

A Hybrid Approach for Determining Traffic Demand in Large Development Areas

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ABSTRACT

Trip distribution is an important element of traffic impact analysis and is typically performed using expert judgment. Impacts are very sensitive to this step, and for large, mixed-use developments with many parcels, trip distribution can be very time consuming and potentially error prone. Regional trip distribution, on the other hand, is generally computed using a gravity model as part of a three or four step modeling process, which is efficient but that does not allow for the introduction of expert opinion, and outputs must generally be smoothed prior to use for traffic or geometric design. We present a hybrid approach that first obtains trip distribution patterns from a regional (TransCAD) model. Origin-destination (OD) pairs and graphical highway network are then imported into an Excel spreadsheet using a comprehensive set of VBA macros. The paper discusses additional macros developed that (1) implement a driveway-spread method to assign peak hour trips, (2) allow for quick, easy, and intuitive revision of flow patterns, and (3) export network and intersection flows in a traffic program (Synchro) for operational analysis and simulation. We provide a real-world case study where the tool was applied within a rapidly growing community (Johnston Iowa, 2,600 -acre development area with 40 sub-zones). The hybrid approach is expected to greatly reduce time and errors associated with manual trip distribution and site impact analysis.

Key words: land use—operational analysis—trip assignment—trip distribution—trip generation

INTRODUCTION

Traffic forecasts are key inputs to planning and investment for large development areas. Roadway designers require reliable and sufficiently detailed forecasts to ensure acceptable road performance initially and over the project's design life. However, traffic demand analysis for large development areas is full of challenges given the uncertain trip generation and distribution potential of undeveloped or redeveloping land as well as the operational nature of adjacent arterials (Hawkins et al. 2007). Manual techniques typically applied to small sites for impact analysis are not well suited for larger developments due to labor requirements and potential errors due to the vast number of calculations and tabulations that must be made and kept track of. More automated methods, such as travel demand network (or four-step) models are similarly unsuited due to their coarse, aggregate nature, and more especially because they do not allow for the ready introduction of expert judgment. This judgment, at the local level, can be superior to the sometimes arbitrary and opaque distribution and assignment decisions made by the computer algorithms.

PROBLEM STATEMENT

For determining traffic demands in large development areas, traditional site impact studies are expensive if not impractical (Ruehr 2000). This is partly because a great number of distribution percentages must be estimated for a large number of parcels or land uses. Here is an example. For a development with 15 external stations and 40 internal land uses (as described in the land use plan), trip distribution for ingress/egress trips for morning and afternoon peak hours requires as many as 2,400 estimates. If distributions between internal zones are taken into account, the number of total distribution pairs can be as many as 8,640. Manual distribution is, therefore, impractical, particularly if estimates must be revised or repeated for various land use scenarios.

For truly large developments, analysts may consider the application of a regional travel model to estimate distribution patterns for the study area. However, these models must probably be refined to include more detail for the site in question (so-called focus or sub-area models). Subdivided zones should reflect the land use plan, which may be quite detailed (parcel level). Regional models are often calibrated only for daily volumes so peak hour adjustments must also be made, as peak hour volumes, by direction, are required for design and traffic purposes. Finally, regional trip generation is typically based on employment and demographics, as these variables are easier to forecast than land use activity levels required as inputs to site-specific trip generation. Community development departments will likely have detailed estimates of land use by type and acreage, at least for current and short-term forecasts. Therefore, the conversion of land use to population/employment-based trip generations must be accomplished before subdivided zones can be seamlessly included in regional models.

Post processing and repackaging of traffic estimates is required prior to use by traffic and design engineers. Regional model auxiliary programs can build sub-area networks and report the origin-destination (OD) flow table for a specific study sub-area. However, as these programs are not developed specifically to support sub-area traffic studies, they may be cumbersome or inflexible to use. For example, it is not easy to quickly review and modify zonal flow patterns thought or known to be incorrect. It is also not easy to set multiple paths (or split trips among multiple paths).

For sub-area study, the analyst should examine land use locations and layout in each zone to determine the percentages of zonal trips to be loaded onto driveways. Trip assignment thus starts at driveways rather than at centroids as is the case in regional models. Regional planning packages lack a convenient way to implement this kind of driveway-spread assignment.

METHODOLOGY

This paper presents an approach that combines the salient features of manual and computer methods currently used to analyze traffic impacts at much smaller and at much larger scales. This hybrid approach takes advantage of trip distribution outputs from a regional travel model, utilizing them as surrogate patterns for distribution of directional, zonal peak-hour trips in the study area. The proposed approach also makes extensive use of the familiar Excel spreadsheet for data input, manipulation, revision and display. An easy-to-use and intuitive set of worksheets was developed, serving as the platform for integration of regional travel modeling, expert judgment, and traffic operational analysis. An application of this approach is presented for the western growth area of Johnston, Iowa.

The hybrid approach bridges a gap between land use and demographic-socioeconomic data based trip generation and enables the use of distribution outputs from a regional travel model. Many Excel VBA macros were developed to implement trip generation, distribution, and assignment for large-scale developments. Some of the macros graphically translate the sub-area network into the spreadsheet and calculate trip generation and distribution percents for each zone in the study area. Others facilitate splitting trip distribution by driveway and assign trips to the network. Still other macros report turning volumes and percents after assignment and display flow pattern by color-coded lines.

Some of the macros facilitate rapid revision of traffic assignment. Others create a sub-area network for Synchro and export intersection volumes to Synchro via Universal Traffic Data Format (UTDF). Synchro may then be used to test different traffic controls, explore the mitigation of traffic impacts from land development, and run simulations for public meetings. A flow chart depicting the hybrid impact analysis approach is shown in Figure 1.

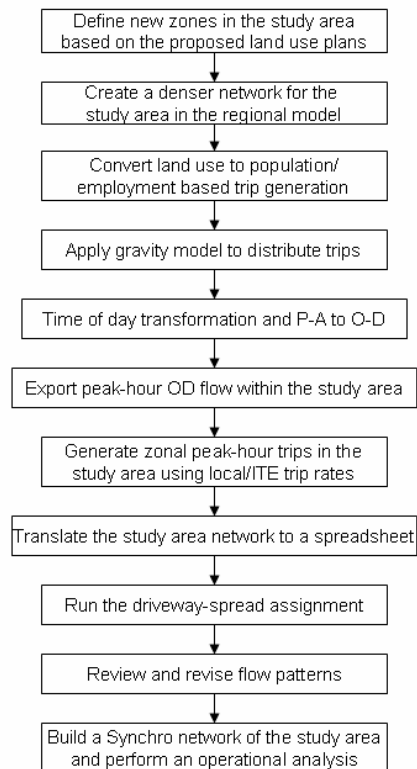


Figure 1. The hybrid approach to traffic demand analysis

CASE STUDY

Located northwest of Des Moines, the city of Johnston is one of the fastest growing communities in Iowa. The city is preparing to improve public roadways in its western portion. Private investment is expected to continue in this area on a large scale. Given the large tracts of undeveloped land (green field), establishing the number of lanes and size of intersections was a considerable challenge. In addition to general roadway design parameters, city staff wanted to know future roadway costs for input to a capital improvement plan. They also wanted to know future traffic conditions in order preserve the appropriate amount of right-of-way and to be better prepared to negotiate with both residential and commercial developers in this yet underdeveloped portion. Each of these required a reliable and sufficiently detailed traffic demand study considering land use impacts at the major driveways, intersections, and turning lanes level.

The case study began with the collection of land use plans and estimation of future trips. The specific uses and acreages of anticipated development within the area were provided by the city. The 2,600 acre study area was subdivided into 40 analysis zones. Subdivision was dependent on the mix of land uses and the ingress/egress routes assumed, and complex areas were subdivided more to allow for higher levels of detail in the analysis. Figure 2 shows the land use information in the study area.

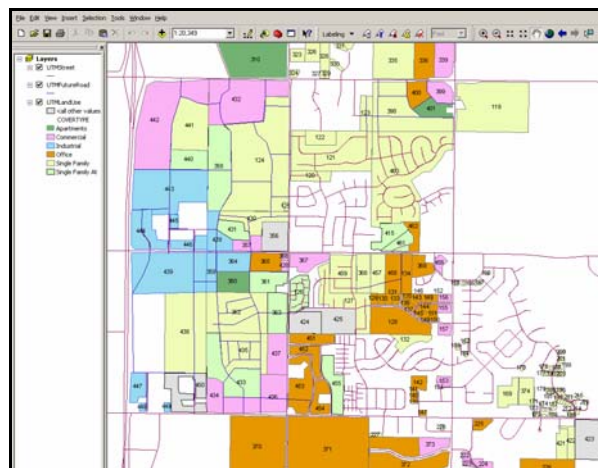


Figure 2. Land uses in the study area

Peak-hour trip generation was calculated using trip rates, pass-by percents and the numbers of development units. Where local rates or pass-by percents were not available, national average values from the *ITE Trip Generation Handbook* (ITE 2003) were used.

In order to provide a baseline trip distribution and reduce potential input errors, the Des Moines area 2030 TransCAD model was used. To acquire distribution percents for each of 40 zones in the development area, the original six traffic analysis zones in the Des Moines model were subdivided into the 40 study area zones. The sub-area roadway network was also updated and densified. Figure 3 shows the revised model network in the study area.

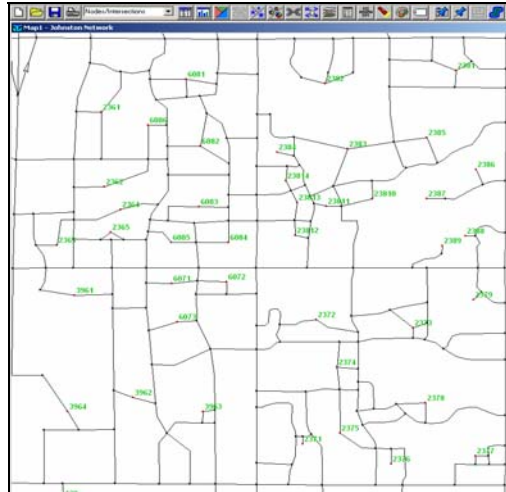


Figure 3. The revised model network in the study area

Before peak-hour distribution patterns could be identified, two limitations of the regional model had to be addressed:

1. Conversion of Land Use to Population and Employment

The 2030 regional model was developed as a 24-hour (daily) model. Daily trips are generated based on estimates of population and employment. Before integrating the subdivided zones with the regional distribution model, land use information for these zones had to be converted to corresponding population and employment numbers. For residential zones, the percentages of household sizes (1, 2, and 3+) for single-family housing, townhouse/condominium, and apartments were estimated considering local demographic characteristics. Regional trip production rates were then applied to these household estimates based on projected income levels in the area.

For business, commercial and industrial land uses, ITE trip rate curves were used to convert land use to employment numbers. For example, 140,000 sq. ft. of general office building generates 1,500 daily trips, which is equivalent to the daily trips generated by the same type of building with 400 employees. The 400 employees were then considered as non-retail employment numbers. Figure 4 illustrates this process. Similarly, retail employment and school enrollment can also be estimated in this way. These conversions and calculations were completed by macros written in the spreadsheet.

Next, the regional trip production and attraction models were applied to the sub-area zones producing daily trips by purpose, including home-based work (HBW), home-based other (HBO), non home-based (NHB), and commercial vehicle (CV).

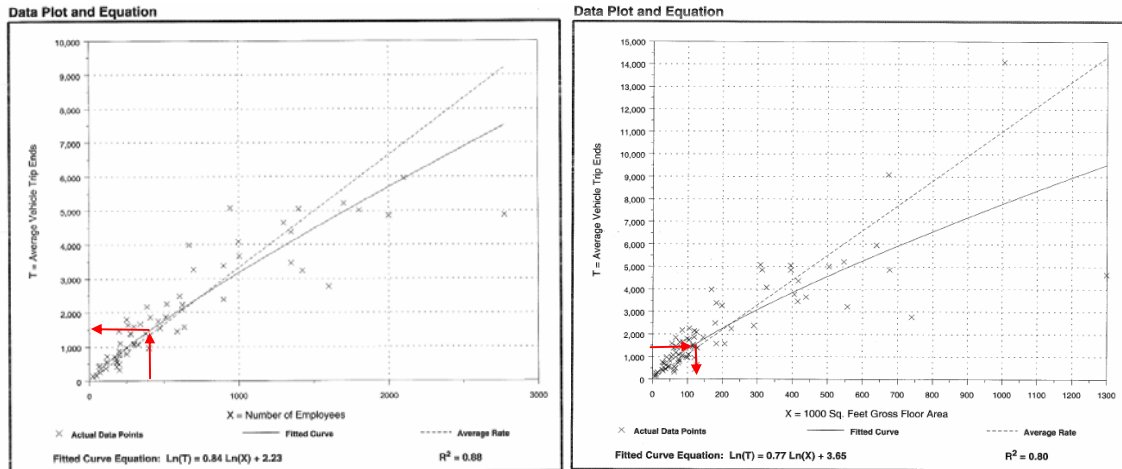


Figure 4. The conversion of land use acreages to employments

2. Time-of-Day Transformation

To convert 24 hour trip generation to peak-hour, it is most helpful to have a local survey. As no such survey was available in our case study, default peak-hour factors from NCHRP Report 187 were used to decompose regional daily production-attraction (P-A) trip table to peak-hour matrices. After the time-of-day transformation, a P-A to OD conversion was conducted to get peak-hour OD matrices.

The last step to obtain zonal distribution patterns for the study area was creating a sub-area OD matrix. TransCAD has a procedure for performing this step (Caliper Corporation 2005). After specifying a cordon line that circumscribes the study area, TransCAD reported this matrix. The final result is the sub-area peak-hour distribution pattern.

Next, the TransCAD network in the area was automatically translated into Excel for further analysis. The macros developed for this process also support the driveway-spread assignment, which provides output at a level of detail more conducive to traffic analysis and design. It also allows the analyst to incorporate local knowledge and expert judgment. An example of the configuration of driveway usage for a zone is illustrated in Figure 5.

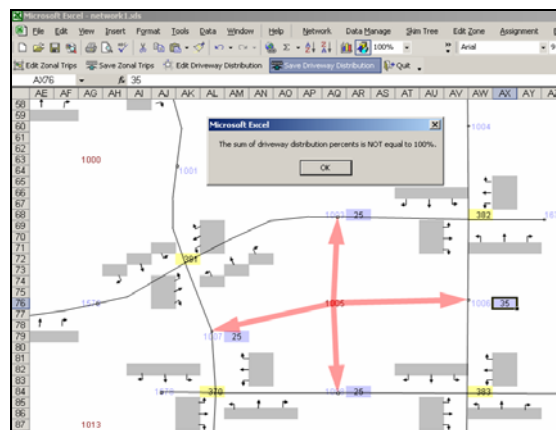


Figure 5. The configuration of zonal driveway usage

The spreadsheet macros also allow quick, easy, and intuitive turning movement analysis and flow pattern modification. For instance, Figure 6 shows traffic flow leaving a centroid through one of its driveways. Upon inspection, analysts can directly make changes on the reported turning percents and revise the flow pattern.

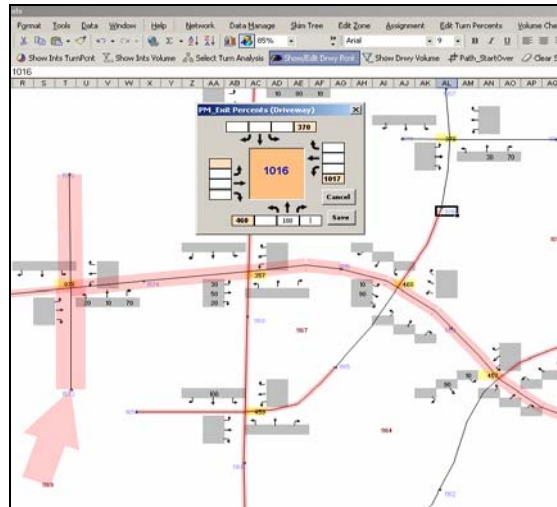


Figure 6. Reviewing and revising traffic flow pattern

The principal goal of this study was to evaluate how road facilities handle traffic under major land development and growth and to forecast intersection level of service. For the Johnston case study, the spreadsheet automatically created the study area's network for Synchro using the node-link data from TransCAD. It also translated volume data to Synchro for more additional operational analysis. The network created by the spreadsheet tool is displayed in Figure 7. Intersections on major roadways and accesses to employment centers and schools were analyzed in the Synchro network.

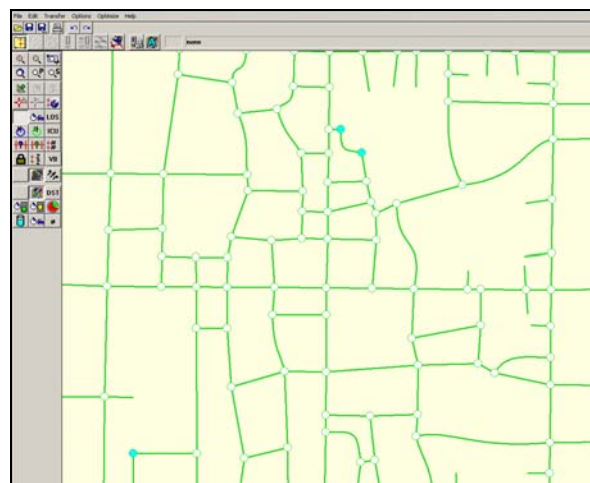


Figure 7. The sub-area network in Synchro

CONCLUSIONS

The hybrid approach introduced in the paper integrated a land use-based approach with population/employment-based trip generation, and trip distribution outputs from a regional travel model

for initial trip assignment in a large development area. Compared to previous manual efforts in similar areas conducted by the authors, the tool greatly reduced the time and errors associated with traditional manual trip distribution and site impact analysis.

The use of the familiar Excel spreadsheet is an important feature of the hybrid approach because it serves as a transparent tool accessing the best features of regional travel models, expert judgment, and traffic operational analysis. While the chief benefits of the described approach lie in its ability to provide outputs most useful for traffic engineering and design (as well as to save time and reduce error), the methodology developed in the study has potential for enhancing sub-area peak-hour travel modeling in general. It is recommended that future efforts address the integration of the analysis steps and facilitate the testing of different land use scenarios.

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