Chapter 4
THE MODEL AND THE MODELING PROCESS

Transportation system modeling is a complex process that provides planners with a very powerful tool for forecasting future travel patterns. It helps planners, engineers, and elected officials make sound decisions on road improvements needed to meet future travel demands. It is the *sine qua non* of transportation planning; we simply cannot plan without it.

A transportation model such as the one we used -- TranPlan, described below -- is composed of a series of mathematical formulas, designed to perform a specific set of calculations in a specific sequence, and a sort of computerized geography within which the formulas operate.

THE ROAD NETWORK COMPONENT

The geography consists of links, nodes, zones, centroids and connectors. Any highway system can be described as a network, made up of streets and intersections. In a transportation model the streets are called "links", and the intersections "nodes". As we have noted before, "zones" are the geographical areas into which all land in a study area is divided. Zones do not overlap, and there are no gaps between them. The highway network and the zones have to be integrated, or attached to each other. This is done by assigning each zone a special kind of node called a "centroid", which is then linked to the highway network with a centroid "connector". The centroids hold each zone's data.

The geography has to be customized to the community. That is, we needed to build a computerized version of our own network of roads and highways,

by assigning and entering attributes to every link. Each link, or road segment, was attributed with its related physical characteristics. That included an exact length, travel speed, vehicle capacity, base traffic volume, location by land use, parking, and number of travel lanes. Intersection characteristics are also assigned by links. That description included data on the existence of signage or signalization, and the presence of a left turn lane.

In the real world, every dwelling unit and every place of employment serves as an origin and a destination for vehicle trips. In the computerized model that simulates the real world, each traffic zone is supplied with a single centroid that serves as the computerized focal point for all origins and/or destinations within a given zone. As such, we needed to place each centroid properly within its zone to approximate actual land use and driving patterns, and then connect them accurately to their surrounding links.

The zonal information incorporated in each centroid is this:

- the total number of persons in each zone,
- the total number of occupied dwelling units,
- the total number of autos,
- the total number of retail employees, and
- the total number of employees.

THE CALCULATIONS

To understand the modeling process, we need to understand the sequence of calculations performed by the mathematical formulas. There are three stages: trip generation, trip distribution and traffic assignment. "Trip generation" determines how many personal-trips are going to begin or end

in each zone. Personal trips are then converted to vehicle trips. "Trip distribution" determines how many of those trips are going to go from any given zone to any other given zone. "Traffic assignment" assigns vehicle trips to specific links in the highway network.

Trip Generation. During the trip generation stage, mathematical formulas convert input data on employment and dwelling units into the number of person-trips that either have an origin or a destination in each zone. A zone's "trip production" is the number of trips beginning in that zone; its "trip attraction" is the number that end there. At this point, the model also converts person-trips to vehicle-trips.

For modeling purposes, not all trips are alike. Three kinds must be distinguished. Those trips between home and work, or work and home, are called "home-based work" trips. Those made to or from home to or from places other than work are called "home-based nonwork" trips. Finally, those with neither origin nor destination related to the home, such as trips from work to a retail store, are called "nonhome-based" trips.

This information on kinds of trips can be gathered in one of three ways. Origin and destination (O-D) studies poll motorists at survey points on the highway network. Groups of individuals can also be asked to complete travel surveys. Both are time consuming, very costly and inconvenient to the public. Also, there are standard tables that provide general information. But these are not specific to a given community.

The Greater Lafayette Area had already participated in an extensive O-D study in the 1970s. That work indicated that our own local trip productions and attractions follow this pattern: home-based work, 15%; home-based

nonwork, 52%; and nonhome-based, 33%. Since that time, recent studies have shown a shift towards more home-based work and nonhome-based trips at the expense of home based nonwork trips. Trips percentages used for this update follow those of the 1992 Kokomo Survey: 21.44% are home-base work, 39.29% are home-based nonwork, and 39.27% are nonhome-based.

Traffic zones that define the Purdue campus have trip attraction and production rates quite unlike rates in most other zones. That has to do with the relative locations of dormitories and other student housing, classroom and administration buildings, parking and recreational facilities, and the ways in which people travel within and to those zones. In this update we continue to use production and attraction rates for these university zones first developed for the 1978 Transportation Plan.

Not only do trips have to be classified by purpose, but they also have to be grouped by where they come from and go to. Thus there are "internal" trips and a few kinds of "external" trips. Internal trips have both an origin and a destination within the study area. External trips have either an origin or a destination within the study area but not both ("internal-external" or "external-internal"), or simply pass through the study area but neither begin nor end there ("external-external").

In the geography of transportation modeling, an "external station" is placed on the outer edge of the study area where each major road crosses it. Information is then attributed, or stored, in each external station in much the same way that it is stored in a centroid. In this case, the stored information is based on the number of trips crossing the study area boundary, whether internal-external, external-internal or external-external.

We determined numbers of internal-external and external-internal trips by examining rush hour traffic counts at external station points. Because the number of trips leaving and entering the study area were about equal, we could postulate that at the external stations, trip productions and attractions were equal. Based on the IRMS External Travel Estimation Model, external to internal and external to external trips were estimated. External-external trips were calculated between I-65, US 231, US 52, SR 25, SR 26, and SR 28.

Trip Distribution. Trip distribution is the second stage of the mathematical process, when the model calculates trips made between each zone and every other one within the study area. The distribution formulas mathematically link zonal productions and attractions to simulate travel patterns. Once current travel patterns are accurately simulated, the same mathematical relationships can be used to determine future travel patterns by using future productions and attractions estimated for each zone.

Historically, the most successful and best documented technique for distributing trips within an urban area is the "gravity model". This mathematical concept relates trip interchange between zones in two ways. First, the number of trips is directly proportional to the relative attraction of each zone; second, the number is inversely proportional to a function of time separation between zones. Simply put, zones with a lot of homes and/or jobs in them produce and attract a lot of trips to and from other zones. But the longer the travel time between zones, the fewer trips there will be.

Trip Assignment. Traffic assignment is the third, and last stage in the mathematical process. Here a trip is assigned to the shortest time path available between its origin and its destination.

The process at first assigns all interzonal trips to the same shortest time path link in the network; that is called "all-or-nothing assignment". But logically, if all trips were made on the same link, that link would quickly become congested, and thus stop being the shortest time path. To bring traffic volumes and travel times back into sync, traffic assignment formulas are run over and over again to achieve "equilibrium traffic assignment". That is, enough of the interzonal trips get shifted to other available routes to keep the primary link as the shortest time path.

TRANPLAN

Historically, calculations involved in the transportation modeling process were done by hand, later by mainframe computers. But the advent of desktop computing, with enough memory to store sophisticated software, has revolutionized the field. We no longer have to incur tremendous costs in either time or consultant fees to model future transportation needs.

Local planners now do the work at their desks. We can collect and generate the needed data base and enter it rather quickly. The computer runs the full process, and in a comparatively short time gives us back volumes and travel times for the whole network, complete with zonal production and attraction figures, link volumes, interzonal trip totals, *etc*.

In 1992 the Indiana Department of Transportation looked at a number of software packages for a statewide model. After careful consideration, they chose TranPlan. Then, in an effort to coordinate modeling throughout the State, INDOT offered licenses to all Metropolitan Planning Organizations. Recognizing the importance of coordination, TranPlan continued to be the modeling software for this area's ***2025 Transportation Plan Update***.

According to the TranPlan manual, the program was originally developed by DeLeuw, Cather & Company with the support of Raif Kulunk. In 1990 the Urbansys Analysis Group acquired TranPlan. Since then, James Fennessy has made significant enhancements to the software. He has also adapted the program so microcomputers, minicomputers, and work stations can use it.

Supplementing TranPlan's trip generation program, INDOT also offered a package specifically designed for Indiana's Metropolitan Planning Organizations such as ours. The program still uses the same methodology, but all trip factors (NCHRP 187 Report) have been replaced with ones specific to Indiana. These factors are based on travel demand surveys conducted in four regions within the past five years. TRIPGEN used all socioeconomic inputs described in **Chapter 3**, and developed the zonal trip productions and attractions.

TranPlan then performed the remaining trip distribution and traffic assignment calculations. Part of its output is in the form of traffic volumes projected for each link in the network.

CALIBRATING THE COMPUTER MODEL

As we have noted, the model becomes a reliable predictor of future travel demands and patterns only if it accurately simulates current conditions. Thus before the model can be used it must be "calibrated", or adjusted, to do just that.

Traditionally, a transportation model is calibrated at several different stages. This helps to reduce errors and improve its accuracy. Initially, the

calibration begins while developing the road network. Next, results from each of the three step processes are reviewed. It is only after the program generates traffic volumes, that statistical comparison are made.

Paths of shortest travel time between points were used to locate errors in the road network. We had the computer show us its generated paths of shortest travel times between different locations. If these paths differed from known experiences, a coding error in the network was possible. However, TranPlan successfully replicated nearly all shortest travel time paths. Those that differed were examined and corrected.

Trip generation results were examined next. If the model over- or underestimates the total number of trips produced, it would also do the same to the projected traffic volumes. Following FHWA recommendations, the total number of trips were compared to the total number of households. For our size of area, the Federal Highway Administration suggests there should be 14.5 trips per dwelling unit. Our model calculated to 14.3. The results show that the model has accurately calculated the total number of trips.

The next step in calibrating is to compare generated traffic volumes to actual traffic counts. Comparisons are not done at just a few locations. They are done along screen lines and cut lines. Screen lines are imaginary lines bisecting the community at key locations. We use the Wabash River and South Street as our screen lines because they divide the study in half both east to west and north to south. Cut lines divide the community at lesser points. One cut line bisects the south side of Lafayette just north of Teal Road. An imaginary north-south line just to the west of West Lafayette marks the location of the second cut line.

A transportation model is considered to be accurate enough for use as a predictor of future traffic volumes if it can be calibrated to within 15% of actual traffic counts. **Table 3** shows how our calibrated model did in comparison to actual (seasonally adjusted) traffic counts taken in 1999, the base year.

We were able to better the 15% standard along all four screen and cut lines. The difference between our model-generated counts and actual, seasonally adjusted counts was 7.2% along Screen Line 1 and 1.2% along Screen Line 2. Comparisons at the cut lines also indicated the same accuracy. The percent differences were less than 3.5% at both cut lines. In total, our model-generated counts were just 1.7% higher than seasonally adjusted traffic counts.

For this Plan update, Staff used the IRMS program CAL_REP to assist in calibration. This program generates very useful statistical information including: percent root mean square, mean loading and percent errors, mean absolute value error, and VMT percentage error. These statistics were generated for and examined by screen lines, cut lines, area, functional class, and routes. Results indicated that the model replicated the system accurately.

With the model successfully calibrated, we could proceed with the job at hand: to see the impacts of projected population and employment growth on our transportation network, and to test alternative solutions to lessen those impacts.

Table 3

COMPARISON OF MODEL-GENERATED AND ACTUAL TRAFFIC COUNTS, FOR BASE YEAR

Location	Actual Traffic Count	Model Generated Count	Difference	% Difference
Screen Line 1				
Grant Road	2,589	2,329	-260	-10.04
SR 225	1,884	1,883	-1	0.00
I-65	38,845	40,189	1,344	3.46
North 9th St.	8,254	8,129	-125	-1.51
US 52	33,292	36,949	3,657	10.98
Harrison Br..	30,521	32,790	2,269	7.43
SR 26 Bdgs.	30,021	33,334	3,313	11.04
Grandville	1,981	2,347	366	18.48
Total	**147,387**	**157,950**	**10,563**	**7.17**
Screen Line 2				
Wabash Ave.	12,275	12,426	151	1.23
4th St.	11,916	15,736	3,820	32.06
9th St.	12,538	15,768	3,230	25.76
18th St.	12,743	13,424	3,911	5.34
Main St.	14,087	14,320	233	1.65
26th St.	3,679	2,775	-904	-24.57
Earl Ave.	9,766	10,086	320	3.28
US 52	41,538	38,389	-3,149	-7.58
Farabee Dr.	8,668	8,243	-425	-4.90
Creasy Lane	26,460	26,029	-431	-1.63
I-65	37,078	37,695	617	1.66
CR 500E	7,521	6,239	-1,282	-17.05
CR 900E	1,959	1,493	-466	-23.79
Total	**200,228**	**202,623**	**2,395**	**1.20**

Table 3, continued
COMPARISON OF MODEL-GENERATED AND ACTUAL TRAFFIC COUNTS, FOR BASE YEAR

Location	Actual Traffic Count	Model Generated Count	Difference	% Difference
Cut line 1				
Wabash Ave.	10,114	9,706	-408	-4.03
4th St.	13,549	13,962	414	3.05
9th St.	13,358	12,233	-1,125	-8.42
18th St.	14,405	11,521	-2,884	-20.02
22nd St.	7,515	9,541	2,026	26.96
26th St.	11,587	7,209	-4,378	-37.78
US 52	24,519	31,220	6,701	27.33
SR 38	23,717	21,213	-2,504	-10.56
Creasy Lane	17,890	15,644	-2,246	-12.55
Haggerty Lane	6,231	5,692	-539	-8.65
CR 475E	4,648	5,055	407	8.76
Total	**147,533**	**142,996**	**-4,537**	**-3.08**
Cut Line 2				
So. River Rd.	2,882	2,206	-676	-23.46
SR 26	8,080	8,654	574	7.10
McCormick Rd.	6,532	5,260	-1,272	-19.47
Lindberg Rd.	5,447	4,822	-625	-11.47
US 52	17,068	17,842	774	4.53
Morehouse Rd.	905	1,280	375	41.44
CR 500N	809	1,366	557	68.85
CR 600N	825	1,796	971	117.70
Total	**42,548**	**43,226**	**678**	**1.59**
OVERALL TOTAL	**537,696**	**546,795**	**9,099**	**1.69**