Adaptive Solution for Time Efficient Emergency Services in Smart Cities

Possible bases for solution:

Fuzzy Logic: Allows for less explicitly defined response strategies, allowing to combine both congestion and emergency levels into a single value.
For example let's say a value between 0 and 1 has to be chosen from a score of the to inputs, where each input has a weight of 50% (i.e. make up a maximum of 0.5 of the value).
Each input's value can be computed as per certain definitions (see inputs section) and then a value equal to or related (for reasons of providing an example an enumeration of different value levels is currently used in the input section) to these value levels is passed into the system to decide on a reaction.

Machine Learning techniques: Using a lazy learning method (for example kNN) could be quite useful, this would involve having a large databases of traffic situations and ideal responses which makes it expensive, however if we assume that smart cities will share similar layouts and traffic demand databases can be reused. However there is a problem with classifications, as the "classes" it must return will be very complex as they will have a wide rage of components (for example the action taken in regard to one particular driving policy.)

Tested Simulation with Decision Tree: This solution assumes that in Smart Cities we have access to all traffic information in a give area and can retrieve it rapidly, this would involve getting a small set proposed solutions deemed to be the most likely to work and testing these in a simulation based on all current traffic information and comparing results to decide the best. A possible method of calculating a worthy set of possible solution could be a decision tree having combinations of congestion and emergency levels to decide how to branch.

At the moment the fuzzy logic solution seems to be the most viable for the scope of this project so the rest of the report will be more geared towards this implementation.

Inputs

The output (adaptive strategy) used depends on two major factors, the level of traffic congestion (higher congestion means we must try and avoid any measures that worsen congestion and that we will have more of a challenge getting the emergency vehicle from point A to point B), and the level of emergency (if there is serious risk to human life of property the emergency response time needs to be faster). There is a significant challenge in quantifying the trade-off between fast emergency response time and minimising traffic congestion.

The two inputs are discussed below:

Congestion Levels:
Congestion levels are measured by the occupancy of a given lane, thus the congestion level of a road is the averaged congestion of a lane and similarly the congestion level of a set of roads or lanes is the averaged value of component congestion.

This measurement tells us a lot but it does not tell us everything, for example the case of one out of N roads having 100% congestion and the remainder having roughly 20%. This will give us an overall congestion of:
$C= (1+(n-1)*1/5)/n$
$C= (6+n)/5n$

Meaning that if n is small it will not return a value too near to any component congestion (for example for n=10 C=32%) and for large n the one congested lane is not reflected at all (if n=100 C = 21.2%).

So it is important to take the congestion of every edge on the emergency vehicle's route individually as the output for 30% congestion and 20% congestion may be different.

Congestion Levels are currently classified as follows, the enum value corresponds to a possible integer value that can be passed to the Adaptive System to denote Congestion Levels:

Congestion Value	**Class**	**Enum**
C <= 10%	Minimal	1
10% < C <= 25%	Low	2
25% < C <= 45%	Moderate	3
45% < C <= 65%	High	4
65% < C	Critical	5

Emergency Levels:
Emergency levels denote the importance of a fast arrival by the emergency vehicle, higher emergency levels permit the adaptive system to de-prioritise Congestion management to some extent.

Emergency levels are classified as follows:

Class	**Cases**	**Enum**
Low	Minor Injuries, Disturbances, Low risk of property damage.	1
Moderate	Serious but non-life threatening injuries or chance of moderate damage.	2
High	Potential loss of human life or excessive property damage.	3

Knowledge Base:

The knowledge base consists of all the actions the adaptive system can perform to aid emergency response, the system will use the knowledge base to decide on output based on Emergency and Congestion Levels.

One of the most significant changes the Adaptive System can make is to driving polices, which govern how vehicles interact and the laws they follow (for example the speed limit), there are a multitude of ways the Adaptive System can interact with the driving policies to ensure the fastest safe response for emergency vehicles.

Driving Policies

Traffic Lights:

Traffic lights controlling links on the emergency vehicles' route can be made to turn to green

or extend the duration of a green phase when an emergency vehicle is approaching. The duration and start of the switch/extension should ideally be based around the estimated arrival time of the vehicle.
Estimated Congestion Impact: Low
Identifier: TL

Speed Limit:

The speed limit can be increased across all edges on the route of the emergency vehicle to increase the turnaround time of vehicles on these roads, this will mean that the emergency vehicle will not be stalled by slower vehicles.
Estimated Congestion Impact: Low
Identifier: SL

Lane Clearance:

In a multi-lane road the emergency vehicle can be given a lane to itself by pushing other vehicles on the road to the other lane, this will not work very well if congestion is high. Can be combined with reserved lanes.
Estimated Congestion Impact: High
Identifier: LC

Reserved lanes:

reserved lanes such as bus lanes and taxi lanes can be temporarily assigned the same qualities as normal lanes, i.e. other vehicles can be moved to a reserved lane when lane clerance is used.
Estimated Congestion Impact: Moderate
Identifier: RL

Turn-offs:

The driving rules can be altered to let vehicles on the ambulance's route make otherwise illegal turns to clear the route of the ambulance, similarly the emergency vehicle can be granted the privilege to do this too to get to it's location faster.
Estimated Congestion Impact: High
Identifier: TO

Re-routing:

Re-routing is not a driving policy as such but can still be implemented to lessen thee amount of occupancy of the roads on the emergency vehicle route, it can also be used to try and reduce congestion from vehicles moved away from the emergency route.
Estimated Congestion Impact: ranges
Identifier: RR

Outputs:

This table maps the inputs (E= Emergency Level, C= Congestion level), if the output shows an identifier (e.g.: TL) this means that TL=true, in other words the Traffic Light change will be implemented.

Input (E, C)	Output
(1,1)	TL, SL, LC, RL, TO
(1,2)	TL, SL, LC, RL, TO

(1,3)	TL, SL, LC, RL, TO
(1,4)	TL, SL
(1,5)	TL,
(2,1)	TL, SL, LC , RL, TO
(2,2)	TL, SL , LC RL, TO
(2,3)	TL, SL , LC, RL, TO
(2,4)	TL, SL, LC, RL
(2,5)	TL
(3,1)	TL, SL, LC, RL, TO
(3,2)	TL, SL, LC, RL, TO
(3,3)	TL, SL, LC, RL, TO
(3,4)	TL, SL, LC, RL, TO
(3,5)	TL, SL, LC, RL, TO

Below are equations derived from the output table to determine if a particular action should be taken or not.

TL = True
SL = (E==3) || (C<5)
LC = E+2 >= C
RL = LC
TO = (E==3) || (C<4)