

# Public Transport Priority within SCATS – a simulation case study in Dublin

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# **Public Transport Priority within SCATS – a simulation case study in Dublin**

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## **1. INTRODUCTION**

As part of the detailed study on the implementation of Dublin's proposed Light Rail Transit (LRT) an important concern is the interaction of the LRT with general traffic in the city centre areas. More specifically the concern was how LRT priority could be achieved within the existing Urban Traffic Control System (UTCS). The city of Dublin introduced in 1989 the area control SCATS (Sydney Co-ordinated Adaptive Traffic System), which is mainly implemented in Australian and Southeast Asian cities. At present the SCATS system in Dublin has 170 traffic signals under its control and is continuously expanding.

The city council has identified four critical traffic loops (set of consecutive signal controlled junctions) within the city centre area which are sensitive to disruptions particularly at peak hours. If any one or more of these loops is constricted along any part of its length for even a short length of time, quite rapidly the entire loop will grind to a halt, and quite soon after that the other loops will be held up leading to gridlock in the city centre. The principal objective of the study presented in this paper was to establish whether LRT priority at signalised intersections is possible and practical within the framework of Dublin's existing SCATS UTC.

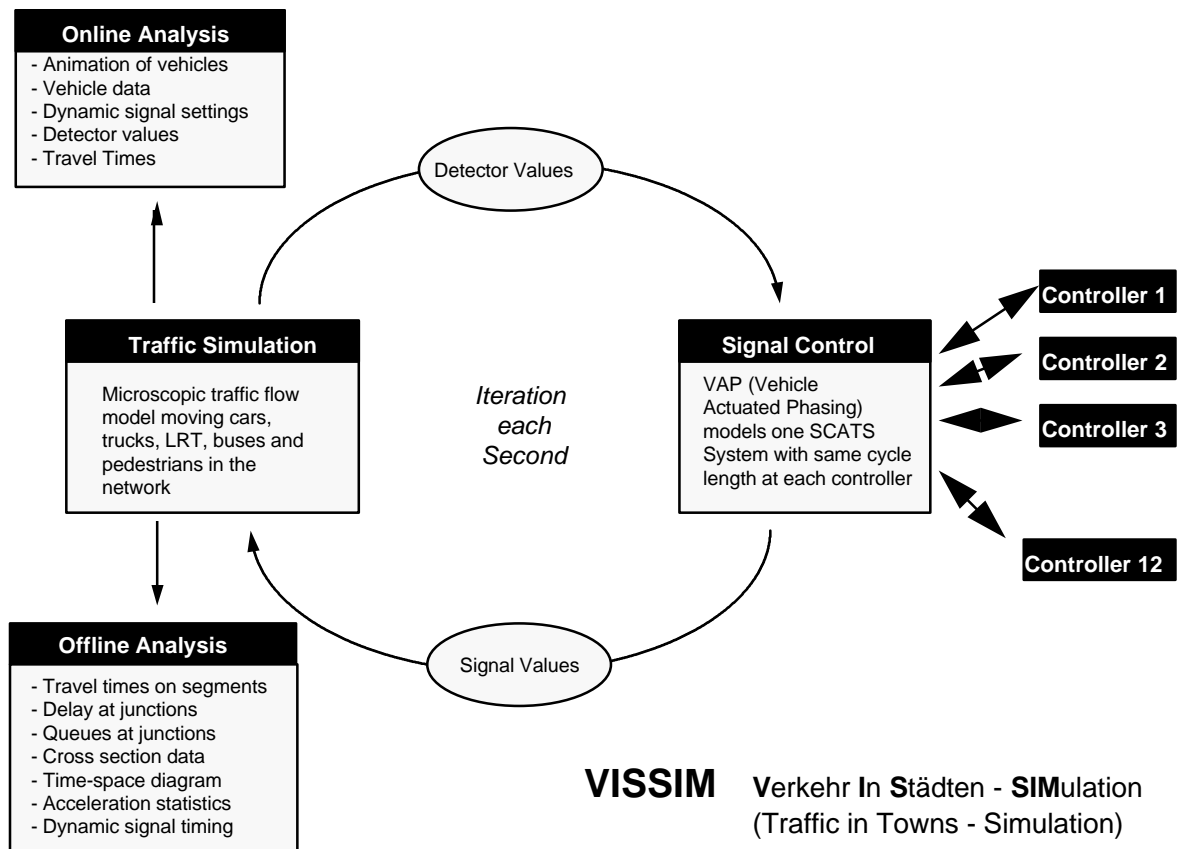
The study was carried out using the microscopic traffic flow simulation model VISSIM. Four control strategies were investigated in order to comprehend a range of possible scenarios within which the LRT priority could operate within the SCATS system.

## **2. THE URBAN TRAFFIC SIMULATION MODEL FOR DUBLIN CENTRE**

### **2.1. The Simulation Model VISSIM**

The traffic flow model used in this study is a discret, stochastic, time step based (1s) microscopic model, with driver-vehicle-units (DVU) as single entities. The model contains a psycho-physical car following model for longitudinal vehicle movement and a rule-based algorithm for lateral movements (lane changing). The model is based on the continuous work of Wiedemann (1974, 1991) and is implemented in a software package called VISSIM (Hoyer, Fellendorf, 1997), which was used within this study.

Vehicles follow each other in an oscillating process. As a faster vehicle approaches a slower vehicle on a single lane it has to decelerate. The action point of conscious reaction depends on the speed difference, distance and driver dependent behaviour. On multi-lane links moved up vehicles check whether they improve by changing lanes. If so, they check the possibility of finding acceptable gaps on neighbouring lanes. Car following and lane changing together form the traffic flow model, being the kernel of VISSIM.



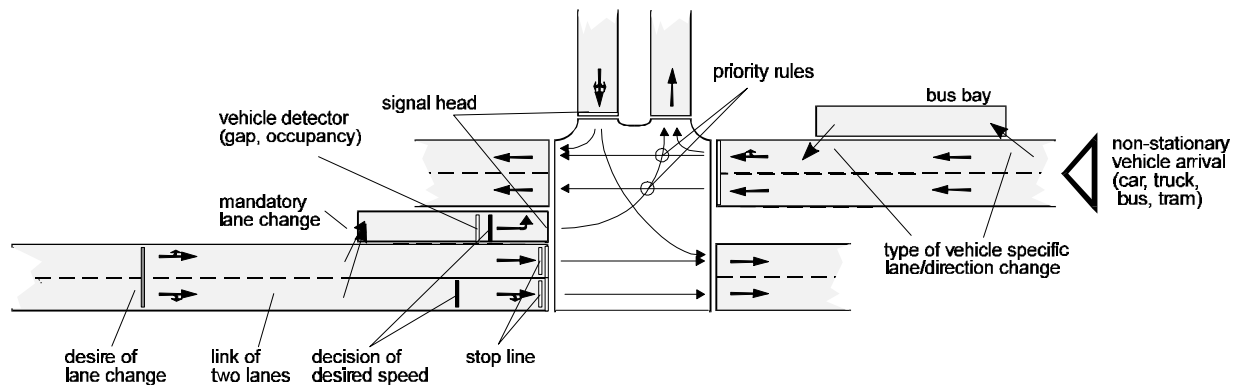
**Figure 1: System architecture of the traffic simulation tool**

The simulation system itself includes first the traffic flow model and secondly the signal control model (Fig. 1). The traffic flow model is the master program which sends second by second detector values to the signal control program (slave). The signal control uses the detector values to decide on the current signal aspects. The regional computer inheriting SCATS is modelled in one overall program (Vehicle Actuated Phasing). The VAP interfaces with each local controller.

## 2.2. Modelling the study area

The basic element of the modelled network is a single or multilane link. The network is composed of links and its connectors. A connector is placed on any position of a link. Connectors are valid for all vehicles, certain types (i.e. buses) or a set of vehicles (i.e. only right turning vehicles). Cross sections markers are placed for turning decisions. They become valid for each DVE which crosses it and is coded to read a signal from that marker.

Signal control is modelled by placing the signal heads at the positions of the stop lines. The signal aspects are part of the underlying SCATS signal control strategy. Detectors measure the traffic for the signal control (i.e. gap, occupancy, presence) and they are used for microscopic and macroscopic measurements (i.e. speeds, volumes, travel times). The desired speed in urban areas is not derived directly from the technical data of a car but rather from the geometrical layout of the street and its junctions. In some cases the desired speed has been reduced around junctions. Semi-compatible movements were modelled by gap acceptance. The values of gap acceptance and waiting positions were measured in Dublin to calibrate VISSIM.



**Figure 2: VISSIM features applied to model a junction**

A public transport route is defined as a sequence of stops along lines using specific bus-lanes if existing. The stops are either on the link or next to it depending on whether the bus-stop has a dedicated layby.

The study area within the City Centre of Dublin extended from Capel Street Bridge to Butt Bridge including O'Connell Street and Trinity College. Fig. 3 displays the chosen lane allocation. It was based on the city centre traffic scheme as anticipated if the LRT will be in place. In many ways it looks like the existing network except along the LRT alignment where road capacity is reduced and where new traffic management measures are put into place.

Each circle indicates a signal controlled junction with unique numbers for each signal controller. The LRT goes down Abbey St, O'Connell St, Westmoreland St, Grafton St and Nassau St. Three LRT stops are counted on this section respectively on Abbey St, O'Connell St and Grafton St Lower. Bus lanes have been kept as existing. The simulation network thus includes three bus lanes.

**Figure 3: Road network with signal controlled junctions as modelled based on the city map**

### 2.3. Traffic Flows

For every vehicle arriving at the entry points of the network, VISSIM has to generate the arrival time and the route the vehicle will take through the network. The arrival profile has been entered as hourly values for the morning peak. Within one time interval VISSIM assumes a POISSON arrival distribution.

The implementation of the LRT system will lead to changes in car traffic due to modal transfers along the future LRT-route, reduced road capacity along the LRT alignment and new traffic schemes in the Northern part of Dublin. Future car traffic has been estimated in a previous origin/demand and assignment analysis. The resulting flows and routes were taken as input flows for the simulation study. The sum of the flows on the junctions with highest volumes will not change by much. The volumes on the crossings of O'Connell Street and the Quays (junction 197 and 196) are forecasted to be around 4,250 resp. 4,400 veh/h in the morning peak. Truck flows were taken as percentages from the car traffic varying between 5% and 10%.

The public transport network is made up of the LRT route and 43 bus routes adding up to about 260 buses within the study area during the peak hour. The LRT is expected to run with a 5 min headway in each direction. The LRT stops have been given a dwell time of 20 seconds and a standard deviation of 3 seconds to reflect variations in stopping time.

### 3. URBAN TRAFFIC CONTROL SYSTEM (SCATS)

SCATS has been developed since the early 1970s. Key elements are described in technical papers by Lowrie (1982, 1989). Features of public transport priority within SCATS are discussed by Cornwell (1986). The objective of SCATS is to optimise traffic flow in terms of delay by making the best use of the available green times. The green-time proportions or splits of stages and offsets between junctions and cycle lengths vary depending on the on-line measurements of the traffic conditions. There is no off-line mathematical traffic model linked to SCATS but the traffic flow measurements and the computations for green splits, offsets and cycle time could be called a feedback control system.

#### 3.1. SCATS implementation in Dublin

In 1996 about 170 out of 450 signal controllers in Dublin were linked to the SCATS central computer unit. Junctions are grouped into systems and a set of interdependent adjacent junctions forms one sub-system. Each sub-system consists of between one and up to ten junctions. One critical junction of the sub-system decides on the parameters such as the cycle time, split plan number and offset choice. This junction is known as the master junction. The sub-system is the basic element of the strategic control level of SCATS. For co-ordination of larger groups of intersections sub-systems are linked as a system, which often functions as a loop or gyratory system. The city centre is divided into four roundabouts or gyratory loops, each treated as one system. Each junction within one loop forms its own sub-system. The sub-systems within the loop are controlled with the same cycle time.

The basic traffic measurement for SCATS on the strategic level is the degree of saturation  $DS$ . The local controllers collect traffic flow volumes and detector occupancy during the green time at each approach. The degree of saturation is defined as the ratio between the efficiently utilised green time and the total available green time. It is worth noting that SCATS considers varying saturation flows with time for the same approach. Instead of just counting the vehicles and their headways, the space a vehicle requires to cross the stop line is counted. The lengths and positions of the loop detectors are of major importance for this space dependent calculation. In Dublin usually loops of 4.5m length are located a couple of metres before the stop line.

The cycle length  $C$  is a function of the highest  $DS$  measured in the sub-system during the previous cycles. The cycle length can vary from one cycle to the next by maximum  $\pm 6s$ . A linear function  $f(C, DS)$  is used to adjust the cycle length between successive cycles. The cycle length has a lower bound of 90s and an upper bound of 140s.

The green time duration of one stage depends on the current cycle length  $CS$  and the currently chosen green time split plan. For each controller a set of four or eight split plans is allocated. A split plan defines the ratio of the total green allocated to each specific stage which can be set for a particular time of day. The stage sequence is fixed within this period on the strategic level. The sum of the ratios adds up to 100% or a chosen cycle time. Inter-green times are part of the stage duration and as such are not labelled explicitly as inter-stage duration.

Above a cycle length of  $CX\%$  (120 sec) all extra time is given to the nominated stretch stage. Between the cycles the chosen split plans can be exchanged. The algorithm basically searches for a plan which would give the lowest  $DS$  taking the traffic counts of the previous cycle.

The phase split duration according to SCATS also includes the interstage period. The interstage period is the time beginning with the end of green time of the signal group shutting down in the one stage and the green-begin time of the signal group in the following stage.

Junction 197 at O'Connell/Bachelor's Walk operates as the master junction in the modelled gyratory system R3 of the study area. Thus 197 defines the  $DS$  for cycle length calculation.

Usually two detectors were used for each LRT signal group: presence detector and cancellation detector, the first located at the travel time length of about 20s before the anticipated arrival at stop line, and the cancellation detector shortly after the stop line with the vehicle rear.

## 3.2. Signal Control Strategies

Four different control strategies were developed to test scenarios of varying degrees of LRT priority and their impacts on vehicle flows.

### 3.2.1. Fixed Time Control (D\_FIX)

For reference reasons a fixed time control has been modelled with 120s cycle. Split plans (stage durations) were adapted to the future flows and the extra provision needed for the LRT. The LRT signal groups were given green in each cycle whether an LRT has been detected or not. This strategy is certainly not the preferable solution but it models the present situation with the addition of the future case of the LRT

### 3.2.2. Split Program (D\_SPL)

On the strategic level SCATS operates a voting system in order to select between one of the pre-set 4 or 8 split plans. The split plan allocates the green for each stage as a percentage of the cycle length. In this strategy extra split plans were provided for cases in which an LRT is detected. If an LRT is detected at least one cycle before it reaches the stop line, a different (LRT compatible) split plan is chosen for the next cycle for this junction. This strategy is in line with all other SCATS features on the strategic level. No local control has to be provided. This strategy is not very flexible in cases where two successive LRTs approach from one direction or passing of LRTs from both sides. Additionally the required detection time of 1 cycle in advance is of little practical use in Dublin city centre.

### 3.2.3. Local Control (D\_LOC)

Cycle length and offsets were determined by the central controller staying in line with the other junctions of the system. Stage sequence and stage duration were altered within a split plan according to local detection of LRT. If a LRT is requested various options might occur: (a) present stage is interrupted, the duration of the present stage and the successive ones are reduced in length, (b) present stage has an early cut off, after the LRT stage the next or second next stage is timed or (c) present stage is prolonged until LRT is cancelled, if present stage includes the requested LRT signal group.

### 3.2.4. Full Priority Programme (D\_FUL)

This strategy is a development of the previous one. The principal difference is that

The common cycle length for all junctions in the system was not retained in contrast to the previous strategy. An LRT stage can interrupt a stage sequence at any point. After the LRT stage the timer jumps back to the stage which was active before the LRT stage. It is analogous to holding a pointer on a cyclic timer for the period of the LRT stage.

## 4. ANALYSIS OF SIMULATION RUNS

Each of the control strategies described in 2.2 was run for a simulation period of 7200s with varying random number seeds. As the principle objective of this study is to establish the feasibility of limited LRT priority within the SCATS system while maintaining traffic flows, the measures of effectiveness most appropriate to demonstrating this are the travel times and the LRT delay times.

#### 4.1. LRT Delay Times

From the point of view of the LRT operator the chosen strategy must provide a reasonable LRT priority in the City Centre. In order to assess the level of priority, the amount of time that each light rail vehicle spends to get through a junction was measured out throughout the simulation. Those « delay times » were then aggregated and sorted. The following table shows the results for all junctions crossed by the alignment in the simulation.

The first line gives the proportion of LRTs getting through the five junctions of the study area (198, 197, 196, 229, 226) in less than 5 seconds. It amounts to giving the priority level. It shows that D\_FIX and D\_SPL provide a very poor LRT priority, with only 55% priority over the simulation area. In D\_FIX no priority is given to the LRT and LRTs get through the junctions only with car compatible movements. In this case 33% of LRTs end up waiting at junctions for more than one minute.

LRTs delay time in sec.	% of LRT's for all junctions and each strategy			
	D_FIX	D_FUL	D_LOC	D_SPL
0-4	55%	73%	72%	55%
5-9	1%	15%	15%	2%
10-19	3%	9%	9%	9%
20-29	2%	2%	0%	8%
30-59	6%	1%	1%	16%
60-89	27%	0%	2%	3%
90+	6%	0%	0%	7%

In the D\_SPL strategy particular split plans including the LRT over-ride the current split plans when an LRT is detected at a junction. This strategy gives better results in terms of LRT priority but 26% of LRTs still get stopped for more than 30 seconds. The change in split plans is triggered by a light rail vehicle going over a detecting loop. To switch to the new split plan early enough the LRT has to be detected one cycle in advance. This means that the detector loop must be located more than two minutes travel time before the following junction. Problems arise when LRTs take more time than expected to cover the distance between the detecting loop and the junction. This occurs in particular when an LRT stop is located between the loop and the junction since stopping time varies according to boardings and alightings. Further more, one of the SCATS features is variable cycle length and the location of the loops can only be approximate. The two remaining strategies are more satisfactory. LRT priority here goes up to 73%.

### 4.2. Travel Time Analysis

Travel time is recorded between any two nominated points along a route within the simulation area. The travel time records the average travel time for all vehicles between two points in the network over the recording interval which is preset before the simulation run. The travel time is inclusive of all delays including stops at red lights, stops by buses and stops by LRTs at stations. Examples of travel time graphs are given for two movements.

Figure 4: Road network with signal controlled junctions as modelled based on the city map

Graphs showing peaks or gradual increases in travel time indicate that there was increases in queuing within the system at those particular times during the simulation run. The delays for strategy with full priority for LRT (D\_FUL) are increasing during the simulation, which indicates an increasing queue. Delays are also quite high using the local priority rule for LRT (D\_LOC) without increasing queues. The fixed time control (D\_FIX) which had been optimized for the car traffic reduces car delay as expected. However the macro level priority strategy of D\_SPL is quite consistent as well for this car movement.

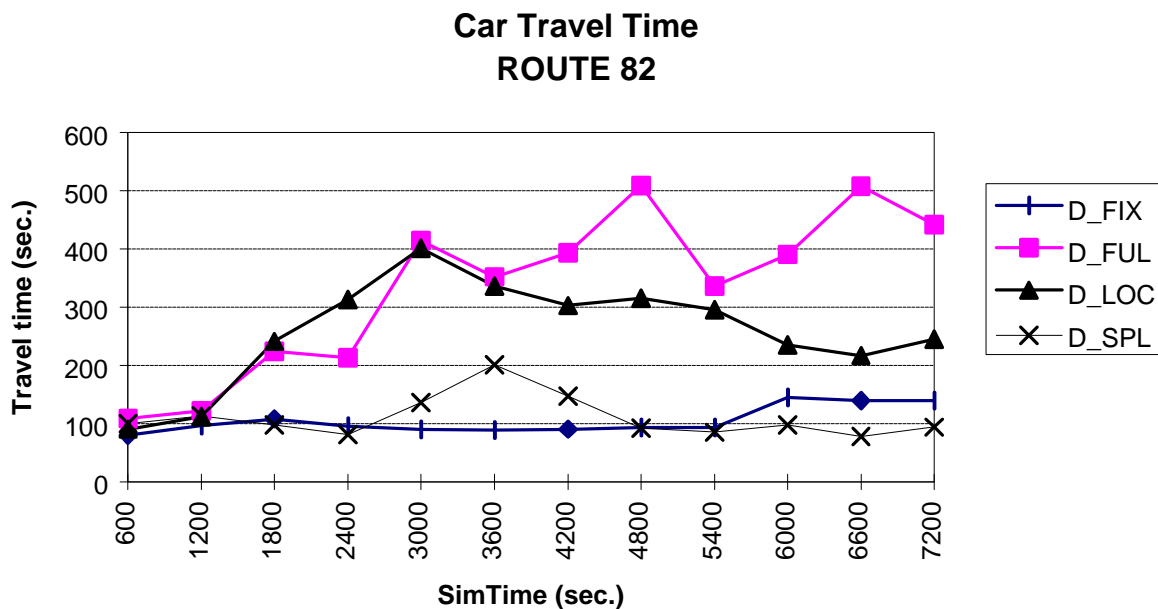


Figure 5: Car travel times over simulation time of route 82 (Eastbound: Bachelor's Walk - Eden Quay)

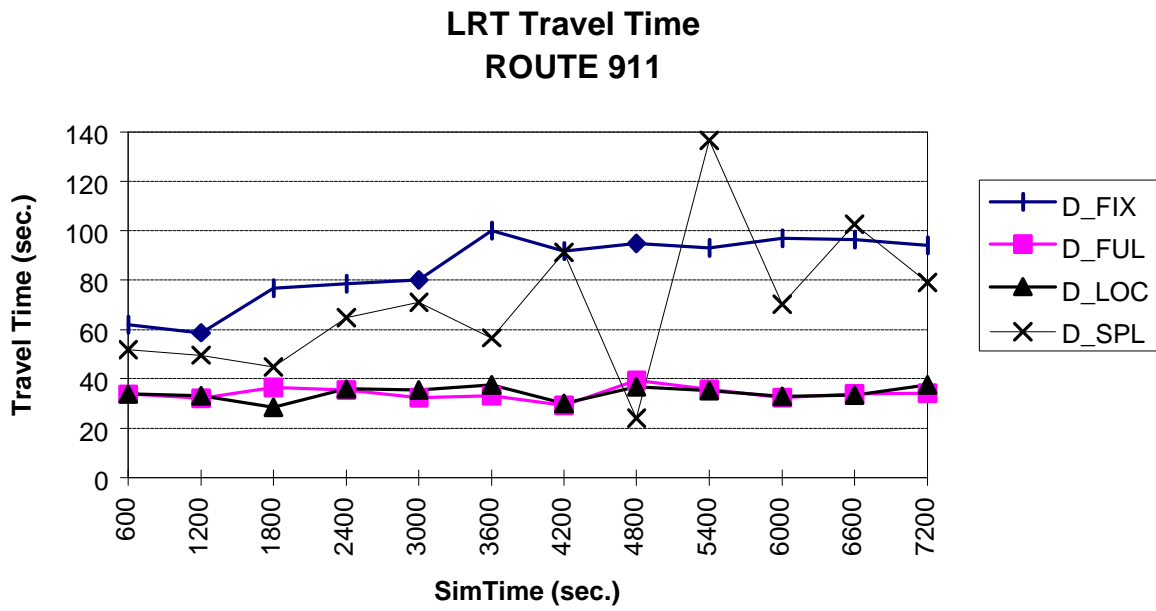


Figure 6: LRT travel times route 911 (O'Connell Street - Abbey Street)

D\_FUL and D\_LOC both provide very consistent priority for the turn of LRT's leaving the stop at O'Connell Street and crossing the main car movement into Abbey Street. D\_FIX has increasing delays to an upper threshold where it remains consistent. The degree of priority at D\_SPL depends on point of LRT request within the cycle.

### 4.3. Online Animation

Visual verification of the function of the simulation is done on-screen, showing the movement of vehicles and LRT in the network as well as dynamic displays of the phasing diagrams throughout the simulation period. The following screen-shot

**Figure 7: Simulation D\_LOC at 7:05 a.m., O'Connell Bridge**

## 5. CONCLUSIONS

Four different control strategies within an area wide control under the supervision of SCATS were tested for the city centre of Dublin using the simulation tool VISSIM. The control strategies were simulated under assumed network and lane allocation arrangements which are expected to be in place when the LRT is commissioned. The simulation indicated that LRT priority is possible within the existing SCATS environment of Dublin.

It appears from a consideration of the travel time graphs that D\_LOC and D\_FIX are the most suitable control strategies in terms of delay to road traffic. The LRT delay times indicated however that D\_FIX gives poor LRT priority where there LRT only has priority 55% of the time with over 33% of the time being spent on delays of over 60 seconds. This level of reliability is not appropriate for efficient and punctual LRT operation. D\_LOC provides priority to LRT by intervention at local controller level while maintaining traffic flows on all compatible movements to a high degree of similarity with the prevailing situation as simulated by D\_FIX.

Detailed features of LRT priority used in the simulation include: (a) LRT detector locations about 20s before expected approach at the stop line but after last possible point of disruption, (b) use of door closing signals at stops close to traffic lights, (c) no storing of LRTs in the city centre, (d) prevention of queued cars on shared sections especially Trinity College and (e) reduction of the present cycle time (120s at morning peak to variable cycle between 95s - 110s)

## AUTHOR INFORMATION

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