# Green Light Pre-emption of Traffic Signals for Emergency Vehicles
# Richmond, British Columbia's Approach

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## INTRODUCTION

Fire-Rescue crews routinely respond to an on-site emergency using established dispatch and response procedures. The optimization of this routine is typically only a small percentage of the total call to on-site response time. The remaining time is en-route, through traffic and traffic signals. The capability to pre-empt regular traffic signal operation to favour emergency vehicles can significantly reduce the overall response time and result in safer travel for both emergency personnel and roadway users. Traffic signal pre-emption is commonly provided for Fire-Rescue services and its availability differs by jurisdiction ranging from none, to selected intersections, to all intersections.

## EMERGENCY PRE-EMPTION SYSTEMS

There are generally two classifications of emergency vehicle traffic signal pre-emption systems (Figure 1);

### 1) Vehicle Transmit/Intersection Receive Systems

The majority of traffic signal pre-emption systems for emergency vehicles utilize a transmit device mounted on an emergency vehicle and receive/decoding equipment at each traffic signal. The receive equipment, traditionally mounted on traffic signal poles, detects transmissions from an approaching emergency vehicle and forwards the signal to a decoding device. This device verifies the emission pattern or code, and sends an electrical command instructing the traffic signal controller to over-ride its current operation to provide a specific signal sequence favouring the emergency vehicle. This type of pre-emption uses transmit/receive recognition technology such as siren, strobe light, radio signals or GPS reference. The flexibility of signal control relies on the sophistication of the control equipment at each traffic signal, pre-empting from one to four directions depending on the pre-emption system and receive hardware installed. Typically, only one fixed signal sequence per approach direction can be selected. Pre-emption is active until the emergency vehicle passes through the intersection or a pre-determined maximum pre-emption time is reached. Equipment and installation of these systems generally costs $2,000 per emergency vehicle and $5,000+ per intersection. Maintenance and troubleshooting of these systems can be onerous to provide city wide reliability.

### 2) Route Pre-emption Systems

Route pre-emption systems assume a certain starting location (i.e.: Fire Hall, Ambulance station) and pre-empt traffic signals on a pre-determined travel "route" from the starting location to an emergency destination zone. The basis of route pre-emption systems is time-distance relationships between start and end points. Route pre-emption systems are either a) a simple series of pushbuttons directly wired to selected traffic signals close to a Fire Hall, b) a sophisticated software based computer program within a computerized traffic signal system or, c) a combination of both a) and b). Richmond's route pre-emption system is a software based system that utilizes remote Personal Computers at Fire Halls to initiate pre-emption. These remote site computers have data communication links to the central traffic computers. To accomplish software based route pre-emption, a certain central computer to traffic signal data communications architecture is required along with specialized software for central and field equipment.

In Richmond's computerized traffic signal system, each traffic signal has a Communications, Control and Monitoring Unit (CCMU) which provides green light synchronization and monitors and records key functions of the signals' operation. This same unit is also used to pre-empt the traffic signal to a desired signal indication sequence for a specific duration. Multiple signal sequences can be selected for each traffic signal approach direction providing flexible pre-emption control.

To initiate traffic signal pre-emption, a route number is keyed into a PC (located in the Fire Hall departure area) which then transmits the request to the traffic computers to load the pre-emption database for specific traffic signals from the Fire Hall to the emergency destination. Once a route is started, the traffic computers send commands to each traffic signal along the route instructing them to transition to a specific light sequence for a defined duration. Since no additional equipment is required at any traffic signal or on any emergency

vehicle to obtain pre-emption - installation, operation and maintenance costs are minimal.

A summary of Transmit/Receive and Route Pre-emption systems is contained in Table 1.

SYSTEM FUNCTIONAL DESIGN

In 1985, The City of Richmond committed to the implementation of a computerized traffic signal system to control and monitor the City's traffic signals. At that time, emergency pre-emption of traffic signals consisted of receive hardware at only 7 of 70 traffic signals, and transmit devices on two Fire Department vehicles. The ongoing maintenance efforts required to provide pre-emption reliability were considerable.

It was recognized that with minimal or no pre-emption capability, the Fire/Rescue crews had established a number of traditional travel "routes" to certain areas or “zones”. The implementation of a route pre-emption system would merely formalize an existing routine and provide pre-emption capability where none existed. The traffic signals group analyzed and concluded that a software based pre-emption system integral to the traffic signal control system would be a practical and cost effective method of providing city-wide pre-emption capability.

The pre-emption system was designed by the City of Richmond and co-operatively developed with the traffic signal system hardware and software supplier. The City functional design team which consisted of Traffic Signal and Fire/Rescue Department personnel reviewed dispatch and departure procedures, determined optimal travel routes, and developed the logistical operation of the system. Throughout this process, several iterations occurred in the development of central and remote PC software, computer to traffic signal interface requirements and enhanced emergency response departure procedures.

Salient points of Richmond’s route pre-emption system are:

- Simultaneous pre-emption of up to seven different routes from seven Fire Halls,
- Capacity of 500 individual routes, each capable of pre-empting up to 30 traffic signals,
- Each route is optimized considering the priority of the fire/rescue vehicle and the requirements to serve other vehicles and pedestrians using the signal system. (i.e.; left turn arrows are only active to clear traffic in congested areas, or if an emergency vehicle is expected to turn left at a specific traffic signal)
- Route pre-emption can be used for up to 90% of emergency responses,
- Vehicle Identification devices are installed on emergency vehicles to track and log the arrival time of each vehicle at key monitoring locations throughout the City.
- All pre-emption activity is monitored by the central traffic computers in the traffic control centre. When route pre-emption is used, the signal sequence and clock time each traffic signal entered and exited pre-emption is logged along with vehicle location monitoring data.
- The pre-emption system is currently used at six of seven Fire Halls. One remote Fire Hall utilizes transmit/receive equipment for pre-emption.
- Route pre-emption is available at 155 of 160 traffic signals in the City. Five remote signals utilize transmit/receive equipment.

**Development of Pre-emption Routes**

The Fire/Rescue Department identifies the entire City by a series of "grids" and each property address belongs to a specific grid number. Although several different routes can be defined, two or more distinct routes are typically developed to access each grid.

A desired travel route from a Fire Hall to a grid is established and a route number is assigned. The computer database for each route requires the user to define each traffic signal (*Intersection*) in order of travel from the Fire Hall to the destination. Between each traffic signal is called a *Link*. Each *Link* is identified as, 1) the distance from the previous traffic signal, and, 2) an average emergency response travel speed between the traffic signals. These two variables determine the expected time of arrival of an emergency vehicle at each traffic signal along the route.

Each traffic signal can belong to several different routes and thus can be approached from various directions. Once the green light (or alternate) sequence is established for each intersection approach within a route, it is coded into the *Intersection* database along with special control features such as "Don't Walk Lights On". The system incorporates a timed queue clearance feature to "clear" an expected vehicle queue prior to the

arrival of the emergency vehicle. Following this period, a pre-emption duration is established for each signal. The queue clearance and pre-emption durations are independently set by the user for each traffic signal within the route to allow for varying traffic conditions at different intersections. This flexibility results in optimum signal sequencing and pre-emption timing for both the emergency vehicles and other road users. The data parameters of any pre-emption route can be fine tuned in seconds by modifying any *intersection* or *link* parameter.

**Initiation of Route Pre-emption**

When the dispatcher sounds the alarm and announces the destination address, the responding team gathers at a *departure station* to collect site specific information and determine the desired route to the destination.

At the departure station a Personal Computer (PC) has a data communications link to the traffic computers located in the Traffic Signal Control Centre. The response team selects a desired travel route from a city map illustrating all grid numbers and available routes (which are colour coded and numbered for easy identification). A responding team member enters a four digit route number (which corresponds to the desired travel route) into the PC via six keystrokes, which takes under 10 seconds. This instructs the traffic computers to load the requested route in preparation for implementation. When the computers load the data, two green lights are illuminated on a single pushbutton panel adjacent to the PC indicating the selected route is ready to start. When the responding team leaves the departure station for the trucks, the button is pushed sending a command to the traffic computers to start the pre-emption. At this time the green lights on the pushbutton panel turn off, indicating the pre-emption of the required signals has started.

Monitoring of departure activities revealed that the trucks typically cleared the Fire Hall doors averaging 15-25 seconds after the responding team left the departure station. (closest to furthest truck from the departure station) The duration of leaving the departure station to exiting the Fire Hall was found to be the primary factor to successfully enter the green "time window" and proceed smoothly through the pre-empted traffic signals on the travelled route.

Traffic signals adjacent to Fire Halls are pre-empted to Red in all directions which allows for the signal to quickly transition to a safe condition for road users, pedestrians and emergency vehicles exiting the Fire Hall. As all traffic signal indications at these intersections are red, fire vehicles turning left out of a Fire Hall can use opposing direction lanes to gain clear access through the intersection regardless of vehicle queues.

To pre-empt regular traffic signal operation, the traffic computer sends control commands to each traffic signal on the route to transition to a specified signal sequence prior to the arrival of the emergency vehicle. Traffic signals in each route are typically pre-empted for 40 seconds which includes time to clear vehicle queues and to account for the fluctuation in emergency vehicle travel speeds resulting from traffic or weather conditions.

Vehicle identification devices mounted on Fire/Rescue vehicles are used to monitor their arrival time at strategic locations throughout the City. The system immediately logs the time that each vehicle passes over vehicle identification detectors. This information is used for two purposes.

1) The time the vehicle is detected is compared to the range of time the emergency vehicle is expected at the particular monitoring station. If the time is within the established “time window” the system merely logs the vehicle arrival time. This data can then be used to fine tune the database of the particular route.
2) If the vehicle is late in the “time window” the system automatically extends the green light pre-emption duration for the remaining signals along the route. Once the pre-emption duration expires, the traffic signal is instructed to return to its scheduled operation. The system logs all automatic route duration extensions.

SYSTEM EVALUATION

The software based route pre-emption system has been a tremendous success and has proven particularly cost effective for installation, operations and maintenance. The system including enhancements has cost about $100,000 and is capable of pre-empting all traffic signals under computer control from seven Fire Halls - effectively the cost of implementing a transmit/receive pre-emption system at only 18 traffic signals and 5 fire/rescue vehicles. Theoretically, 500 traffic signals could be pre-

empted under the current communications configuration of Richmond's system. New traffic signals are automatically available for route pre-emption at no additional cost, once the CCMU is installed and communications to the traffic control centre are established.

Operational costs encompass Fire/Rescue and traffic signal staff designing new or modified travel routes and developing the computer database, typically a minor effort. Changes to pre-emption parameters for any route or traffic signal can be accomplished from the traffic control centre in seconds.

Maintenance costs for remote site Personal Computers and communications modems are minimal. While the communications network, master computer and intersection Communication, Control and Monitoring Units are utilized in accomplishing route pre-emption, they are included in the annual scheduled maintenance of the traffic signal system.

Since the implementation of Richmond's route pre-emption system, the Fire Department has observed the following:

- Improved organization of crews on departure, as more attention is paid to pre-planning response,
- Reduced vehicle maintenance and fuel costs,
- Lower and smoother travel response speeds,
- Reduced call to on-site response time,
- Reduced driver and crew anxiety,
- Response team confidence that system works effectively and reliably,
- Increased traffic safety for Fire crews and road users.

While this system is currently used only by the Fire/Rescue Department, it is suitable for any agency (such as ambulance) which has a specific starting location for the majority of emergency responses.

## FUTURE ENHANCEMENTS

Although Richmond's route pre-emption system is being continually enhanced, we have included most of the realistic operational features for a system of it's kind including real-time adjustment of the pre-emption duration through vehicle identification and tracking.

The next logical level is to include expanded real-time adjustment of routes including dynamic routes using Global Positioning Systems (GPS). While the logistics will be complex, the intent will be to provide an emergency response system from any starting point to any ending point, with real time adjustments of traffic signal indications being initiated from the central traffic computers similar to our current method. Such a system will allow responding vehicles to reasonably deviate from established routes and still receive traffic signal pre-emption.

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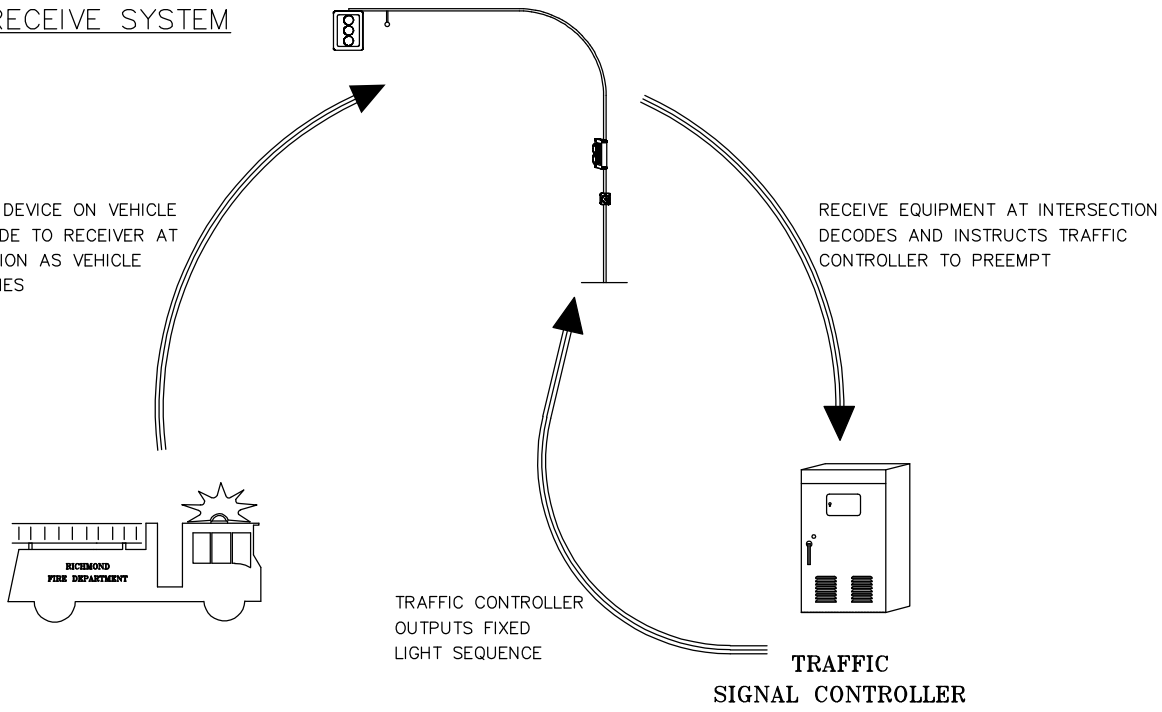
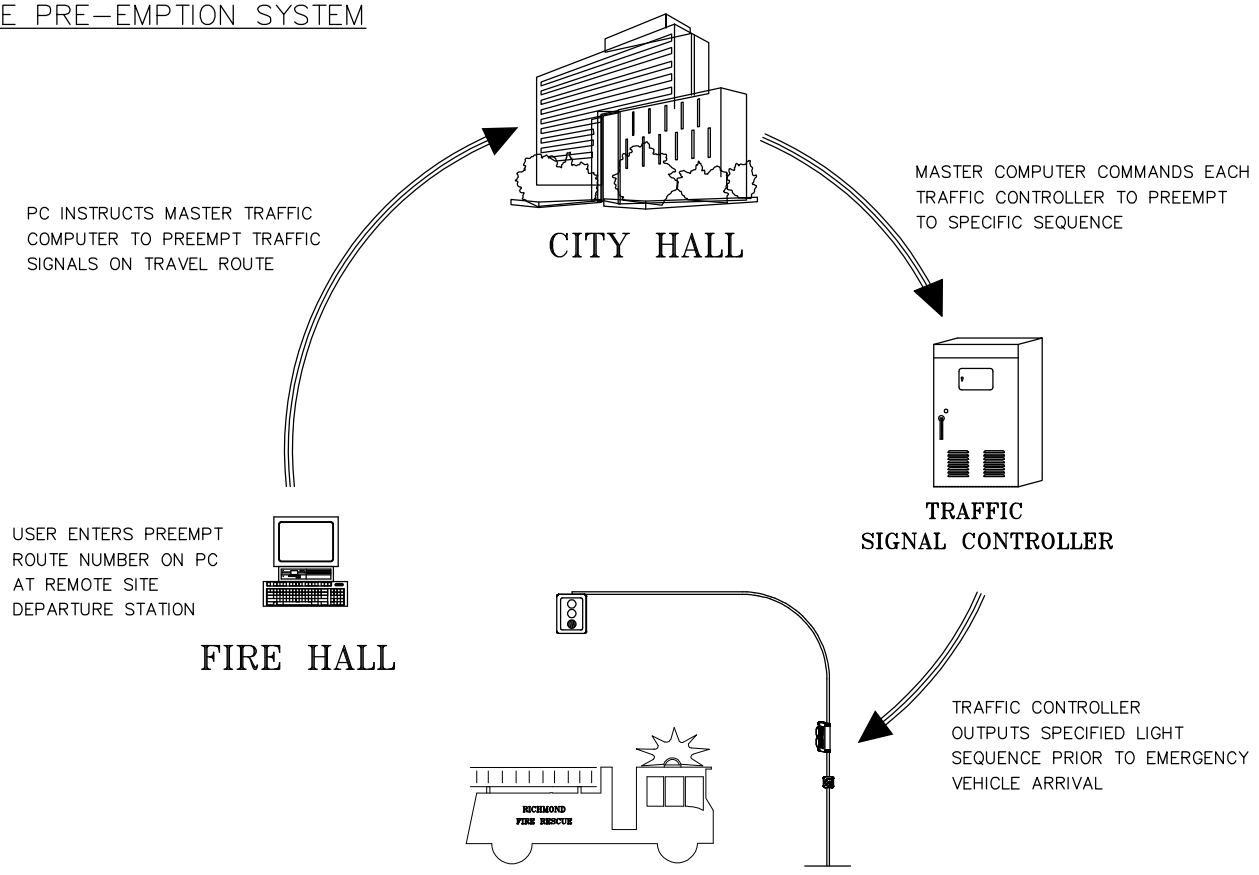
FIGURE 1

## TRANSMIT / RECEIVE SYSTEM




## ROUTE PRE–EMPTION SYSTEM




City of Richmond

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TITLE:

TRANSPORTATION & TRAFFIC SECTION

TRAFFIC SIGNAL PREEMPTION SYSTEMS

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| DESIGN: | J.R.B. / P.S. | | | | |
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**TABLE 1.**

**SUMMARY OF TRANSMIT/RECEIVE AND ROUTE PRE-EMPTION SYSTEMS**

| Summary Item | Transmit/Receive System | Route Pre-emption System |
|---|---|---|
| **General Functionality** | Requires specialized transmit device on each emergency vehicle and receive/decoding equipment at each traffic signal. | Software integral to a computerized traffic signal system. PC required at each remote Fire station with data communications link to the central traffic computers. |
| **Preemption Availability** | Can be used only by vehicles with special transmit device on vehicle and at individual traffic signals containing compatible receive/decoding equipment. Applicable to all calls passing through signals with preemption equipment. | Can be used by any vehicle starting at a defined location(s). Preemption is available from each direction at any traffic signal connected to a central traffic computer. Generally applicable to 85% to 90% of calls. |
| **Preemption Sequences per Traffic Signal** | Up to four. Generally one fixed sequence per approach. | Up to thirteen. Several different signal control features can be used for the same signal on different routes. |
| **User Interface** | Generally transparent to user. Some systems require response team to occasionally manually select approach direction, usually when turning. | User must determine and implement travel route on PC prior to leaving Fire Hall. Chosen travel route must be followed to receive preemption. |
| **Advanced Clearing of Vehicle Queues** | Receive device must first "detect" an approaching vehicle to provide preemption. Less effective with signals in close proximity following left or right turns, as minimal time is available to transition traffic signals to a pre-emption sequence. | Signals in close proximity are pre-empted early to clear vehicle queues before emergency vehicles arrive or turn on to subsequent streets. Provides excellent vehicle clearance except in traffic gridlock. |
| **Disruption to Other Road Users** | Generally only one preemption sequence per approach. Can restrict optimum traffic flow for other users by engaging a fixed green light sequence for each approach. | Multiple approach sequences available. Left turn arrows can be activated for queue clearance or where a left turn is expected on a specific route. Similarly, left arrows can be shut off where another route using the same signal passes through the intersection |

| Summary Item | Transmit/Receive System | Route Pre-emption System |
|---|---|---|
| **Other Traffic Control Features** | Strategic preemption generally cannot be implemented as receive device must detect a transmission from an approaching vehicle to provide any preemption. Also, only the fixed sequence for the approach direction is available. | Traffic signals that an emergency vehicle does not approach or pass through can be strategically pre-empted to restrict conflicting vehicles from entering the travel route |
| **Information on availability of individual signals for preemption** | Minimal advanced information of potential preemption failures or problems. Most problems reported by emergency crews if signal did not change as expected. | 24 hour monitoring of all signals provides data for immediate notification of which signals may be temporarily unavailable. |
| **Logging of Pre-emption Events** | Some systems provide information on pre-emption activity. | Central system logs all clock times and preemption sequence for each traffic signal entering and exiting preemption. |
| **Repair and Testing** | Generally require on-street preemption test at individual intersections following equipment repair. | Minimal field testing required. Preemption testing can be conducted in minutes from the central site. |
| **System Volatility** | System problems can occur on vehicle transmit devices or receive/decoding equipment at individual intersections. Multiple signals could have failure problems in a larger system, but not likely to occur on successive intersections. Most problems reported by emergency crews. | Main traffic computer or local PC problems could render all or part of the system temporarily unavailable. Communications outages to individual traffic signals would result in such signals being unavailable for preemption. These would be immediately reported to the central computer. |
| **Changes in Preemption Data Parameters** | Usually requires field visit to program or wire preemption changes. Some changes can be done from a central location | Changes in preemption parameters are made in seconds within central software. No field visit required. |
| **Capital Costs** | Generally $5,000.00+ per traffic signal and $2,000.00 per vehicle. A signal system with 200 traffic signals and ten emergency vehicles with transmitters would cost over $1,000,000 to implement. | Costs are associated with central software and remote site computers/modems. Generally there are no costs associated at any traffic signal for preemption. Once route preemption software is established, 10, 200 or 500 signals can be pre-empted with a minimal increase in capital cost. A 200 signal system could cost under $150,000 to implement. |

| Summary Item | Transmit/Receive System | Route Pre-emption System |
|---|---|---|
| **Special Features** | Varies upon system. | Emergency vehicle identification devices allow tracking of each emergency vehicle at strategic locations. This information is used to calibrate pre-emption routes and to automatically extend the pre-emption duration if vehicles are near the end of the green light time window. |
| **System Maintenance** | Maintenance of transmit devices on vehicles, and receive/decoding hardware at each signal. Maintenance efforts and costs are considerably higher than a route pre-emption system to provide system-wide reliability. Malfunctioning of remote components for most systems cannot be automatically detected at a central location. | Communications links, PC's and modems at Fire Halls. Maintenance efforts and costs are negligible. Vehicle identification devices and field receive equipment at selected locations requires occasional maintenance. Malfunctioning vehicle ID devices or receive equipment is monitored by the central computer and failure of either component is detected by the central traffic computers. |
| **Future Enhancements** | Unknown – Varies depending on system characteristics, but increased central monitoring and communications to remote units could be expected. These systems would still generally be independent from a central traffic signal control system. | Global Positioning Systems (GPS) could be utilized for real time pre-emption adjustment of traffic signals. This enhancement would allow pre-emption of traffic signals when emergency vehicles are not starting the emergency response from a Fire Hall or home station. |