trips only (i.e., not disaggregated by trip purpose) are estimated, although a majority of these trips are either work-based or business -related. Table 3.1 also shows trips from outside the GTA to inside ("External->Internal") and *vice versa* ("Internal->External"). As shown in the table, these contribute in total an additional 87,926 trips, or 3.4% of the total trips using the GTA transportation network which have at least one trip end within the GTA.

Note that, at this time, no through-GTA trip movements (i..e., trips which neither originate or end within the GTA but pass through the GTA network) are included within the model, although "gateways" at which these flows could be loaded onto the network do exist within the model. Similarly, no truck or goods/services movements are currently represented within the model.

3.3.5 Modes

Given the importance which modal splits play within GTA transportation policy analysis, the most detailed portions of GTAModel involve the representation and modelling of the alternative modes of travel available within Metro and the surrounding GTA. Seven modes are explicitly modelled in GTAModel. These are defined as follows.

Mode 1: *Auto-passenger allway*. That is, the trip-maker is a passenger in an automobile for the entire length of the trip from home to work. This mode is assumed to be available to all travellers.

[5] An interzonal trip is one in which the trip destination is not in the same traffic zone as the trip origin. While intrazonal trips (i.e., trips whose origin and destination are contained within the same traffic zone) are also estimated within GTAModel, the foc us of the model is on interzonal trips, since these are the trips which load flows onto the transportation network within the model.

Table 3.1
1996 TTS Morning Peak-Period Interzonal Trips by Purpose and Mode

(a) Internal GTA Trips

Mode	Home-Work		Home-School		Non-Work/School		Total	
	Trips	%	Trips	%	Trips	%	Trips	%
Auto Passenger	117700	9.1%	107464	12.6%	34778	9.4%	259942	10.3%
Transit Allway	189992	14.6%	120946	14.1%	17822	4.8%	328760	13.0%
Subway Park & Ride	16533	1.3%	3130	0.4%	560	0.2%	20223	0.8%
GO, Transit Access	10413	0.8%	831	0.1%	366	0.1%	11610	0.5%
GO, Auto Access	28074	2.2%	1322	0.2%	473	0.1%	29869	1.2%
Auto Drive	895930	68.9%	172902	20.2%	308440	83.7%	1377272	54.6%
Walk/Other	41628	3.2%	448968	52.5%	6034	1.6%	496630	19.7%
Total	1300270		855563		368473		2524306	

(b) Trips from/to External Zones, All Purposes

Mode	External->Internal		Internal->External		Total	
	Trips	%	Trips	%	Trips	%
Auto Passenger	6283	10.7%	3252	11.2%	9535	10.8%
Transit Allway	658	1.1%	313	1.1%	971	1.1%
Subway Park & Ride	212	0.4%	18	0.1%	230	0.3%
GO, Transit Access	16	0.0%	0	0.0%	16	0.0%
GO, Auto Access	642	1.1%	15	0.1%	657	0.7%
Auto Drive	49628	84.4%	24257	83.3%	73885	84.0%
Walk/Other	1381	2.3%	1251	4.3%	2632	3.0%
Total	58820		29106		87926	

Mode 2: *Transit allway* (excluding use of GO-Rail for part of the trip). Travellers using this mode access the transit system by walking to a bus stop or subway station. All origin-destination pairs within finite transit travel times generated by the EMME/2 transit assignment procedure (i.e., all O-D pairs which are connected to the transit system) are assumed to have this mode available for use. GO-Bus services are included within this mode.

Mode 3: *Subway with auto access*. Travellers using this mode use the auto (as either a driver or a passenger) to access the transit system at a subway station. Thus, the first transit sub-mode used must be the subway (surface transit may be used once the traveller exits the subway). Currently, only subway stations with "park & ride" parking lots are permitted within the model to act as access stations for this mode. See Volume II for the detailed rules defining availability of this mode on an O-D basis.

Mode 4: *GO-Rail with transit or walk access*. GO-Rail is the "line-haul" sub-mode for this trip. Access to the GO-Rail system is obtained by either walking to the nearest station or by using the "local" transit system. All GO-Rail stations with connections to local transit are permitted to act as access stations for this mode. See Volume II for the detailed rules defining availability of this mode on an O-D basis.

Mode 5: *GO-Rail with auto access* (as either a driver or a passenger). Again, GO-Rail is the line-haul sub-mode, but access in this case is by automobile. Only GO-Rail stations with parking lots are permitted within the model to act as access stations for this mode. See Volume II for the detailed rules defining availability of this mode on an O-D basis.

Mode 6: *Walk allway*. This mode is considered available to the trip-maker if the straightline distance between origin and destination zone centroids is 5 km. or less. If mode 6 is considered available for a given O-D pair, then by definition modes 3, 4 and 5 are considered to be unavailable.

Mode 7: *Auto-drive allway*. This mode is only available to trip-makers possessing a driver's licence and who reside in a household possessing at least one vehicle.

Table 3.1 summarizes morning 1996 peak-period interzonal GTA travel by mode and purpose. Points to note include:[6]

1. The auto mode (drive plus passenger) is the dominant mode of travel for the journey to work within the GTA, with 78% of all interzonal morning peak-period trips being made by this mode.

2. Auto is even more dominant in the non-work/school and external trip categories, accounting for 93-95% of all such trips (drive plus passenger combined).

3. Walk/other modes (principally, in this case, school bus) account for a little over half of all home-school trips. The other half of the trips are reasonably evenly divided among the auto passenger, transit and auto drive modes. Although not shown in Table 3.1, this modal usage varies in obvious ways with student age and municipality (e.g., students in Toronto are more

[6] For a more detailed discussion of GTA travel patterns and trends, see among others, Miller and Shalaby [2000].

likely to take transit; while students outside of Toronto are far more dependent on school buses).

4. GO-Rail serves a very small number of trip-makers within the overall GTA travel market. These trips, however, carry a heavy weight given their relatively long distances and the fact that the primary alternative mode in these cases would be to drive on already very congested highways within the region. Further, GO-Rail usage is dominated by work trips (92.8% of all morning peak-period trips).

5. The auto passenger mode is a significant mode of tra vel, attracting over 10% of all trips, and, in most non-central areas possessing high modal shares than public transit.

3.5.4 Travel Cost Calculations

As is discussed in somewhat more detail in the next chapter, auto and transit travel <u>times</u> are primary outputs of the road and transit assignment stages within the four-stage process. Modal travel <u>costs</u>, however, must, in general, be provided or calculated by the user as somewhat independent tasks. Four major cost variables are used within GTAModel: auto "in-vehicle" costs; auto parking costs; road tolls; and transit fares.

Auto "in-vehicle" travel costs consist in principle of perceived out-of-pocket costs associated with using the auto for a given trip, excluding parking costs at the destination. In GTAModel these costs are simply computed on the basis of a fixed average cost per kilometre, multiplied by the origin-destination trip distance as computed by the EMME/2 road assignment procedure. The average cost per kilometre assumed in the model is $0.0645 (1996 dollars), which is the estimated average fuel cost per kilometre for the GTA 1996 [Mwalwanda, 1999].

Average zonal 1996 daily parking costs were assembled by the City of Toronto Planning for the following areas:

1. Toronto Central Area;
2. Yonge-St. Clair area;
3. Yonge-Eglinton area;
4. Yonge-Lawrence area;
5. North York City Centre; and
6. Scarborough City Centre.

All other zones within Toronto, as well as all non-Toronto zones are assumed to have zero average daily parking costs for workers employed in these zones.

1996 transit fares have been compiled on an origin-destination basis for the entire GTA. In general, they are based on local transit agency calculations of average 1996 adult fares. If more than one transit system must be taken to make a trip from a given origin to a given destination, then the sum of the transit fares involved is recorded. More detailed documentation of the assumptions made in constructing the transit fare matrix (especially concerning cross-Toronto boundary trips and treatment of GO-Bus services) is provided in Miller, *et al*. [1992].

No toll roads existed in the GTA in 1996. Toll roads, however, can be represented within GTAModel, so as to properly handle Highway 407, as well as any other future toll roads which might be proposed for the GTA.

CHAPTER 4

OVERVIEW OF SUB-MODELS

4.1 INTRODUCTION

Figure 4.1 presents a flowchart of the major sub-models within GTAModel. Volume II discusses in detail the mathematical structure, statistical estimation and base year validation of each of these sub-models. In this chapter, a very brief, and as qualitative as possible, summary of the key features of these sub-models is presented.

The main focus of GTAModel is on modelling morning weekday peak-period trips from home to work. Section 4.2 discusses the modelling of these trips. Sections 4.3 through 4.5 then more briefly discuss the procedures used to model the two non-work trip purposes, home-to-school (HS) and non-work/school (NWS), and trips to/from areas external to the GTA, respectively. The trip prediction models depend upon various socio-economic attributes of the travelling public. The determination of these attributes within the modelling system is performed in the "demographics" sub-model, discussed in Section 4.6.

Once trips by all modes and purposes have been computed, these trips are combined into two groups: auto-drive trips, which are assigned to the road network, and transit trips which are assigned to the transit network. Section 4.7 discusses the road and transit assignment procedures provided within EMME/2 which are used within GTAModel. It also discusses the way in which overall "equilibrium" in the GTA morning peak-period travel market is computed within GTAModel.

Finally, Section 4.8 briefly discusses "pre-" and "post-" model run data processing capabilities within GTAModel, a subject which is discussed in greater detail in Volume III.

4.2 HOME-TO-WORK SUB-MODELS

As shown in Figure 4.1, GTAModel deviates from the standard four-stage modelling process described in Chapter 2 in three important ways:

1. The conventional "trip distribution" model which links predicted work trip origins with predicted work trip destinations has been replaced by a model which links the residential locations of workers to these workers' places of employment. Trip generation then follows this Place of Residence - Place of Work (POR-POW) model, converting the residence-workplace linkages into work trips from the home origin zone to the workplace destination zone.

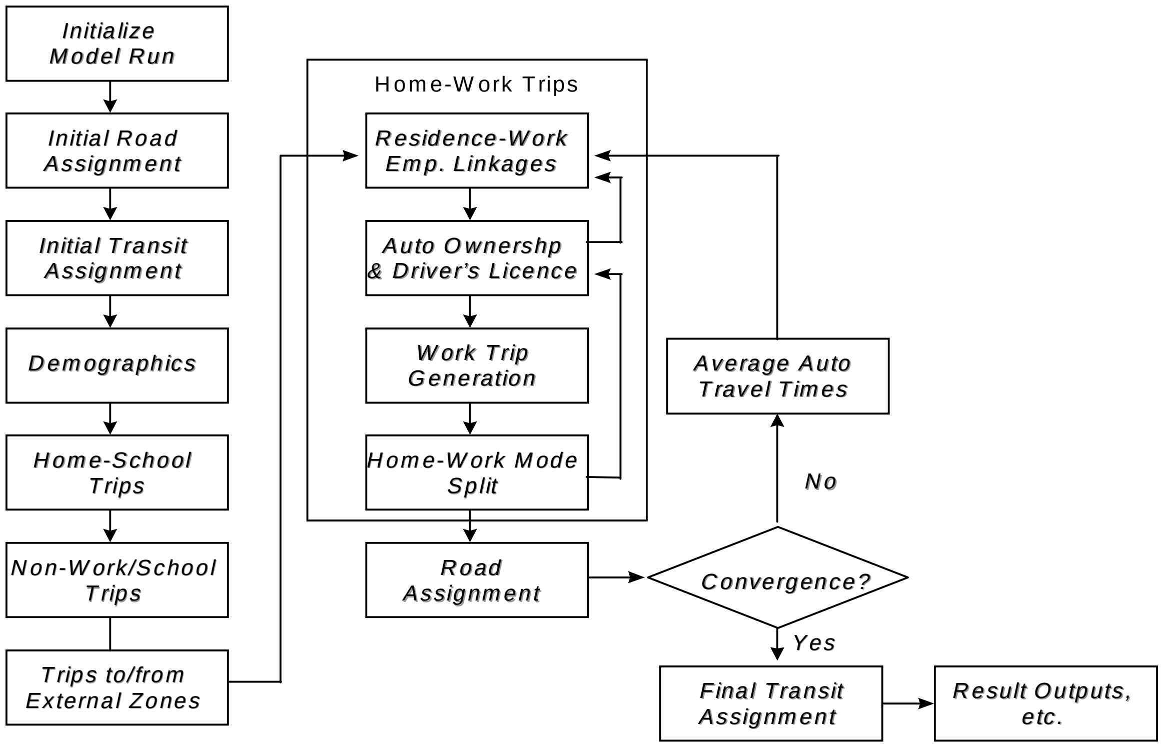

Figure 4.1
Major GTAModel Components

2. Auto ownership (and possession of a driver's licence) is endogenously predicted within GTAModel in the "Auto Ownership and Driver's Licence" sub-model.

3. As is described further below, POR-POW linkages, worker auto ownership level and work trip mode choice are modelled in an internally consistent, theoretically sound fashion using a "nested logit" formulation. This nested modelling structure is indicated in Figure 4.1 by the "feedback loops" shown in the Home-Work Trip box between the lower- and higher-level sub-models within the Home-Work modelling system.

Given the nested logit model structure, it is convenient to discuss the sub-models "from the bottom up". Sections 4.2.1 through 4.2.3 discuss the work trip mode choice, worker auto ownership level choice and POR-POW linkage models respectively. Section 4.2.4 then discusses the work trip generation model, which is not part of the work trip nesting structure.

4.2.1 Work Trip Mode Choice Sub-Model

A disaggregate "nested" logit model is used to model HW modal splits. At least three key features of this model should be noted. First, it is labelled a "disaggregate" model in that it is based on the observed mode choices of individual trip makers. It can be shown that the disaggregate approach makes more efficient use of available data, minimizes biases within the model, and facilitates the development of policy-sensitive models relative to comparable "aggregate" (i.e., zone-based) approaches.[7]

Second, logit models are probabilistic models which estimate the probability that an individual trip-maker will chose any given mode from a set of feasible alternatives. The model is derived from basic theoretical principles of utility maximization. The general form of the logit model is:

$$P_{mt} = \frac{\exp(V_{mt})}{\Sigma_{m'\in Ct} \exp(V_{m't})} \qquad [4.1]$$

where:

P_{mt} = probability that trip-maker t will choose mode m

V_{mt} = "systematic utility" of mode m for trip-maker t

$$= \beta' X_{mt} \qquad [4.2]$$

β = vector of utility function parameters

[7] For a detailed discussion of disaggregate choice models, see Ben-Akiva and Lerman [1985], Ortuzar and Willumsen [1994], or Meyer and Miller [2001].

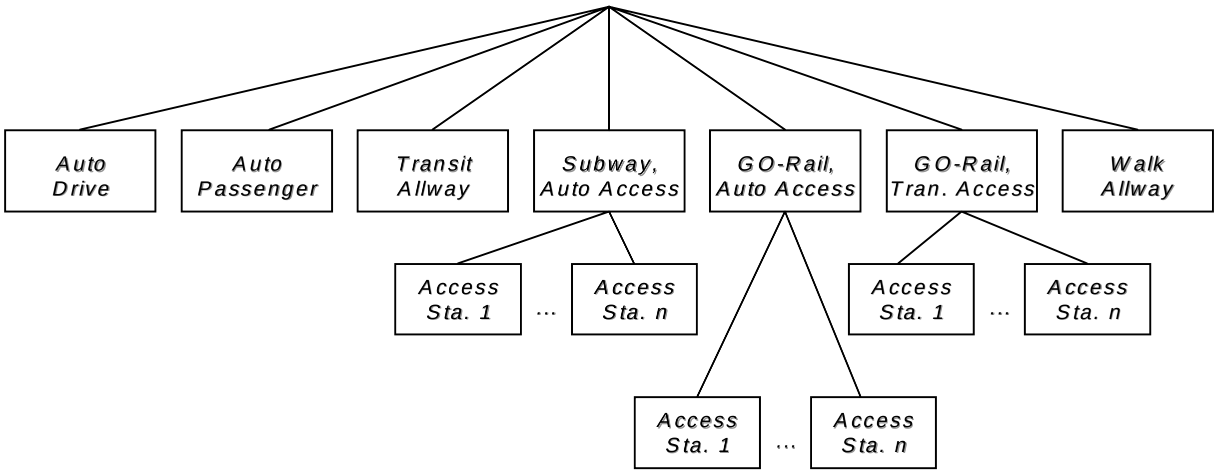

Figure 4.2
Home-Work Mode Choice Model Structure

X_{mt} = vector of explanatory variables in the utility function for mode m for trip-maker t (includes characteristics of mode m and/or person t)

C_t = "choice set" of alternative feasible modes for person t (note that different people may have different feasible choice sets)

Third, a "nested" model is one in which several, inter-related choices are modelled in a consistent, integrated manner. Figure 4.2 illustrates the "choice process" or "decision tree" being modelled in this case. The "upper level" of this decision tree is the choice of travel mode. Three of these modes (subway with auto access and the two GO-Rail modes) involve a "lower level" or secondary choice of access station.[8] In the nested logit formulation, this lower level access station choice is modelled as an ordinary logit model which yields the probability of an individual choosing each of the feasible access stations, given that he/she is going to use the given travel mode associated with these access stations. These access station probabilities then "feed up" in a theoretically consistent way into the calculation of the main travel mode utility functions, thereby affecting the overall choice probabilities for this mode (e.g., if all the access stations are relatively inaccessible, then this mode will be less likely to be chosen than some other mode which has more attractive accessibility). Variables which enter into the three access station choice models include:

- in-vehicle travel time, by sub-mode
- out-of-vehicle travel time
- auto travel costs and transit fares[9]
- number of peak-period trains serving the station (GO-Rail modes)
- number of parking spaces in the parking lots (for subway and GO-Rail with auto access modes).

In order to calculate the travel times and costs associated with the three "mixed modes" of travel (subway with auto access, GO-Rail with transit access, GO-Rail with auto access), the overall trip from origin to destination must be broken up into "trip links" defined by each sub-mode taken. Figure 4.3 illustrates this process for the GO-Rail case.[10] Given this decomposition of the mixed mode trips, auto trip link travel times and costs can be computed within the road network assignment

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8 These access stations in general will be located on two or more different GO-Rail or subway lines. Hence, the choice of access station also involves the choice of rail line.

9 Parking charges at TTC park & ride lots exhibit insufficient variation to be statistically significant in the access station choice model. These parking charges do, however, enter the "main mode" utility for the mode. Parking at GO-Rail stations is free.

10 Subway with auto access trips are broken down into two trip links: the auto access trip from origin zone to access station, and the "transit" trip from the access subway station to the final destination (which may include use of surface transit between the subway egress station and the final destination).

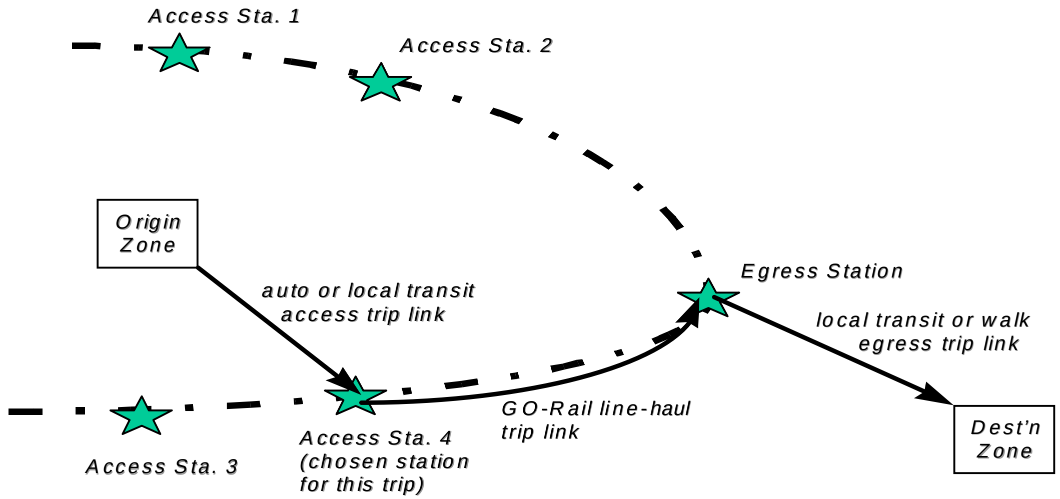

Figure 4.3
Representation of GO-Rail Trips

process, while transit and GO-Rail travel times can be computed within the transit network assignment process. Similarly, auto and transit trip link flows (i.e., from origin to access station; from access station to egress station, and from egress station to final destination) can ultimately be assigned to their respective networks.[11]

This detailed treatment of the mixed travel modes is one of the key distinguishing features of GTAModel. While it requires extensive calculations to generate the full set of auto and transit travel times and costs by trip link, this detailed treatment of these modes is felt to be well justified, given the current and growing policy importance of these modes in within the GTA, and given that without such detailed treatment these modes simply cannot be adequately modelled.

Another distinguishing feature of GTAModel is the explicit modelling of auto-drive and auto-passenger trips as separate modes of travel. This means that "auto occupancy factors" do **not** have to supplied as exogenous inputs to the model for HW trips (as is the norm in most models). Rather, these factors are endogenously generated within the model. It also means that the basic model structure is well suited to the analysis of auto-passenger related policies (ride-sharing programs, HOV lane implementations, etc.). Unfortunately, however, it must be noted that the current implementation of this mode is very simplistic and is not currently able to support detailed analysis of most such policies. In order to improve on current capabilities in this regard will require: (1) improvements in our road network codings which explicitly incorporate HOV lanes, etc. within the road network representation; and (2) improved base data on carpooling and ridesharing behaviour which will allow us to develop improved models of these activities. Thus, the current GTAModel represents an important first step towards a fully policy sensitive model of the auto passenger mode, but much work remains to actually achieve full policy sensitivity.

In addition, note that the walk mode, although very simply represented, is included as a "regular" mode within the mode split calculations. Also note that bicycles are **not** included within this mode or within the model due a number of non-trivial technical difficulties,[12] including sparse observations of this mode in the 1996 TTS database and lack of adequate network representation of this mode within the EMME/2 modelling system.

Explanatory variables in these models include:

- in-vehicle travel times by mode;
- transit out-of-vehicle travel times;
- auto "in-vehicle" travel costs and transit fares;
- average daily parking costs for auto modes;
- walk distance for the walk allway mode;

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[11] For further discussion of the treatment of the "mixed modes" of travel, see Volume II.

[12] Except for HS trips, in which case cycle trips are included with walk trips.

- number of household vehicles;[13]
- various spatial factors affecting mode choice over and above pure time/cost factors (e.g., destination within walking distance of a subway station); and
- age of the worker.

Separate models are have been developed for each of the four occupation groups included in the 1996 TTS database:

1. professional/managerial/technician (P);
2. general office (G);
3. sales (S);
4. manufacturing and other (M).

4.2.2 Automobile Ownership and Driver's Licence Sub-Model

The work trip mode choice model depends, among other factors, on the number of personal use vehicles in the worker's household and whether the worker has a driver's licence or not. In particular, work trip mode choice probabilities predicted by the work trip mode choice model vary depending upon which of the following five categories the worker belongs to:

1. No driver's licence and/or no car in the household;
2. No driver's licence and one car in the household;
3. No driver's licence and two or more cars in the household;
4. Driver's licence and one car in the household; and
5. Driver's licence and two or more cars in the household.

For each origin-destination zone pair (or, equivalently, home-workplace zone pair), a logit model is used to predict the fraction of workers who belong to each of these five "worker categories". Variables included in this logit model are:

- age;
- spatial attributes (live in Planning District 1, etc.); and
- The "expected maximum utility" of the work trip mode choice, given the choice of a the worker category. This is the means by which the work trip mode choice "feedbacks" or influences the upper level auto ownership/driver's licence choice, as illustrated by the arrows in Figure 4.1. Mathematically, the expected maximum utility of the lower-level mode choice, given the choice of worker category w for person t, I_{wt}, for a logit model is defined by:

$$I_{wt} = \Sigma_{m \in Ct} \exp(V_{mt}) \qquad [4.3]$$

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13 Possession of a driver's licence does not enter utility functions as an explicit explanatory variable; rather it helps determine the choice set (and hence the model "sub-market") for the given worker.

Thus, the probability of worker t belonging to worker category w, P_{wt} is given by:

$$P_{wt} = \frac{\exp(V_{wt} + I_{wt})}{\Sigma_{w'=1,5} \exp(V_{w't} + I_{w't})} \qquad [4.4]$$

where V_{wt} is the utility of worker category w to worker t, excluding the effect of the expected maximum utility term. Separate models have been developed for each of the four occupation groups (P,G,S,M) supported by the 1996 TTS database.

4.2.3 Place-of-Residence -- Place of Work Linkage Sub-Model

Given the number of workers in each occupation living in each zone i and the number of workers in the same occupation group employed in each zone j ($i \neq j$),[14] a doubly-constrained entropy model predicts the POR-POW linkages for each of the four occupation groups in the model. For a given occupation group, the number of workers living in zone i and working zone j, W_{ij}, is given by:

$$W_{ij} = A_i * B_j * ELF_i * EMP_j * \exp(I_{ij} + K_{ij}) \qquad [4.5]$$

where:

ELF_i = Employed labour force living in zone i
EMP_j = Employment in zone j
$A_i B_j$ = "Balancing factors" which ensure that $\Sigma_j W_{ij} = ELF_i$ and $\Sigma_i W_{ij} = EMP_j$
K_{ij} = "K-factor" for origin-destination pair i-j[15]
I_{ij} = expected maximum utility of choice of worker category for worker t living in i and working in j
= $\Sigma_{w=1,5} \exp(V_{wt + Iwt})$ [4.6]

4.2.4 Work Trip Generation Sub-Model

Given that a worker in a given occupation group lives in zone i, works in zone j ($i \neq j$), and is in age category a, then the probability that this worker makes a morning peak-period home-to-work trip, WR_{ija} is simply given by:

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[14] See Section 4.4 for discussion of how resident workers and employment by occupation by zone are predicted with the model. Section 4.4 also discusses the treatment of intrazonal workers; i.e., workers who live and work in the same zone.

[15] K-factors are model calibration adjustment factors, which capture systematic zonal spatial interactions not explained by other explanatory variables in the model. In this model, they are defined by origin Planning District - destination Planning District pairs. 57 PD-PD pairs have non-zero K-factors out of a total of 2116 (i.e., 46^2) such pairs in the GTA.

$$WR_{ija} = HWR24_{ija}*HWPPF_{ija} \quad [4.7]$$

where:

$HWR24_{ija}$ = probability that a worker makes a work trip is made during a typical weekday
$HWPPF_{ija}$ = probability that a worker makes a work trip is made during the morning peak period, given that a trip is made that day

$HWR24_{ija}$ and $HWPPF_{ija}$ default values are observed average 1996 TTS rates defined on a Planning District basis. Four age categories are used:

1. Under 19 years old;
2. 19-25 years old;
3. 26-30 years old; and
4. Over 30.

The POR-POW model, equation [4.6] estimates total POR-POW linkages for each i-j zone pair (for each occupation group), regardless of age. In order to disaggregate these linkages by age group, the average fraction of workers living in i and working in j who are in age category a, as observed in the 1996 TTS, A_{ija}, is used, where these averages, again, are computed on a Planning District basis.

Putting the various submodels together, the number of home-to-work trips from zone i to zone j by mode m, WT_{ijm}, is given by:

$$WT_{ijm} = W_{ij} * [\Sigma_a A_{ija}*WR_{ija} * (\Sigma_w P_{w|ija}*P_{m|ijaw})] \quad [4.8]$$

4.3 HOME-SCHOOL SUB-MODELS

The Home-School (HS) model follows the standard four-stage process of trip generation, distribution and assignment. These sub-models are discussed in turn in the following sub-sections.

4.3.1 Trip Generation

Home-to-school trip generation is handled in a manner very similar to work trips. The number of HS trips generated by home zone i, ST_i is given by:

$$ST_i = \Sigma_a [POP_{ia}*SCHPR_{ia}*HSR24_{ia}*HSPPF_{ia}] \quad [4.9]$$

where:

$SCHPR_{ia}$	=	probability that a person in age category a living in zone i is a student
$HSR24_{ija}$	=	probability that a student makes a school trip during a typical weekday
$HSPPF_{ija}$	=	probability that a student makes a school trip during the morning peak period, given that a trip is made that day

In all cases, these probabilities are based on average frequencies observed in the 1996 TTS at the Planning District level. Six age categories are used in the home-to-school model:

1. 11-15 years old;[16]
2. 16-18 years old;
3. 19-25 years old;
4. 26-30 years old;
5. 31-65 years old; and
6. over 65.

HS trip destinations are **not** estimated within the trip generation stage, since it is felt that they cannot be accurately estimated for future years on the basis of future year input data (i.e., population and employment). Instead, they simply are the outcome of the one-dimensional HS trip matrix updating procedure, discussed in the next sub-section.

4.3.2 Trip Distribution

A simple "Fratar" or "proportional updating" method is used to "update" the observed 1996 TTS HS O-D trip matrix to satisfy forecast y ear zonal trip generation totals. In the case of HS trips, in which only forecast year trip origins are estimated, a simple one-dimensional update of the base year matrix to reproduce the forecast year zonal trip origin totals is performed.

A common problem with updating procedures is that they propagate base year zero cell values into the future. This is particularly problematic if an entire row and/or column in the base year matrix is zero (usually due to lack of development of the zone in the base year). In order to circumvent this problem, the base HS year matrix has been "seeded" to eliminate all zero rows and columns (and, thereby, most zero cells within the matrix itself). In this case, all origin zones and destination zones with zero observed trips in the base 1996 TTS trip matrix have been "associated" with two adjacent zones with observed 1996 trips. One trip from each associated zone is subtracted from its total and allocated to the zero-trip zone, with the distribution of this trip across destination zones being defined by the observed distribution of trips for the associated zone.

4.3.3 Mode Split

Observed 1996 TTS average mode splits, computed for Planning district O-D pairs, by age group, are used to split HS O-D flows into flows by the following modes:

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16 TTS does not record trip information for children under 11 years old.

1. auto passenger allway;
2. transit allway (excluding GO-Rail);
3. subway with auto access;
4. GO-Rail with walk/transit access;
5. GO-Rail with auto access;
6. auto drive allway;
7. "other" (principally walk, bicycle and school bus).

Access station choice for modes 3, 4 and 5 is modelled using the HW access station model; that is, a separate model for HS access station choice has not been developed. Note that since HS mode splits do not depend on modal service levels (travel times, costs, etc.), HS trip calculations need only be undertaken once within the overall modelling system, and do not need to be included in the iterative model equilibration process.

4.4 NON-WORK/SCHOOL SUB-MODELS

The Non-Work/School (NWS) model also follows the standard four-stage process of trip generation, distribution and assignment, and is generally similar in design to the HS model. The NWS sub-models are discussed in turn in the following sub-sections.

4.4.1 Trip Generation

The NWS trip generation sub-model differs from the HW and HS trip generation sub-models in that regression equations are used to predict both zonal trip origins, $NWSO_i$, and destinations, $NWSD_j$ as a function of zonal population and employment. The general form of these equations is:

$$NWSO_i = a + b*POP_i + c*EMP_i \qquad [4.10.1]$$

$$NWSD_j = d + e*POP_j + f*EMP_j \qquad [4.10.2]$$

where POP_i and EMP_i are, respectively, the population and employment in zone i, and a, b, etc. are model parameters or coefficients estimated through linear regression. Both population and employment are used in both the trip origin and destination equations since trips can be both "produced" or "attracted" by both population- and employment-based activities.

Although NWS trip rates undoubtedly vary by age, no disaggregation of NWS trip-making by age is incorporated in this version of the model. Separate models, however, have been developed for zones located in:

1. City of Toronto;
2. Region of Hamilton-Wentworth; and
3. the remaining regional municipalities of Durham, York, Peel and Halton.

This spatial disaggregation is intended to capture systematic spatial variations in NWS trip rates which occurs across the GTA. One source of this spatial variation is the fact that walk trips are not collected in TTS for NWS trips. Higher density areas such as in the City of Toronto tend to have lower vehicular (auto plus transit) trip rates than in lower density regions because (possibly among other factors) people living in these higher density areas have greater opportunities to walk.

The trip origins and destinations calculated using equation [4.10] are proportionally "balanced" so that they sum to the same total number of trips. In this case, the average of the raw trip origin and destination totals is used as the predicted total number of trips.

4.4.2 Trip Distribution

A two-dimensional proportional updating or "Fratar" procedure is used to update the observed 1996 TTS NWS O-D trip matrix to the predicted forecast year row and column totals defined by the zonal trip origins and destinations computed in the trip generation sub-model. As with HS trips, the base year matrix is seeded to eliminate zero rows and columns, using the procedure described in Sub-section 4.3.2.

4.4.3 Mode Split

As with HS trips, observed 1996 TTS NWS average mode splits defined on a Planning District to Planning District basis are used. The same seven modes used for HS trips are used fo r NWS trips. Rail access station choices for modes 3, 4 and 5 are determ ined by the HW access station model.

4.5 EXTERNAL TRIP SUB-MODELS

Trips from/to adjacent areas external to the GTA to/from the GTA are also modelled using a simple generation, distribution, mode split framework. No external-to-external flows or other "through" flows are modelled. External-to-internal (EI) and internal-to-external (IE) trips are modelled on a total trip basis (i.e., there is no disaggregation by trip purpose), nor is there any disaggregation by demographic attributes (e.g., age). The external trip sub-models are briefly described in the following sub-sections.

4.5.1 Trip Generation

Observed 1996 TTS trip rates per capita by external zone are used to predict total external-to-internal trips originating in each external zone i, EIO_i, and total internal-to-external trips destined to each external zone j, IED_j. That is, these trip ends are computed as follows:

$$EIO_i = POP_i * REI_i \qquad [4.11.1]$$

$$IED_j = POP_j * RIE_j \qquad [4.11.2]$$

where REI_i and RIE_j are the average zonal trip rates for EI and IE trips, respectively.

4.5.2 Trip Distribution

The observed 1996 TTS EI trip matrix is proportionally updated to the predicted new row totals defined by the EIO_i external zone trip origins computed using equation [4.11.1]. The observed 1996 TTS IE trip matrix is similarly proportionally updated to the predicted new column totals defined by the IED_j external zone trip destinations computed using equation [4.11.2].

4.5.3 Mode Split

Observed 1996 TTS EI and IE mode splits are used to split the total EI and IE flows. The mode splits are computed on an O-D basis, where the external trip end is defined on an individual external zone basis, while the GTA trip end is defined on a Planning District Basis. Based on the observed 1996 usage of modes, the modes used to split EI flows are:

1. auto passenger allway
2. subway with auto access;
3. GO-Rail with auto access;
4. auto drive allway; and
5. "other" (which includes transit).

Modes used to split IE flows are:

1. auto passenger allway;
2. auto drive allway; and
3. "other" (which includes transit and GO-Rail).

No attempt is made to save the transit trips (i.e., mode 5 for EI trips, mode 3 for IE trips) for eventual assignment to the transit network (see Sub-section 4.7.2). These represent an extremely insignificant component of EI and IE trips, many of which may well only exist in the base data due to coding errors.

4.6 MODELLING SOCIO-ECONOMIC ATTRIBUTES

The basic user-defined socio-economic inputs to GTAModel are forecast year population and employment totals for each traffic zone in the modelling system.[17] As described in the previous sections, however, the travel demand models require, by zone:

- population by age group;

[17] In the case of population, this includes population totals for the external zones included within the model.

- employed labour force living in each zone, by occupation and age group;
- employment in each zone, by occupation.

The conversion of population totals into population by age and into employed labour force by occupation and age, and the conversion of employment totals into employment by occupation group, is automatically performed within GTAModel. Observed 1996 TTS population age distributions, labour force participation rates (by age and occupation) and employment occupation distributions are used for these purposes. These distributions can, however, all be changed at the user's discretion, in order to investigate the impacts of alternative future scenarios concerning changes in GTA age structures, employment base, etc., as is discussed further in Volume III.[18]

The labour force and employment calculations are complicated by the need to identify workers who "work at home" (and hence do not generate work trips at all), as well as workers whose employment location is in the same zone as their home (i.e., "in trazonal workers", who, while making work trips, do not generate flows which can be modelled within EMME/2, since they never leave their home zone and, hence, never "show up" on the computerized representation of the road or transit networks). Estimates of "work-at-homes" and "intrazonal workers" by traffic zones are generated as part of the labour force/employment calculations. These are subtracted from the employed labour force (ELF) and employment (EMP) in each zone, so that the ELF and EMP values which are passed to the home-work model to construct POR-POW linkages (see Section 4.2.3) consist only of workers who make interzonal trips to their jobs and, conversely, jobs which are filled by workers living in zones other than the one in which a given job is located.[19]

4.7 NETWORK MODELLING

4.7.1 Road Network Equilibrium Assignment

Given a predicted matrix of auto-drive O-D flows for the morning peak-hour,[20] these flows can be assigned to specific paths (and, hence, links or roadway segments) within the road network using EMME/2's *user equilibrium* assignment procedure. The fundamental assumption of user

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[18] Indeed, as is discussed in detail in Volume III, <u>all</u> base year trip rates, etc. are explicit inputs to the modelling system (i.e., they are not "hard wired" or buried within the software code), and can be changed at the user's discretion, via the user input interface to the modelling system.

[19] This process is further complicated by the need to account for GTA workers who are employed outside the GTA and for GTA jobs which are filled by workers who live outside the GTA, while also "balancing" internal GTA ELF and EMP totals (since the POR-POW linkage model assumes that the GTA ELF and EMP sum to the same total number of workers/jobs). See Volume II for detailed discussion of these calculations.

[20] Where, as noted in Section 3.5.1 peak-<u>period</u> flows are converted to peak-<u>hour</u> flows using a GTA-wide conversion factor.

equilibrium assignment is that each trip-maker chooses the path through the system which provides the lowest possible travel time for that user. Equilibrium occurs when no user can be individually switched to another route without incurring a longer travel time.[21] Major outputs from the road assignment procedure include:

1. average link speeds;
2. average link travel times;
3. link peak-hour volumes;
4. link peak-hour volume-to-capacity ratios;
5. origin-destination auto travel times; and
6. origin-destination auto travel costs.[22]

In addition, "select link" analyses can be performed within EMME/2 which permit the analyst to identify the origin-destination distribution of trips using a particular link or set of links.

4.7.2 Transit Network Assignment

Similarly, a predicted peak-period set of transit flows can be assigned to the transit network using the transit assignment procedure provided within EMME/2. The entire peak-period is assigned since the transit assignment procedure does not depend on the capacity of individual transit routes in determining transit riders' path choices. The assignment procedure used within EMME/2 is essentially based on finding the minimum total travel time path from each origin to each destination, although multiple paths between O-D pairs will be assigned non-zero flows if more than one "good" path exists for a given O-D pair.[23] Outputs from the transit assignment procedure include:

1. peak-period boardings and alightings by node;
2. peak-period boardings and alightings by route;
3. peak-period volumes by link;
4. origin-destination "in-vehicle" travel times;
5. origin-destination "out-of-vehicle" (walk, wait and transfer) travel times; and
6. other information, such as average number of transfers by O-D pair, etc.

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[21] For detailed discussion of user equilibrium assignment methods, see Sheffi [1985]. For a detailed description of the implementation of user equilibrium assignment within EMME/2, see Inro Consultants [1999].

[22] Based on the fixed travel cost per kilometre assumption discussed in Section 3.5.4, plus any road tolls incurred.

[23] See Inro Consultants [1999] for details of the transit assignment procedure. Also note that it is the "aggregate", zone centroid to zone centroid assignment procedure which is used within GTAModel. EMME/2 provides a second, "disaggregate", point-to-point transit assignment procedure as well. While very useful for certain transit planning purposes, this procedure is simply infeasible to use for long-range, comprehensive, multi-model planning purposes.

In order to ensure that GO-Rail trips are properly assigned (i.e., that they actually use GO-Rail rather than a parallel "local" transit path), GO-Rail trip links are assigned specifically to the GO-Rail component of the overall transit network, while all other transit trip links are assigned to a representation of the transit network which excludes the GO-Rail component. Thus, the "transit assignment" task actually involves two independent assignments: one of "local transit" trip links, and one of GO-Rail "line-haul" trip links. The net result, however, is one fully and consistently assigned transit network which contains both local transit and GO-Rail flows.

4.7.3 Overall Model Equilibrium

As indicated in Figure 4.1, auto travel times and costs are initialized within GTAModel by performing an initial auto assignment of a known or assumed auto-drive O-D matrix (the default case being the observed 1996 TTS auto-drive trip matrix). This initial set of auto travel times and costs permits HW trip distributions and modal splits to be computed (as discussed in Section 4.3, non-work trip distributions and modal splits do not depend on travel times and costs within GTAModel and so can be computed independently of this process). One output from the HW modal split calculations is a new estimate of HW auto-drive trips, which, when combined with the estimated non-work auto-drive trips, can be assigned to auto network, yielding new estimates of auto travel times and costs.

Given the new auto travel times and costs, new estimates of HW trip distribution, auto ownership levels, and modal splits must be computed. This results in a new auto-drive trip matrix which must again be assigned to the network. This iterative process of road assignments and HW travel demand calculations continues until the system converges, as signaled by a lack of change in road network travel times. Once convergence is achieved, a final transit assignment is performed in order to get final transit loadings by route and link.

4.8 "PRE" AND "POST" MODEL RUN PROCESSING

4.8.1 Model Run Setup

As described in detail in Volume III, "setting up" a model run within GTAModel consists of three major steps:

1. defining the road and transit network to be tested, using normal EMME/2 network editing procedures;

2. defining the zonal population and employment inputs required by the trip generation models; and

3. defining all other model run parameters within an interactive, menu-based "front end"

program.[24]

4.8.2 Post-Processing Model Run Results

All model run results are stored either within the EMME/2 databank or in disk files located within a user-defined, run-specific directory. These results can be analyzed by the user using EMME/2 data manipulation and display procedures. In addition, standardized post-processing procedures (generate predicted cordon counts by mode, etc.) can be requested through the interactive GTAModel "front end" program (see Volume III for details).

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[24] These can include replacements for all of the default 1996 trip rates, labour force participation rates, etc.

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