STAFF REPORT ON THE 1994 CALIBRATION/VALIDATION OF THE TRAFFIC FORECASTING MODEL FOR THE CEDAR RAPIDS METROPOLITAN AREA TO 1994/1993 TRAFFIC COUNTS AND TRAVEL TIME SURVEYS

Prepared by the Linn County Regional Planning Commission

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June 1999

The "on-line" version of this report is missing several of the referenced tables, figures, and Appendices. To receive a copy of any of these materials, contact Sam Granato at phone 319-286-5042, fax 319-286-5141 or e-mail samg@cedar-rapids.org

The preparation of this report was financed in part through a grant by the Federal Highway Administration under the provision of the 1962 Federal-Aid Highway Act, as amended, and/or a grant by the Federal Transit Administration under Section 8 of the UMTA Act.

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I. SUMMARY OF FINDINGS

This report summarizes the work performed by the Linn County Regional Planning Commission staff in preparing a traffic forecasting model that can adequately simulate existing traffic patterns in the Cedar Rapids urbanized area. This is done so that the model can be effectively used as an aide in answering many "what-if" questions in transportation project design including street corridor studies, traffic impacts of proposed land developments, and long-range transportation plans. The objectives of this work are, in declining order, to minimize the difference between modeled and counted traffic volumes (especially during "peak" travel hours that usually serve as the basis for project design), minimize differences between modeled and field-measured travel times on arterial streets, and maximize the number of count locations where the modeled difference from counted volume is less than the sample error of the traffic count.

As discussed in Section IV, the modeling procedure documented in this report has a root-mean-square (RMS) error rate of 29% in predicting the 1994 average daily traffic count pattern for Cedar Rapids, identical to the results of the previous model validation to 1990 counts. This overall error rate is influenced by the dominance of small traffic counts, as over half of the traffic count locations have 5,000 vehicles per day or less. Perhaps the most important finding is that on the relatively high-volume streets (where traffic counts generally exceed 15,000 per day) where travel time studies are also taken, the average 11% discrepancy between modeled and counted volumes is not significantly different from the expected traffic count error reported by the U.S. DOT (Reference #35), and the roughly 14% average difference between modeled and field-measured travel times is also within sampling error for 72% of the field observations. Comparable success has also been achieved in modeling the AM and PM peak hour traffic patterns.

The standard of accuracy that has been achieved for this metro area vastly exceeds what has been accomplished by other metropolitan planning agencies around the country (as discussed in Section IV of this report), and this has been made possible primarily by three major differences in traffic modeling philosophy from common agency practice.

First, the partitioning of the metro area into traffic zones is based on access patterns to the transportation network being modeled. In many other planning agencies, zones tend to more closely conform to Census tract/block group geography regardless of actual access patterns.

Second, trip generation rates are based on field-measured vehicle trip rates and driveway traffic counts rather than the common practice of a stated-response travel survey of the public. (In other words, on what people do rather than what they say they do.) While surveys from other cities were used to help develop an initial distribution of total travel into various trip purposes, these totals had to be considerably adjusted to conform to the field-observed totals.

Third, and most important, the modeling is based on the integration/iteration of traditional traffic forecasting processes with intersection traffic control analysis based on Highway Capacity Manual (HCM) methods. (The standard agency practice is "static" street capacity coding that does not vary with changes in modeled traffic conditions, and travel speeds that vary only as a function of volumes on that street and not on crossing streets and opposing approaches at intersections.) Table IV-5 indicates the variation that occurs in a street's actual capacity at intersections based on type of traffic control and traffic conditions by hour of day.

II. DETERMINATION OF PARAMETERS FOR INITIAL TRAFFIC MODELING

The 1994 model calibration effort is performed without a travel survey of area residents. Field-measured travel generation, traffic counts and travel time surveys, not stated responses to interview questions that may or may not reflect actual behavior, serve as the final determinant of model parameters. As discussed in this report, travel surveys done in other parts of the country were sometimes used to set initial model parameters that cannot be determined from field studies, such as allocations of travel totals to individual travel purposes. These initial parameters are then adjusted to fit local field data.

Trip generation totals are based on field studies conducted nationwide, while trip distribution is initially based on the final trip-length distribution from the 1990 "base-year" traffic forecasts and the 1990 Census (modeled, not stated, travel time from reported journey-to-work travel origins and destinations). Generation and distribution are jointly (albeit indirectly) calibrated based on how the sum of traffic counts compares to total simulated traffic at the count locations. Traffic assignment is ultimately validated based on the comparison of modeled to field-measured volumes for individual street segments.

A. Development of Street And Highway Network

The modeled street network includes all expressways, all arterial streets, some collector streets, and some commercial driveways and frontage roads where necessary to properly depict access points to and traffic control on the major street network. Some street segments were added to this network for this model update, which are listed in Appendix A. Over 600 traffic-controlled intersections are also modeled in accordance with HCM-related procedures (References #1,18), which include all but two of the roughly 190 signals that were maintained by metro area jurisdictions in 1994 (not including pedestrian and emergency vehicle signals), along with about 50 all-way stops. The computer-generated representation of the major street network and modeled intersections is shown in Figure II-1.

In addition to adding street segments, the characteristics of the streets in the network file were changed in some cases from the 1990 model in order to incorporate updated software capability, such as updated parameters from the 1994 Highway Capacity Manual. The software program used (QRSII by AJH Associates) utilizes the following street section data to estimate travel volumes and travel times:

1) "Capacity"--more precisely, an hourly saturation flow estimate for through traffic at intersections or along freeways or uncontrolled roads as described in the current edition of the HCM (Chapters 4, 9, and 10) based on calculations as shown in Appendix B. Operational capacity for surface streets (arterials, collectors, and driveways) is calculated and adjusted several times during the modeling process based on intersection turn movements at each iteration of traffic assignment and the traffic control. On (two-way) two-lane streets and roads, operational capacity is also adjusted for opposite-direction traffic volumes based on the guidance from Chapter 8 of the HCM.

(These distinctions are important to make at the outset, as there are many planning agencies around the country who claim that they are utilizing street capacities in their model applications based on HCM methodology. Several of these agencies have even gone so far as to classify network nodes by intersection types in their applications to guide capacity calculations (References #41, 42, and 43). However, these applications resulted in simply more elaborate stratifications of roadways with (still) fixed-number capacities that are not allowed to vary with modeled volumes and turn movements and the adaptations that traffic control systems can make that impact capacities. The impact that this has on eventual model accuracy is quite substantial as discussed in Section IV of this report.)

2) Speed and free-speed multiplier--travel speeds are coded for individual street segments. The free speed multiplier factor is a “global” parameter used to set a certain percentage increase to all coded speeds before there is any “capacity restraint” in the traffic assignment routine i.e. the assumed speed if there was only one vehicle on the street. Based on research findings on the relationship between posted speed limits and “85th percentile” travel speeds at mid-block locations on city streets (Reference #8), the free speed multiplier is set to 1.20 and coded speeds, normally set within 5 mph of the posted speed limit, are adjusted upward for most streets where the posted limit is 35 mph or less. (The importance of distinguishing between “coded” speeds and “free” speeds is that coded speeds are the basis for determining acceleration/ deceleration delay at intersections - for those vehicles that need to stop due to traffic control.)

3) Turn lanes--whether left-turn lanes or a right-turn lane are on this street’s intersection approaches. (The saturation flow and operational capacity of turn lanes at intersections is estimated after each iteration of traffic assignment.)

4) Street direction codes-- used to indicate whether a street is east-west, north-south, or diagonal. This is used for determining which link-to-link movements at an intersection are left turns, right turns, and through movements. (They are also used to determine which approaches to intersections have “green time” during which signal phase, so those signalized intersections with “split phasing” can be faithfully represented by assigning different direction codes to the two opposing approaches to the intersection. At locations where no “permissive” left turns are allowed (during through-movement green time), the left-turn lane or lanes are coded as a separate approach into the intersection with a separate direction code.

5) Progression--adjusts intersection delay based on quality of traffic progression through a series of signalized intersections. Typically, street segments inside “coordinated section groups” (as described in Reference #2) are considered to have slightly favorable (Type 4 as defined in the HCM) progression, in keeping with HCM recommendations for future traffic forecasting. Virtually all other approaches to intersections are considered to have random vehicle arrival (Type 3 progression).

6) If left turns should be prohibited--coded at approaches where such turns are prohibited, and to model traffic patterns at right-in-right-out-only points of access.

7) If traffic is controlled by stop signs or not.

Other information (coded directly at modeled intersections) refers to:

8) Type of intersection--signalized, all-way stop, or “some-way” stop.

9) Cycle length (for signalized intersections) for the time of day being modeled. For full-day assignments, a weighted average of cycle lengths used during the day are utilized. At “isolated” signals where cycle lengths can vary cycle-by-cycle, an estimated average value is used.

10) Allowable U-turns--coded where prohibited turns at adjacent intersections make such u-turns likely.

11) Turn penalties--these penalties are used quite liberally to model traffic in this urban area to include and differentiate delay by turn movements that the model software program often cannot portray properly, and discourage the assignment of “zig-zag” travel paths that would not likely be used by motorists even if use of such paths actually did reduce travel time slightly. For the initial model application, intersection turning penalties (for determining travel paths between origins and destinations) are based on the procedures outlined below. The QRSII program assigns penalties to types of movements at an intersection rather than individual movements, so in many cases (particularly at some-way stops) penalties often have to represent

an weighted average of what is needed for several movements at that intersection. Also, some penalties are adjusted for the time of day for which traffic is modeled.

1. A "base" penalty of 3 seconds for all left turns and right turns for vehicles not required to stop for traffic control, based on the need to slow down to about 10-15 mph to make the turn. This penalty is waived for all-way stop intersections (where all vehicles are presumed to stop) and modified where necessary at other intersections to take into account high-speed (over 40 mph) approaches on major streets and intersection configuration (such as right-turn radii). (The determination of the percentage of turning vehicles stopping at signalized and some-way stop intersections for setting these penalties is conducted interactively based on modeled intersection performance.)

2. On two-way streets with left-turn lanes at signalized approaches, an additional time penalty is established for left turns based on the difference between modeled delay for left turns and for through traffic. These penalties are established on a "trail and error" basis based on previous model calibration attempts.

3. On "coordinated" sections of major arterial streets, added delay for left and right turns is established. For the minor street approach, this delay reflects vehicle arrival at the "downstream" intersection on the major street during the time interval when the guaranteed green phase is not likely to occur (although "early release" green on "major" approaches at the downstream end is more likely to occur during the off-peak period and penalties are adjusted by time of day). For the major street, this would essentially represent a "de-crediting" of modeled reduction in intersection delay for turning movements that is calculated in QRSII based on the progression code which is meant to apply primarily to through traffic at intersections. This added delay is initially established as 20 seconds(a typical side street green+yellow interval) * (1-.767 actuation factor where g/C = .5 and the progression factor=4), which equals 4.66 seconds. With the 3-second base penalty included, the new base penalty at these locations is 7.66 seconds, or .128 minutes.

4. On downtown streets with moderate to large pedestrian volumes, an additional penalty of up to 10 seconds is added (constrained to ensure traffic volume calibration). This delay is initially established as 5 seconds for the start of calibration.

5. Large penalties (up to 5 minutes) are used where necessary to act as de facto turn prohibitions, such as right-in-right-out access-drive intersections.

6. Large traffic volumes on major approaches to some-way stops often lead to extremely large delays on minor streets, because traffic volume assigned to the minor street on the first iteration of traffic assignment does not take into account the delay that would occur. Even with no volume assigned during several successive iterations and a minimum guaranteed approach capacity, equilibrium delay for later traffic assignment iterations can still be excessive and unrealistic. While a "pre-delay" assignment iteration is desired to provide some informal weighting to travel distance in a model that only (explicitly) uses travel time to determine travel paths, penalties are added where needed to reduce minor street volume to the point where outcome delays are deemed reasonable (i.e. no more than 100 seconds). This will be of primary value in assessing future travel patterns on a "baseline" network. (Modeling of stop-controlled intersection approaches incorporate the vehicle gap-acceptance guidelines of the HCM, but it is likely that motorists often take chances with smaller gaps at congested locations, leading to a safety problem at least as much as a congestion problem.)

7. There are several at-grade railroad crossings in the metro area with enough train traffic to delay vehicle traffic sufficiently to (at least occasionally) discourage their use. About 20 such crossings are modeled as intersections with time-penalized "through" movements to reflect usage of those

streets by vehicles that is less than would be the case without the chance for long delays. The setting of time penalties at these crossings is set based on studies conducted by RPC staff at specific locations, and extrapolated to the other modeled locations. At-grade crossings with few trains (generally, less than six per day) are not included.

8. One "special case" location on a freeway off-ramp where right turns as well as left turns are prohibited at the downstream signalized intersection. Rather than set a right-turn penalty that would also affect the other four approaches to the intersection (the ramp "merges" with a city street to form a common directional approach at the signal), the ramp is effectively removed from the intersection and re-connected to the street downstream from the signal, with a through-movement penalty set comparable to the average through movement delay experienced at the signal.

Default model settings are described in reference #18, and the settings used in the application for this metro area, shown in Appendix G, use <u>most</u> of these defaults. Changes are sometimes made based on the results of local field studies. These include:

1. Uniform wait at all-way stops (from Richardson's M/G/1 queuing model) - re-set from 3.6 to 3.4 seconds based on the results of a field study for the city of Marion.

2. Minimum flow ratio at signalized intersections - re-set from 0.33 to 0.10 based on city of Cedar Rapids signal settings (minimum green phases at "minor" street approaches) as described in Reference #2. The flow ratios are deliberately kept at low values, especially during off-peak hours modeling, as only a small percentage of the signals in the metro area are fixed-time phasing (most in the downtown grid). At the other signals, phases for minor street approaches can and are often skipped if there are no vehicles on the minor street during the programmed signal cycle length.

Adjustments and unorthodox model coding is sometimes used to get around certain limitations in the selection of signal phasings in the QRSII software, such as "split" phasing (opposing approaches on different signal phasing) and protected-only left turn phasing. Version 3 of QRSII (used for the 1990 base year model application) did not incorporate any dual-ring phasing options, and the update to Version 5 incorporates only a limited number of such dual-ring options. The banning of "permissive" left turns at locations where this done for both of the opposing approaches (about a dozen intersections) is accomplished by coding street approaches as two-way no left turn links, and left turns are put onto separate one-way links into the intersection with "diagonal" approach codes with time penalties to discourage thru and right-turners from entering the link (which is then subtracted from the left-turn penalty at the "main" intersection node. At roughly a dozen other signal locations where split phasing is utilized, one of two opposing approaches is coded with a diagonal approach code, with any dedicated left-turn lane treated as a through lane for hourly saturation flow coding. Full dual-ring phasing with overlap is not available for use.

B. Traffic Zone Boundaries

Zones are established based on current (and anticipated future) patterns of vehicle access to the modeled street network. Figure II-2 shows the zone system from the start of the 1990 model calibration effort. Many of the 334 zones shown in this figure have been subdivided to create a total of 482 zones for the 1994 model update, due to the addition of several street segments in the modeled network and recent land developments (both built and platted) that warranted changes in previously-assumed patterns of access to the major street system.

C. Estimate of Vehicle Trip Generation in The Metropolitan Area

Full-week and weekday trip generation by hour of day is done "off-model" in spreadsheets shown in Tables II-1 and II-2. As explained in the summary, this consists of utilizing vehicle-trip studies for specific types of housing and commercial developments that have been conducted and documented around the country, in lieu of any recent travel surveys in the urban area. Local traffic and driveway counts are utilized where they can help in isolating total or hour-of-day travel to specific types of land developments. Surveys of the public from other cities are used to fill gaps in the results of field studies, such as purpose of travel. These factors are then adjusted to reflect hour-of-day patterns in local traffic counts (which establish the weekday pattern for arterial streets), and permanent traffic counters established statewide (which establish the freeway and weekend travel patterns).

Due to travel forecast needs for design studies, trip generation is estimated for three different daily patterns:

1) Weekdays when school is in regular session

2) Holiday (Christmas) shopping season

3) Average day throughout the year, including Saturday, Sunday, and holidays.

Peak-hour travel forecasts are factored where necessary to provide design hour traffic estimates (estimate of 30th highest hourly volume in a year) for transportation project design needs, utilize either the first or second pattern depending on what time of year the design hour for the project is believed to occur. Average annual daily traffic forecasts (and, more importantly, average daily vehicle-miles and vehicle-hours of travel) are used for estimating overall project benefits (often done for competitive project applications such as the local Transportation Improvement Program or statewide competitive funding programs) and for pavement design.

While adjustments to trip generation variables and values can easily be made as part of the calibration of the overall model application, considerable effort is made to have the best possible estimates available at the start of the model application. (As in mathematics class, when one has more unknown values for variables than independent equations to solve for these unknowns, the final answer is somewhat dependent on the starting point. Trip generation for several different types of trips without a reliable travel survey that breaks down the type of travel involves solving for many unknowns.)

For the 1990 model application, nine variables (total housing units, total population, total household vehicles, retail employment, downtown retail, service employment, downtown service, hospitals, and other employment) were utilized to predict zone-level travel. Due to the availability of more land-use data for the 1994 model, particularly from the 1990 Census Transportation Planning Package and the Iowa Department of Employment Services, the number of socio-economic variables is now expanded to include finer breakdowns of employment categories (17 based on SIC code and area type) and household data (persons, workers, vehicles, and four levels of school enrollment per dwelling unit) to better differentiate the daily and the hour-of-day distribution of travel. Concentrations of employment are also evaluated for trip generation. For example, office buildings or complexes with a large number of employees (a cutoff of 100 is used) have been found to attract relatively few vehicle trips per employee per day, even if they are considered "service" employees by the SIC definition.

Residential socio-economic data used for travel forecasting (dwelling units, population, workforce, vehicle ownership, and school enrollment) come primarily from the 1990 Census (References #4, 32), with updates to the population dwelling units count to 1994 coming from local building permits and Census biennial estimates for municipalities. The 1990 dwelling unit and population counts come from the "100% count" portion of the Census documented in the STF1 files, and other data comes from the sample count as documented in the Census Transportation Planning Package (CTPP) for this metro area. 1990 Census figures on workforce, vehicles, and school enrollment by type per zone start with the figures reported for each zone in the CTPP and then adjusted twice - first for any differences between sampled households and all households in a zone regarding persons per dwelling unit, and second to ensure that zone totals for these data then sum up to the metro area "control total" established using Census data for the entire metro area. Census figures on population, workforce, vehicles, and enrollment per dwelling unit by zone are then presumed to remain constant between 1990 and 1994. (1994 enrollment data reported by local K-12 school districts (Reference #5) are compared to figures calculated at households for 1994 to determine the number of students commuting to metro area schools from outside the area.)

Travel to and from residential areas

A report referenced in the ITE Trip Generation manual (Reference #10) contains a series of regression equation coefficients describing the relationship between vehicle trips per day to and from dwelling units (not necessarily the same thing as travel made by household members), persons per dwelling unit, and vehicles per dwelling unit. Equations with these coefficients were utilized for the 1990 model. These equations did a good job in matching typical field study trip rates for the whole metro area and at individual locations where counts were available to verify rates for specific housing developments, given the local mix of dwelling unit types and persons and vehicles per housing unit at the zone level (see Table II-3).

However, usage of these coefficients has two disadvantages. First, separate equations were used for different types of housing units, and Census data at the zone level in 1990 did not separate population by type of unit. Further, the research in this report indicates that density by itself is not significant in predicting vehicle trip rates, which calls into question the need for separates trip rates by type of housing unit. Second, the regression equations were linear, whereas household travel surveys conducted around the country indicate that as persons and vehicles per household go up, travel increases at a rate that is more logarithmic rather than linear. (While such surveys consistently underestimate total travel due to respondent's lack of recall and/or willingness to reveal complete personal travel information, the logarithmic rather than linear pattern of total travel as a function of persons and vehicles per household is consistent across numerous such surveys, and intuitively logical.)

For the 1994 model update, cross-classified travel survey data from the 1995 National Personal Transportation Survey (NPTS) (Reference #6,11), adjusted for vehicle trip control totals for the metro area, was utilized to assist in developing estimated daily (and time of day) vehicle trip totals per housing unit. The daily vehicle trip equation is:

Daily vehicle trips/dwelling unit = (12.3*log (persons/dwelling unit + 0.5)) + (8.5*log (vehicles/du + 0.5))

This equation was developed with the dual objective of replicating the relative differences between households found in a subset of the NPTS survey data (Reference #6) and coming as close as possible to the vehicle trip per housing unit estimates for the metro area from field studies (Reference #9) when applied to the 1990 traffic zone data set. The calculated metro area average is 8.62 vehicle trips per dwelling unit (7-day average) compared to a "target" rate of 8.49 from the ITE field data shown in Table II-3 (Reference #9 - based on the local housing mixture and trip rates by type of housing).

Being a national survey, a large portion of the NPTS survey population can be considered to incorporate travel behavior not indicative of this metro area due to responses from rural areas or very large urban areas, or other regions of the country that differ considerably from Cedar Rapids in terms of lifestyle or feasibility of other modes of travel. There were too few respondents from the state of Iowa itself for the survey to be statistically meaningful. However, in one state that borders the Midwest, planning agencies for two medium-size metro areas requested and received "add-on" data for their model needs that provide a reasonably suitable match for the needs of this model update (Tulsa and Oklahoma City, Oklahoma). Therefore, it is the Oklahoma subset of about 4,000 surveyed households for the NPTS that was used to assist in developing the housing trip generation equations listed above, and much of the initial estimates of trip purpose by hour-of-day described later in this report. Relevant tables from the 1995 NPTS are included in Appendix C.

Travel to and from commercial areas

Iowa Department of Employment Service data (Reference #3) are utilized to determine the number of employees by type of employment in each traffic zone. The ITE Trip Generation manual and local traffic counts (Reference #21) were used as the source for (initial) overall daily trip rates per employee. In 1990, three separate classes of employment based on SIC codes (retail, service, and other) was used based on differences in vehicle trips attracted per employee. While this had worked well for forecasting daily and PM peak hour travel in the 1990 model, problems were discovered with AM peak volumes near schools. This is because while daily traffic at schools per employee is not much different from many other service employees, the hour-of-day distribution of travel is significantly different. Therefore, schools were separated from other service employees for the 1994 model and, for trip distribution as much as generation by hour of day purposes, broken into four separate categories- public elementary schools (grades K-8), public high schools (grades 9-12), private schools (grades K-12), and colleges/trade schools.

The two major malls in the metro area are treated separated from other retail, due not only to smaller trip generation per employee, but also differences in trip types found in "pass-by" travel studies documented in the ITE Trip Generation manual and the availability of local traffic volume counts for all driveways into and out of these malls. (While very small retail establishments often generate a far higher number of vehicle trips per employee than shown in the table, such as convenience stores and fast-food restaurants, they were not evaluated as a separate category due to the percentage of these trips being a stop on a trip chain with little or no impact on travel route also being high.

The two major hospitals were treated as "special generators" in 1990 as nationwide studies indicate that hospitals only attract about 5 trips per employee, considerably less than other "service" employees. For the 1994 model, all medical facilities (SIC code 80) are now treated in this fashion. As in 1990, retail and service trip generation in the downtown area is also reduced from rates used in the rest of the metro area, based on travel survey results from the Denver metro area (Reference #13).

Travel between the metropolitan area and areas outside

Traffic counts taken at or near the 56 "external stations" (streets and highways crossing the metropolitan planning boundary) in 1993 and 1994 serve as the basis for determining all of the external travel to be taken into account by the traffic model application. Two kinds of travel are included in this category--travel with either the trip origin or destination inside the planning boundary and the other end outside (external-internal trips), and trips not originating or heading anywhere within the metro area but simply passing through the area (external/external or "through" trips). The determination of the portion of these trips being through trips is discussed in Appendix D. The remainder of the counts are considered to represent external/internal travel and are allocated to trip purposes based on the 1990 Census journey-to-work data, school locations and district boundaries, and to balance internal trip origins with destinations.

Determination of trip origins ("productions") and destinations ("attractions") by type of travel

Determining trip origins and destinations for each trip purpose was done for both completely internal travel and external/internal trips. Ten trip purposes are used, including the three purposes that are considered the industry standard--home-based work, home-based nonwork, and non-home based. Four trip purposes for school travel by type and grade level of school are also defined and utilized as discussed earlier, and non-home based travel is broken into two categories to separate out from this large grouping of travel those in which the trip to/from the workplace is at the end of a "trip chain" from home to work (due to the differences in hour-of-day and directional patterns). The other trip purposes used are external (through) travel and "supplemental" airport trips distributed on a "per-capita" basis to all traffic zones (per person and per employee, regardless of time or distance to the airport). (However, the QRSII software program is only capable of distributing four purposes at a time interactively with traffic assignment and other model steps. Therefore, through trips, home-to-college/trade school trips, and supplemental airport trips are distributed "off-model," and the other three home-to-school trip purposes are distributed in a model run separate from other purposes and saved as a fixed matrix of trip origin/destination pairings (trip table) to be added to the forecasts made of travel from other purposes.)

For home-based work trips, attractions are set at an average of 0.98 (7-day average) and 1.23 (weekday average) per employee at a workplace, based on data from the 1990 Census and 1990 National Personal Transportation Survey (NTPS) as synthesized and compiled in a report prepared for the FHWA (Reference #3). Local journey-to-work data from the 1990 Census (Reference #4) indicates that about 85% of workers in Cedar Rapids got to work in 1990 driving alone or driving a carpool vehicle, which would indicate about 1.7 weekday work trips "round trip." However, this does not take into account adjustments for stops made during the trip to work, people who make more than one round-trip to work per day, or absenteeism rates and part-time workers. Reference #3 provides numerical adjustments to make for these factors, which are also used for the hour-of-day and directional distribution of direct home-to-work travel, as well as the new "non home based-work chain" trip purpose. This information is supplemented by the 1995 NPTS data from Oklahoma cited earlier to add other information such as the type of travel destinations used in the trip chaining.

It is reasonable to assume that there are industry-based differences in the number of daily work trips per employee, based on the relative mixes of full and part-time workers. However, no reliable data has been found on how work trips per employee per day are affected, either from the travel survey data or from labor force data. However, statewide information on hours worked per week by industry code (Reference #12) can be and is used to estimate days worked per week by SIC code of industry in conjunction with absenteeism rates discussed earlier to estimate the work-trip rates by employment category shown in Tables II-1 and II-2.

Home-based school vehicle trips are also difficult to estimate due to lack of studies, and the high and quite variable vehicle occupancies depending on the level of school bus usage. Even the 1995 NPTS data does not provide good answers due to the nature of trip purposes utilized in the survey. (Vehicle trip generation field studies plus the number of school employees indicate that school travel should be about 11% of travel in this metro area. The 1995 NPTS data from Oklahoma indicates only about 2% of vehicle trips have school destinations, but another 15% of vehicle trip purposes are drop-off or pick-up passenger, a large portion of which are to schools.) A range of possible trip rate values were tested that could reasonably match daily vehicle trip total estimates for schools. Initial model runs use .5 home-based vehicle trips per student per weekday (.365/day over a 365-day year). For college student travel, this is adjusted to .1 trips per weekday for students living on or adjacent to college campuses (zones 51, 57, 226, and 227 from Figure II-1) and .575 trips per student per day in other zones.

Residential areas are estimated to "attract" a small number of trips as well each day, such as delivery/service vehicles and personal visitors. The travel surveys conducted in the Denver and Seattle metro areas (References #13, 25) served as upper and lower bounds for the estimation of possible trip rates, with the initial estimate of trip rates shown in Tables II-1 and II-2 developed to equalize total productions and attractions by trip type in the metro area. All other travel to/from housing units is then considered to be home-based other trip productions. To avoid negative values initially calculated for four zones near the downtown area, the last term of the logarithmic regression equation shown earlier is adjusted to (vehicles/du + 1.0). The rest of the travel going to and from businesses are allocated between home-based non-work and non-home based trip types--initially based on Reference #13 and adjusted where needed to equalize productions and attractions for all home-based other trips in the metro area. Non-home based productions and attractions (except for those modeled separately at the end of the work trip chain) are expected to equal each other for each traffic zone and each hour of the day.

The allocation of external-internal trips to various trip types was done for the 1990 model based initially on the patterns found in the 1965 Travel Survey done for this urban area (Reference #16) and then adjusted for 1990 Census journey-to-work data, with the ratio of total home-based trip productions to home-based trip attractions set based on the Census estimate of the ratio of workers who live outside the metro area and work inside to those workers who live inside and work outside the metro area (Reference #32). For the 1994 model application, figures were adjusted based on 1993/94 traffic counts, growth in metro area employment relative to population, school locations and district boundaries, and adjusted to ensure internal equalization of trip productions and attractions by trip purpose.

Vehicle travel per employee to retail and service businesses located in zones in the downtown area are assumed to be considerably less than for comparable businesses outside downtown, based on the supposition that downtown retail and service employees attract mostly walk-in customers from adjacent office buildings, rather than driving customers. The rates developed are based on the patterns found in the Denver metro area travel survey (Reference #13). Reduced vehicle trip rates per retail employee also apply (to a lesser degree) to major shopping malls, where typically the anchor tenants (department stores) attract the (vehicular) customers while other stores typically attract customers as they walk inside the mall. For these malls (but not downtown), travel data from ITE is available to quantify the reduction in vehicle travel and, to some degree, estimate the differences from other retail in terms of the share of home-based versus trip-chain travel (Reference #9).

Due to pavement and geometrical design needs, truck travel (both "single unit" and "combination" trucks) is also estimated. However, this is not regarded as a separate trip purpose per se. The truck traffic generation is estimated as a function of land use in each zone within other trip purposes based initially on a survey done in the Phoenix metro area (Reference #14), and then distributed and assigned to a street network modified to reflect the established truck routes in the metro area, than modified where necessary based on a comparison of modeled volume to truck traffic counts. The modified network takes into account travel time differences by type of vehicle due to acceleration/deceleration characteristics at traffic-controlled intersections (stops and signals). To "get around" traffic assignment problems that could arise with car traffic not being modeled, the modified network starts with coded speeds based on equilibrium travel times from the all-vehicle model runs, a free-speed multiplier reduced to 1.0, and a multi-iteration assignment that effectively "double counts" intersection delay (as acceleration/deceleration characteristics of trucks are considerably different from cars). This effectively makes the truck forecast a "post-assignment" model application.

Hour of day of travel

It is necessary to supply information about the time of day that travel is made when conducting any type (single-hour, multi-hour, or full-day) of forecast, so that the traffic assignment routines can properly gauge the expected level of congestion in the roadway network. Information on traffic volumes by hour of day comes from the Cedar Rapids and Iowa DOT traffic counting programs for specific street segments, and from local and ITE field studies for specific land developments. Information on travel by hour of day by purpose and direction, as shown in the bottom half of Tables II-1 and II-2 come from a variety of sources. The 1990 Census journey-to-work data for this metro area (Reference #32) is used to develop the hour of day pattern for trips from home to work, for both the metro area as a whole and for specific zones. Local and ITE field studies help determine peak hour percentages of daily travel and directional patterns during the peak hours for different types of land uses. Surveys of the public in other cities, most notably the NPTS, and the update to the original QRS manual (Reference #11) helped estimate (initially) the hour of day and direction for non-work travel purposes. These hour-of-day distributions for all purposes were then adjusted to match the distribution found in the traffic counts.

As shown in Tables II-1 and II-2 comparing the second and final adjustments to the hour of day distribution, there is about a 25% RMS difference in travel percentages by purpose, direction, and hour of day for both the weekday and full-week patterns, indicating that the Census, NPTS, and other surveys are not accurately replicating the actual hour-of-day travel pattern in this metro area.

There are four distinctive travel periods in a day based on traffic volumes, patterns of travel, signal timing plans, and quantity of transit service available. These are the morning peak period, midday, afternoon peak period, and evening/night period. Within these periods, individual hours of the day that can be used as “design hours” for particular streets projects based on their location and surrounding land use are:

1) AM peak hour (7 a.m. - 8 a.m. at most locations, 8-9 am at some school locations)
2) Noon hour (12 - 1 p.m. for areas with high concentrations of restaurants and office workers)
3) PM peak hour (4:30 - 5:30 p.m. at most locations, earlier at school locations based on type of school)

For the 1994 model update, unlike the 1990 model, estimates of work travel by hour of day by zone are developed, as the time-of-day pattern of work travel does vary considerably by zone. Much of this can be attributed to the type of industry, but Census Transportation Planning Package data does not provide an explicit time-of-day breakdown of journey-to-work by industry as it does for individual zones. Therefore, when modeling travel for individual hours of the day, adjustments can be and are made where justified by BOTH Census journey-to-work data and hourly traffic count data.

Adjustments for weekday and holiday travel patterns

As peak travel hours normally occur on weekdays, and weekday travel patterns are different from weekends, trip generation and hour-of-day patterns were developed for weekdays when school is in normal session (i.e. not summer school), which provides the starting point for estimating “design hour” traffic characteristics as described in the next section. This was done by researching trip generation differences by land use on weekdays and weekends. For most streets, weekday travel volume is higher than on weekends, as documented in counts at “permanent” count sites maintained by the Iowa DOT (Reference #23). On weekdays when school is in session, 24-hour traffic counts on the average are about 6% higher than AADT, but this will vary on individual streets depending on the mix of surrounding land uses.

The holiday adjustment primarily involves increasing travel to retail shopping areas, based on Christmas season trip generation studies documented in the ITE Trip Generation manual. Traffic counts used to analyze the acceptability of modeled volumes come from a recent study of a arterial street adjacent to one of the two major shopping malls in the metro area (Reference #44).

Determination of factors for design hour and peak-hour factoring (PHF)

For future-year project design needs, determination of the adjustments to the percentage of travel by purpose during the peak travel hours is made based on ATR station data. It had been previously estimated that design hour (30th highest hour in a calendar year) traffic volumes for the AM and PM peak periods are estimated to be about 15% higher than the average percentage of travel occurring during the 7-8 am and 4-5 pm periods, respectively (comparing Reference #21, full-week average, to Reference #23). A portion of this increase has already been accounted for in the previously-described setup of weekday (Monday-Friday with school in session) time-of-day factors by purpose, and the remainder is accomplished with a common factoring of all trip purposes/directions.

The QRSII software cannot explicitly model variation in traffic flows within the one-hour peak period, and therefore implicitly calculates travel time and delay assuming uniform traffic flow within that period. For the purpose of calculating future-year travel times for both typical weekday peak hours and "design hours," a separate factoring of the hourly rate file by trip purpose has been prepared. As with the hourly distribution of daily travel, incorporation of the PHF within the model process pre-assignment allows for the PHF to be calculated as a function of land uses (and trip purposes) served by a section of street and the degree of traffic congestion, rather than as a fixed post-assignment adjustment factor.

Unlike the factoring done for the design hour volume file, there are clear differences in the PHF by trip purpose. From local field studies, peak hour factors in the .6 to .7 range have been observed at access drives to offices and schools (References # 37 and 38). For other purposes such as shopping, these factors tend to be much flatter as (other than store opening/closing times) there are no formally-established arrival/departure times as exist at the workplace and schools. Utilizing the available inventory of peak hour counts on major streets with 15-minute interval data (Reference #39), peak hour factors by purpose were developed from two independent equations (observed AM and PM peak hour factors with previously-established percent breakdowns of travel by purpose) and three unknowns (PHF for trips from origin to work/school destination, PHF for these purposes from the work/school destination, and PHF for other purposes in both directions). The third unknown was solved first based on PM peak hour counts at a shopping mall driveway (PHF found to be .95), and then the first two PHFs solved by simultaneous equations as shown below.

AM peak hour: (.604)/(work/school factor P->A)+(.035)/(w/s factor A->P)+(.361)/(.95)=1/AMPHF
= 1.146 (observed)

PM peak hour: (.039)/(w/s factor P->A) + (.233)/(w/s factor A->P) + (.728)/(.95) = 1/(PM PHF)
= 1.084 (observed)

The coefficients represent the percentages of travel covered by the subject purpose/direction during the respective peak hour of travel. From this, initially established PHF's are .85 from origin to work/school destination and .64 when leaving from these destinations, as well as .95 for the other purposes (home-based other and non-home based trips that are not part of the "work chain").

The QRSII software also cannot estimate variations in traffic flows between one-hour periods as a function of traffic congestion (commonly called "peak spreading"). However, it cannot be determined if this is an issue that warrants study and resolution for this model application. A nationwide study of traffic by hour of day collected at permanent count stations (ATR's) indicates that the percentage of daily volume occurring during peak travel hours is actually higher now than during the 1970's and early 1980 when overall traffic volumes were lower (Reference #48). This indicates that peak spreading is not significant outside of a handful of the most congested streets and highways in the nation and/or such spreading is offset by other factors such as changes in the distribution of travel by purpose. Locally, the highest volume ATR on Interstate 380 does show a reduction in peak hour percentage of daily travel over time as daily travel increases, but it is not known if this constitutes spreading or just a changing in the travel purposes found at that location.

Truck Traffic

For pavement and geometric design purposes, average daily truck traffic by type of vehicle (single-unit or combination vehicle) is estimated and traffic patterns modeled. As with design hour and peak hour-factors, the idea behind this is to ensure the forecasts reflect the land uses served by a section of street, instead of a post-assignment factoring based on historical data that may not hold in the future. Trip generation rates are initially based on a study done for the Phoenix metropolitan area that have been incorporated into a TMIP-sponsored reference manual on truck forecasting (Reference #14) due to lack of truck information in standard trip generation manuals.

D. Trip Distribution

As shown in Tables II-1 and II-2, equilibrium trip-length averages from the 1990 model were about 9 ½ minutes for home-based work trips and about 7 ½ minutes for other types of trips. 1990 Census Journey-to-Work data made available after the model calibration, however, shows that home-based work trips should have averaged about 11 minutes, and with a more even distribution of travel times by minute than used in the 1990 model (References #32 & 36). Since the 1990 model had modeled volumes at count locations within 1% of those traffic count totals, an increase in trip length for one trip purpose means that a reduction would have been needed in either overall trip generation or average trip lengths for other trip purposes. The result, as shown in Tables II-1 and II-2, shows a variety of changes are being used to try to match overall traffic patterns.

Multiple-iteration trip distribution is used to insure that modeled trip destinations to each zone would be within 1% of initial calculations from the trip generation process. These extra iterations, however, can and do alter the average trip lengths for each trip type. Impacts are discussed in Section III-D of the report.

E. Mode Split

Current public transit ridership in the metro area is about 4,200 riders per weekday. Given local field-measured vehicle occupancy rates and vehicle trip generation rates, this makes the transit mode split about ½ of 1% of all motorized person trips, which makes development of a mode split model difficult to justify and even more difficult to develop with the proper statistical confidence. Even for workers who work in downtown Cedar Rapids, transit mode split in 1990 is only estimated to be about 3% (Reference #32). (RPC staff does review ridership data and how ridership is affected by changes in services, which has allowed for development of "off-model" means of determining benefits of transit service projects for the local allocation of federal funding in the TIP. This review is ongoing and will serve as the basis of development of a mode-split component to the model if future circumstances require.) Ridership figures by individual route for Fiscal Years 1994 and 1995 are shown in Appendix H.

F. Traffic Assignment

Traffic assignments are developed within a multi-iteration "feedback" loop that includes zone-to-zone shortest path determinations and trip distribution. The overall methodology, often referred to as the "Method of Successive Averages" (MSA), allows for an equilibrium assignment solution to be developed with a relatively small number of iterations through the full model application. For any particular iteration in the process, the vehicle trip table and assignment to the street network developed during that iteration is averaged with those developed during previous iterations so that the shortest paths through the network connecting all zones developed for the next model iteration is accomplished with a minimum of oscillation. Mathematically, the weight given to the iteration in progress is one divided by the total number of iterations to that point, so that all iterations end up weighted equally in the final solution.

At the beginning of the model application process, travel times on all street segments are based on free flow speeds. Subsequent travel time calculations for any time period from 1 to 24 hours are calculated after traffic assignment (and before the next iteration of shortest path determinations and trip distribution) as:

Free flow time + Average intersection approach delay +
{B*((total volume/one-hour saturation flow on through lanes)^X) *
summation (probability of vehicle assigned to a 1-hour period ^(X+1)) over all hours in analysis period}

Intersection delay is based on the turning movements and the traffic control in the downstream direction of the street segment, and averaged over all turn movements and hours of the analysis period. (This includes both stopped delay as calculated by HCM methods and standard rates of acceleration from and deceleration to stops from the coded speeds.) Coded saturation flows are based on the calculations shown in Appendix B and are interactively adjusted where necessary for left and right turns made from lanes shared with through movements. Free flow times are calculated from coded speeds and multiplied by a calibrated "free speed" factor. For this equation, volumes for two-lane streets and highways includes 40% of opposite-direction volume on the street based on the guidance from Chapter 8 of the HCM. B and X are calibrated coefficients as discussed in the next section of the report.

(In the current planning environment, it cannot be stressed enough that saturation flow on arterial streets is NOT the same as a street's traffic-carrying capacity. Capacities on individual streets (even by number of lanes and "area type") vary considerably by time of day and traffic flow conditions. This variability is dramatized in Table IV-6 later in this report showing calculated intersection approach capacities as an end result of peak-hour traffic forecasts.)

Travel path selection criteria is explicitly made on the basis of travel time alone. The practice of having the first iteration of path selection based only on free-flow speeds provides some informal weighting to distance in the overall traffic forecasts, as the practical effect of this is to favor city streets with lower operating speed streets with more direct routing to travel destinations over more indirect but higher-speed facilities such as freeways.

For one-hour traffic forecasts for freeways and other multi-lane roads with uninterrupted flow, this equation reduces to what is popularly recognized as the "BPR formula" (Reference #19). The most important difference between the BPR formula and the one utilized for this model application, in addition to intersection delay, is the ability to model a multiple-hour or full-day period without establishing separate peak and off-peak coded speeds on streets and highways, which is common practice at many planning agencies. This practice adds considerably to computer run times for forecasting, which often becomes the "justification" for not adopting a feedback mechanism to ensure travel time calculations for traffic assignment are consistent with those used for trip distribution (Reference #40).

On arterial streets, coded speeds and delay at intersections are the most important determinant of travel time. Therefore, it is primarily on freeways and rural highways where the setting of the B and X parameter values can significantly impact travel time and travel assignment/diversion forecasts. The parameters were initially set to the equilibrium values from the 1990 model. It was anticipated that as part of model calibration adjustments would be needed, as recent growth in travel on freeways in the metro area exceeds the pace forecasted previously. This may indicate that even though the two freeways in the metro area were open for several years before 1990, the motoring public may still be adjusting to their presence. Travel habits are often slower to change than model predictions, which assumes perfect knowledge of travel route alternatives that people often do not explore until they change jobs, workplaces, or favorite places to shop or recreate.

For truck traffic assignments, the following modifications are made. First, initial coded speeds are re-set to the final calculated travel speeds from the general daily traffic forecast. A multi-iteration truck travel assignment with (added) intersection delay thus reflects the added acceleration/deceleration delay that trucks as experience relative to cars and vans. (The free-speed multiplier is re-set to 1.0.) Second, to reflect legal restrictions on the movement of through trucks on all but specifically-designated truck routes, volume/delay curve parameters are radically changed for the functional classes of minor arterial and lower to discourage their (modeled) use. The initial values used for these curves are B=1.9 and X=0.5.

III. CHANGES IN MODEL PARAMETERS MADE FOR VALIDATION

A. Development of the Street and Highway Network

Some of the coded speeds for street sections were changed as discussed in Section D.

B. Estimate of Daily Vehicle Trips

The only trip generation adjustment made for average daily forecasts were for the Kirkwood Community College zones, as the comparisons between initially modeled and counted traffic on the main access roads indicate that ITE trip generation rates for community colleges are too low for traffic volumes measured on and near Kirkwood College. For weekday (Monday-Friday) forecasts when school is in session, adjustments were made to overall trip generation for a limited number of land uses where the weekday/full-week ratio is not well documented and the need exists to get overall weekday volumes to about 6% higher than full-week averages, as found from data collected at ATR stations throughout the state of Iowa (Reference #23).

For truck travel, adjustments were made to the trip generation rates of several zones. For the industrial zones on the south side of the metro area (including the airport), initial trip rates for single-unit trucks are doubled for zones south of U.S. Highway 30. For combination trucks, the trip rates are increased 100% for those zones north of US 30 (zones 216-219, 221-225, and 255) and 300% for the zones south of US 30 (zones 230-231 and 236-246). For the Rockwell Collins zones (zones 81 and 82), the trip rates for SIC code 01-51 employment were changes to the rates for office/service employment (SIC codes 60-89).

C. Trip Distribution

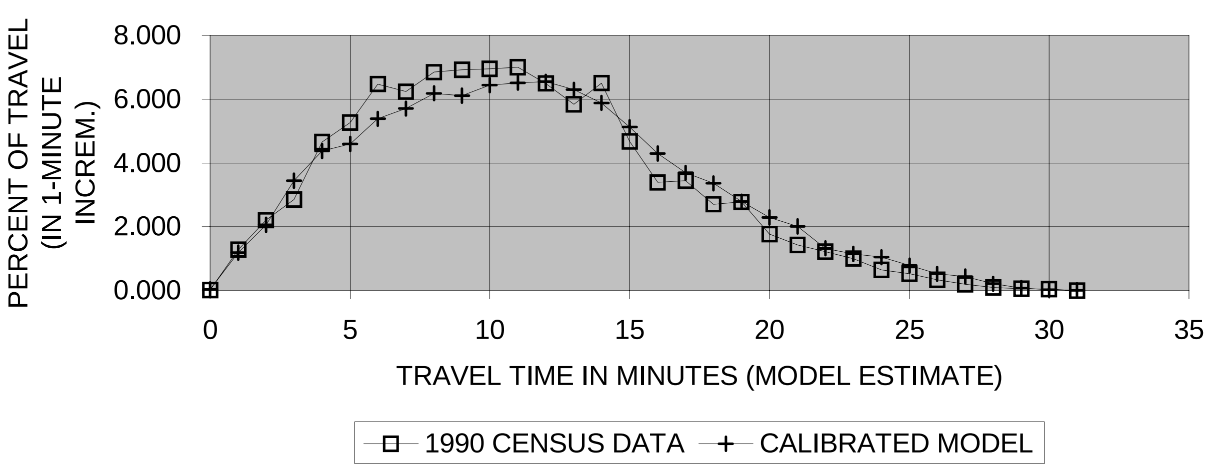
Initial trip-length estimates by trip purpose are revised in order to bring the total modeled average daily traffic at the 1994 traffic count stations in Cedar Rapids to within 1% of the sum of the traffic counts at those locations. The comparison of initial and final trip length averages for daily travel is shown in Table III-1. A slight increase in work trip length from the 1990 Census for 1994 is deemed reasonable in light of increasing numbers of workers commuting in from outside the metro area (from a comparison of employment and workforce trends from References #7 & 31). Modeled traffic at IDOT's count locations for the 1993 traffic count program was 15% higher than the sum of IDOT's counts. (However, it was found that for the 96 locations counted by both IDOT in 1993 and Cedar Rapids in 1994, the sum of the 1994 counts was about 11% higher than the sum of the 1993 counts.) The initial 10 trip purposes identified for trip generation are consolidated into four purposes for the trip distribution and hour-of-day summary reports, with home based school trips combined with the non home based-work chain trips, through trips combined with the other non-home based trips, and the airport supplemental trips split between home-based other (the residentially-based) and non-home based (business-based). Home-based work trips are estimated to average about 11 ½ minutes in length in 1994, other purposes combined about 8 minutes.

Table III-1
Initial/Final Estimated Trip-Length Averages by Consolidated Trip Purposes (7-day averages)

	Initial Estimate (From trip generation)	Final Values (calibrated)	Percent Change Initial to Final
Home-Based Work	11.0 minutes	11.4 minutes	4% increase
(Non-Home Based Work Chain plus Home-Based School)	6.6 minutes	6.7 minutes	2% increase
Other Non-Home Based	7.0 minutes	7.45 minutes	6% increase
Other Home-Based	8.1 minutes	8.6 minutes	6% increase

Figure III-1 shows the modeled trip-length distributions for home-based work trips compared to the 1990 estimate based on the 1990 modeled travel times and the 1990 Census journey-to-work findings (References #32 & 36). Figure III-2 shows the modeled trip-length distributions for the other three consolidated trip purposes listed above.

FIGURE III-1 HOME-TO-WORK TRIP LENGTH DISTRIBUTION COMPARISON OF 1990 CENSUS TO 1994 MODEL



For the AM and PM peak hours of travel, distribution parameters were altered (see Appendix G) to increase modeled trip lengths, due to forecasted volumes at count stations being less than the estimate of count totals using the full-day distribution parameters. The comparison of final average trip lengths to the daily estimate by trip purpose is shown in Table III-2. Given comparable travel distances, travel times would be expected to be longer in peak hours (especially the afternoon peak) than off-peak hours due to congestion levels. The dilemma encountered in modeling the morning peak hour is that efforts to boost total traffic volumes to match counts also increased RMS error levels. Therefore, the sum of AM peak modeled volumes were left at considerably less (10%) than the sum of traffic counts for the Cedar Rapids count locations.

FIGURE III-2 TRIP LENGTH DISTRIBUTION BY PURPOSE
1994 MODEL CALIBRATION

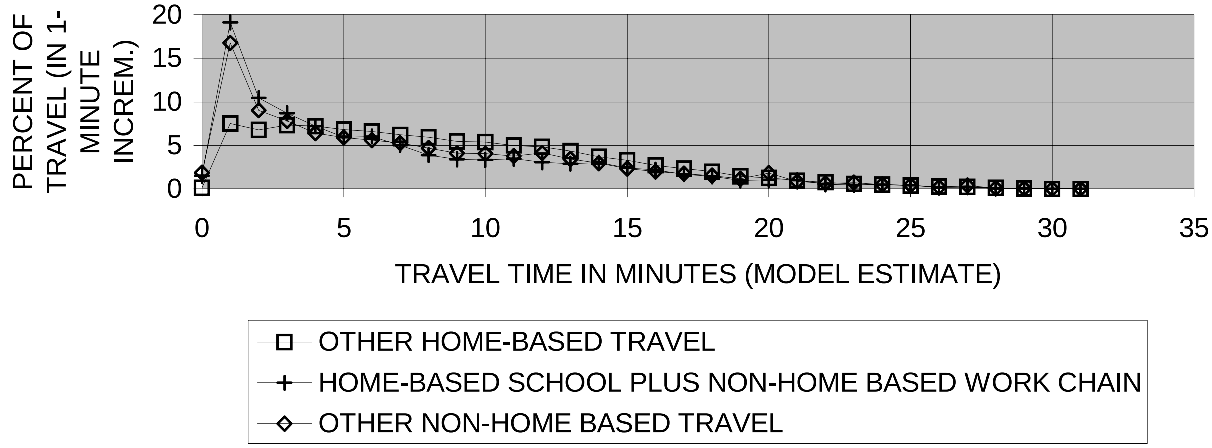


Table III-2
Estimated Average Trip Length by Consolidated Trip Purpose and Time of Day

	24-Hour Average	AM Peak (7-8 am)	PM Peak (4-5 pm)
Home-Based Work	11.45 minutes	11.3 minutes	11.9 minutes
(Non-Home Based Work Chain plus Home-Based School)	6.7 minutes	6.9 minutes	7.1 minutes
Other Non-Home Based	7.45 minutes	7.4 minutes	7.8 minutes
Other Home-Based	8.6 minutes	8.6 minutes	9.0 minutes

For truck traffic modeling, as in other cases, trip length averages are adjusted to match the sum of observed truck traffic counts. Final average trip lengths for truck travel are estimated to be:

Single-unit trucks:	Internal travel:	8.9 minutes
	Through travel:	18.4 minutes
Combination trucks:	Internal travel:	13.6 minutes
	Through travel:	19.2 minutes

D. Traffic Assignment

The "BPR curve" parameters B and X discussed previously were adjusted on a trial-and-error basis in concert with other changes with the primary focus on better replication of the general freeway/arterial volume split. The calibrated parameter values are significantly different from those values that fit volume/speed relationships for freeways found in the HCM. For the 1990 model, parameter values of B=.9

and X=1.5 were used for all functional classifications. For the 1994 calibration, the coefficient for X was raised to 2.25 for both freeways and major arterial streets, and kept the same as 1990 for the "lower" functional classes. For modeling truck traffic, substantial changes are made to keep "through trucks" off streets that are not legally-designated truck routes. For single-unit trucks, parameter values of B=3.5 and X=0.2 are used for classifications of minor arterial and lower. For combination trucks, the BPR exponent values used for major arterials are B=2.0 and X=0.6. Several streets were also functionally "re-classified" due to truck route designations and to improve validation, including Blairs Ferry Road, Edgewood Road (for combination trucks only), 2nd and 3rd Avenues in the downtown area, 33rd Avenue between I-380 and 6th Street, Waconia Street east of the U.S. 30 interchange, and Wiley Boulevard north of 16th Avenue SW.

Coded travel speeds on Interstate 380 near downtown Cedar Rapids, as in the 1990 model application, were kept below posted speed limits to help validate the model and to reflect the sharp curves and closely-spaced on and off-ramps, which serve to reduce operating speeds relative to other sections of this freeway with the same design speed and posted speed limits.

Another means of reducing modeled freeway volumes relative to arterials that was implemented are additional turn movement penalties at freeway on/off ramps. Through-movement penalties were also introduced at several bridge crossings where initial model volumes greatly exceeded counts.

As discussed earlier, the free-speed multiplier was changed from the 115% of coded speed used in 1990 to 120% for the 1994 model application, while coded speeds on most streets that are posted at 35 mph or lower were adjusted upward. This was done to allow coded speed/free speed ratios as a function of posted speed limit to more closely approximate research findings sponsored by the U.S. DOT's TMIP program (Reference #8). Typically, a street with a posted limit of 35 mph had a coded speed 2.5 mph higher, while streets with posted limits of 30 mph and below had coded speeds 5 mph higher. For final calibration of the model, changes to these coded speeds were sometimes necessary. Coded speeds were allowed to deviate 10 miles per hour (plus or minus) from the posted speed limit after the previously-described adjustments.

The peak-hour factor for work and school trips (attraction -> production direction) was changed from the initial value of .64 to .75, based on comparisons of modeled to observed peaking characteristics at 10 major intersections in the metropolitan area (see Appendix J).

IV. MODEL PERFORMANCE

The tables and charts shown in this section indicate the level of discrepancy that remains between the modeled and field-counted traffic volumes and travel times.

A. Average Daily Traffic

1. All Vehicles

A summary of modeling error levels is shown in Table IV-1. This table is based on the traffic count data shown in Appendix E, and a detailed breakdown of calibration error at specific locations is shown in Appendix F. The calibration standards used include the U.S. DOT's planning error guidance (Reference #19) and expected traffic count error (Reference #35).

TABLE IV-1
COMPARISON OF MODELED TO COUNTED TRAFFIC VOLUMES
A) CEDAR RAPIDS TRAFFIC ENGINEERING DEPARTMENT 1994 COUNTS (Reference #21)

Volume (AADT) Range	Number of Counts Taken	Average Count/ forecast	Average Difference From Count	(%)	% of Counts Meeting FHWA's Planning Error Standard	% of Counts with Error Less than Standard Deviation of One-day Count (From AADT) Unfactored	Factored
0-4999	407	2,816	3,021	51.1	63.1	29.2	21.9
5000-9999	218	7,148	6,685	26.2	78.0	35.8	29.8
10000-14999	61	12,386	11,647	16.2	96.7	49.2	31.2
15000-19999	35	17,082	17,898	12.9	94.3	54.3	42.9
20000-40000	62	25,655	26,111	10.4	95.2	54.8	43.6
ALL	783	7,214	7,207	36.5	73.8	35.8	27.5

Overall Root Mean Square Error = 2136, %Rms Error = 29.6

B) IOWA DEPARTMENT OF TRANSPORTATION 1993 COUNTS (REFERENCE #22)

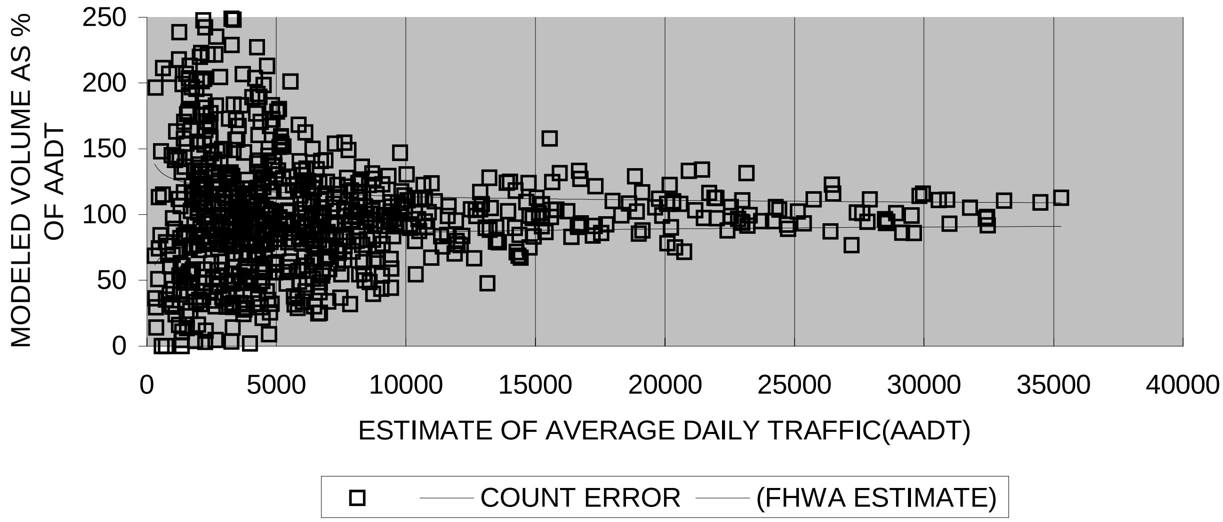
Volume (AADT) Range	Number of Counts Taken	Average Count/forecast	Average Difference From Count	(%)	% of Counts Meeting FHWA's Planning Error Standard	% of Counts with Error less Than Standard Deviation of One-day Count (From AADT) Unfactored	Factored
0-999	88	347	643	142.6	51.1	30.7	28.4
1000-4999	118	2,703	3316	48.6	69.5	32.2	28.0
5000-9999	35	7,461	8209	28.9	68.6	40.0	28.6
10000-40000	23	16,759	17939	17.3	87.0	47.8	39.1
ALL	264	3,773	4347	74.6	64.8	34.1	29.2

Overall Root Mean Square Error = 1949, %RMS Error = 51.7

Root Mean Square=square Root of ((Sum of ((Observed-simulated Volume)^2))/(# Counts -2))
% RMS = (Root Mean Square / Average Traffic Count Value) * 100

Figures IV-1 and IV-2 show graphically the error rates and error standards for the different (counted) levels of traffic volume. It should be noted that FHWA's estimate of traffic count error is based on unadjusted counts (Reference #35). Counts conducted locally are factored based on the day of week and month taken, and the author estimates that this factoring reduces count error by about 25% (Reference #29). Therefore, the number of count locations with model error less than a factored count error is estimated to be 28% from CR TED counts and 29% from Iowa DOT counts.

FIGURE IV-1
MODELED VS COUNTED TRAFFIC IN '94-CRTED



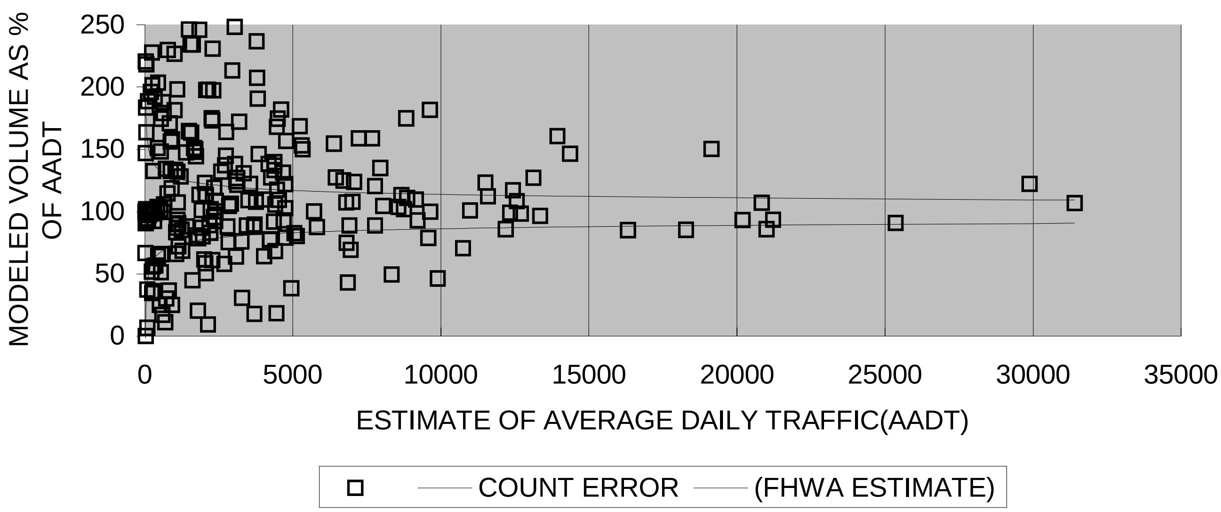
Shown in Table IV-2 is, for different levels of traffic volume, whether the model error is significantly different than the unfactored traffic count error as published by the FHWA (Reference #35). Consistent with the previous model calibration of 1990, count locations over 15,000 ADT generally speaking have model errors that are not significantly different than the sample error one could expect from a one-day traffic count to estimate AADT.

TABLE IV-2
COMPARISON OF MODEL ERROR TO SAMPLE TRAFFIC COUNT ERROR
A) CEDAR RAPIDS TRAFFIC ENGINEERING DEPARTMENT
1994 DAILY COUNTS (Reference #21)

Volume (AADT) Range	Number of Counts Taken	Average Difference from Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different From Count Error?
0-4999	407	51.1	48.3	46.4-55.8	21.2	YES
5000-9999	218	26.2	20.6	23.5-28.9	15.4	YES
10000-14999	61	16.2	11.1	13.3-19.0	12.9	YES
15000-19999	**35**	**12.9**	**11.8**	**8.9-17.0**	**11.6**	**NO**
20000-40000	**62**	**10.4**	**8.2**	**8.3-12.5**	**10.1**	**NO**
ALL	783	36.5	40.0	33.7-39.3	17.6	YES

B) IOWA DEPARTMENT OF TRANSPORTATION 1993 DAILY COUNTS (Reference #22)						
Volume (AADT) Range	Number of Counts Taken	Average Difference From Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different From Count Error?
0-999	88	142.6	203.7	99.4-185.8	46.2	YES
1000-4999	118	48.6	47.1	40.0-57.2	21.3	YES
5000-9999	35	28.9	23.4	20.9-36.9	15.2	YES
10000-40000	**23**	**17.3**	**15.8**	**10.5-24.2**	**11.9**	**NO**
ALL	264	74.6	131.6	58.7-90.5	28.0	YES

FIGURE IV-2 MODELED VS COUNTED TRAFFIC FROM IDOT'S 1993 COUNT LOCATIONS



The Iowa DOT maintains 4 “permanent” traffic count stations within the metro area, all in Cedar Rapids, (Reference #23) which record traffic data continuously. (All other traffic counts are a one-day count taken during a roughly 7-month counting season, and then factored for the Annual Average Daily Traffic.) Table IV-3 indicates how modeled traffic compares to the annual average daily average traffic volume at these stations. With all three sets of traffic counts combined the overall error of prediction (% RMS error) was found to be about 34%.

TABLE IV-3
Traffic Count and Forecast Information from Permanent Count Stations Maintained by the Iowa DOT

Count location	Counted Volume	Modeled	Modeled volume is . . .
Interstate 380 at J Avenue NE	68,504	67,945	0.8 % too low
Interstate 380 s/o Wilson Ave SW	50,302	54,828	9.0 % too high
Johnson Avenue NW west of Janice Drive	10,091	10,887	7.9 % too high
Iowa Highway 922 east of U. S. 30	7,267	4,096	43.6 % too low

2. Truck volumes

Using 76 traffic count locations where vehicle classification data is available (References # 22, 24, and 39), % RMS error is shown below. The initial error of prediction compares modeled truck volume to counted truck volume, while the error of prediction of percent trucks in modeled volume compares the ratio of modeled trucks to modeled AADT in 1994 to the ratio found in the traffic counts. A detailed table showing all count locations is included in Appendix F.

TABLE IV-4
COMPARISON OF MODELED TO COUNTED TRUCK TRAFFIC VOLUMES

Vehicle classification	Average count	% RMS error-truck count	% RMS error-percent of volume
Single-unit trucks	406	39%	
Combination trucks	291	49%	
All trucks	697		59%

B. Typical Weekday and Peak Hour Volumes

Model performance in measuring daily and peak hour volumes during a typical (school in session) weekday is also evaluated. Adjustments made to trip generation factors led to modeled traffic volumes on city streets at count locations that are about 5.65% higher (6% higher volumes overall with freeways included). The comparison of weekday modeled volumes to counts adjusted to 105.65% of estimated AADT led to no appreciable change in summary model error as shown in Appendix F although some appreciable changes can be found near school locations.

Summary statistics are shown below for peak hour traffic counts and modeled volumes. A detailed comparison by location is shown in Appendix F. Sample traffic count error shown in this table (unfactored) assumes that a location's PM peak hour error is the same as the 24-hour count error for that location, and that AM peak hour error can be determined as if it were the 24-hour count - consistent with findings from the hourly count data from the Johnson Avenue permanent count station (Reference #29). Pending a more detailed evaluation of field data, however, no conclusions are made regarding the comparison of AM peak hour model application error to traffic counting error.

TABLE IV-5
SUMMARY OF MODEL VALIDATION TO PEAK HOUR TRAFFIC COUNTS
A) RMS ERROR SUMMARY

Count Hour	Agency	Average # Counts	Avg. Count	Forecast	% RMS Error	% of Count Locations With Error Less Than Counting Error
7-8 am	Cedar Rapids	783	471	423	40.4%	*
7-8 am	Iowa DOT	264	263	256	55.2%	*
4-5 pm	Cedar Rapids	783	625	625	35.9%	32.4%
4-5 pm	Iowa DOT	264	322	368	57.2%	33.7%

B) CEDAR RAPIDS TRAFFIC ENGINEERING DEPARTMENT 1994 AM PEAK COUNTS

Volume (AADT) Range	Number of Counts Taken	Average Difference From Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different From Count Error?
0-799	648	44.5	41.5	41.3-47.7	*	*
800-9999	135	22.2	13.7	19.9-24.5	*	*

C) IOWA DEPARTMENT OF TRANSPORTATION 1993 AM PEAK COUNTS

Volume (AADT) Range	Number of Counts Taken	Average Difference from Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different From Count Error?
0-799	241	85.2	164.4	64.3-105.1	*	*
800-9999	23	22.3	11.6	17.3-27.3	*	*

* Due to the use of daily volume error rates to match FHWA chart values, count error in most categories are found to EXCEED model errors. Given lack of field studies to anchor the assumption that AM peak model error is based on the daily volume count rather than the smaller AM peak count, no finding is published.

D) CEDAR RAPIDS TRAFFIC ENGINEERING DEPARTMENT 1994 PM PEAK HOUR COUNTS

Volume (AADT) Range	Number of Counts Taken	Average Difference from Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different From Count Error?
0-999	643	42.9	46.0	39.3-46.5	19.0	YES
1000-9999	140	18.2	14.5	15.8-20.6	11.3	YES

E) IOWA DEPARTMENT OF TRANSPORTATION 1993 PM PEAK HOUR COUNTS

Volume (AADT) Range	Number of Counts Taken	Average Difference From Count (%)	Standard Deviation	Range of 95% Confidence Interval (%)	Average Error of Field Count (%)	Forecast Error Significantly Different from Count Error?
0-999	243	95.6	185.8	74.7-116.5	29.4	YES
1000-9999	21	20.4	15.4	13.4-27.4	11.9	YES

Finally, as discussed earlier in the report, intersection approach capacities during the peak hours are shown below. The variability in such capacities, even when accounting for number of lanes and area type, is evident in the coefficient of variation statistic, which ranges from 15-20% for all-way stops to 40-45% for two-lane streets at signalized intersections and stop signed approaches where the cross street does not stop or yield.

TABLE IV-6
MODELED PEAK HOUR APPROACH CAPACITIES AT INTERSECTIONS

	AM peak hourly capacity			PM peak hourly capacity		
Location, number lanes, and traffic control	Average	SD	CV	Average	SD	CV
A. Signalized intersection approaches, downtown						
One thru lane on subject and crossing street*	709	257	36%	584	206	35%
One thru lane, 2 + lanes on crossing street*	689	284	41%	603	281	46%
2 + thru lanes, one lane on crossing street*	1598	647	40%	1617	493	30%
2+ thru lanes on subject and crossing street*	1613	614	38%	1557	688	44%
B. Signalized intersection approaches, other locations						
One thru lane on subject and crossing street*	706	185	26%	728	286	39%
One thru lane, 2 + lanes on crossing street*	533	210	39%	482	210	43%
2 + thru lanes, one lane on crossing street*	1790	476	26%	1889	523	27%
2+ thru lanes on subject and crossing street*	1316	472	35%	1443	537	37%
C. All-way stop approaches, all locations	854	137	16%	778	161	21%
D. Signed approaches at some-way stops**	1464	508	35%	1271	574	45%

* Exclusive left-turn lanes not included.
**Right-turn capacity not included.

C. Travel Time

Modeled travel times on streets are also compared to field-measured times, and used to estimate the benefits of individual major street and intersection projects. For the (7-day) average 24-hour period, vehicle-miles of travel in the metro area was found to total 3,266,106 and vehicle-hours of travel 98,737 (or an average speed of 33 miles per hour). These figures include travel on unmodeled local streets represented by “centroid connectors” and “intrazonal travel.”

A travel time survey of eight major arterial streets was conducted by the Regional Planning Commission staff in the summer of 1993 during midday and PM peak periods (Reference #30). A comparison of these surveys to modeled traffic flow indicates an average 14% difference between modeled travel times and surveyed times. For 72% of the 32 observations (corridor, direction, time of day), this level of error is within the 95% confidence interval of the survey findings. A detailed table is shown in Appendix F. While we do not know how this compares to the findings (if any) of other agencies, it does show that accuracy in predicting traffic volumes was not achieved at the expense of any reasonable travel time calculations.

The significance of this level of travel time accuracy is that there is no need for any “post-processing” of forecasts of travel time or vehicle-hours of travel for project benefit assessment and design needs, or for other applications such as "conformity" under the Clean Air Act that consumes a considerable amount of time and effort for many planning agencies around the country.

D. Comparison to Other Planning Agencies

Tables IV-7 and IV-8 indicate how the model application in this metro area compares to applications developed by other metro planning agencies around the country. The improvements compared to other agencies that have been achieved twice during the past five years are quite substantial, and have occurred in spite of the lower average traffic counts that occur in this metro area relative to the other metro areas. To provide a sense what specific actions have caused these improvements, the results from a student thesis project (Reference #47) are also shown in which the model application was run without any intersection controls to determine the impact on air quality calculations. Most of the improvement is shown to be directly related to the intersection modeling in lieu of the standard practice of assuming fixed street capacities. Other differences such as trip generation based on field studies rather than stated survey responses are shown to have had a more minor role, and primarily impact model accuracy on the lower-volume streets.

The lack of comparable studies from other planning agencies is due to relatively few agencies analyzing (and releasing for public view) their model performance in (the author's opinion) a statistically appropriate fashion. Many agencies instead use such methods as "screenlines" or correlation coefficients to measure model performance. Screenlines that aggregate traffic count locations tend to "hide" errors via the agglomeration of individual street traffic forecasts that are both higher and lower than field counts. The correlation coefficient can be misleading in the sense that it does not measure the discrepancy between forecasts and counts as much as the relationship between the two as a function of the size of forecast or count. This is dramatized by the fact that model applications in the Des Moines and Dallas metro areas, despite having RMS model errors much higher than the Cedar Rapids application (43% in Dallas and 48% in Des Moines vs 29% in Cedar Rapids), have better r-square statistics than Cedar Rapids (.94 in Dallas and .90 in Des Moines vs .88 in Cedar Rapids).

TABLE IV-7
COMPARISON OF %RMS ERROR IN DAILY TRAFFIC ASSIGNMENT TO OTHER METRO AREAS

Metro Area and Year		Volume Range (* 1,000 Vehicles per Day):							Number of Avg. Counts	Size
		-5	5-10	10-25	25-50	50-100	100+	Overall		
Cedar Rapids	**1994**	**60**	**32**	**17**	**11**	**5**		**29**	**783**	**7,350**
Cedar Rapids	**1990**	**55**	**32**	**17**	**15**	**6**		**29**	**735**	**7,246**
Phoenix	1993	80	44	29	26	11		37	4,467	9,703
San Diego	1995	n/a	55	39	32	28	12	39	n/a	n/a
Dallas	1998	n/a	58	41	32	21	15	43	5,203	n/a
Memphis	1995	78	70	51	32	27	30	45	423	22,763
Chicago	1992	85	46	41	38	14		47	7,096	10,671
Des Moines	1992	105	53	37	29	22		48	1,462	10,421
Quad Cities	1990	62	41	27	63			50	n/a	n/a
Washington	1990	n/a	67	49	43	21		50	6,184	13,315
Cedar Rapids Without Intersection Controls	1990	76	44	31	30	47		48	735	7,246

(References # 34, 41, 45, 46, 47, 50, 51, 52, 53, and 54)

TABLE IV-8
COMPARISON OF % RMS ERROR IN PEAK HOUR TRAFFIC ASSIGNMENT TO OTHER METRO AREAS

Metro Area and Year		Time Period	% RMS Error	Number of Average Counts	Count Size
Vancouver	‘96	PM Peak (1 Hour)	28	992	645
Cedar Rapids	‘94	PM Peak (1 Hour)	36	783	625
Albuquerque	‘92	PM Peak (2 Hours)	37	988	2,213
Phoenix	‘93	PM Peak (2 Hours)	40	1,293	2,368
Cedar Rapids	‘94	AM Peak (1 Hour)	40	783	471
Phoenix	’93	AM Peak (2 Hours)	51	1,286	1,797

(References # 43, 54, and 55)

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APPENDIX A – STREET SEGMENTS ADDED TO STREET AND HIGHWAY NETWORK SINCE 1990 (1994 CHANGES SHOWN IN BOLD)

A) ACCESS ROADS

Collins Access Road--Twixtown to Northland

I-380 Access Roads--8th Avenue to 27th Avenue SW

B) COMMERCIAL DRIVEWAYS

Lindale Mall (5)	**Lindale Mall access road--Collins Road to First Avenue**
Westdale Mall (5)	
Collins Road--east of 1st Avenue, two access drives between C Avenue and Northland, and one drive between Council and Rockwell	
Kirkwood College--south loop road to Kirkwood Blvd	
First Avenue--private drives facing Lindale Mall and Glenbrook Dr	
K-Mart Access Drive e/o Williams Blvd	**Linn-Mar schools access driveways**

C) STUB STREETS

27th Avenue SW--6th St to J St	**Country Club Parkway--Cottage Grove Avenue to 2nd Street SE**
Emmons Street (Hiawatha)--w/o Robins Road	
4th and 5th Avenues SE--e/o 19th Street	
Waconia Ave--w/o US 30 off-ramp to e/o 6th St	**9th Street SW--5th Avenue SW to Wilson**
Miller Road--e/o Kirkwood	
66th Avenue--w/o Kirkwood to e/o Kirkwood	**10th Street NW--First Avenue to E Avenue**
Ely Road--s/o Old River Road	
East Road--n/o US 30 (near Ely Road)	**North Pine Drive--s/o Blairs Ferry Road**
Hawkeye Downs--w/o 6th Street to J St	
16th Avenue--12th Avenue to 3rd St SE	**Leisure Drive--s/o Blairs Ferry Road**
2nd and 3rd Streets SE--12th Ave to 16th Ave	
2nd Street SE--s/o 1st Ave and n/o 8th Ave	**Wilder Drive--Mt Vernon Road to Bertram**
C Avenue NE--w/o 7th St	
Prairie Drive--Eastern to n/o 29th St	**Midway Drive--West Post Road to Johnson Avenue**

Golf Road--Old Marion Road to n/o 42nd St
Wenig Drive--n/o 42nd Street
Rockwell Drive--Collins to n/o Blairs Ferry

Jacolyn Drive--E Avenue to 16th Avenue

Northwood--Council to Robins
15th Street SW--1st Ave to s/o 8th Ave
B and E Avenues NE--e/o 20th St
21st Street NE--w/o 1st Ave (facing Cottage Grove)
J Avenue--e/o Oakland Road
F Avenue NE--s/o Old Marion Road and n/o Collins Road
Westwood--e/o Edgewood (facing Rogers Road)
Johnson Avenue--w/o West Post Road
Grand Avenue (Marion)--w/o 11th Street
35th Street (Marion)--n/o 10th Ave
44th Street (Marion)--n/o 10th Ave to s/o 10th Ave
Tama Street--s/o Marion Blvd
Armar Drive--s/o Marion Blvd
Glenbrook Drive--s/o 1st Ave
40th Street E--w/o C Ave and e/o 1st Ave
38th Street E--w/o 1st Ave to e/o 1st Ave
35th Street Dr--e/o 1st Ave
32nd Street Dr--e/o 1st Ave
27th Street NE--w/o 1st Ave
Bever Avenue--e/o 34th St and w/o East Post Road
Trailridge Road--w/o East Post (facing Bever)
42nd Street SE--s/o Mt. Vernon Road
40th Street SE--n/o Mt. Vernon Road
38th Street SE--n/o Mt. Vernon to s/o Mt. Vernon
10th, 15th, and 34th Streets SE--s/o Mt. Vernon
29th Avenue SW--e/o Edgewood Road
Trent Street--w/o Williams Blvd
51st Street NE--e/o Center Point Road and w/o Council St
42nd Street NE--from w/o Ushers Ferry to Edgewood Road
Ushers Ferry--from 42nd Street to Blairs Ferry Road
1st Avenue W--w/o Stoney Point Road and e/o Johnson Ave
8th Avenue NW--w/o Williams Blvd
3rd Avenue Marion--e/o 11th Street and e/o 35th Street
1st Avenue Marion--w/o 11th Street

APPENDIX B – HIGHWAY CAPACITY/SATURATION FLOW CALCULATIONS

Coded “capacities” in the street network file are based on the hourly through-lane saturation flow calculations from the Highway Capacity Manual. For most streets, ideal saturation is assumed to be 1800 vehicles per hour per lane, with 2000 used for facilities with a high degree of access control - freeways and expressways. Variables such as lane width, estimated percentage of heavy vehicles, on-street parking, and lane occupancy (with 2 or more through lanes each direction) were utilized to make the capacity calculations. The adjustment factors for left and right-turning traffic from shared lanes are not utilized directly, as these are determined as part of the traffic modeling process.

The calculation of the hourly through-lane saturation flow that is typically coded is shown in Table B-1. For each section of street, the coded saturation flow would be the “ideal” saturation flow listed times the adjustment factors for lane width, per cent heavy vehicles, street grade, bus blockage, and the presence and turnover of on-street parking. The coded saturation values based on these adjustments are shown in Table B-2. The values of the adjustment factors are explained in Chapter 9 of the Highway Capacity Manual.

As an example, on-street parking is assumed to exist on most two-way two-lane streets, but not on most two-way multi-lane streets. Research recently reported in the ITE Journal (Reference #33) indicates that streets with relatively dense commercial driveway spacing have saturation flow reductions comparable to on-street parking even if no such parking is on that street, so for planning purposes modeled arterials with these characteristics have coded saturation flows based on the on-street parking reductions.

Saturation flows in the downtown Cedar Rapids area are calculated assuming a large amount of on-street parking turnover, and then compared to a minimum saturation flow value used by the modeling software to determine the number of through-traffic lanes present on the street for intersection analysis. This assumed number of thru lanes is the coded capacity divided by 1800, then rounded to the nearest integer. In most cases, the calculated saturation flows downtown had to be adjusted upward to maintain the correct number of lanes. For one-way four-lane streets in the downtown area, the calculated saturation flow was so far below the “minimum” four-lane value that the coded saturation flow was adjusted upward only to meet the three-lane standard. For the purposes of traffic modeling, “downtown” streets are considered to be those streets where on-street parking is metered (Reference #27).

Table B-1 Calculation of thru lane saturation traffic flow per hour							
Two-way street: One thru lane each way:	Lane Ideal flow	lane width	%truck	Grade	Parking	Bus	Occup.
With on-street parking	1800	1.07	.99	.99	.80	1.0	1.0
No parking, 24+ft.wide	1800	1.00	.99	.99	1.00	1.0	1.0
No parking, 20-22 feet	1800	.93	.99	.99	1.00	1.0	1.0
Two lanes each way, no parking	3600	1.00	.99	.99	1.00	.99	.95
Two lanes, 10-11' each	3600	.93	.99	.99	1.00	.99	.95
Two lanes with parking	3600	1.00	.99	.99	.89	.99	.95
Three thru lanes each way	5400	1.00	.975	.99	1.00	.99	.91
Expressway, 2 lanes each way	4000	1.00	.98	.99	1.00	1.0	.95
Expressway, 3 lanes each way	6000	1.00	.965	.99	1.00	1.0	.91
One-way street:							
One lane	1800	1.00	.975	.99	.85	.99	1.0
Two lanes	3600	1.00	.975	.99	.85	.99	.95
Two lanes, no parking	3600	1.00	.975	.99	1.00	.99	.95
Three lanes	5400	1.00	.975	.99	.89	.99	.91
Four lanes	7200	1.00	.975	.99	.92	.99	.87
Freeways:	2 lanes each way: 4000 pcph ideal * .74 truck factor 3 lanes each way: 6000 pcph * .77 truck factor * .99 lateral clr (Assuming 2% grade, 12% trucks on 2-lane sections, 10% trucks on 3-lane sections, Et factor=4)						
Two-lane highways:	Rolling terrain, 60-100% no-passing zones, 12-foot lanes, 2-foot shoulders, 7% trucks, .95 PHF.						

The freeway capacities shown in Table B-2 are coded in areas downstream of on-ramps. For planning purposes, the capacity of an on-ramp is considered to be half the capacity of the outside freeway lane, or one-sixth the value of a three-lane freeway. The on-ramp capacity value is then subtracted from the freeway capacity immediately upstream from the on-ramp.

Table B-2
Hourly Through-Lane Saturation Flow Values Used

Two-way streets: One lane each way:	Downtown Streets	Other Streets
With on-street parking	910	1510
No parking, restricted width	--	1640
No parking	--	1764
Two lanes each way:		
No parking	--	3318
No parking, restricted width	--	3086
With on-street parking	2710	2954
Three lanes each way:	--	4696
Expressway, two lanes each way		3687
Expressway, three lanes each way		5218
One-way streets		
one lane	--	1462
two lanes	2710	2778
two lanes, no parking	--	3268
three lanes	--	4180
four lanes	4510	5507
Two-lane rural road	--	1260
Freeways		
two lanes one way		2960
three lanes one way		4574
On-ramps	762	762
Off-ramps	based on downstream intersection	

APPENDIX D – ANALYSIS OF EXTERNAL TRAVEL

Enclosed in this Appendix is documentation of the methodology used to determine how traffic at the external stations of the Transportation Study Area (TSA) was allocated between various types of trips, including the derivation of the "through-trip" table. Most of this methodology was developed for the 1990 model, and updates for 1994 primarily consist of adjustments for updated traffic counts, expansion of trip purposes, and adjustments needed to maintain control totals initially developed during the 1990 work.

A) Analysis of through (external/external) travel.

Traffic counts were available at all 56 external stations in 1993 (county roads) and 1994 (primary roads). Also available were the results of the 1965 Travel survey report for this urban area, which provides documentation of travel by type of trip for each of the external stations surveyed. Due to the expansion of the TSA since 1965, not all of the existing stations were surveyed. Table D-1 summarizes for each station the latest recorded traffic count, the percentage of travel at that station found in 1965 to be through trips (if available), and a calculated percentage of through trips based on a regression equation developed from the 1965 survey (see Figure D-1). Without a more current survey, some means of estimating the amount of through travel at non-surveyed stations is necessary, and this Figure relating the amount of through traffic as a function of total traffic is the best means available for providing the needed estimates. Many of the stations that were surveyed in 1965, due to their small traffic volumes, have percentages of through travel that may be statistically suspect. Therefore, the final column in Table D-1 (in which the initial estimate of total through travel is presented) shows calculated through trips at 1965-surveyed stations as an average of the surveyed percentage of travel and the regression equation-derived percentage of travel.

As shown in the lower right corner of Table D-1, this initial calculation of through travel represents over 28% of the station traffic counts. In 1965, through travel represented 15% of the station counts. The percentage of the traffic representing through travel may have changed over time; however, it cannot be determined at this time how much of a change may have occurred. The only other reference material providing guidance on this subject (Reference #11) also suggests using 15% of the total traffic count as through travel.

Three things were done to reduce the through-travel percentage down to 15%:

1) Assume that some streets that are adjacent to higher-speed limited access highways will not have any through travel, because such travel could be made more conveniently on that highway. The Iowa 965 and Center Point Road stations were examined in this manner. Due to the locations of the external stations on these roads with respect to interchanges on Interstate 380, all through travel was dropped on Iowa 965, but retained on Center Point Road at the initial estimate.

2) Remove from consideration all "low-volume" stations, which would have little impact on general through-traffic patterns while simplifying the development of the through-trip table. Table D-2 shows stations selected to remain in the trip table, based on a minimum number of calculated through trips.

3) Set a cap on the percentage of travel at any external station that can be represented as through-travel. To bring system-wide through travel down to 15%, the cap was set at 19.25%, affecting travel at the four highest-volume stations on Interstate 380 and U. S. 30. The revised estimate of through travel at these stations is also shown in Table D-2.

A through-trip table was developed based on these travel totals, and is shown in Table D-3. The through-trip table used for the historical model maintained by the Iowa DOT was utilized as a “seed table” with individual station-to-station trip movements adjusted based on the new row and column totals.

B) Analysis of external/internal travel.

All travel at the external stations that is not through travel becomes external/internal travel. That is, this travel has origins or destinations within the TSA, and are broken down into the same trip purposes as used for internal trip generation.

In 1990, total home-based work trips were set to 1.5 times the number of workers estimated to cross the TSA boundary each day (those who live in the TSA and work outside, plus those workers who live outside the TSA and work inside the TSA). The calculated total of trips represents 33% of all external/travel, within 1% of the home-based work trip percentage found in the 1965 survey. The overall allocation of trips into the other two trip types (home-based nonwork and non-home based) was based on the 1965 Travel Survey totals.

As discussed in the main report, the splitting of all home-based trips into which were “productions” and which were “attractions” is also based on the analysis of the number of workers who cross the TSA boundary daily. Total non-home based productions were set equal to total non-home based attractions. The production and attraction totals for home-based nonwork trips were utilized to determine the amount that “internal” home-based nonwork trip attractions would have to be adjusted to reach a system-wide balance.

County/municipal journey-to-work data from the 1990 Census data was used to estimate work-related travel for the highest-volume external stations, and the low-volume stations were then adjusted to maintain overall trip totals for all trip types.

For 1994, adjustments were made for new traffic count totals, the expansion of trip purposes, differences in overall traffic patterns between weekday and 7-day averages, and revised estimates of daily work trips per worker. The modeled hour-of-day splits of traffic follow the patterns set out for internal traffic by travel purpose.

The number of external/internal trips by trip types estimated for each external station are summarized in Table D-4.

APPENDIX F – MODELED TRAFFIC VOLUME AND TRAVEL TIME DATA

Enclosed in the following spreadsheets is a listing of all the street segments with (24-hour) traffic counts (except for the four permanent count stations maintained by Iowa DOT), and how those counts compare to the traffic simulation discussed in the report. Peak hour (7-8 a.m. and 4-5 p.m.) traffic count and model data are also shown on these same pages.

In each column, the first data item is an abbreviation of the major street, and the two crossing streets the count is located between. A list of abbreviations is enclosed on the next page. The two numbers after the @ symbol represent the a and b nodes in the modeled street network for that particular street segment. For example, AAV-11S-12S @ 432 431 means A Avenue in Cedar Rapids between 11th Street and 12th Street, and from node 432 to 431. 24SM-10A-MCG means 24th Street in Marion between 10th Avenue and McGowan Boulevard.

The rest of the numbers in each column are the traffic count, the modeled volume, and the modeled volume as a percentage of the traffic count. A value of 80, for example, indicates that the modeled volume was 20% less than the actual traffic count, while a value of 130 means that the modeled volume was 30% higher than the traffic count.

Also shown as noted below are detailed tables on modeled travel times, truck volumes, and a list of new node numbers and locations that were added from the original PLANPAC model maintained by the Iowa Department of Transportation.

Summaries:	
Modeled daily and peak hour traffic volumes compared to counts:	Pages F-2 through F-11
Plot of modeled daily traffic volumes:	Pages F-12 through F-15
Plots of modeled AM and PM peak hour percentages of travel and PHF:	Pages F-16 through F-20
Modeled travel times compared to field studies:	Pages F-21 through F-23
Modeled daily truck volumes compared to counts:	Pages F-24 and F-25
Plot of modeled percentage of trucks on streets:	Page F-26
List of new node numbers and locations:	Pages F-27 through F-31

APPENDIX I – FILE NAMES, DIRECTORY LOCATIONS, AND NAMING PROTOCOL

A) SYSTEM-WIDE PARAMETER AND "ADD" FILES

3. External station trip data for major trip purposes - files for various options are stored in the QRS5 directory, with the preferred option for modeling to be attached to the network file.

Model scenario	File name
Weekday average (24-hour)	PAEX945.TXT
Full-week average (24-hour)	PAEX1994.TXT
Full-week truck average (24-hour)	PAEX94TK.TXT

4. Other files

Purpose	Model scenario	Required file name for QRS5 directory	Stored in GNE5 directory as file name
Productions and Attraction file by zone	3 K-12 school purposes	ADDPSAS.TXT	ADPASCHS.TXT
	4 major purp.7-day average	"	ADPA1994.TXT
	" - weekday average	"	ADPA945.TXT
	" -weekday with peak hour variations by zone		ADPA945P.TXT
	Trucks-7-day average (both SU and combo)		ADPA94TK.TXT
Hourly trip rates by purpose	3 K-12 school purposes	HRATES2.TXT	HRATESCH.TXT
	General, 7-day pattern	"	HRAT7DAY.TXT
	General, 5-day pattern	"	HRAT5DAY.TXT
Overall travel by hour of day	7-day pattern	VOLHOUR.TXT	VLHR7DAY.TXT
	5-day pattern	"	VLHR5DAY.TXT
with hour avg. Factors by fn. Class	weekday AM peak hour	"	VLHRAMPK.TXT
	weekday PM peak hour	"	VLHRPMPK.TXT
	weekday noon hour	"	VLHRNOON.TXT
Added trip tables for thru, school, and airport travel.	7-day pattern	ADDTRIPS.TXT	AADT1994.TXT
	5-day pattern	"	ADDT945.TXT
	Single-unit trucks, 7-day pattern		ADDT94SU.TXT
	Combination trucks, 7-day pattern		ADDT94CM.TXT
(STORED ON QRSII DIRECTORY)			
Functional class changes for trucks	Single-unit trucks		TRK94APC.TXT
	Combination trucks (w/ Edgewood Road)		TK94APCE.TXT

B) MODEL RESULT FILES (all stored on QRS5 directory)

Purpose	Initial file name in Model scenario	QRS5 directory	Stored in QRS5 directory as file name
Network with final volumes/travel times	7-day AADT	OUTPUT.DTA	CAL947.DTA
	weekday average	"	CAL945.DTA
	Weekday AM peak hour	"	CAL94AM.DTA
	Weekday PM peak hour	"	CAL94PM.DTA
Trip-length distributions (in minutes) by (major) travel purpose	7-day average	LENGTHDS.TXT	TPLD7DAY.TXT
	weekday average	"	TPLD5DAY.TXT
	weekday AM peak hour	"	TPLD94AM.TXT
	weekday PM peak hour	"	TPLD94PM.TXT
Vehicle turning movements:			
A) Modeled Intersections	wkdy AM peak hour	MOVE1.TMP	ATMV94AM.TMP
	wkdy PM peak hour	"	ATMV94PM.TMP
B) Freeway ramps	wkdy AM peak hour	TURNMOVE.TXT	FTMV94AM.TXT
	Wkdy PM peak hour	"	FTMV94PM.TXT
Link labels	All	LINKLABL.TXT	LL94CAL.TXT
Node labels	All	NODELABL.TXT	NL94CAL.TXT
Intersection delay files:			
A) Signalized	wkdy AM peak hour	SIGNAL.TXT	SIG94AM.TXT
	wkdy PM peak hour	"	SIG94PM.TXT
B) All-way stops	wkdy AM peak hour	ALLWAY.TXT	AWS94AM.TXT
	wkdy PM peak hour	"	AWS94PM.TXT
C) Some-way stops	wkdy AM peak hour	SOMEWAY.TXT	SWS94AM.TXT
	wkdy PM peak hour	"	SWS94PM.TXT
Zone-to-zone trip table	7-day average	TABLE.BIN	ZTZT947.BIN
Zone-to-zone equlibrium travel times	7-day average	HIGHDIS.BIN	ZTZM947.BIN
	wkdy AM peak hour	"	ZTZM94AM.BIN
	wkdy PM peak hour	"	ZTZM94PM.BIN
Text file of volumes with link labels	7-day average	extract "BC" from	VL947DAY.TXT
	wkdy AM peak hour	output network file	VL94CLAM.TXT
	wkdy AM peak hour		VL94CLPM.TXT
Travel times w/labels	wkdy AM peak hour	extract "B34"	TT94CLPM.TXT
Vehicle miles/hours of travel	7-day average	extract "L73", "L526" Or "L93A4"	VMT947.TXT
Truck volumes	7-day average		TRK94VAL.TXT