# Incorporation of Non-Persistent Delays in Macroscopic Network Modeling

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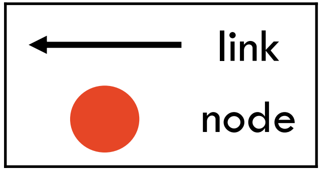
# Introduction

## The importance of traffic assignment models

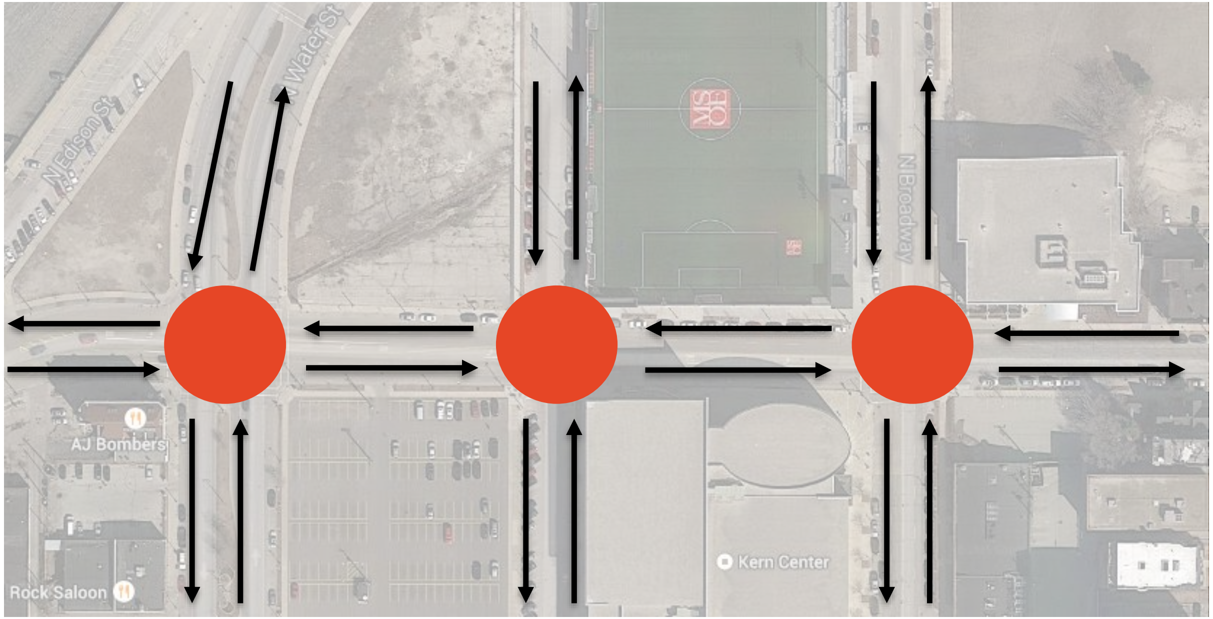

**Transport planning**

**Traffic management**

# Introduction




## Dynamic network loading model

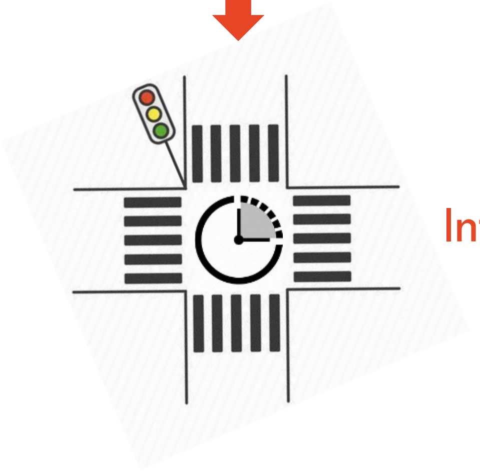



Source: https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources

# Introduction

## Dynamic network loading model – main outcome

Travel time



Intersection delay

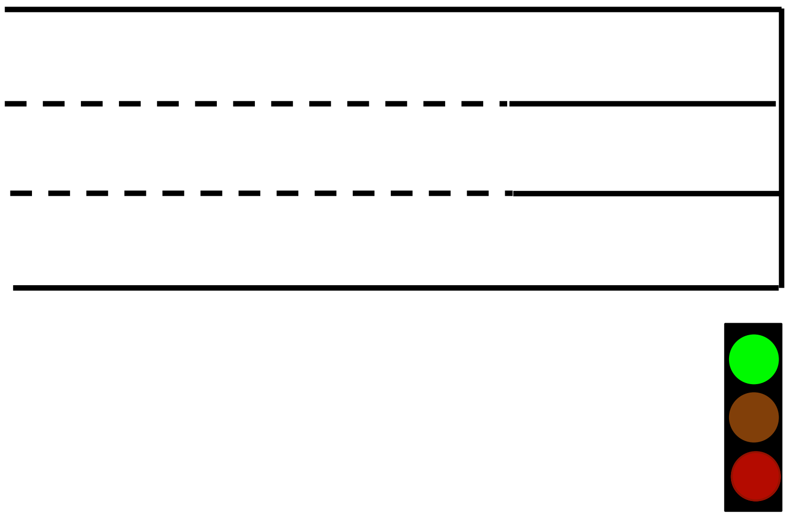
# Intersection delay


Source: https://madison.com

- Persistent delay
- Non-persistent delay

# Intersection delay

## No delay

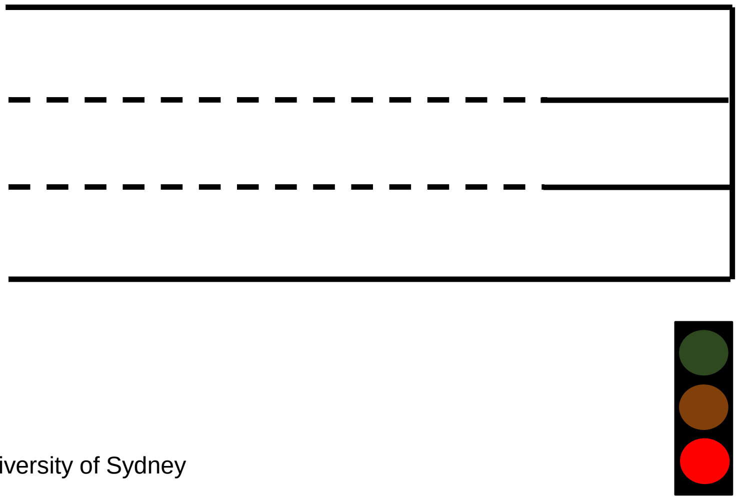


No delay

# Intersection delay

**Non-persistent delay**

- Temporary delay
- Within a cycle



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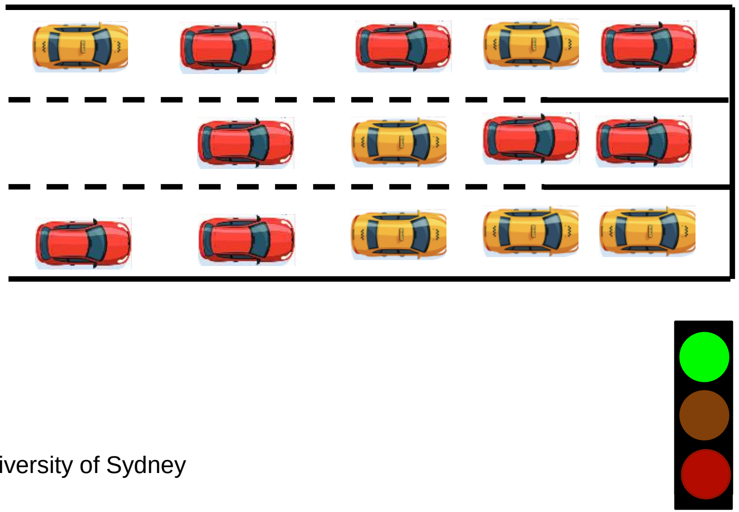
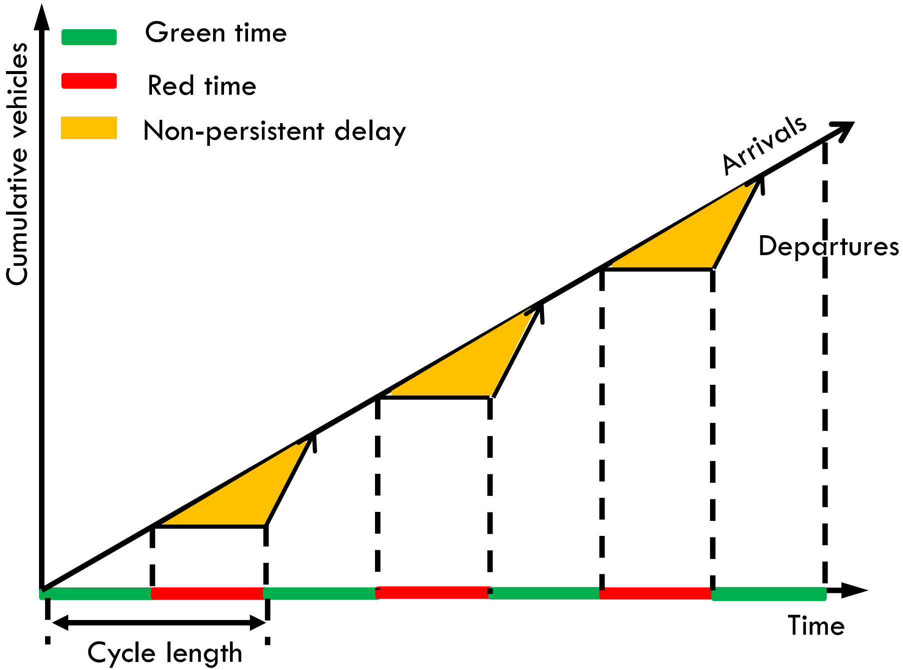
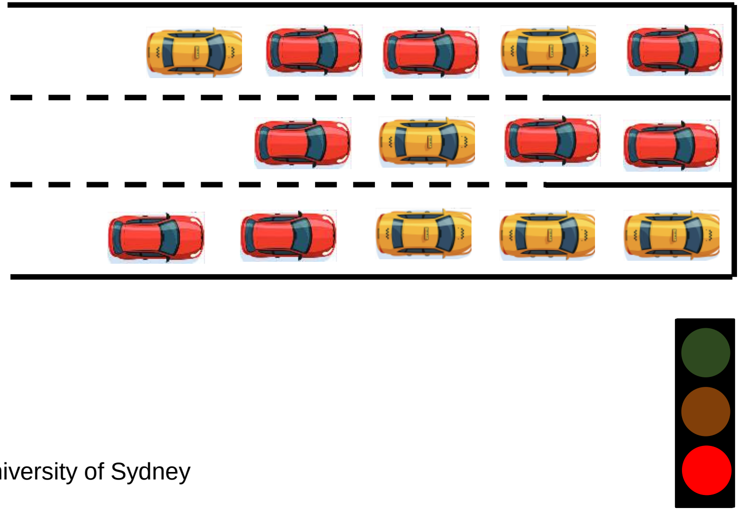




# Intersection delay

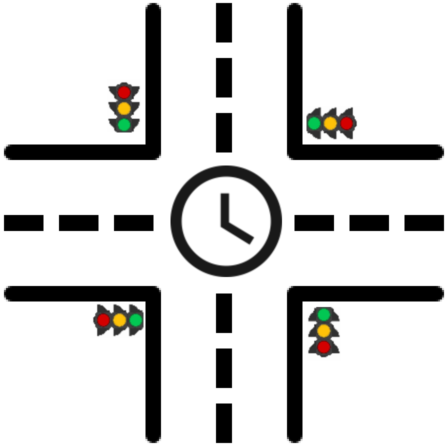
**Persistent delay**

– Queuing delay
– Among multiple cycles



# Research purpose

Propose a novel link transmission model (LTM) that embeds non-persistent delay consistently

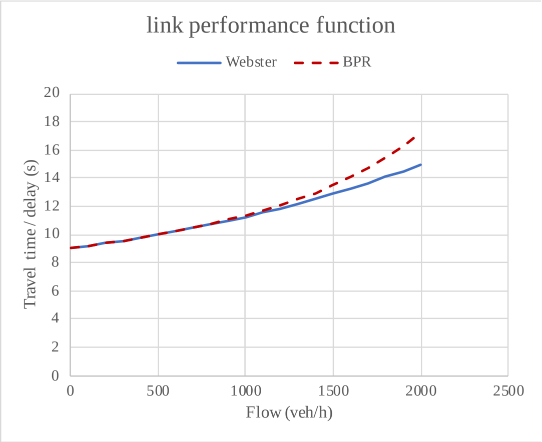


# Methodology

## Link transmission model extension

– Non-persistent delay

- Embeds delays in LTM on a virtual link
- LTM requires Fundamental Diagram (FD) to determine travel time and delay
- Webster's delay is a well-known type of non-persistent delay
- Novel conversion of Webster's delay function into FD



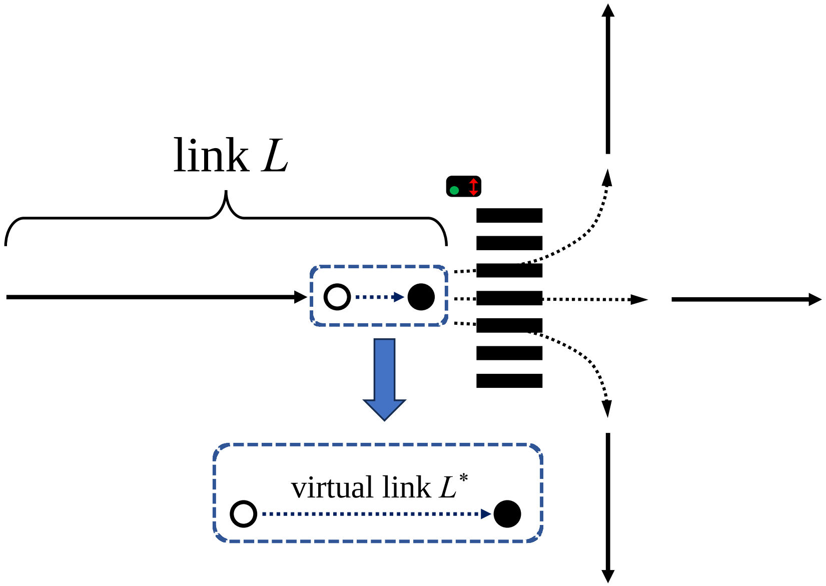

Travel time as a function of the flow rate

# Methodology

## Link transmission model extension

– Link model representation with virtual link

| Input | |
|---|---|
| green time (g) | saturation flow (Q) |
| cycle length (c) | |
| inflow rate (q) | maximum speed $\sigma_{max}$ |



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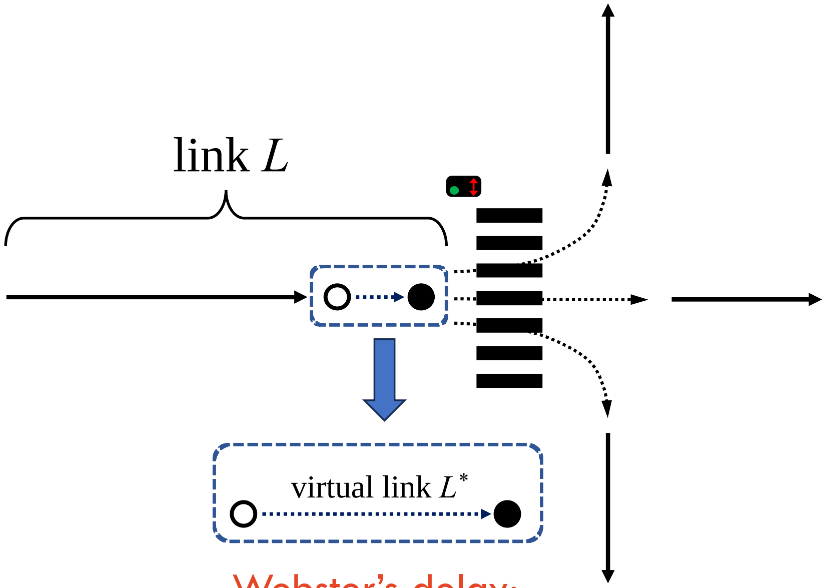



Webster's delay:

$$w = \frac{c(1-\delta)^2}{2(1-\delta \cdot \varphi)}$$

$$L^* = \frac{\sigma_{\max} c (1-\delta)^2}{2}$$

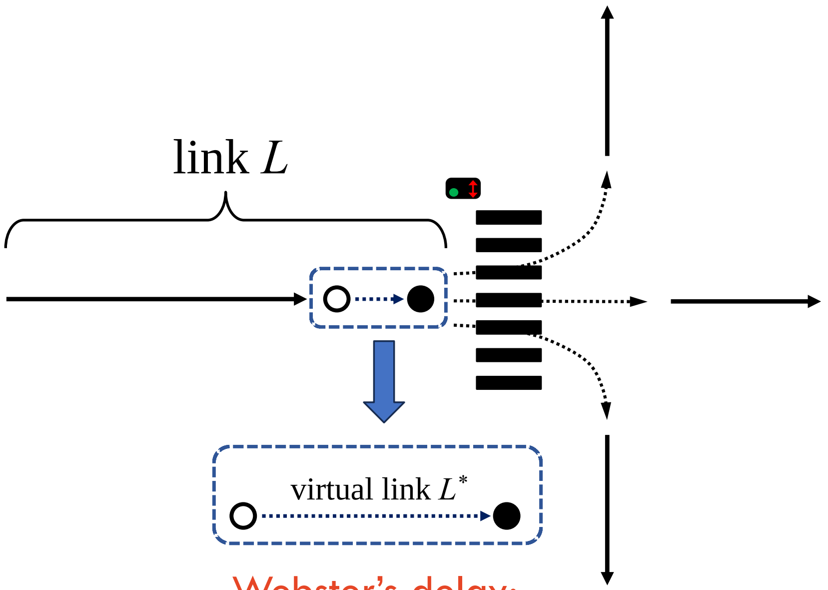
# Methodology

## Link transmission model extension

– Solves kinematic wave model (Lighthill-Whitham-Richards, 1956)
– Lax-Hopf formula on virtual link


$$\vec{U}(t) = \min_{q \in [0,Q]} \left[ U\left( t - \frac{L^*}{\gamma(q)} \right) + \xi(q) \right]$$

cumulative inflow in earlier time period

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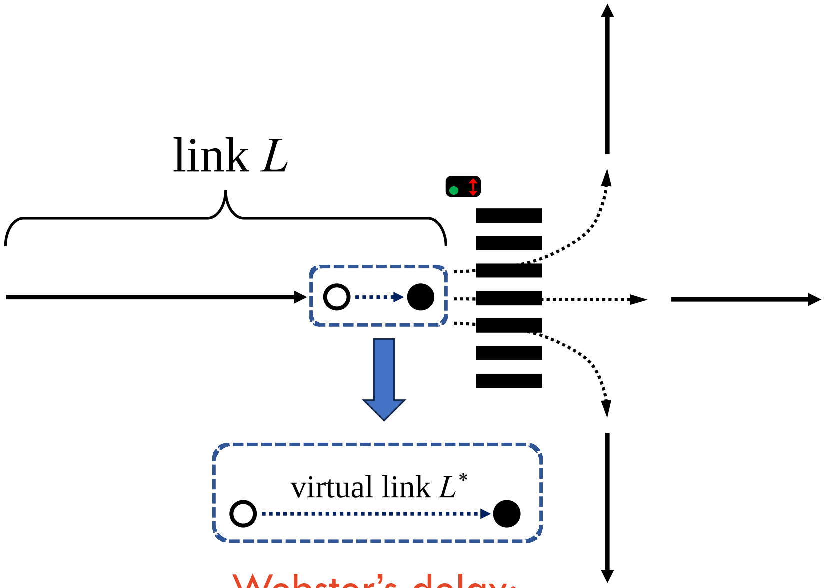
$$\vec{U}(t) = \min_{q \in [0,Q]} \left[ U\left( t - \frac{L^*}{\gamma(q)} \right) + \xi(q) \right]$$

number of vehicle that the observers will be passing when they move at a kinematic wave speed

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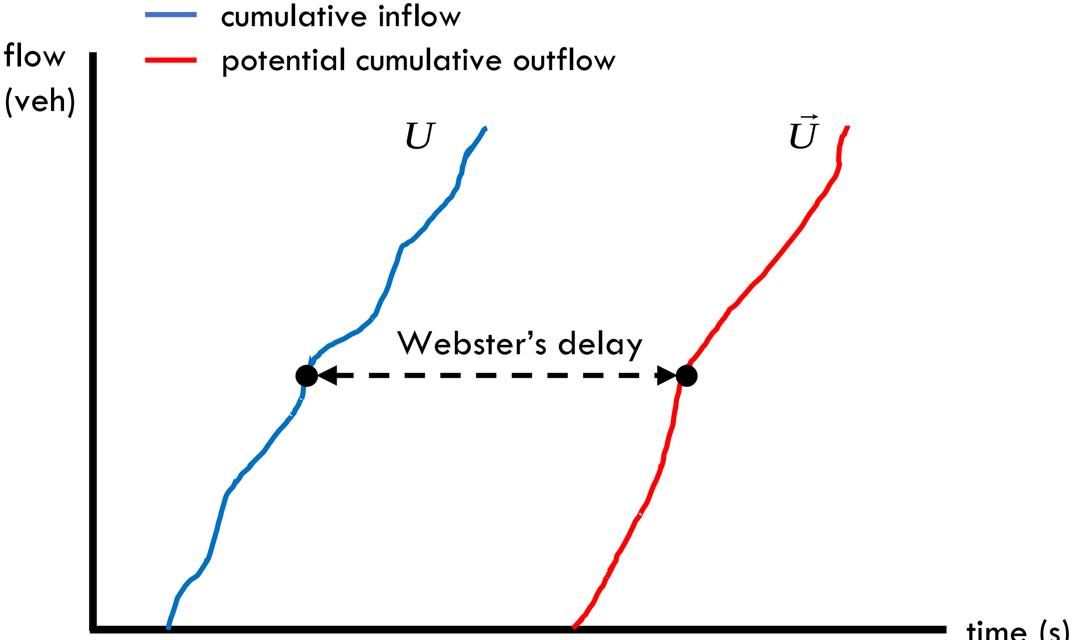
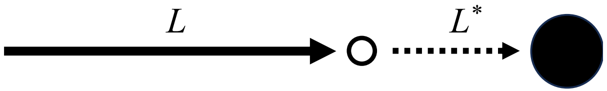
# Methodology

## Link model formulation

– Non-persistent delay

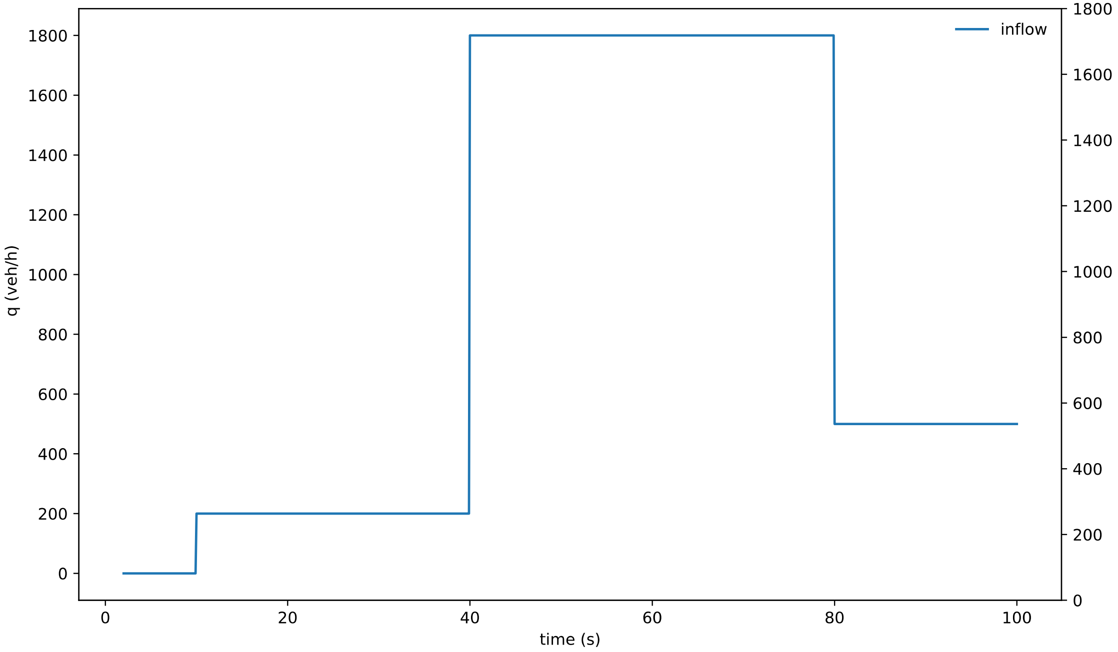


# Example




| Input | |
|---|---|
| green time = 35s | saturation flow = 2000veh/h |
| cycle length = 60s | maximum speed = 100km/h |
| inflow rate (see figure) | |

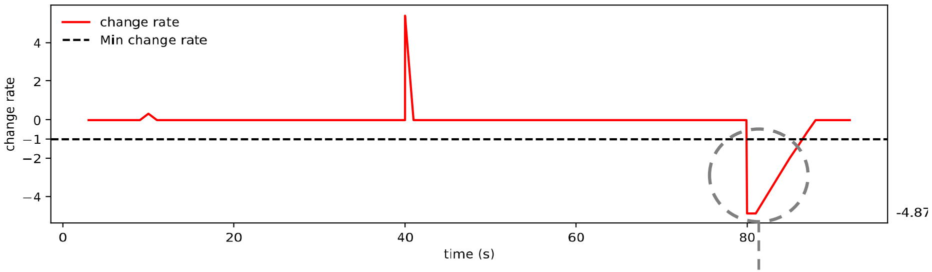
Input - inflow rate:



# Example

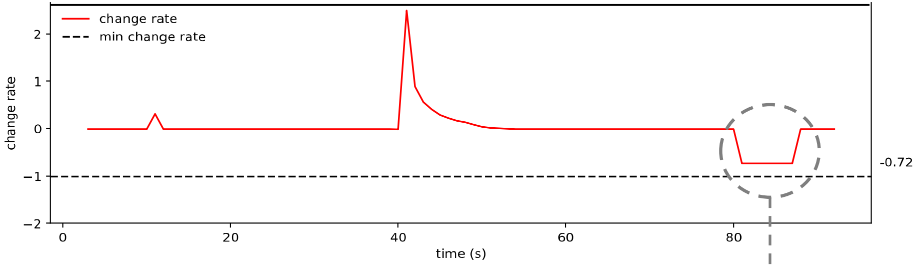
## First-in-first-out (FIFO)

FIFO condition fulfilment :
The change rate of webster delay
within a time unit larger than -1




FIFO violation

Naïve method

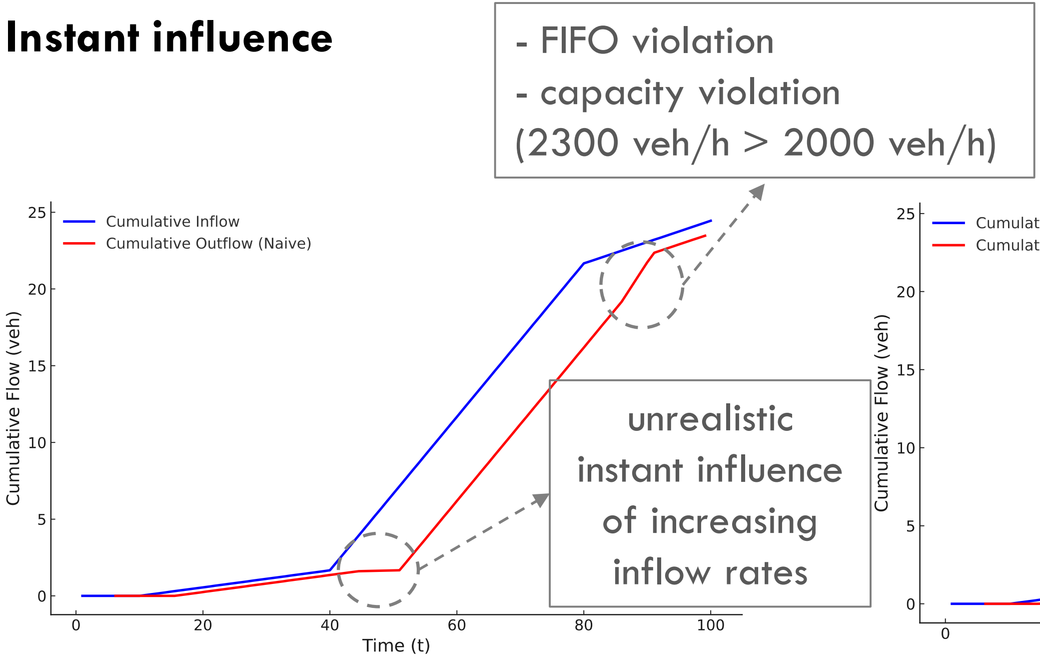



satisfy FIFO

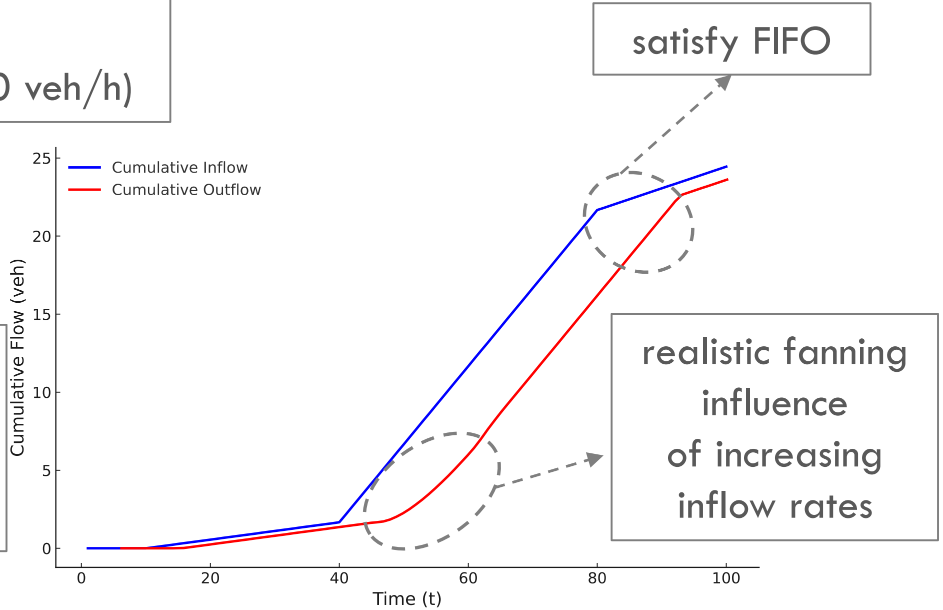
Proposed method

# Example

## Instant influence



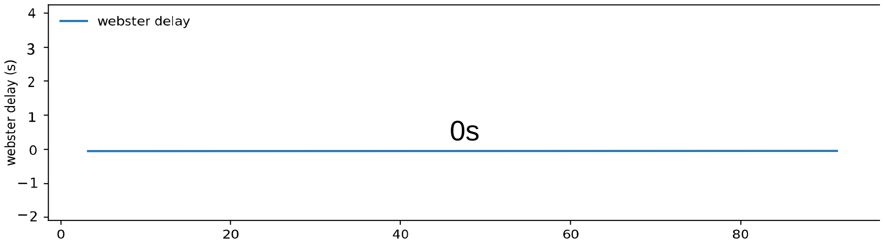

Naïve method



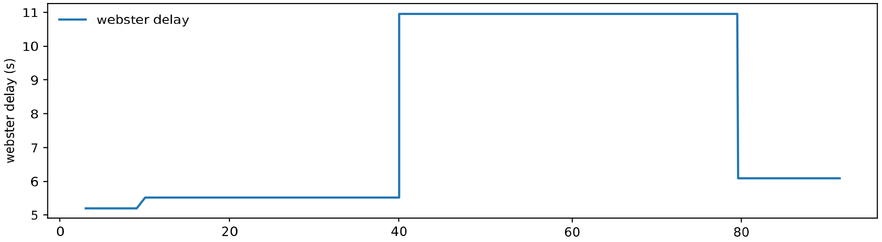

Proposed method

# Example

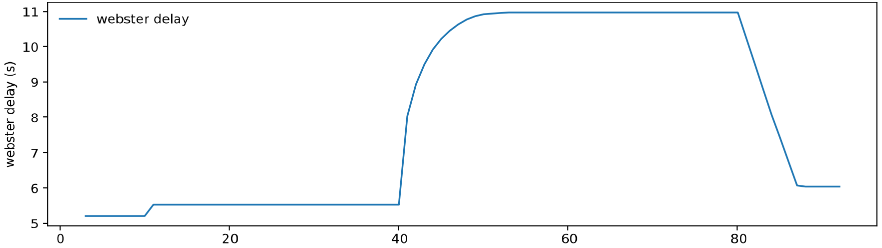
## Travel time




Webster's delay in current LTM model



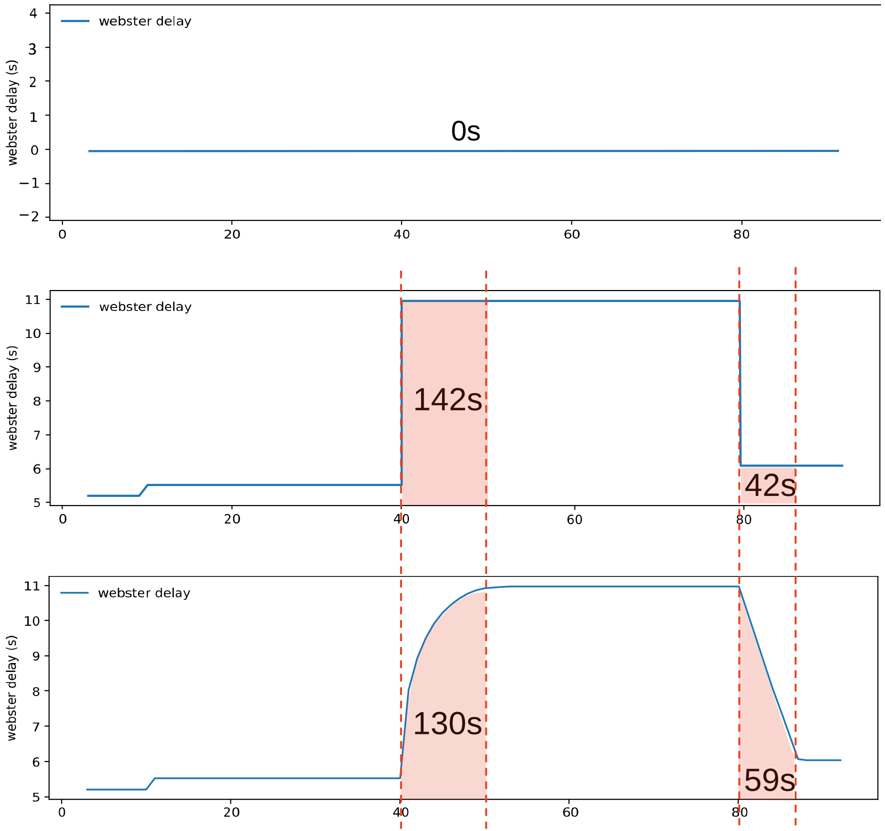

Webster's delay in naïve method




Webster's delay in proposed method

# Example

## Travel time




Webster's delay in current LTM model

Webster's delay in naïve method

Webster's delay in proposed method

Overestimated: 2 s/veh Underestimated: 6 s/veh

# Contributions

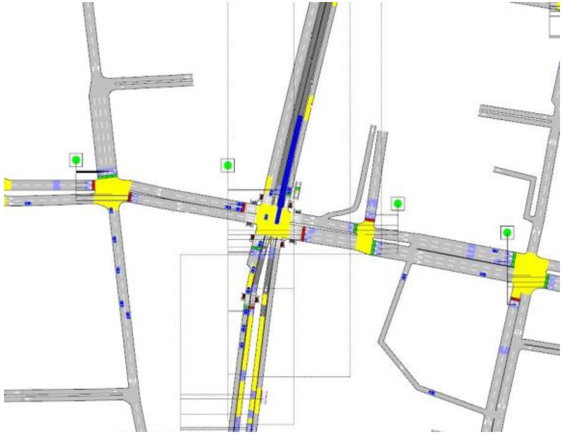
**Theoretical**

- Incorporate non-persistent delays into the LTM, adhering to the FIFO principle.
- This is an unprecedented approach.
- Provide a macroscopic resolution, calculating average flow rates for each time instance within the entire cycle.

# Contributions

## Practical

- Can be embedded in LTM implemented in
  - OmniTRANS
  - AIMSUN
- For transport planners
  - an effective way to describe traffic more realistically
  - more accurate travel time and traffic flow forecast
- For decision makers
  - infrastructure investment
  - cost-benefit analysis



Sydney CBD AIMSUN model

Road construction, NSW

# Thank you!

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