PROPOSED SCOPE OF WORK

ADAPTIVE CONTROL APPLIED TO CONGESTION AVOIDANCE / RELIEF ON LOWER BROADWAY, MANHATTAN USING ITS INFRASTRUCTURE OF NYCDOT

June 14, 2007

This is drafted as a task work order under Contract 20060023797 with GPI and KLD Associates performing the effort, and interacting with Transcore as the systems manager under its own contract(s) with NYCDOT. KLD will take the lead on this task work order.

Background

Manhattan is an ideal test and demonstration environment, because (a) a new network of advanced video sensors and microwave sensors, (b) the tight urban grid that accentuates the need for responsive control, (c) the construction and reconstruction program in Lower Manhattan that will surely involve special movements of materiel, re-routings, queued transport vehicles, and other temporary actions that increase demand or reduce capacity, and affect such facilities as Route 9A.

The focus in the proposed work is on Route 9A between 34th Street and Houston Street, with the specifics to be defined in Subtask 1 (and subject to mutual agreement). The analyses will be applied to a second site, such as Boston Road, to demonstrate by means of simulation its applicability to other locations.

The longer term view (not within this scope) is that combined with the NYC ITS infrastructure that is coming on line (new controllers, wireless communication, upgrades to control centers, sensors, EZPass-based O-D and volumes, etc), a site such as Route 9A or Lower Broadway might provide an excellent opportunity to focus on the NYC use of ITS during the November 2008 ITS World Congress, hosted by NYCDOT.

The Control Policy

Traditionally, cycle length is determined by the overall grid, with offset and phase duration used to exercise control to assure smooth flow on defined arterials and routes. As volume changes, so do queues and therefore the offsets needed to achieve smooth flow must change, in order to clear queues in advance of arriving platoons; concurrent changes in splits – if feasible – can add capacity.

However, when some intersections exceed capacity (v/c > 1.0), queues will continue to grow and *the fundamental control policy needs to change from "smooth flow" to "avoid spillback"*. In terms of encouraging voluntary compliance, the motto of "don't block the box" prevails. Splits and offsets can be (and are) used to reinforce this, by removing opportunities to move into the box at exactly the time that drivers might be tempted to this network-defeating behavior.

The process for improvements is to monitor queues and discharge patterns (namely, evidence of v/c > 1.0), adjust the upstream signal(s) to the new rules when oversaturation threatens the upstream intersection, and *perhaps* adjust the downstream signal to increase the capacity and flush the problem (balancing this approach against the chance of promulgating the problem downstream).

This fundamental problem is documented in [1] and [2], and implemented in various ways in some critical intersection control and network algorithms.

Adaptive Control, a New Era (Approach 1)

NYCDOT is installing a new generation of traffic controllers and central control system (TransSuite). Accompanying this is an extensive infrastructure of sensors (video and microwave) and a wireless communications network to transmit information and control directives. The adaptive controllers can be fully adaptive to local conditions or run as part of an overall control strategy.

It is recommended that the section of Route 9A between 34th Street and Houston Street be controlled with an overall control strategy specifically designed for congested control ("don't block the box"), developed and tested using simulation, refined, and installed --- first in limited tests, and then as a governing control strategy that takes that segment of Route 9A into the congested control mode and out of it (i.e. into standard smooth flow control).

This approach requires an effective congested control algorithm, supporting simulation to identify benefits and test the alternatives, and a means of implementing the decisions.

Historic Approach in NYC (Approach 2)

Signals throughout Lower Manhattan are controlled by the Vehicle Traffic Control System (VTCS) that has the capability of implementing up to 32 pre-stored (and pre-approved) control plans either in response to observed traffic conditions or by time of day. The system is divided into pre-defined "subsets" or "segments", and when control is changed, it must be for all signals within a given subset.

Consider the following existing issues:

1) Of the 32 possible signal control plans that can be stored, only 5-6 plans are routinely used, with up-to-date pre-approvals;
2) If a new candidate plan is to be developed, it is now done manually off-line by NYCDOT engineers. It is subject to off-line testing and evaluation, pre-approval, manual entry into the data base, acceptance testing, and then actual use;
3) The system operator can choose to switch from one pre-approved plan to another within any given zone or subset;
4) The system operator can override the signal settings at a specific intersection by a manual process, but this process --- if applied to several signals --- becomes a time-consuming

process. There is no automated process for doing this, nor is there likely to be one in a relevant timeframe.

Can responsive control be implemented within this framework? As a backup, this will be considered as a minor activity and as a "fail safe".

Route 9A Segment

The proposed activity is to focus on the portion of Route 9A between 34th Street and Houston Street. The primary objective will be to use adaptive control to avoid spillback affecting major cross streets.

In order to fully and actually implement the control, the following infrastructure will be needed:

1) The new traffic adaptive controllers installed at all intersections on the cited segment and at contiguous intersections on (at least) Route 9A;
2) The new traffic adaptive controllers may or may not need to be installed at contiguous intersections on the major cross streets. This can be determined in the initial simulation analysis, but for scheduling purposes at this time, it is best to assume that it is needed;
3) Four to six video sensors ("vids") will need to be installed so as to fully detect queues and flows in the links on Route 9A just downstream of the major cross streets, and perhaps at other locations. The final recommendation will be made after the initial simulation analysis;
4) A limited number of microwave sensors will be needed, at locations to be specified.
5) For the sensors in #3 and #4, the following data will be needed at the control center each cycle (90, 135 or 150 second cycle is presently assumed):
   - average occupancy over the period, where occupancy is defined as % of the link filled with vehicles;
   - peak occupancy over the period;
   - if possible, the average occupancy in the 1st, 2nd, and 3rd parts of the link, assuming that the detection software can segment the link in this way;
   - outflow in vehicles, for the period;
   - inflow in vehicles, for the period, preferably broken into parts based upon the signal indication at the link entry. This would allow an estimate of through and turn-in contributions to the link.
6) The information in #5 available as an SQL file at the central location, preferably on a PC dedicated to the segment. Also, the information available in user-friendly screen displays (it is assumed that these have been designed, and will be available).

The present scope is limited to extensive simulation of the traffic and control in the cited segment, with the end product of recommending the control algorithm and the sensors needed to assure effective, responsive, adaptive control over a range of traffic demands. But the simulations, interfaces, and data links will be designed in anticipation of a full and actual implementation in a later stage.

Methodology

The methodology is in three parts:

a) Demonstrate the effectiveness of the change in control philosophies, using a responsive simulation that allows an operator to accept changes identified by monitoring queue and flow;

b) In conjunction with NYCDOT,
   - identify a set of probable scenarios that are likely to occur;
   - use simulation to assess their impact;
   - develop controls that provide remedies or mitigation, using the probable scenarios to test the generalized control algorithm that will be needed;
   - provide supporting rules ("expert system") for matching field data to the scenario inputs, to identify and test and recommend the plan to be implemented;

c) Develop the capability to run the simulator in real time, in conjunction with an algorithm to develop control plans, in the eventuality that an improbable scenario (closures, special event, etc) occurs and needs a tailored response; match the recommended plan to the pre-plans in "b", choose the closest to implement, and advise the operator on manual changes needed to tailor the response.

For clarity:

1) The demonstration in "a" takes the form of a small network and an interactive front end, primarily for illustration as the effort progresses;
2) The additional "plans" cited in "b" are *only* for the zone containing the cited segment of Route 9A, and are to consider *only* offset and split changes to a finite number of intersections on or contiguous to the cited segment; the rest of zone remains unchanged;
3) The expert system advisor cited in "b" is a (preferred) option, but not a critical path item;
4) Likewise, "c" can be divided into basic capability and enhancing options.

The next section defines specific subtasks, including options.

Detail Scope of Work

The work is proposed in eight subtasks, according to the schedule shown in Table 1 (with options indicated). The effort under this task order would be done by KLD with the participation of GPI, but the cooperation of Transcore will be needed.

Phase 1: Subtasks 1-5

Subtask 1: Task Design Definition Report
The task will be to document the implementation needs and schedule, assure that NYCDOT and the relevant contractors are in agreement, and detail all other tasks.

The communication processes will be evaluated to ensure the development of the model input and output will enable the DOT to perform real time evaluation of modeled network.

The size and location of the pilot test site and the input and output graphical use interfaces will be identified.

We will identify in menu type GUI different traffic related issues that can be modeled to present roadway closures, congestion, blockages, special events, etc. in any location within the network.

Coordination with Transcore on the location and detector data source will be achieved. It is our present understanding that Transcore is the consultant on detector placement and control system design for the relevant areas, and wishes our input on detector location, sampling frequency, and summary data needs.

The goal of this subtask will be to identify all aspects of the proposed model have been considered prior to implementation and document the inputs, output, network size, GUI and communication processes of the model.

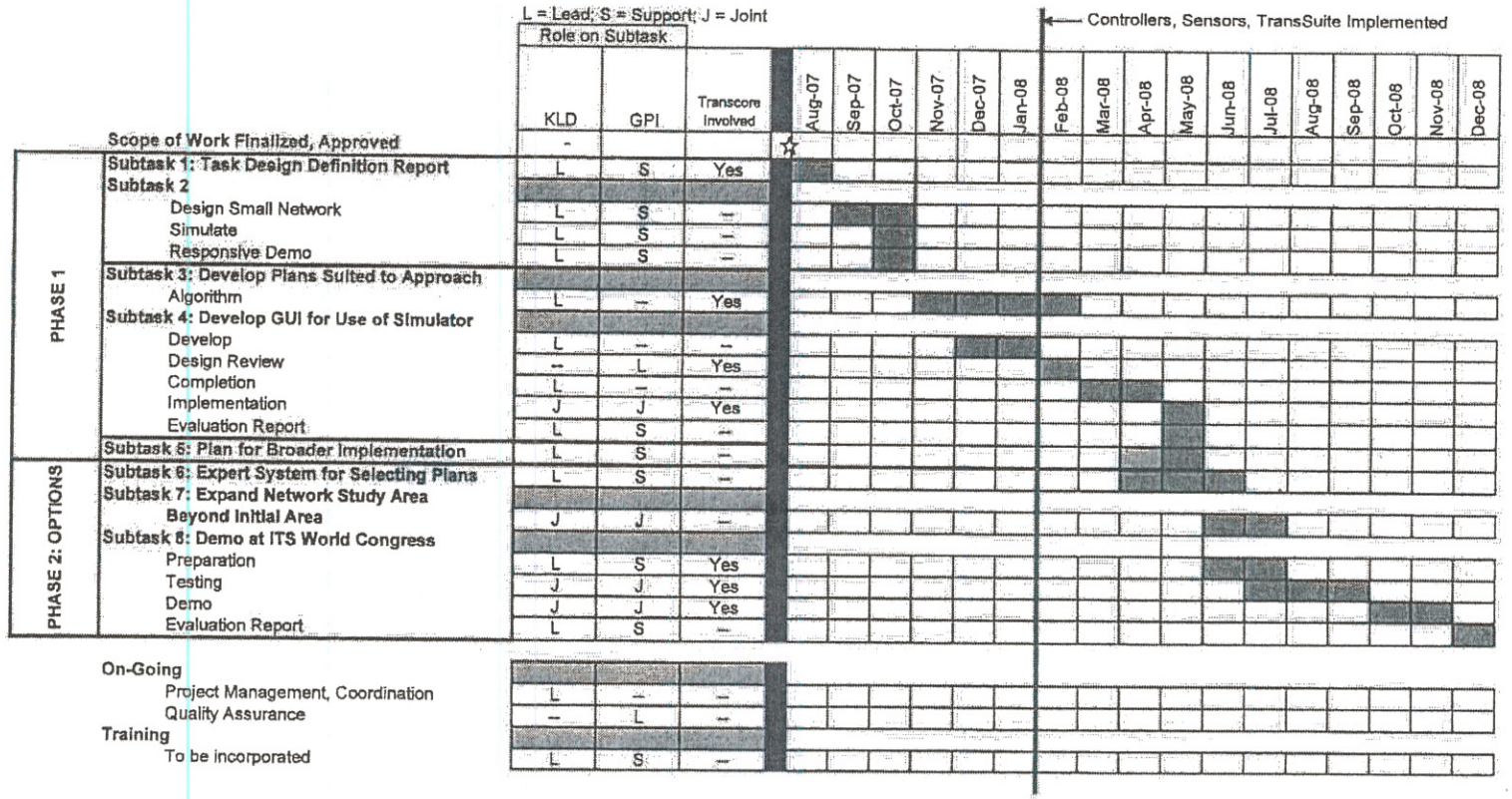
Subtask 2: Design Small Network, Simulate, Responsive Demo
The arterial and its contiguous signals will be modeled, using the recommended simulator (WATSim, with 2D and 3D capability, or mutually agreed alternate). Historic input data will be obtained, as described in the design report from Subtask 1.

For present purposes, it is assumed that up to 21 intersections will be involved in the simulations on the Route 9A segment and its environs, and that up to another 15 intersections will be involved at a second site (such as Boston Post Road). If actual control is to be implemented, that will be done in a later phase, beyond this scope.

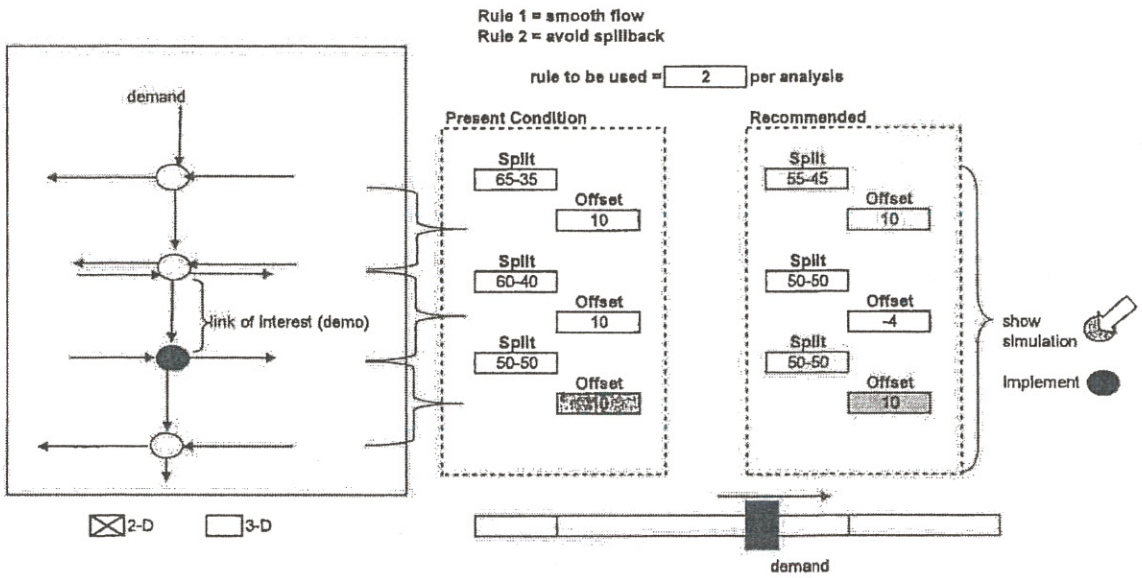
The network will be simulated, using a small specialty GUI for this demo / proof of concept, first using a demo case and then a sample from real time data.

Refer to Figure 2 regarding the demo. The demand slider will be movable by cursor. The screen will show 2-D or 3-D displays (user-specified). As the demand increases, the screen will show simulator output for the existing offsets and splits. Based upon the principles discussed on Pages 1-2 herein, a *recommended* set of offsets and splits will be displayed, with the Rule being invoked also displayed. The user can use the cursor to see the results of the simulation of the recommended offsets, and can then choose to implement them (or not) by another cursor click.

TABLE 1: GANTT CHART FOR PROJECT TASK WORK ORDER



☆ = Notice to Proceed



Notes: (1) Display on left is simulator output, with bitmap background; use cursor to make choices on right

FIGURE 1: RESPONSIVE DEMO FOR SUBTASK 2

Subtask 3: Develop Plans Suited to Approach

Subtask 3 will focus on the development, pre-testing, and implementation of a control algorithm. The congested traffic control algorithm will be based upon principles already discussed, earlier work cited in [1] and [2], and work undertaken by KLD for NYSERDA and others [3, 4, 5].

Subtask 4: Develop the GUI for Use of the Simulator in Decision-Making

Referring to Figure 1, consider its expansion in the following way: one display shows the subject area of Route 9A in real time, with traffic data that is being recorded into the simulator input data base concurrently; another display shows a menu that allows the operator to select a plan to be evaluated; that second display then shows the simulation being run in faster than real time; the operator can choose to implement (or not) that plan, and/or select another candidate.

Subtask 4 has as deliverables: (a) a PC with the algorithm and GUI installed, plus the simulator runtime version or executable[1], (b) a cumulative report, including an explanation of the algorithm, (c) user documentation for the GUI, (d) a 1-2 day training course at the TMC for NYCDOT personnel, (e) a license to NYCDOT for its use of the

[1] For certain simulators, NYCDOT will have to acquire a license separately, at its cost.

KLD algorithm code at the two sites cited herein, and for the use of the underlying concept by its personnel at other locations within NYC.

Subtask 5: Plan for Broader Implementation

Once the Route 9A analysis is well underway and the second arterial simulation is defined, it will be timely to have discussions with NYCDOT on the most suitable locations for further implementations. This subtask is not presently priced, but is intended to include the necessary technical work on enhancing the control policy based upon the Route 9A experience, and doing the necessary simulation and network coding activities, testing, and interactions with NYCDOT.

The base activities within Subtasks 1, 2, and 3 include a short white paper making recommendations related to Subtask 5.

Phase 2: Options (not priced or scheduled at this time. Period of performance Feb-Nov 2008)

Subtask 6: Expert System for Selecting Plans
This is an optional subtask. The consultant will develop an expert system that will (a) observe the system measures such as volumes and queues, taking note of the control plan in force, (b) assess which of the plans and algorithms best match the observed demand conditions, (c) run the simulator with that plan, (d) recommend (or not) that an alternative plan be implemented.

Subtask 7: Expand Network Beyond Initial Area
This subtask also includes additional intersections that feed the Route 9A segment or intersections "downstream" of the Route 9A segment in both flow directions.

It is an optional subtask, and would represent a significant expansion of Task 4 in terms of size of the network being simulated, monitored, and/or controlled.

Subtask 8: Demo at ITS World Congress

The purpose of this subtask is to provide on-site support for the NYCDOT demonstration of adaptive control on Route 9A (or an alternate, instrumented location) during the 2008 ITS World Congress. The primary activities are:

- preparation
- testing
- participation in the demonstration
- evaluation report, post-event

The duties will include pre-tests, support leading up to the event, preparation of a one-page four color handout, and web pages related to the project.