Active Traffic Management through Adaptive Signal Control on Midtown Manhattan Grid Network

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Greenman-Pedersen, Inc. with KLD Associates, Inc.
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This scope of work is prepared as part of the NYCDOT ESA held by the GPI Team, with GPI as the prime contractor and KLD as the relevant subcontractor. This particular assignment will be done by KLD, as Phase 3 of the ACDSS work. KLD will be supported by its affiliate, KLD Engineering, P.C.

As detailed in Table 1 at the end of this document, a number of tasks require the primary or support involvement of TransCore. The associated cost estimate is not included herein.

BACKGROUND

The objective of this project is to keep traffic flow in the designated Midtown Manhattan Grid moving. The measures of effectiveness (MOEs) used are to be discharge flows sampled within and near the designated Grid, and changes in point occupancy (or link occupancy, when video detectors are in place).

Active traffic management (ATM) can be defined as dynamically managing and controlling traffic based on prevailing conditions. Using integrated systems and coordinated response, ATM can reduce congestion level, improve roadway safety and throughput under both recurrent and non-recurrent congestion situations. ATM can be an effective operational strategy for congestion management.

Under the general ATM umbrella, strategies including speed harmonization, temporary shoulder use, dynamic signing and rerouting have been successfully employed by transportation agencies in Denmark, England, Germany and the Netherlands.

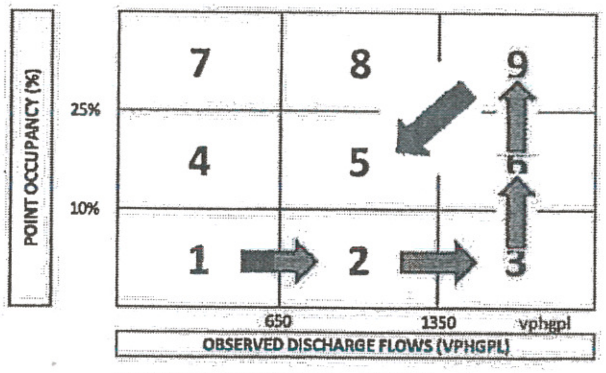
In this work, adaptive signal control is to be implemented as a new active traffic management strategy for enhancing traffic operations in a Midtown Manhattan grid network. The objective of using adaptive signal control as part of ATM is to *systematically* alleviate congestion by adjusting the traffic signals in real time – selecting from a library of pre-designed plans --- based upon real time detection.

The NYCDOT effort in this regard is to be based in the development of the Adaptive Control Decision Support System (ACDSS). ACDSS implements an innovative signal optimization algorithm that handles both under- and over-saturated traffic while provides real time decision support using just-in-time traffic simulation technology. As of the Spring of 2010, ACDSS was on field trial running autonomously on a section of Victory Boulevard near the College of Staten Island.

As a continuation of ACDSS efforts, this project advances the development and implementation to a highly congested grid network in Manhattan. The special features are to be:

1) The control algorithm is to be extended to a grid in which decisions are based upon zones and subzones, and the relative level and duration of congestion within the zones and subzones;

2) The level of congestion is to be characterized by aggregate levels of flow and point occupancy as illustrated in Figure 1, investigated by simulation and calibrated by field observations;



g/C	observed discharge flows, vphpl	
0.35	228	473
0.40	260	540
0.45	293	608
0.50	325	675
0.55	358	743
0.60	390	810
0.65	423	878

Figure 1 Illustrative Flow Regimes Set Based on Field Observation

3) The control plans are to be selected from a pre-designed library of plans, and implemented based upon alleviating or preempting congestion in the zones/subzones. Some of the pre-designed plans may well have the effect of internal and/or external metering, to govern demand. Plans focused on external metering are to take into account the effect on nearby zones, external to the one being studied;

4) The control is to emphasize change of splits, with some consideration of change of offsets during the design of the library of plans. Cycle length is to be maintained unchanged, because of the underlying cycle length in Manhattan;

5) The system is to allow NYCDOT to select the frequency with which plans are to be changed. Plans can be downloaded to the controllers in advance, or

implemented using the web services interface of ACDSS, using a central library for the test zone;

6) The features of ACDSS such as the web services interface, the recording of data, the forecasting of the next period(s), and the control computations are to be ported over or adapted to suit the need of the zone control;

7) Displays and reports shall be designed so that they are based upon zone/subzone levels of congestion, and not simply point levels of occupancy or flow. These displays – or metrics based upon them --- shall be used in decision-making on plan selection;

8) The system shall be implemented in such a way that it provides information by which additional plans can be designed off-line and added to the library (or replace some entries therein);

9) While not part of the initially planned mode, the system shall be implemented in such a way *that it does not preclude* future evolutions, namely:
    a. A system that is self-learning, in that it refines the plans based upon field measurements and updates the library over time;
    b. A system that is self-learning and adaptive, in that it can implement some changes within a selected plan (e.g. splits, within certain limits) without moving to a new plan;

10) The overall context is to be a set of zones based upon the topography and major flow patterns in Manhattan, with subzones based upon the same principles. The present scope shall be focus on one major zone, with sensors both external and internal to the zone.

For the present scope, the zone is as defined in Figure 2, namely the study area bounded by an area between 60th Street and 40th Street in the north-south direction, and 6th Ave and 3rd Ave in the east-west direction inclusive (6 arterials, 20 streets). Some subzones internal and external to the zone are *illustrated*, but it shall be part of the defined work to more fully define the zone into a set of subzones, that can include the ones shown in Figure 2 and arterial segments (e.g. the designated thru streets, segments of 6th Ave or 3rd Ave or 57th Street).

Figure 2 also shows a *preliminary* specification of detector locations, but this may be refined in the early stage of the actual project (i.e. Task 1.1). The detectors are to be RTMS units. Supplemental sources of information will be considered as part of the undertaking in order to establish overall patterns; this is defined within the individual tasks.

TASKS

Specific tasks of this project are defined below, including primary responsibility for the tasks or subtasks, and deliverables. The schedule is shown on pages 15-16 in MS Project, and identifies critical path items.

The overall project schedule is defined by the following:

- The development of the control and related software is concentrated in the first 4-5 months of the project, concurrent with the procurement and installation of the detectors (programmed for 5-6 months, including acceptance);
- The collection of relevant data from the detectors, development of library of plans, and installation of the system in the next 4-5 months;
- The implementation of the system, with periods for before and after evaluation, refinement, (3-4 months), and continued operation beyond the project duration.

The responsibility by task and subtask is defined in the project schedule.

Task 1: Specify Detectors, Procure, Install, Test

This task involves determining locations of detection for the study area and installing detection units to the selected locations. NYCDOT will be responsible for this task. KLD will provide limited incidental support.

1.1 Preliminary Plan for Detectors

The preliminary plan for the detector locations is shown in Figure 2. These will generally be RTMS units, but video will be considered in select locations, or used where it now exists. The plan will be reviewed and refined in the first week of the project, with the identification of subzones also discussed. KLD will participate in Subtask 1.1 is a support role to NYCDOT, consistent with the staffing level.

1.2 Detailed Plan

NYCDOT will develop the detailed plan, including the exact location of each detector, the power and other implementation details, and a robust set of communication channels so that information is sent from the detectors via NYCWIN to NYC_TCS for uses comparable to the ACDSS system.

1.3 Contracting & Installation

NYCDOT will implement and oversee these processes in accord with its standard practices.

1.4 Testing

NYCDOT will require its standard acceptance testing of the installation, and assure that the objectives as stated in Task 1.1 are achieved.

The *deliverable* for Task 1 is the implementation of the detector system in accord with Task 1.2, and visible to the control system in accord with the assigned detector identification codes. KLD will verify that the control system is properly registering the detectors, and notify NYCDOT of any problems.

Figure 2 Study Area and Proposed Detector Location

Task 2: Adapt Tools to Project Objectives

There are a set of existing tools that need to be adapted or expanded in order to serve the needs of the present project. KLD is primarily responsible for Tasks 2.1 to 2.3, and TransCore for Tasks 2.4 and 2.5.

2.1 AIMSUN Model of Network

There is a substantial effort by NYCDOT Planning to build a calibrated AIMSUN network of a large segment of Manhattan. Several agencies are coordinating their efforts in this regard (e.g. NYCDOT, MTA, LMCCC). KLD is one of the set of consultants working on various elements of the overall area being modeled. The full set of models is available for use on NYCDOT projects as needed.

In this subtask, KLD will obtain existing models that are relevant to the present undertaking, and code other intersections within the defined zone (Figure 2) as needed. No new data collection will be done.

2.2 Web Services Interface

The web services interface used in the ACDSS is a powerful tool for moving data from detectors and controllers to the control algorithm that will select plans in the present undertaking[1], and for moving the new control settings to the field. The interface requires an inventory of the detector and controller codes, and the links to the control algorithm, as well as the related generalized coding that will identify detectors and controllers with zones and subzones. Based upon lessons learned to date, adaptations may be needed related to controller firmware, conditions under which control is dropped in subzones, and related issues.

2.3 ACDSS

The ACDSS structure exists, but some adaptation is needed. For instance, the concurrent simulations are not needed as part of the decision process. One simulation display (contingent upon hardware, display capability, and coded network) may be desired for illustration of the control. (Simulations will be used in the testing, but it will be decided within Task 2.3 whether they should be available for either on-line or post-decision visualizations).

2.4 Systems Integration

This subtask relates to assuring that the overall system works in the NYC_TSC environment, and is the responsibility of TransCore.

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[1] In the Victory Blvd application, the control algorithm computed the plans in real time.

2.5 Testing

This subtask supports Subtask 2.4, and is the responsibility of TransCore.

The *deliverable* for Task 2 is the set of adaptations specified above, resulting in the necessary integrated system to support the control.

Task 3: Design Control, Based upon Zones & Subzones

Task 3 is a core activity, for which KLD is primarily responsible, with the active involvement of NYCDOT.

3.1 Develop Control Algorithm

The purpose and intent of the control algorithm is specified in ten points enumerated in the "Background" section of this scope. Those points define a library-based system that can receive updates in an off-line mode, and can store data for later use in refining plans. The control is to be implemented in a way as to "not preclude" relatively easy future expansion to an adaptive, self-learning autonomous system, but the implementation of such a system is not part of the present scope.

The actual control implementation is by subzone, *and may extend to subzones that are external to the zone shown in Figure 2.* Specifically, if a subzone within the zone is for instance an arterial segment and the control change is split and offset, then the offset change will have to be "tapered" back from the boundary intersection to (for an AM southbound flow) an upstream intersection at which "no change" is planned ---- there can be no disrupt, discontinuous changes at the boundaries, lest problems be induced.

Likewise, the same thinking needs to apply in the PM for flows approaching the zone from the south, and from other directions. Hence, the control area can be thought of as the zone shown in Figure 2, with "fingers" extending beyond it, to assure that changes are tapered and smoothed as needed. This has to be an explicit part of the control algorithm.

The control algorithm conceptual work must also consider:

- ➢ The reality that control is motivated by subzone performance, taking into account the state or condition of contiguous subzones;
- ➢ The reality that overall zone control is built from the subzones, and from the "fingers" beyond the zone shown in Figure 2;
- ➢ The possibility that overall zone control will require that metering be done beyond the zone, in one of more of the "fingers";
- ➢ If control is set for periods of up to 3 hours, in the plan selection one must balance the information received in (a) the most recent 15-30 minutes with the (b) pattern to date for the given day;
- ➢ If the control is set for periods of up to 3 hours, the value of having some more frequent adaptations of split, within the specified plan.

The possible need for decision "by exception" within a given control period must also be considered, as a rare necessity. That is, the possibility that an incident or event within the longer control period may trigger the need for operator intervention.

The purpose of Task 3.1 is to design and document the structure of the control algorithm, and to obtain NYCDOT approval on the white paper documenting that structure. It is expected that NYCDOT will be actively involved in the discussions leading to the design.

3.2 Algorithm to Forecast Traffic

The existing algorithm within ACDSS used to provide estimates of future traffic at the anticipated time control is implemented is to be considered and adapted.

A complicating issue that will need to be considered is the length of time for which control is to be implemented. Specifically, if the control period is to be blocks of two hours or more, the very concept of the basis for decision / plan selection may require a re-definition of what one means by "forecast". For instance, what observations in which time period are to lead the system to decide *in advance* on the control plan to put into effect from 4pm to 6pm on a given day?

This subtask shall have to address such issues, and integrate the findings and recommendations into the Task 3.1 document.

3.3 Code or Adapt Code

After NYCDOT accepts the Task 3.1 document, KLD will have to adapt the existing code and/or add new code, with regard to the control algorithm and the decision process.

3.4 Design Test Plan, Tasks 3 & 5

The control as implemented has to be tested on two levels:

- The concepts need to be tested in a simulated environment, within Task 3;
- The testing has to be re-run with the refined algorithm and the specific set of plans, again in a simulated environment, within Task 5, in advance of field implementation.

Subtask 3.4 will provide the test plan, expressed in terms of the flow levels, combination of conditions, and special events (e.g. an incident that reduces capacity in a subzone, or weather that reduces overall capacity). The test plan will have to be consistent with the scheduled time and staffing.

NYCDOT will have to sign off on the test plan.

3.5 Execute Test Plan, Task 3

Subtask 3.5 is the implementation of the test plan developed in Subtask 3.4.

3.6 Refine Control Algorithm

Subtask 3.6 is the refinement of the control algorithm and/or its code, based upon the results of Subtask 3.5.

The *deliverables* for Task 3 are the documents cited in Subtasks 3.1 and 3.4, the acceptance of each by NYCDOT, and the revised control code of Subtask 3.6.

The deliverables will include a rack-mounted PC on which the control algorithm and system software will reside, and from which the network in Figure 2 will be observed and controlled via a web services interface. The rack-mounted PC will be expandable (memory, processors) so as to handle a larger network, but that expansion is not part of the deliverable. The AIMSUN software on the existing ACDSS rack-mounted software will be accessed and run on that machine, so that an additional license is not needed.

Task 4: Design Displays for Decision-Making, Based upon Zone/Subzone

KLD has primary responsibility for Subtasks 4.1 and 4.2. TransCore has primary responsibility for Subtask 4.3.

4.1 Select Metrics, Design Displays

The guiding principles are (a) the metrics are to be based upon occupancy and flow, as shown in Figure 1, (b) the focus is on subzones rather than links, (c) if Optional Task 11 is activated by NYCDOT, the metrics may include travel time to some extent.

4.2 Implement re Task 3 & 6

The *deliverable* is to be a real time GIS map displaying on a monitor screen the color-coded network for sub-zones or for links by their performance or by their flow condition.

4.3 Implement re Task 7

The *deliverable* is to be the same real time GIS map, but on the front displays and operator positions in the JTMC.

Task 5: Develop Library of Plans

KLD has primary responsibility for Subtasks 5.1 and 5.2. TransCore has primary responsibility for Subtask 5.3.

5.1 Develop Concept for Set of Plans

Between 12 and 15 distinct plans are to be enumerated for different flow/occupancy conditions, covering at least 5 distinct periods (AM, midday, PM, overnight, weekend). Existing plans shall be taken into account. Consideration shall be given to whether plan selection in one subzone limits plan selection in contiguous subzones. NYCDOT may choose to reduce the number of distinct plans, to concentrate on certain plans or periods. The *deliverable* is to be a short tech memorandum specifying the plan/periods/combinations to be developed.

5.2 Develop Plans

Subtask 5.2 will be executed after data becomes available from the system detectors in Task 1, and the results are available from most of Subtask 3.5.

5.3 Store, Test Retrieval

The plans of Subtask 5.2 will be stored on the system, and the retrieval tested. NYCDOT will sign off on the completion when appropriate.

Task 6: Test Control Off-line, Verify Functionality

KLD has primary responsibility for Subtasks 6.1 and 6.2. NYCDOT has primary responsibility for Subtask 6.3.

6.1 Execute Test Plan, with Task 5 Plans in Use

Refer to Subtask 3.4 and Task 5. Execute the Test Plan, which shall have been designed with the time and budget assigned to this subtask.

6.2 Assess & Refine

Based upon the results of Subtask 6.1, modify the control algorithm as needed.

6.3 Acceptance Testing

NYCDOT has responsibility for accepting the results of this Task, after which work may proceed on Task 7.

Task 7: Install & Field Test System

TransCore has primary responsibility for Task 7. KLD will be available in a support role.

7.1 Install, Integrate

Self-explanatory.

7.2 Field Tests, Off-Peak & Peak

Self-explanatory.

Task 8: Operate System

NYCDOT has primary responsibility for Task 8. TransCore will be available in a support role.

8.1 Before Data, System Detectors

Self-explanatory.

8.2 Operate System

Self-explanatory.

8.3 After Data, During Operation

Self-explanatory.

8.4 Summary of Results

Self-explanatory.

Task 9: Reporting

The responsibilities by subtask are indicated below. The deliverable will be a written report, not to exceed 100 pages with appendices, and related electronic files. If the tasks or subtasks for which the named party was responsible involved computer data files or code, electronic copies will be provided to NYCDOT, as will a non-exclusive license to use the related intellectual property by NYCDOT personnel in their work for NYC.

9.1 Detectors, Control, Displays

KLD is responsible for this subtask.

9.2 Integration & Implementation

TransCore is responsible for this subtask.

9.3 Operations & Evaluation

NYCDOT is responsible for this subtask.

Task 10: BPM & O/D

The Best Practices Model (BPM) of NYMTC has been used in a number of the modeling efforts cited in Subtask 2.1 and in other efforts.' KLD has done some of these applications. It can be used in the present undertaking to identify flows within and near the zone of interest, and to consider the effects of changing impedances. This can be used to guide expected changes in routing induced by control plans.

Existing calibrations and the product of concurrent on-going NYCDOT or other work will be sought, using the good offices of NYCDOT in sharing such information as the MTM and other AIMSUN modeling (networks, calibrations, use of BPM, other O/D information).

10.1 Use Multiple Sources, Synthesize

The BPM is to be used as specified above, and in conjunction with other means of obtaining insight into flow and O/D patterns including but not limited to (a) the AIMSUN O/D features, (b) work product from other efforts, to the extent that they become available in a relevant time frame, (c) general traffic operations knowledge and experience in the area.

10.2 Integrate into Tasks 3 & 5

The knowledge gained in Subtask 10.1 will be used in Tasks 3 and 5, both to guide the work and to be incorporated as specific knowledge.

Task 11 (Optional): Taxi Data for O/D, TT, Other

The GPS data base of taxi trips in NYC has become available in some form for use by NYCDOT, that form being trip ends and travel times. This has allowed supplemental and confirmatory travel time data to be extracted for verification purposes. KLD has done some of this work.

Such data can be used in the present undertaking to confirm travel time estimates. Should more detailed data become available from the same data base, or a feed of more real time data become available, the information can be used as part of the traffic signal plans. Alternatively, the existence of such data can be anticipated, and its use designed into the control algorithms in Task 3 as part of a data fusion effort.

11.1 Acquire Data Base Feed via NYCDOT

Any data of the sort described would become available to NYCDOT, and can be used in the control algorithm design as described above.

The preference would be to design the use of historic, periodically updated, or even real time data into the control decisions. An alternate plan could be the development of a white paper by which such data could be used in control decisions, as another data source.

11.2 Use as O/D Source in Task 10

One specific use is a supplement to O/D estimates provided by BPM or other sources, recognizing that it is specific to one mode, but a significant one.

11.3 Use as Travel Time Source in Task 4

Another specific use is for travel time data. It is anticipated that this Subtask 11.3 will actually be accomplished under NYCDOT Planning/Modeling funding, so no cost is included for this subtask.

The *deliverables* in this effort can range from a white paper to integration into the control algorithm decision process, depending upon information and/or a decision by NYCDOT on the probable available of the data.

Extensions beyond Present Scope

The material described in this section is not within the present scope, schedule, or cost. Rather, it describes that which can be built upon the foundation laid in the present undertaking.

The undertaking described in the scope provides the foundation for optimum signal control in real-time using an evolutionary self-learning library plus granular split level adjustment. That is, artificial intelligence (AI) elements can be incorporated into the system to provide robust control for the target grid network on a strategic level (e.g., detecting pattern changing) while the system fine tunes the operations tactically using real time split adjustments dictated by real time traffic variations.

To be sure, the library *starts* with a list of pre-designed control plans considering historical traffic flow patterns but can keep updating itself in a self-learning fashion whenever a *new pattern* is encountered. Then this selected pattern is further modulated in real time according to the detected traffic variations.

As part of the effort, a pattern matching algorithm can be implemented, leading to the implementation of a self-learning system/self-evolving library.

Schedule

Table 1 shows the proposed project schedule, in MS Project format.

As cited at the beginning of the "Task" descriptions, the overall project schedule is defined by the following:

- The development of the control and related software is concentrated in the first 4-5 months of the project, concurrent with the procurement and installation of the detectors (programmed for 5-6 months, including acceptance);
- The collection of relevant data from the detectors, development of library of plans, and installation of the system in the next 4-5 months;
- The implementation of the system, with periods for before and after evaluation, refinement, (3-4 months), and continued operation beyond the project duration.

The responsibility by task and subtask is defined in the Table 1 at one of three levels (oversight, primary, incidental). Incidental with no planned involvement at all is shown by "---". Consultant 1 is KLD, of the GPI ESA Team. Consultant 2 is TransCore.

Budget and Staffing

The KLD staffing is shown in Table 2, and the associated budget is shown in Table 3. Optional Task 11 is shown separately, and is not part of the core activity.