Analysing the Effects of Stop-&-Go Conditions in Traffic Assignment Models

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Abstract

Stop-&-Go waves also known as traffic oscillations are the conditions characterized by sudden braking followed by acceleration. This leads to an increase in fuel consumption, CO₂ emissions, safety risks, increased heart rate and blood pressure level of drivers. It causes discomfort, delays and frustration to the driver thus making them to avoid travelling in such conditions. This paper will test the hypothesis: More is the frequency of stop-&-go waves on a given route; the more is the likelihood of a driver to shift to a different route with a slightly higher travel time but lesser number of stop-&-go waves. The study will analyse the results of traffic assignment models (route choice or user equilibrium) by introducing the frequency of stop-&-go into the link cost function. This analysis will be carried out on the software package AIMSUN using one of its test networks. The results of two experiments, one with only travel time in the link cost function and other with both travel time and frequency of stop-&-go will be compared. The comparison will provide insights upon giving weightage to measure of discomfort (number of stop-&-go) rather than emphasising only on minimizing the travel time. A sensitivity analysis will also be carried out by varying the trade-off value between number of stop-&-go and travel time.

Keywords: Route choice models, equilibrium assignment, value of stop
1 Introduction

Stop-&-Go waves also known as traffic oscillations are the conditions characterized by sudden braking followed by acceleration. These waves are often prevalent in congested traffic conditions on urban road networks. In an oscillation, vehicles are forced to decelerate and travel at slower speeds or even come to a halt before resuming their original free flow speed (Shott 2011). This leads to an increase in fuel consumption, CO$_2$ emissions and safety risks (Bilbao-Ubillos 2008; Zheng, Ahna and Monsere 2010; Barth and Boriboonsomsin 2009). It also has a negative impact on the heart rate and blood pressure level of drivers as they have to be more focussed while driving in stop-&-go traffic (Levinson et al. 2004). Thus, it causes discomfort, delays and frustration to the driver. One of the objectives of this study is to test the hypothesis: the more the number of stop-&-go waves on a route, more the likelyhood of a driver to shift to a different route with a similar distance, slightly higher travel time but lesser number of stop-&-go waves. The study attempts to estimate the willingness to pay in minutes for reducing one occurrence of stop-&-go on the travelled route.

The traffic assignment algorithms minimize the generalised cost of drivers, which is usually the travel time. But, in reality, drivers try to minimize their travel time or discomfort or both. Figure 1 gives a motivational example for the proposed research problem.

![Illustrative example of the hypothetical scenario to the drivers](image)

**Figure 1:** Illustrative example of the hypothetical scenario to the drivers
The figure shows two alternate routes between origin O and destination D. The two routes have similar commute distance but varying traffic conditions (travel time and number of stop-&-go). The traffic assignment module assigns vehicles on R-I. But in reality, some proportion of drivers might choose R-II. The proposed study will lead to introducing the frequency of stop-&-go into the objective function of traffic assignment. This will enable weightage being given to comfort thus simulating the real world traffic conditions in a better way.

The study aims to test and validate the hypothesis that more is the frequency of stop-&-go waves on a given route; the more is the likelihood of a driver to shift to a different route with a slightly higher travel time but lesser number of stop-&-go waves. This will lead to the formulation of stop-&-go effect into the traffic assignment algorithm to account for the discomfort.

The organization of the paper is as follows: Section 2 provides a literature review highlighting the gaps in research that the study will address. Section 3 discusses the hypothetical scenario that was generated to test the hypothesis. Section 4 highlights the process of identification of a stop-&-go in Aimsun 8.0. Section 5 discusses the initial observations from the results obtained so far. Section 6 lists down the conclusions and future works.

2 Need for study: Background

Small et al. (2000) determined the value of travel time savings under the congested conditions. They defined congested driving conditions as stop-&-go traffic corresponding to the level of service (LoS) E and F in the HCM manual (HCM 2000). A stated preference survey was conducted in which respondents were asked to make a choice between two routes with different travel time and stop-&-go conditions. Figure 2 shows one of the choice tasks given to the respondent. The experiment evaluates the route choice behaviour based on the percentage of total travel time spent in stop-&-go traffic. However, the duration of stop-&-go time doesn’t intuitively give an idea of the travel conditions. For example, the stop-&-go times for choice A and B can be calculated to be 4 and 3 minutes respectively. This doesn’t give any idea of whether the 4 minutes on route A are due to more stops of less duration or
vice versa. The travel becomes more onerous in case of former. The proposed study tries to determine the trade-off between the route choice and the frequency of stop-&-go.

**EXPERIMENT #2 (SAMPLE QUESTION)**

<table>
<thead>
<tr>
<th>PLEASE CIRCLE EITHER CHOICE A OR CHOICE B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Total Travel Time:</td>
</tr>
<tr>
<td>11 minutes</td>
</tr>
<tr>
<td>Percent of total time spent in stop and go traffic:</td>
</tr>
<tr>
<td>36%</td>
</tr>
<tr>
<td>your cost: $0.25</td>
</tr>
<tr>
<td>Choice A</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Average Total Travel Time:</td>
</tr>
<tr>
<td>8 minutes</td>
</tr>
<tr>
<td>Percent of total time spent in stop and go traffic:</td>
</tr>
<tr>
<td>38%</td>
</tr>
<tr>
<td>your cost: $1.50</td>
</tr>
<tr>
<td>Choice B</td>
</tr>
</tbody>
</table>

**Figure 2: A paper based choice task comparing two hypothetical routes**

[Source: Small et al. (2000)]

The authors estimated the VTTS of $/hr 2.64 to 8.05 for low and high income households respectively from the data. The VTTS values were obtained using the logistic regression technique. However, it has been widely accepted now that the standard logit model under-estimate the VTTS due to its rigid framework which causes irrelevant alternatives property (IIA) (Bhat 1995; Hensher 2001; Hess, Bierlaire and Polak 2005).

Shott (2011) applied the mesoscopic LWR model to observe the creation and propagation of stop-&-go waves on a freeway with an on-ramp. The effect of oscillations on en-routing decisions was also studied making available the travel time during oscillation for each of the two routes given to the drivers. This study however didn’t see the impact of the frequency of stop-&-go waves on routing decisions.

### 3 Hypothetical Example

In order to test the hypothesis, a hypothetical network was built using the Aimsun 8.0 software package. The network comprises of 4 centroids, 4 nodes and 16 links. A dynamic scenario was built in Aimsun using the stochastic route choice (SRC) model for the traffic
assignment and microsimulation model for the traffic flow. The simulation period was set as 1-hour during which a demand of 1800 cars and 450 trucks was loaded from A to B. The shortest path calculation period was set at 10 minute interval during the simulation period. Figure 3 gives the snapshot of the hypothetical network. The length of the sections is in meters.

Figure 3: Hypothetical network built in Aimsun 8.0

Given the network conditions, two possible routes exist, the upper route (A-362-355-377-B) and the lower route (A-362-370-377-B). Table 1 shows the other route details.

<table>
<thead>
<tr>
<th>Route Name</th>
<th>Nodes on route</th>
<th>Length (m)</th>
<th>Signals on nodes</th>
<th>Total green time for movement (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>A-362-355-377-B</td>
<td>6000.95</td>
<td>355, 377</td>
<td>40+25=65</td>
</tr>
<tr>
<td>Lower</td>
<td>A-362-370-377-B</td>
<td>5331.52</td>
<td>370, 377</td>
<td>25+25=50</td>
</tr>
</tbody>
</table>

The distance from A to B is greater while travelling through the upper route. In order to create stop-&-go waves on the sections, traffic signals were placed at the nodes 355, 370 and
The green time of the signals on both the routes were adjusted so as to have a lesser green time on the lower route. This was done so as to increase the number of occurrences of stop-&-go on the lower route, which is comparatively shorter in trip length.

### 3.1 Dynamic Scenario: Stochastic Route choice with Microsimulation

We created 2 dynamic scenarios in AIMSUN8 where the traffic assignment was done through stochastic route choice. The path interval was updated every 10 minutes during a 60 minute simulation. Traffic flow was accomplished through microsimulation models.

**Default case:**

A dynamic scenario was created using the default link cost function. The default link cost function comprises of the link travel times only, i.e. \( Z = f(TT) \). Default link cost functions were set for the initial, dynamic and K-initial shortest path cost functions.

**Modified case:**

A python script was written so as to define a new link cost function \( Z = \text{travel time} + \mu \times \text{no. of stop-&-go} \). This script was linked to the dynamic scenario through the dynamic and K-initial shortest path cost functions. The parameter \( \mu \) which represents the willingness to shift to another route was assumed to be 60 sec per stop-&-go for the study.

### 4 Identification of stop-&-go in Aimsun 8.0

In Aimsun, a user can define two threshold speeds limits namely the queue entry speed and the queue exit speed. A queue entry speed is the lower threshold below which a vehicle is considered as stopped. The vehicle then remains in this stop condition until its speed goes beyond the upper threshold which is the queue exit speed. Figure 4 shows a diagrammatic representation of the speed profile of a particular vehicle. The queue entry and exit speeds were set as 1 m/s and 4 m/s respectively in the study. The stop duration is the difference between the queue exit and entry times. Aimsun considers this duration as one stop. For example, for the given speed profile, Aimsun considers the vehicle to have made 2 stops, the second stop is still ongoing.
5 Results

Both the default and the modified cases were executed and the following results were obtained. Figures 5 and 6 represent the percentage vehicles assigned during the 10 minute interval on the upper and lower paths respectively. Figures 7 and 8 depict the average number of stops experienced on the upper and lower routes respectively.
Figure 6: Vehicles assigned on lower route during 10 minute intervals

Figure 7: Average number of stop-&-go on upper route during 10 minute interval

Figure 8: Average number of stop-&-go on lower route during 10 minute interval
From the figures 5 and 6 it can be observed that the path assignment was higher on the upper path during the first 40 minutes of the simulation. This is because there were higher number of stop-&-go experienced over the lower path, which can be seen in figure 8. However, the percentage path assignment dropped a bit in the last 20 minutes of the simulation as the number of stops increased on the upper path resulting in more assignment on the lower path. On the other hand, the default case had roughly similar percentage of vehicles assigned as those were determined purely on the basis of link travel time. Thus, it was observed from the results that greater proportion of vehicles were assigned to the upper path during the first 40 minutes, even though it was longer but had lesser number of stop-&-go existing over it. This somewhat leads us to validate the hypothesis. However, it was also observed the travel time was also increasing with an increase in the number of stop-&-go. There seems to be an issue with an aimsun module and we are currently working upon rectifying the same.

6 Future works

One of the on-going tasks will be to further explore the reason behind increasing stop-&-go and travel time. Other future task would be to determine the willingness to shift parameter μ through experimental studies. The experimental studies like stated preference survey and driving simulator tests will be conducted in future to determine the parameter value. The study will also explore and come up with other methodologies to determine the number of stop-&-go on urban road networks in future.
References


