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An Integrated Model for Planning and Traffic Engineering

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This contribution summarizes our experience in building and using the City of Lynnwood's "Base Transportation Model" (BTM). The BTM is an integrated database that provides input for three different kinds of analysis:

- Macroscopic travel demand forecast and planning,
- Signal timing optimization,
- Microscopic traffic simulation.

These planning and engineering tools are by tradition separated. The BTM integrates their data management, while maintaining them as separate analysis tools with specific fields of application. Data integration increases the workflow efficiency and the overall consistency of the transportation analysis.

The paper focuses on the integration of macroscopic demand modeling with microscopic traffic simulation. First the characteristics of both approaches are described. Then various aspects of the integrated data model are highlighted: a geographically detailed node-link graph that and serves for location based data storage; interactive editors and data structures for intersection geometry and signal timing that are relationally embedded in the node-link-network; the automated generation of microscopic simulation input from the macroscopic model.

Background

The City of Lynnwood, WA with a population of 35,000 is located in the Pudget Sound Region at the junction of Interstates 5 and 405. Lynnwood is a designated urban center, serving the Northern part of the region with a large shopping mall and an important business concentration. Current transportation issues in the City include an expansion of the mall, the development of a CBD, the creation of a convention center and ITS implementations like transit signal priority, video detection, 2070 controllers and central control software. In traffic operations, the City is heading towards real time analysis and adaptive signal control.

The Base Transportation Model (BTM) was built between August 2001 and March 2002, using existing data including GIS, a signal database and an existing demand model. Since then the BTM has been used for the CBD planning project as well as for transit signal priority analysis.

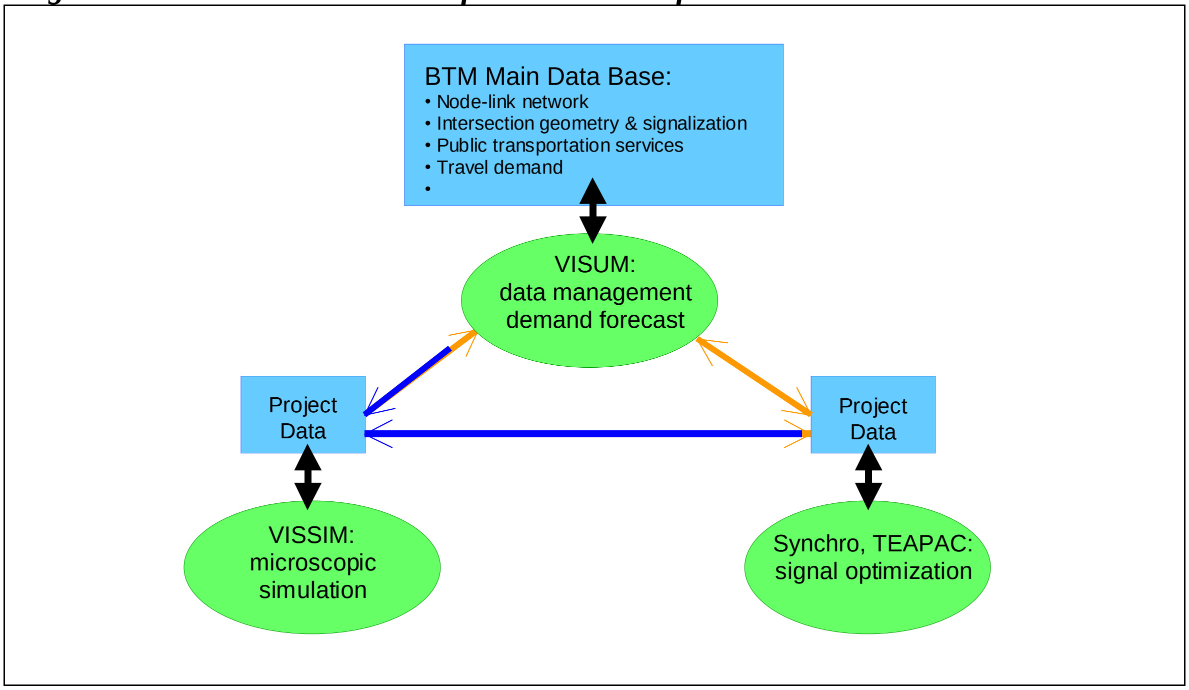
The integrated model design of the BTM addresses the specific needs in the traffic department of the City of Lynnwood: Planners and engineers work hand in hand in the process from transportation planning to traffic operations. Consequently, there is a strong interest in integration of data and tools.

Second, the conventional analysis, which is based on generic volume-capacity and LOS analysis, does not always reflect the realities of traffic operations on the streets. The City wants to use operations data in the planning process, in order to develop more robust alternatives that are compatible with traffic operations. The ultimate goal is to feed real time data from ITS equipment to the BTM.

A third motivation came from ITS implementations on the City's streets. Microscopic traffic simulation is the appropriate tool to test settings of the traffic control equipment and to measure the performance of ITS implementations. In this context, microsimulation plays a key role in the City's modeling toolbox and the new model has to be compatible with the microscopic traffic simulator VISSIM.

Model Architecture

Figure 1: Model Architecture: Software and Interfaces



As figure 1 shows, the model integrates four software tools:

- VISSIM for microscopic simulation,
- VISUM for demand modeling and for data management,
- SYNCHRO and TEAPAC for static signal analysis.

The interfaces between the different software packages are continuously improved. In the following, we will focus on one interface that we have used extensively in practice: the interface between demand modeling in VISUM and microscopic simulation in VISSIM. We will describe the method of microscopic subarea analysis and address related issues.

Comparing Static Demand Modeling and Microscopic Simulation

Before we look at interaction and integration, we highlight the differences between the two approaches:

Table 1: Comparing the Macroscopic and the Microscopic Approaches

Macroscopic Demand Modeling	Microscopic Traffic Simulation
Paradigms: • Aggregation: vehicles and trips are modeled in groups • Traffic flow is replicated in a static model; the result represents an average over time. • Emphasis on links, simplification of intersections • Long term forecast	**Paradigms:** • Individual vehicles and trips are modeled • Dynamic simulation in real time • An engineering tool with focus on intersections • Typically short term forecast
Speed and Capacity Model: • All trips share the same speed for one particular network object • Capacity is a model input; it is "soft" as it can be exceeded by the flow volume. • Cannot explain congestion, speed is a strictly decreasing function of flow volume.	**Speed and Capacity Model:** • Every trip (vehicle) determines an individual speed in reaction to other vehicles and to traffic control • Capacity is not an input, but a result of geometry and driving behavior. This resulting capacity is "hard". • Can replicate the congestion breakpoint, can also explain queue building and spill back from one network object into others.
Level of Detail of the Network Model: • Simplistic modeling of the intersection as a point without geometry.	**Level of Detail of the Network Model:** • Each intersection is represented in detail by several data objects

From this display of differences in table 1, two questions arise: First, how to deal with these differences during data exchange from one side to the other? We will try to give some answers to this question from our experience with the Lynnwood model further below.

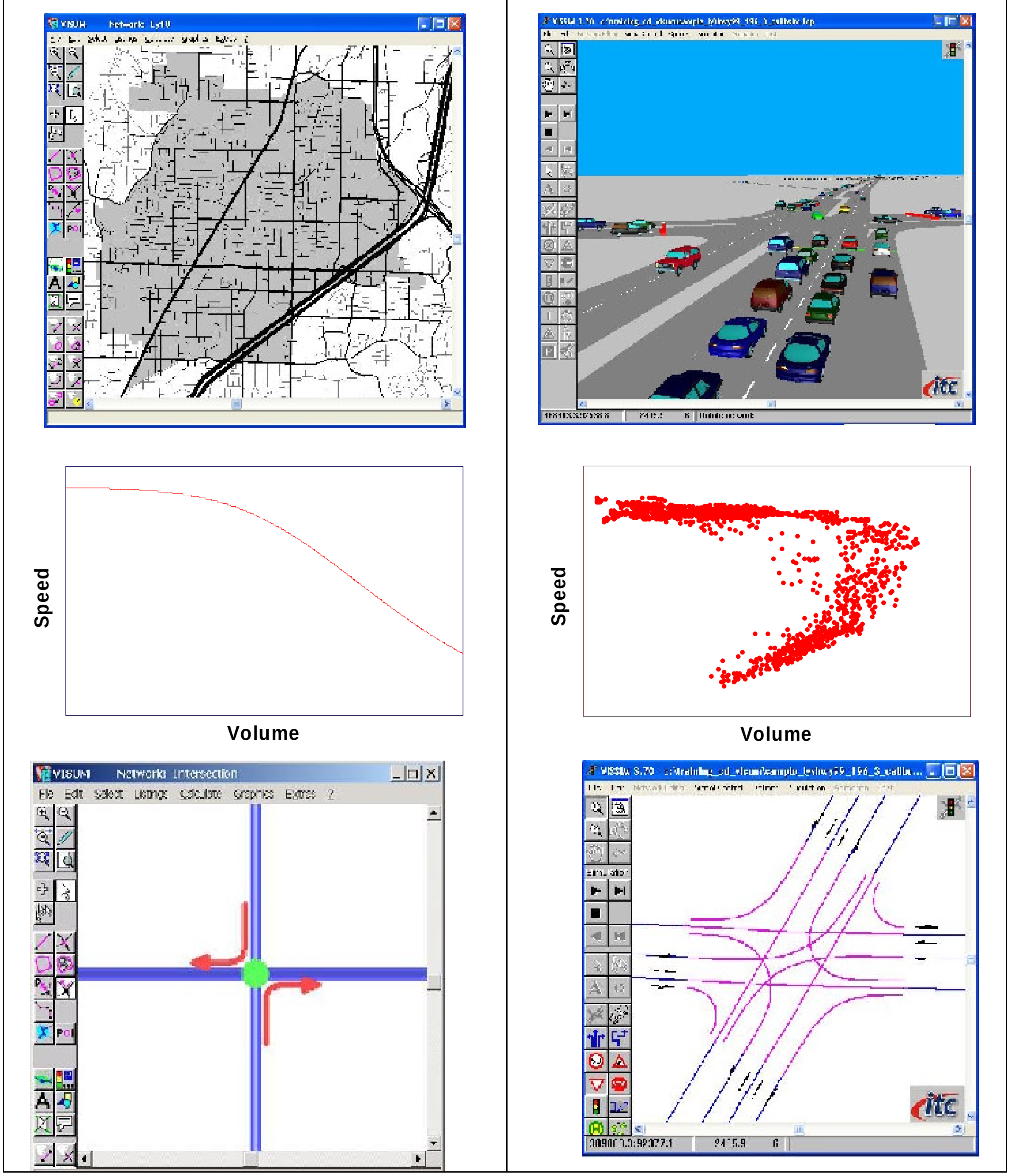
The second question is: what kinds of transportation problems are better addressed by macroscopic modeling, which ones by microscopic? We believe that a model should only be as complex as necessary. Given a certain transportation problem we will use the easiest and quickest model that is available to address the particular questions. With more complexity, the need for data, education and resources increases. In addition errors become more likely (7., pp. 70-73). Thus the static and macroscopic models are to be preferred for most planning applications, as they are simpler and quicker than microscopic simulation. There are however some situations, where the macroscopic and static analysis is insufficient and where we recommend microscopic traffic simulation:

- Congested areas: as pointed out in table 1, congestion is a major weakness of static modeling approaches. When alternatives are compared that all lead to congestion, microscopic sub-area analysis is a very helpful supplement to the conventional planning model.
- Understanding the capacity of key network elements in a planning project: For example, when in doubt whether key intersections can be operated with a new pattern of traffic flows, microsimulation can be used for capacity analysis.
- As static models create only average statistics, microsimulation is a better tool if reliability becomes an issue, e.g. if the impact of certain scenarios on bus operations is to be evaluated.
- Traffic operation strategies where the control devices react to events that occur at random and at a low probability. This is the case in many ITS strategies like transit signal priority or incident management.
- If changes in traffic operations are expected to have an impact that will go beyond the concerned group of intersections, e.g. converting parallel one-ways into two-ways.
- In addition, there is a wide field in traffic engineering where microsimulation is recognized to be the appropriate tool for analysis as the static approach of the Highway Capacity Manual (HCM) is not sufficient. (See 2., pp. 14-15 and 6., p. 31-16 for listings of such traffic engineering situations)

This listing shows that microscopic traffic simulation is a tool not only for traffic engineers. It can be a complementary tool for planning studies as well.

Figure 2: Comparing the Macroscopic and the Microscopic Approaches

Macroscopic Demand Modeling	Microscopic Traffic Simulation



Microscopic Sub-Area Analysis

Microscopic sub-area analysis starts from a given planning scenario in VISUM. In the first step a specific corridor or sub-area is selected. All network data and assignment results for this sub-area network are then handed over to the microscopic traffic simulator. Finally a microscopic simulation is run.

The workflow can be broken down into the following steps:

1. Identify sub-area in the macroscopic network
2. Cut sub-area network (automated)
3. *Refine the node-link network and the TAZ system (if necessary)*
4. *Adjust turning movement volumes (if necessary)*
5. *Add intersection geometry and signal timing data (if necessary)*
6. Generate VISSIM input data (automated)
7. Run microscopic simulation
8. *Refine the simulation (delay calibration, graphics)*

In the Lynnwood BTM applications, we are able to streamline some of the steps above while we can skip others altogether. The four steps printed in *italic* are those that can be skipped or at least be performed faster than with conventional planning models.

There are two main reasons why we could streamline the process:

- New features of the ptv-Vision software, including the automated interface between demand modeling (VISUM) and microscopic traffic simulation (VISSIM) and the relational data model that includes the node-link graph as well as transit routes and intersection data (lane geometry, signal timing).
- The design of Lynnwood network model with more street detail than most planning models, enables the easy export to the microscopic simulation.

The Automated Micro-Network Generator

From any given planning network and assignment in the demand modeling software VISUM, a consistent VISSIM network can be generated automatically. The following data items can be transformed:

- Nodes are transformed into intersections, where the node position determines the center of the intersection.

- A microscopic intersection in VISSIM is composed by several turning lane objects, priority objects and signal objects. All of them can be edited by the user. The network generator must create all these intersection objects. It will determine a shape for all turn lanes according to the angles of the intersection legs and the available space.
  As will be explained below, relational information about all turn bays and their length can be stored on the node object. This information will be crucial for the intersection layout. If no detailed data are given, a default layout is created.
- For access controlled junctions, weaving areas are created.
- Signal information is handed over to VISSIM and editable signal heads are created at the stop line locations.
- Links and their attributes, speed and number of travel lanes, are translated into street objects.
- Transit lines, stop locations and the schedules are transformed into VISSIM format and embedded into the simulation network.
- The static highway assignment can be translated into routes, which then remain fixed during microsimulation – the volume on the routes does not need to be constant over the simulation period.
- An alternative to fixed traffic routes is to export the OD matrix into VISSIM and perform a dynamic traffic assignment during simulation.

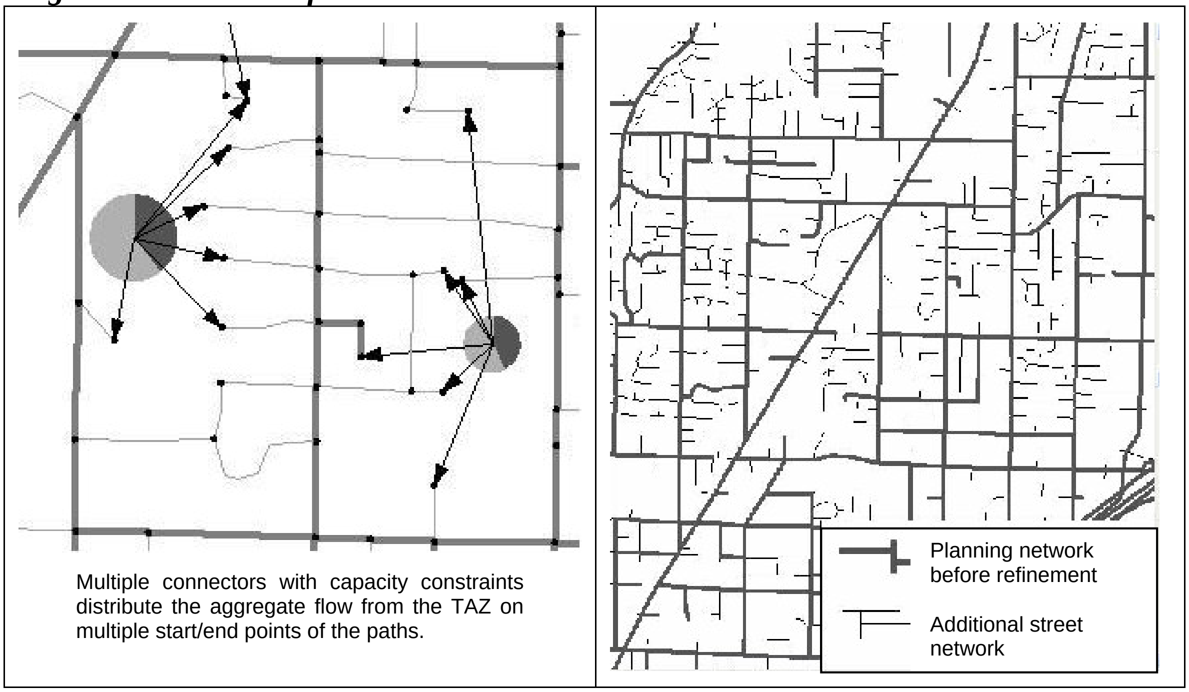
Obviously one macroscopic network object will generate several microscopic network objects. The user can control the result by global settings of the network generator or by local attributes and data for single objects (intersections and streets).

Streamlining the Process with a Refined Network Data Model

Conventional planning models do not emphasize turning movement volumes. They show unrealistic concentration of traffic in side streets, because the demand of entire zones is injected into a few network points. These unrealistic side street flows translate into turning volumes on intersections of collectors or minor arterials that are beyond capacity. For the planning of arterial highways, this problem can often be ignored. For export into microscopic simulation this is not an option, since turning volumes that exceed capacity will create unrealistic queuing and spill back.

In our network modeling approach we have addressed this issue by refining the street network and by introducing multiple zone connectors with soft capacities.

Figure 3: Network Refinement



Another important enrichment of the VISUM network model is the storage of intersection data on the node object: this includes turn lane geometry and signal timing. This data can be used for two purposes:

- For export to VISSIM: they are used by the micro-network generator to build complete intersections.
- For node delay during static assignment: signal timing and the number of lanes per turning movement are the basis for a turn capacity constraint model.

Outlook

The City of Lynnwood intends to take the following steps to further develop the Base Transportation Model in the near future:

- Storage of the basic signal data for all intersections in the BTM main database, including phasing, green times and detectors.
- Recalibration of the macroscopic assignment using intersection delay models that ware based on signal timing data.
- Set up a traffic count database and build an automated link to the BTM.
- Extension of the demand model to include different time of day periods.
- Creating an automated interface between VISUM and the signal optimization software.

The long-term goal is:

- Let the BTM reflect the time of day dynamics of traffic.
- Feed the real-time data that are collected by the ITS equipment directly into the BTM for analysis.

Conclusions

- Our approach to integration maintains two modeling approaches: macroscopic demand modeling and microscopic traffic simulation. The model user has a choice to use either the macroscopic or the microscopic approach according to the requirements of a particular transportation study.
- Model integration is not only a task for software development, but also for the modeler.
- A customized concept to model data management, in particular a refined network model and location based data storage, is the corner stone of integration.
- Data integration improves the model results in both the microscopic and macroscopic analysis.
- Microscopic traffic simulation can complement the conventional planning toolbox, especially around two issues: congestion and ITS implementation.
- Another lesson we learned is that model integration is an opportunity to acquire new skills. In our project team, traffic engineers got hands-on experience on demand models, and planners got introduced to intersection data and microscopic simulation.

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