LOOKING OUT FOR YOU

CITY OF TORONTO'S DEPLOYMENT PLAN FOR ARTERIAL TRAFFIC CAMERAS

Rajnath Bissessar, P.Eng., Manager – ITS Operations, Traffic Management Centre
City of Toronto
703 Don Mills Road, 5th Floor, Toronto, Ontario, Canada, M3C 3N3
Tel: +1-416-392-8826, Email: rajnath_bissessar@toronto.ca

Linda Lee, P.Eng., Senior Engineer – Urban Traffic Control Systems
City of Toronto
703 Don Mills Road, 5th Floor, Toronto, Ontario, Canada, M3C 3N3
Tel: +1-416-397-5769, Email: LLee1@toronto.ca

Perry Craig, P.Eng., Transportation Systems Manager
Parsons Inc.
625 Cochrane Drive, Suite 500, Markham, Ontario, Canada, L3R 9R9
Tel: +1-905-943-0508, Email: Perry.Craig@parsons.com

Paper prepared for Presentation at the
Road Traffic Operations & Management or Intelligent Transportation System (ITS) Sessions
of the 2014 Conference of the
Transportation Association of Canada
Montreal, Quebec

TORONTO

PARSONS

ABSTRACT

The City of Toronto's Traffic Management Centre continuously strives to enhance the safety of all road users and improve the traffic flow for all modes of transport, and is constantly upgrading its traffic control and management systems. As the City's roads and other public transport routes become more congested, there is a growing need to monitor the transport network and manage demand and congestion more effectively. Closed circuit television (CCTV) traffic surveillance cameras provide the ability to directly monitor the road network.

While the City has ample CCTV coverage on its expressways, CCTV coverage on the City's arterial network is minimal. The City and Delcan conducted a study to develop strategies and criteria for the deployment of CCTV traffic surveillance cameras on selected major urban arterial streets within the City, including guidelines for locating the camera. The ultimate object was the preparation of a proposed plan for the deployment of 120 CCTV cameras within the next three years; from 2014 to 2016.

This paper / presentation will highlight key considerations in the selection and deployment of CCTV traffic surveillance cameras along urban arterial streets, and describe:

- Key factors that contribute to traffic congestion in the City;
- Strategy for selected deployment of CCTV traffic surveillance cameras across the City;
- Review of available camera technologies;
- Camera mounting options and guidelines for locating the cameras on the street;
- Communications network requirements and cost-effective solutions to bring camera images back to the Traffic Operations Centre; and
- City of Toronto's final deployment plan, including the camera locations, cost and benefit estimates, benefit / cost ratios, and priorities for the deployment of the cameras.

1 INTRODUCTION

1.1 Project Background

The City of Toronto's Traffic Management Centre Section of the Transportation Services Division continuously strives to enhance the safety of all road users and improve the traffic flow for all modes of transport, and is constantly upgrading its traffic control and management systems. As the City's roads and other public transport routes become more congested, there is a growing need to monitor the transport network and manage demand and congestion more effectively. Closed circuit television (CCTV) traffic surveillance cameras provide the ability to directly monitor the road network.

The purpose of this study is to develop strategies and criteria for the deployment of CCTV traffic surveillance cameras within the City of Toronto, including guidelines for locating the cameras on-street. The ultimate objective is the preparation of a proposed plan for the deployment of 120 CCTV cameras within the next three years; from 2014 to 2016.

1.2 Key Traffic Congestion Contributing Factors

Travel demand continues to rise in the City of Toronto as the population increases and the economy grows. New road infrastructure is not able to keep up with this increase in travel demand – in fact, it is impractical to build enough roads and infrastructure to comfortably accommodate this demand. The resulting situation – where travel demand exceeds the capacity of the transportation network – is *traffic congestion*. Each area of the city has different factors that contribute to traffic congestion. Roads in one area may be affected by issues related to parking and stopping or construction work zones; others by infrastructure bottlenecks that decrease road capacity; traffic in all parts of the city can be affected by unexpected collisions and other traffic incidents. The following are five key factors that contribute to traffic congestion in the City:

- Urban freeway operations, including recurrent and non-recurrent incidents that result in:
  - Traffic queuing back from the freeway on-ramps onto the arterial streets; and
  - Traffic diverting from the freeway onto the major arterial streets;
- Intersection operations including:
  - Outdated signal timings and/or phasing due to variations in traffic volumes and/or variations in peak traffic demand times-of-day; and
  - Incidents and vehicle collisions;
- Travel lanes occupied due to:
  - Illegal vehicle parking / standing / stopping; or
  - Roadway and building construction;
- Transit and priority vehicle competition including:
  - Transit vehicle stops (i.e., with passenger loading and unloading); and
  - Transit signal priority, high occupancy vehicle lanes, etc.; and
- Special events (e.g., major sporting events, Canadian National Exhibition, etc.).

1.3 Problem Statement

The most congested locations in the City are often those signalized intersections:

- On arterial streets that intersect with the urban freeway (i.e., at ramp terminals and adjacent major intersections):

- For example, the most congested intersections are often adjacent to:
  - Highway 401;
  - Gardiner Expressway; and
  - Allen Road.
- Along major arterial streets that run parallel to the freeway (i.e., to form a major transportation corridor):
  - The problem is particularly evident whenever an incident (e.g., congestion, collision, etc.) occurs on the freeway that causes traffic to divert to alternative routes within the same transportation corridor.
  - The three major transportation corridors in the City are:
    - Gardiner Expressway;
    - Don Valley Parkway; and
    - Highway 401.
  - Major arterial streets that parallel these major corridors include, for example:
    - Lake Shore Boulevard;
    - Don Mills Road; and
    - Wilson Avenue / York Mills Road.
- Adjacent to major special events within the City:
  - Such problems are typically localized around either Exhibition Place, Rogers Centre or Air Canada Centre.

As a related matter, the Pan Am Games will be a major sporting event to be held in the City in 2015. It will be important for the City to manage traffic congestion to ensure that athletes arrive within reasonable times at their sporting venues. The newly-constructed Athletes' Village, which will be home for 10,000 athletes, coaches and officials, will be located in the West Don Lands (i.e., centred on Front St, between Bayview Ave and Cherry St); while the games will be located throughout the Greater Toronto Area. Competition "venue clusters" will include the following facilities:

- Etobicoke Pan Am Complex (i.e., at Centennial Park);
- Markham Pan Am Complex;
- Mississauga Pan Am Complex;
- Toronto Pan Am Park (i.e., at Exhibition Place);
- University of Toronto (Scarborough) Pan Am Complex;
- University of Toronto (Downtown) Pan Am Complex; and
- York University Pan Am Complex.

1.4 Traffic Monitoring Needs

As the City's roads and other public transport routes become more congested, there is a growing need to monitor the transport network and manage demand and congestion more effectively. CCTV traffic surveillance cameras provide the ability to directly monitor the road network; specifically, to view the traffic movements and queuing at the signalized intersections. In this respect, the City's traffic monitoring needs can be best addressed through the deployment of CCTV traffic surveillance cameras at signalized intersections:

- On major arterial streets that intersect with an urban freeway (i.e., at ramp terminals and adjacent major intersections);
- Along major arterial streets that run parallel to an urban freeway (i.e., to form a major transportation corridor);

- Adjacent to major event facilities including Exhibition Place, Rogers Centre, and Air Canada Centre;
- Along routes between the Pan AM Games Athletes' Village and sporting venues; and
- At other very high volume major intersections.

2 DEPLOYMENT STRATEGY

2.1 General

The proposed strategy for the deployment of CCTV traffic surveillance cameras in the City of Toronto is a two-step process:

- First – determine the arterial street routes to be monitored; and
- Second – determine the locations along the selected routes to place the cameras.

The following sections detail the guidelines for implementing this process.

2.2 Arterial Camera Deployment Strategy

The City of Toronto is a large metropolitan area; covering an area of 630 square kilometres, with a maximum north-south distance of 21 km and a maximum east-west distance of 43 km. Even with the significant planned program of deploying 120 CCTV traffic surveillance cameras within the City, choices will have to be made and priorities set for locating these (and future) cameras.

The following points set out the strategic approach for deploying CCTV traffic surveillance cameras within the City. CCTV cameras shall be deployed to view the traffic movements and queuing at the signalized intersections:

- Along "Major Arterial" routes (as defined by the City's existing Road Classification system; that is routes with greater than 20,000 vehicles per day; greater than 5,000 bus passengers per day, and speed limits of 50 to 60 km/h);
- At the intersections of Major Arterials based on the following strategic approach:
  - On Major Arterials that intersect with the following urban freeways:
    - Gardiner Expressway;
    - Don Valley Parkway / Highway 404;
    - Highway 401; and
    - Highway 400 / Black Creek Drive;
  - Along Major Arterials that parallel the following major urban freeways:
    - Gardiner Expressway;
    - Don Valley Parkway / Highway 404; and
    - Highway 401;
- Adjacent to Exhibition Place, Rogers Centre, and Air Canada Centre, and along routes that serve the upcoming Pan Am Games Athletes' Village and the various sports venues in the GTA;
- Other major intersections based on the highest average 24 hour volume and/or most congested intersection locations; and
- Distributed geographically across the City.

2.3 Arterial Camera Field Location Guidelines

With respect to the placement of CCTV traffic surveillance cameras, past experiences of the City and other jurisdictions have shown that often not all location guidelines can be met at every location. Therefore, to ensure that the most important guidelines are satisfied, the following list of location guidelines are prioritized (with Priority 1 being the higher):

<u>Priority 1 Guidelines:</u>

- Provide full viewing coverage of traffic movements and queuing at the selected signalized intersection;
- On the street, locate to promote the joint use of existing poles (i.e., to provide easy access to power, communications and roadside cabinets); and
- Provide safe and convenient maintenance access.

<u>Priority 2 Guidelines:</u>

- Where feasible, locate on City-owned buildings to maximize the number of signalized intersections that can be viewed;
- On the street, locate in a similar location (e.g., on the same side of an intersection) to provide a consistent point of view along the corridor, particular at closely spaced adjacent intersections;
- Maximize view of any intersecting major arterial street and/or any connecting freeway ramp;
- On the street, preferred to not locate on an intersection centre island / median pole (i.e., to minimize the potential for knock-downs by vehicle collisions); and
- On the street, preferred to locate close to the existing traffic signal controller cabinet (i.e., to minimize the need for new underground conduit or new overhead cabling).

3 TECHNICAL CONSIDERATIONS

3.1 Camera Technologies

The review of CCTV camera technologies focused on cameras appropriate for intersection and corridor monitoring with respect to suitability for transporting video signals to the Traffic Operations Centre (TOC) using the proposed communications medium (see subsection below), compatibility with the City's existing Video Switch Matrix (VSM), and compatibility with the City's future Video Management Software (VMS).

CCTV cameras available in today's market can be divided into two main categories based on the video output available for viewing:

- Analogue cameras; and
- Network (or IP) cameras.

Analogue cameras produce composite video output that is suitable for viewing on legacy video monitors as well as used as an input to legacy VSMs such as the City's existing matrix switch. Analogue video signals from the field cameras require dedicated broadband communication medium involving video multiplexers and fibre optic backbone.

Analogue video can be encoded and compressed using embedded or external video encoders to produce video streams over a network. Analogue cameras with embedded encoders are referred as network or IP cameras, and output digital (IP) video streams directly to the network.

Encoded video streams are transported over a standard Ethernet network over LAN or WAN services using compression techniques such as MPEG2, MPEG4, and H.264, with H.264 being the most recent standard. Currently MPEG4 and H.264 are the most widely used formats in the industry. H.264 provides a higher compression ratio, and can be used over low bandwidth communications.

In summary, IP video streams are more suitable for transporting the video signal from the field camera to the TOC via widely used Ethernet networking technology.

Analogue Camera with Encoder vs. Network Camera

Both an analogue camera coupled with external encoder and an IP camera produce digital IP video streams, but there are some differences that affect the operation and installation of the system. Below are some points to consider in choosing which method to deploy for this project.

<u>Network or IP Camera:</u>

- Video is encoded and compressed internally and streamed directly on to the network;
- Requires less cabling, standard Cat5 LAN cable and power cable (some cameras can be powered through the LAN cable using power-over-Ethernet (PoE) techniques and hence only require Cat5 LAN cable);
    - Note that PoE is constrained by a maximum cable length of about 100 m;
- Most IP cameras support ONVIF (Open Network Video Interface Forum) – a camera control protocol standard that makes them compatible with most Video Management Software (VMS);
    - Currently, major VMSs support most IP cameras in the market (e.g., Genetec, Milestone, and others have lists of supported cameras and encoders in their datasheets);
- IP cameras are becoming more popular as the CCTV industry is switching from analogue to the digital world;
- Encoded video streams can be decoded back to analogue for input to the existing 'AD' VSM; and
- Camera control for most IP cameras are not supported by the existing 'AD' matrix switch.

<u>Analogue Camera Coupled With Encoder:</u>

- Existing analogue cameras can be converted to IP streams using external encoders;
- Requires cabling for analogue video (typically co-axial cable), camera control (RS232 or RS422) and for power;
- IP streams can be decoded back to analogue to be fed to the existing 'AD' matrix switch;
- Camera control from the 'AD' matrix switch passed transparently through decoder/encoder pair to the analogue camera;
- Currently, camera control from the 'AD' matrix switch is compatible with those cameras that support 'AD' protocols only;
- Most encoders and camera control protocols for analogue cameras are currently supported by major VMSs (i.e., camera control from the VMS is routed through the network and encoder to the analogue camera); and
- Major VMSs publish 'hardware supported' list that include cameras, encoders, hardware matrices, and CCTV keyboards as well as list of supported PTZ protocols.

Compatibility with Existing Video Switch Matrix

The existing 'AD' matrix switch provides the switching functions for the existing PTZ and dome cameras currently in operation. The City is currently migrating the existing analogue CCTV system to IP video, which includes new Video Management Software by 'Genetec' to replace the existing analogue Video Switch Matrix (VSM), and the existing 'AD' switches will be replaced.

In the interim, it is assumed that the analogue VSM will be maintained and operated in parallel with the new VMS until such time that all cameras are converted to IP and all CCTV functionalities are migrated and cutover to the new system. All existing analogue cameras will be digitized using encoders at the TOC to interface with the 'Genetec' VMS so that video will be available to both systems until the cutover is complete.

'Genetec' also offers support for hardware matrix switches through a special software module that can be used to support PTZ functions for existing cameras. This functionality would allow the City to emulate the VSM's functions from the 'Genetec' workstation for the interim operation, provided that camera control protocol for the existing cameras is supported by 'Genetec'.

Recommendation for IP Camera Selection

The installation of the 'Genetec' VMS presents the City with an opportunity to shop from a vast selection of IP cameras fully supported by the new VMS. 'Genetec' maintains a vast inventory of supported hardware; compatibility can easily be confirmed from the list that can be downloaded from the 'Genetec' website.

The challenge in camera selection lies in the evaluation of the quality of the picture provided by the camera under various environmental conditions, which includes operation in various lighting conditions from low light facing car headlights to bright sunshine, and operations in conditions such as winter, summer, wind, rain, etc. The City is recommended to gather information from other municipalities and agencies currently using the 'Genetec' VMS about the type of camera employed and their performance with the VMS, and conduct field tests involving several cameras from different vendors to evaluate and compare the performance of each.

3.2 Communications Network Requirements

As part of their 'RESCU' Advanced Traffic Management System (ATMS) deployment, the City has an extensive fibre optic cable based communications backbone installed along the City's expressways and freeways, including the Gardiner Expressway, Don Valley Parkway and Highway 401. Currently, a small portion of available bandwidth is utilized, which can be very useful in minimizing project costs, and simplifying installation and integration efforts. Therefore, whenever possible, this existing communications infrastructure will be used to transport the video streams from the field location to the Traffic Operations Centre.

Various options were considered to provide the communications platform to transport the camera video stream to the Traffic Operations Centre (TOC), including:

- Spread spectrum radio network in combination with the existing RESCU fibre optic plant. This solution provides a wireless Ethernet backbone to bring the video streams from the cameras to the nearest access point to the existing RESCU fibre optic backbone;
- Cellular data services using HSPA+, 4G and LTE networks offered by major service providers;

- Leased DSL lines at intersections and at the TOC, with video streams passed over the internet;
- Managed network services; and
- Leased dark fibre.

As illustrated in Figure 1, a City-owned spread spectrum radio solution in conjunction with the City's fibre optic communication system is recommended for this project, as the solution provides ample bandwidth to support the video streams from all cameras.

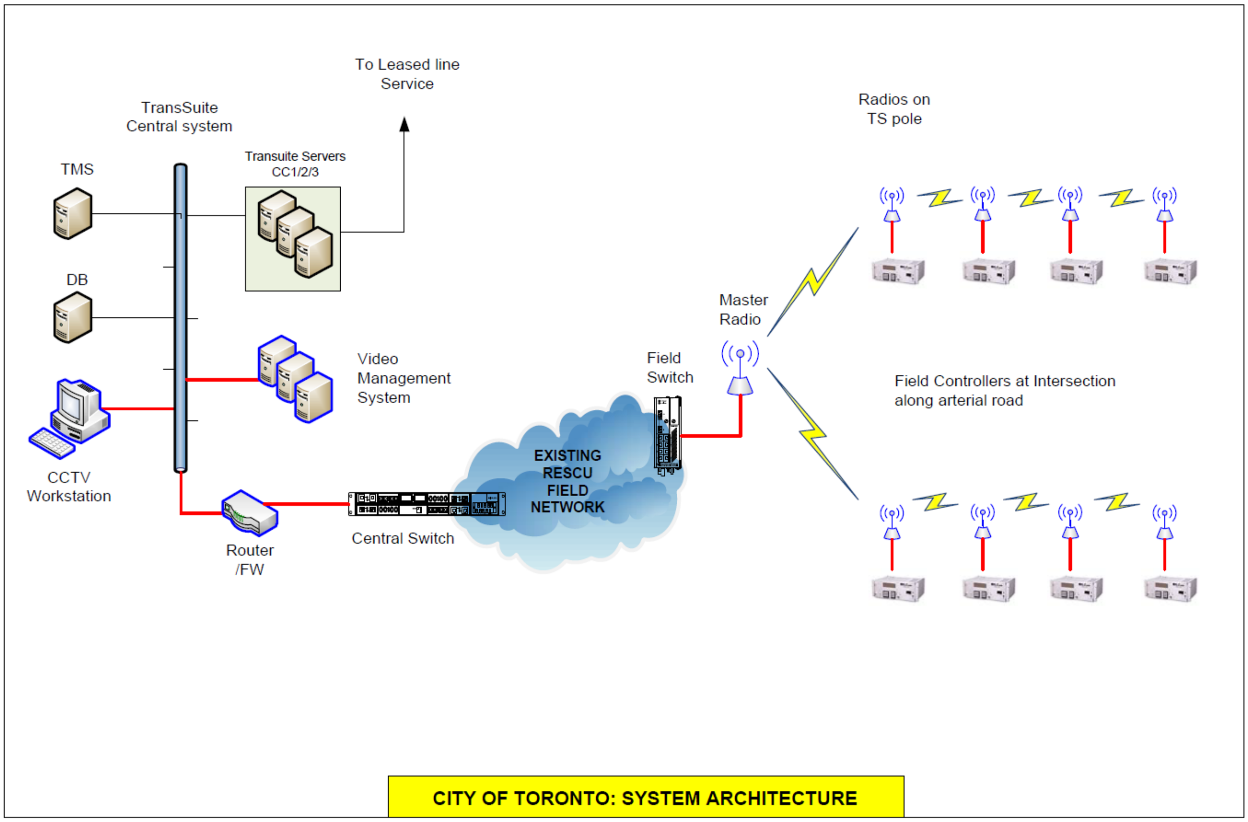

Figure 1 : Recommended Communications System Architecture

In this configuration, the current RESCU data node locations, which are distributed along the fibre path, will be used as a concentrating point for collecting data from signalized intersections and transporting it to the TOC over the RESCU backbone.

The existing RESCU node locations include the Ethernet switches in the west ring along the Gardiner Expressway, OTN nodes in the north and east rings along the DVP, and OTN nodes along Allen Road.

Spread spectrum radios can be used to radiate out from the node locations to individual intersections. The configuration is based at the master radio being installed at the node location with slave / repeater radios installed at each intersection. Camera poles located at a node location or anywhere along the fibre path can be used for the installation of master radios to reduce infrastructure costs.

3.3 Camera Mounting Options

For the mounting of the cameras in the field, there are two key considerations:

- Height at which the camera is mounted (and hence, the viewing distance and angle); and
- Rigidity of the camera mounting pole or mounting base (for improved image quality).

Camera Height

The higher that the camera is mounted above the ground, the greater is the potential for longer and wider camera fields of view. In this respect, it is often preferable for the camera to be mounted at a height of 12 m to 18 m (40 ft to 60 ft) to provide a "bird's eye view" of the overall traffic flows around the camera location (i.e., signalized intersection), and to possibly also monitor adjacent intersections.

That said, the primary objective for the deployment of CCTV cameras is to enable City staff to view the traffic conditions at the selected signalized intersection such that, when necessary, appropriate signal timing changes can be made in response to congested traffic. Therefore, as a minimum, the camera should be mounted at a height of 7 m to 8 m to provide a view of all traffic movements at the intersection. (For reference, the traffic signal heads are typically mounted at a height of 4.5 m to 5 m.)

In addition, the height of the camera should be selected such that the view is not obstructed by the tree canopy, adjacent buildings and/or other overhead structures.

Camera Mounting Poles

CCTV traffic surveillance cameras are typically mounted on a roadside pole. The type of pole used to mount the camera is extremely important in regards to the resultant image quality. For ITS applications, CCTV cameras are typically installed on solid steel, concrete or wooden poles. The main reason being that the pole should provide the necessary rigidness and strength so that the image transmitted from the camera is stable in all weather conditions. This is even more important for IP cameras for the following reasons:

- The digital compression techniques used typically only transmit those parts of the video image that has changed. If the camera is continuously moving, then the entire video image must be continuously transmitted (i.e., with no effective video compression).
- As a result, the digital video stream generated for shaking video takes up significantly higher bandwidth, which results in reduced network capacity. This is particularly a problem with a low bandwidth network. Also, in the case of those cameras on a leased communications link with limited data capacity, such as cellular service, this higher demand could easily exceed the monthly data cap and incur overage charges.
- Also, the video encoder is often overloaded by the generated digital video stream, resulting in "tiling" of the video image, which can be severe. Consequently, the shaky video produced from an IP camera is worse than what it would have been for traditional analogue video, and hence, more difficult to watch and deemed unacceptable by most TOC Operators.
- While image stabilization software in the newer IP cameras can reduce the amount of camera shake in an image, it cannot (yet) remove the shake from a camera that is continuously and significantly moving (e.g., on a gusty day).

In general, a dedicated, purpose built pole is preferred in order to maximize the potential field of view while providing a rigid mounting base. However, in the older, more densely populated areas, such as the downtown core, there is limited space to install an additional pole. Moreover, the joint use of existing poles for the mounting of cameras will minimize the deployment costs.

In consideration of the preferred camera heights and the above points, the following recommendations are made:

- Where cameras are to be installed along Lakeshore Boulevard under the Gardner Expressway, the mounts can be installed on the concrete structure in the same way as the existing cameras. The work shall be coordinated with the City's Bridges Engineer to ensure the installation would not compromise the structural integrity of the highway.
- Where cameras must be mounted at street level to provide the required view, then to again minimize deployment costs, it is recommended to use existing solid steel, concrete or wooden traffic signal poles and solid steel architectural lighting poles.
- Due to their flexibility, sectional steel traffic signal poles are not preferred (i.e., because in gusty wind conditions, the variable wind loading on the signal heads will cause the signal pole to move.)
- For intersections located in the more densely populated areas where sectional steel traffic signal poles have been installed, the City may wish to experiment with the installation of cameras on such poles (i.e., as the camera image may be acceptable most days). Where the resultant image quality is unacceptable, then the sectional steel pole could be replaced with a solid steel or similar pole (i.e., it is often possible to replace an existing pole with one of the same design, but custom made to be more rigid).
- For large intersections (typically in the suburban areas) where sectional steel traffic signal poles have been installed, a new dedicated 12 m (40 ft) concrete pole is recommended (as this is the maximum height that could be serviced with a typical traffic signal maintenance bucket truck).

The use of purpose-built steel street lighting poles for camera mounting was also considered and found to be unacceptable as the pole does not provide the required stiffness for a stable video image. Typically, the deflection characteristics of the top of the lighting pole in a windy environment would produce shaky video images that would be unacceptable for the reasons indicated above.

The use of existing Toronto Hydro poles is also currently not a feasible option due to an Ontario provincial regulation that requires a structural analysis of the impact of mounting an additional device on an existing pole. Due to the number of typically unknown parameters that would be involved in such an analysis, most professional structural engineers will not certify that the existing pole is suitable. Notwithstanding, it is noted that City senior staff has been engaged in discussions with Toronto Hydro with the aim of coming up with an amicable solution that would allow the City to proceed under a less rigorous process.

As a related point, it should be noted that, at different signalized intersections, the traffic signals (i.e., arms and signal heads) could be mounted on a hydro pole, and power lines could be mounted on a traffic signal pole. Therefore, before installing a camera on an existing traffic signal pole, it is recommended that the City's ownership of the pole be confirmed.

4 DEPLOYMENT PLAN

As part of the City's 'RESCU' ATMS deployment, the City currently has 74 CCTV traffic surveillance cameras previously deployed – primarily along the City's urban freeways, including:

- Gardiner Expressway (and Lake Shore Boulevard);
- Don Valley Parkway; and
- Allen Road.

Applying the strategies previously set out for the deployment of CCTV traffic surveillance cameras, the following additional corridors, arterial routes, and streets are proposed to be monitored:

- Highway 401 corridor;
- Bloor Street West (including connection with Dundas Street West);
- Arterial and collector streets adjacent to Exhibition Place, Rogers Centre, and Air Canada Centre;
- Major intersections along routes and adjacent to Pan Am Games venues within the City; and
- Other high volume major intersections.

5 COST ESTIMATES

5.1 Capital Cost

The budgetary capital cost estimate for the deployment of 120 CCTV traffic surveillance cameras along arterial streets within the City of Toronto is $3.5 million. (Note that this excludes the additional cameras that are expected to be provided to the City from the Metrolinx LRT projects.)

In preparing this preliminary budget estimate, the following assumptions were made:

- For the radio links, clear line-of-sight (LOS) will be available between signalized intersections and/or repeater sites;
- Site surveys will be required to confirm LOS;
- One radio repeater site will be required for transmission distances between 500 m and 1 km; for distances over 1 km, a maximum of two repeater sites has been assumed;
- In the downtown core area, all CCTV cameras and radios will be installed on existing infrastructure (e.g., traffic signal poles, etc.); cameras in the suburbs will be installed on existing traffic signal steel or concrete poles, if available, or else on new dedicated concrete poles;
- It has been assumed that approximately 50% of the cameras in the suburbs, or 25 locations, will require the installation of a new concrete pole; site surveys will be required to confirm;
- 12 m poles without camera lowering devices (as this is the maximum height that could be serviced with a typical traffic signal maintenance bucket truck);
- For the preliminary estimate, dual radios have been assumed at all signalized intersection locations; this should be fine-tuned during the detail design phase (as intersections at the end point of a radio network segment would be equipped with a single radio);
- The radio network will feed into the existing fibre optic network infrastructure to send the signal to the TOC; no fibre optic network upgrade has been included in the estimate;
- The fibre optic network backbone will have enough capacity to support the additional traffic from the new cameras;
- 20 hub locations will be required to connect the radio network to the fibre optic network backbone;

- Leased line service, such as a DSL line, has been assumed to be suitable for this project; hence costing is based on DSL service for businesses, which will provide a minimum of 1 Mbps upload speed and unlimited monthly data usage;
- IP cameras will be deployed; assuming the new 'Genetec' Video Management System at the TOC;
- Encoders will be installed to provide digital video feeds to the video switch matrix from the existing analogue cameras; and
- As it is a preliminary cost estimate, a contingency of approximately 30% has been assumed.

5.2 Operating and Maintenance Cost

Four additional TOC Operators and two additional TSOG engineering technologists were recommended to be employed during the day to monitor the additional 120 CCTV video images and actively update the traffic signal timings, etc. The four TOC Operators are estimated to cost a total of $200,000 per year, and the two TSOG engineering technologies are estimated to cost a total of $170,000 per year.

Based on the City's experience with their existing ITS infrastructure maintenance costs, the operating and maintenance costs associated with the operation of 120 CCTV cameras is assumed to be 10 percent of the capital costs or an estimated $350,000 per year.

CCTV cameras are estimated to have a life-span of approximately five years, after which time the cost to maintain the cameras begins to increase. Accordingly, it is assumed that the cameras will be refurbished and/or upgraded every five years. The cost to refurbish the cameras is estimated to be $750,000 per five year period.

6 ESTIMATED BENEFITS

6.1 Qualitative Benefits

The qualitative benefits of monitoring traffic through CCTV surveillance cameras are:

- Based on traffic demands as seen from the CCTV cameras at the monitored intersections, TOC staff will be able to identify traffic management needs and manage traffic congestion in a timely manner by deploying an appropriate signal timing plan and/or modifying the current traffic signal timings. As a result, traveller delays due to signalized intersections could be reduced. Other related benefits as a consequence of reduced traveller delays includes reduced fuel consumption, reduced greenhouse gas emissions, and reduced traveller frustrations.
- Emergency response and incident clearance times could be reduced, through gathering relevant details of the incident as early as possible and dispatching appropriate personnel and equipment for site clearance. Relevant incident information could include exact location of incident, direction of travel, number of lanes blocked, number of vehicles involved, any possible injuries, etc. Potential benefits can include saving lives through quicker response times, and reducing travellers' delays by bringing the system capacity back to normal conditions quicker.
- Travellers could be alerted in a timely manner (e.g., through dynamic message signs (DMS), social media, etc.) in advance of work zones, incidents and special events delays not planned earlier and possibly advised to use alternate / detour routes in the network through traffic monitoring.

- Traffic speed is an important determinant of emissions and it directly affects the air quality. Through congestion management, vehicle throughput at any given intersection could be increased, which will change the demand and improve the speed of the arterial network. As a result it will improve the concentration of pollutants and the overall air quality.
- CCTV camera images will be provided to the news media as well as made available at the City website. Travellers will be able to visit the website or download an application to their cellular phone to plan a trip and receive traffic updates regarding traffic congestion, any incident, construction activities, lane closures for any planned event, etc.

6.2 Quantitative Benefits

The quantitative benefits of monitoring traffic through CCTV surveillance cameras were estimated by modelling traffic operations at selected sample signalized intersections. The "measures of effectiveness" (MOE's) that were considered were:

- Intersection delays;
- Incident delays; and
- Fuel savings.

For the purpose of the analysis, five sample intersections from across the City were selected from the proposed camera deployment locations, and average MOE's per intersection were calculated. These five intersections were as follows:

- Bayview Avenue at York Mills Road;
- Bathurst Street at Bloor Street;
- Blue Jay Ways at Front Street;
- Bay Street at Lake Shore Boulevard; and
- Islington Avenue at The Queensway.

To estimate the benefits in reduction of intersection delay and incident delay time, the following conservative assumptions were made:

- Intersection Delays:
- Over the 10 most congested months of the year, the signal timing at each signalized intersection that is being monitored would be modified once in that month in response to operator-identified incident or congestion at that intersection. So for the 120 signalized intersections being monitored, the signal timings would be modified, on average, a total of 1,200 times per year.
- Based on the Synchro modelling results, the average delay time savings resulting from modifying the signal timings during the AM or PM peak hours is 140 hours per event. So for the 120 signalized intersections being monitored, the total time saved per year would be 168,000 hours.
- Incident Delays:
  - On average, the time saved in incident related delay at a signalized intersection that is being monitored would be 2 minutes[1].
  - Over an average one month period, it is assumed that 25 of the 120 signalized intersections being monitored would encounter incident related delay, during the AM or PM peak hours, that could be reduced.
  - Based on the Synchro modelling results, the average incident delay time savings during the AM or PM peak hours would be 888 hours per event. So for the 120 signalized

[1] Ref: FHWA ITS Deployment Analysis System (IDAS)

intersections being monitored, the total time saved per year would be 22,200 hours per month or 266,400 hours per year.

- Fuel Consumption and Unit Costs:
  - Value of travel time $15.86 per hour[2];
  - Fuel costs in Toronto $1.25 per litre[3].

Table 1 summarizes the annual benefits that have been conservatively estimated from average reductions in intersection delays, average reductions in incident delays, and savings in fuel consumption. The total annual quantitative benefits are estimated to be approximately $7 Million per year.

Table 1 : Network Benefits of CCTV Cameras Deployment Plan

	Intersection Delay			Incident Delay			Fuel Savings		
	Average Percent Delay Reduction	Time (hrs) Saved per Event *	Time (hrs) Saved per Year *	Average Percent Delay Reduction	Time (hrs) Saved per Event *	Time (hrs) Saved per Year *	Average Percent Fuel Saving	Fuel Saving per Day (Litres)	Fuel Saving per Year (litres)
Peak Hours	39%	140	168,000	20%	888	266,400	25%	755	188,700
Annual Benefits (Rounded Down)	**$2.66 Million**			**$4.23 Million**			**$0.24 Million**		

*Weekday Peak Hours Only; 250 Weekdays per Year

6.3 Benefit / Cost Ratio

The benefit / cost ratio of the proposed arterial CCTV camera project was estimated to be 6:1 based on:

- Capital cost estimate of $3.5 million;
- Three year installation program;
- Annual operating cost estimate of $370,000;
- Annual maintenance cost estimate of $350,000;
- 5-year refurbishment cost estimate of $750,000 (to be implemented over a three year period);
- Annual quantitative benefits estimate of $7.1 million (phased in over the initial three years);
- Ten-year life cycle; and
- Annual discount rate of 4%.

[2] ITE Journal published in 2008
[3] Approximate price for regular gasoline in Toronto in October, 2013

7 SUMMARY

The City of Toronto's Traffic Management Centre Section of the Transportation Services Division is constantly upgrading its traffic control and management systems to enhance the safety of all road users and improve the traffic flow for all modes of transport. As the City's roads and other public transport routes become more congested, there is a growing need to monitor the transport network, and manage the demand and congestion more effectively. Closed circuit television (CCTV) traffic surveillance cameras provide the ability for the City's TOC Operators to directly monitor the road network.

This paper summarizes the strategies and criteria developed for the deployment of CCTV traffic surveillance cameras within the City of Toronto, including guidelines for locating the cameras on-street. Potential camera technologies were reviewed and the communications network requirements necessary for bringing the camera images back to the Traffic Operations Centre were identified. Applying these strategies and criteria, a plan for the deployment of 120 IP cameras across the City was developed.

The deployment of the 120 CCTV cameras is expected to provide positive benefits to the City in terms of reductions in vehicle delays and fuel savings, with an estimated benefit / cost ratio 6:1.

The City's Traffic Management Centre Section has subsequently proceeded to prepare the detail design and contract package for the installation of cameras at an initial 40 intersection locations by 2015; with the remaining 80 CCTV cameras planned to be tendered separately and installed by 2016.