A Practical Method for Adjusting Temporal Origin-Destination Matrices for Dynamic Traffic Assignment

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Abstract

One of the biggest challenges in the successful development of a dynamic traffic assignment (DTA) model is the estimation of a temporal matrix for the period modeled. The most common source of information on the origin-destination (O-D) matrix is the regional travel demand forecasting model. One can derive a static O-D matrix for a sub-area by computing a traversal matrix for each class of traffic. Then temporal traffic counts can be used to adjust the static sub-area demand for each time slice to obtain a time-varying demand suitable for DTA. Further dynamic adjustments are often necessary to account for differences between the static assignment and the dynamic assignment.

This paper summarizes the solution algorithm for static O-D adjustment, explains how it is applied to generate time-varying demand suitable for DTA, and introduces an additional process to adjust the demand based on select-link analysis from the DTA.

Keywords: O-D matrix estimation, dynamic traffic assignment

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Introduction

The static adjustment of origin-destination matrices has been studied extensively and several practical methods have been developed for medium to large scale applications. These methods were developed first for networks that were not subject to congestion, that is, the travel times were constant. Later, these methods were extended to consider congestion where the underlying route choice was obtained by carrying out an equilibrium assignment. Some of these contributions are due to LeBlanc and Farhangian (1982), Nguyen (1984), Fisk (1988), Fisk (1989), Spiess (1990), Yang, Sasaki, Iida and Asakura (1992), Yang, Iida and Sasaki (1994), Florian and Chen (1995) and Florian and Noriega (2009). The gradient method proposed by Spiess was used with good success in practice and was extended to multiple classes and the consideration of deviations from a reference matrix by Florian and Noriega (2009).

Analytical methods that attempt to estimate a temporal matrix from counts have not yet been successful in providing reasonable estimates for medium and large scale problem instances. The dynamic O-D estimation/adjustment methods (see for instance Cascetta, Inaudi, Marquis (1993), Ashok (1996), Van der Zijpp (1996), Crittin (2004), Kattan, Abdulhai (2006), Balakrishna (2006), Zhou and Mahmassani (2006), Cipriani, Florian, Mahut, and Nigro (2008)) are still in the research domain and do not yet provide a method that can be used routinely in applications. The challenge is that differences between assigned flows and counts may arise due to at least two reasons. Firstly, the demand may be too low, and increasing the demand causes the assigned flow to increase. Secondly, the demand may be too high, and bottlenecks or the resulting queues prevent demand from reaching the count location and time, no matter how much the demand is increased.

In this paper we describe a hybrid method, that uses both static O-D matrix adjustments and dynamic adjustments to obtain a temporal matrix for DTA. First, a sequence of static O-D matrix adjustments are carried out. The results of the static adjustment are time-sliced matrices for each class of traffic considered. These matrices are used for initial dynamic traffic assignment. The resulting differences between the assigned flows and the counts are analyzed by a sequence of select-link assignments that provide information on which origin-destination pairs contribute to the flows of a link in each time interval for which there are counts. Then this information is used together with an analysis of the traffic flows on the network to determine whether the related cells of the origin-destination matrix should be increased or decreased. The process is heuristic. Nevertheless, it uses implicitly the information of the assignment map, that is which origin-destination pairs contribute flows to a particular link in a particular time period.

The Static Matrix Adjustment Model and the Solution Algorithm

The adjustment of an O-D matrix to traffic counts is a commonly used method to update or refine an existing O-D matrix. The matrix for each class of traffic to be adjusted may be the demand for a regional model or for a sub-area of the region. The method makes use of link and turn counts and includes, as well, deviations from the O-D matrix to be adjusted. The adjustment method used is a gradient method that is described in detail by Florian and Noriega (2009). It can be used to adjust simultaneously the O-D matrices for several classes of traffic.

The formulation of the model is rather straightforward. Given reference matrix g, the aim is to obtain a new matrix g' for each class such that the weighted sum

$$\alpha \sum_{O-Ds} (g' - g)^2 + (1-\alpha) \sum_{\substack{\text{links}\\ \text{with}\\ \text{counts}}} (q(g') - count)^2$$

is minimized, where α is a weight less than 1 and larger than or equal to 0, and the assigned flow $q(g')$ is the result of an equilibrium assignment.

The solution algorithm is based on an adaptation of the gradient approach developed by Spiess (1990). The main difference, apart from the multi-class generalization, is the addition of the demand term in the objective function. The general steps of the gradient method are shown below for one class.

Step 0. Initialization

Step 1. Equilibrium assignment to obtain the link volumes

Step 2. Compute the link derivatives and the objective function

Step 3. Compute the gradient matrix

Step 4. Compute the link derivatives

Step 5. Compute the maximal gradient and the optimal step length; update the demand matrix

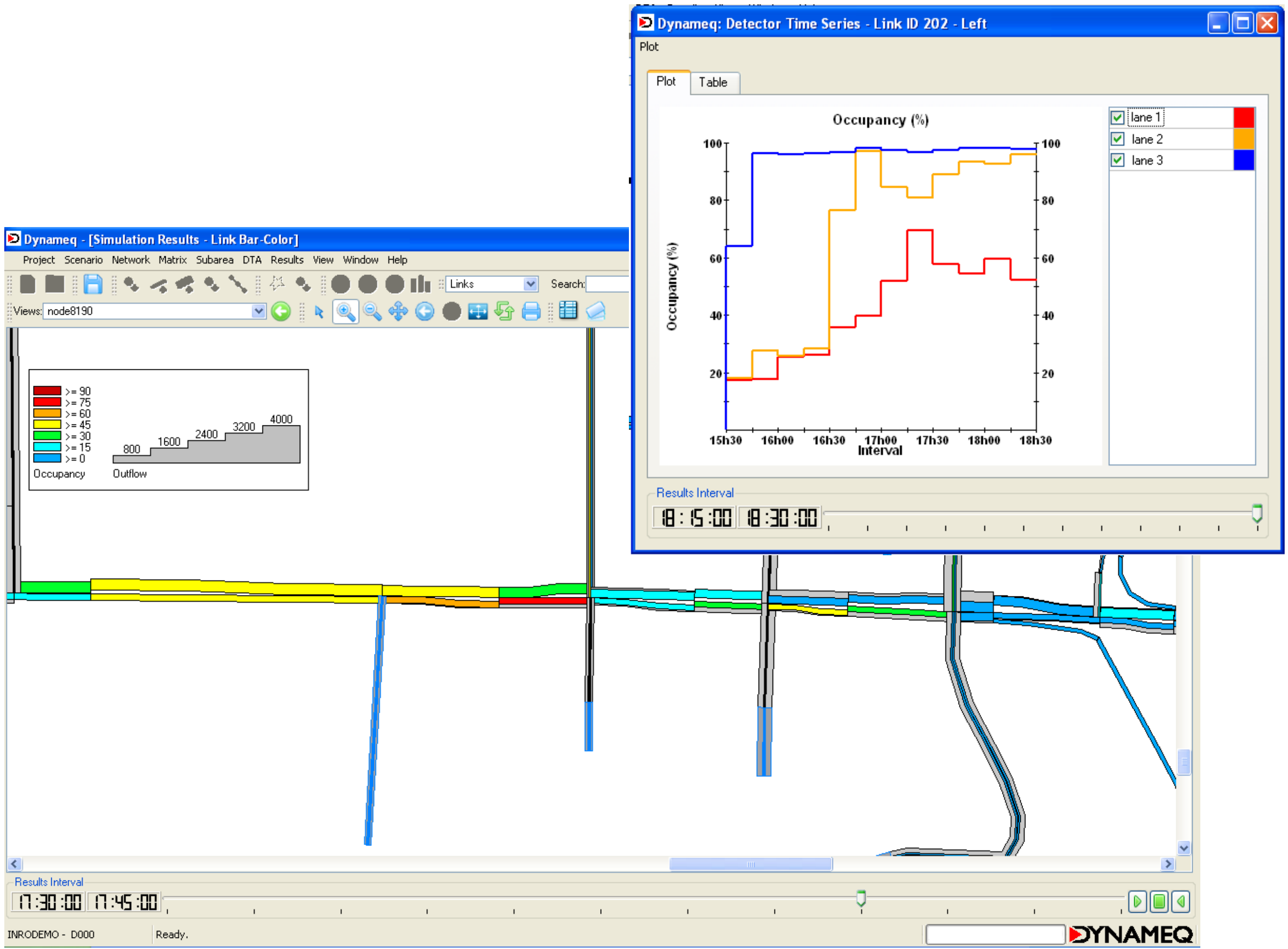
Step 6. If the maximum number of iterations is reached STOP; otherwise, update the iteration counter and go to Step 1

In the adjustment process judgment should be exercised to determine if an adjusted matrix is “reasonable”. So, there is quite a bit of art that complements the use of a rigorous model in order to obtain reasonable and justifiable results. The resulting adjusted O-D matrices are quite sensitive to the weight parameter α. In general, several values of α must be experimented with before arriving at a satisfactory adjusted matrix.

The Dynamic Adjustment Procedure

The dynamic adjustment procedure accounts for differences between the static and dynamic assignment maps. The O-D pairs that contribute to the flow on a given link in a static equilibrium assignment will not necessarily be the same in a dynamic equilibrium assignment due to differences in the supply model.

For example, static models do not represent queues, so at an intersection approach the through movement and the right turn are unaffected by an oversaturated left turn. In dynamic models, an oversaturated left turn may spill across lanes, which raises the cost of the through-movement and the right-turn. The red bar in the bandwidth plot below is such an approach. The time series graph shows the occupancy of the left turn lane (blue, lane 3) rises near 100%, the through movement (orange, lane 2) rises at 16:30 due to spillover, and the right turn lane (red, lane 1) follows. All paths that use this intersection approach become less attractive in the dynamic model than in the static model. The static demand adjustment may need further adjustment in the dynamic context.



A select-link analysis reveals the assignment map for a given link, but the necessary adjustment depends on the congestion upstream, on, and downstream of that link. In a dynamic demand adjustment for an uncongested network, as in a static demand adjustment, if the count is larger (smaller) than the assigned flow, then the demand should be increased (decreased) for all O-D pairs that contribute to that assigned flow. In a dynamic demand adjustment for a congested network, unlike a static demand adjustment, the position of bottlenecks dictates how the flows may be adjusted to better fit the count. Several examples of dynamic demand adjustments from real-world DTA projects will be presented, along with overall calibration results.

Conclusion

Despite the lack of a practical analytical method to estimate a temporal demand matrix from counts, DTA models are being successfully calibrated for real-world projects with reasonable data requirements and labor. The static-dynamic hybrid approach to demand adjustment has been successful on a number of projects, even for very congested networks of thousands of links. The hybrid method is described and examples are provided.

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