Contending with Congestion from both Demand and Control perspectives

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The University of Hong Kong (December 2015)

Why contending with congestion?

Economic Competitiveness

Environmental Sustainability

Ecological Compatibility

**Livable Community
(Efficiency, Safety, Beauty)**

Culture Harmony

MAJOR CITIES
21st CENTURY

CONGESTION VS. CIVILIZATION

CIVILIZATION VS. CONGESTION

ROMAN EMPIRE-Pompeii was threatened by traffic gridlock
With traffic restrictions lifted during the two hours before nightfall, the driver races his chariot between stepping stones over which two ladies have just walked to avoid the puddles of rainwater.

- **ROMAN EMPIRE**

6th -7th CENTURY BC

- **21st CENTURY**

- **SONG DYNASTY**

CHINA - SONG DYNASTY — The landscape of the capital, Bianjing
Song Dynasty Painting: Along the River During the Qinming Festival

New York · Paris · Sao Pualo · Toronto

Seoul · Moscow · Tokyo · Taiyuan

REDUCE THE CONGESTION LEVEL

Decrease the Travel Demand

Demand-side Strategies

- Reduced trip generation
- Reduced peak-period trip demand
- Convert auto trips to transit trips
- Multi-modal coordination systems

Best Use the Capacity of Available Infrastructure Systems

Control Strategies

- Freeway recurrent/non-recurrent control
- Corridor recurrent/non-recurrent control
- Urban network control
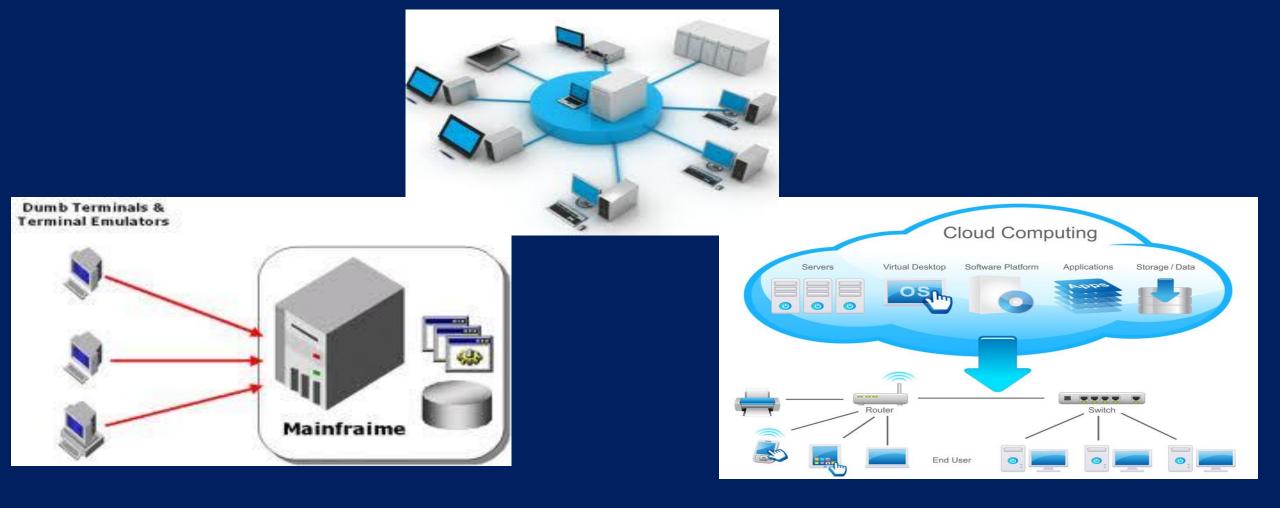
Decrease the Travel Demand

Reduced Trip Generation

- **Reshape urban structure**

Reduced Peak-hour Trip Demand

Reshape the urban structure

Is it time for a mega city, (functioning like an old IBM mainframe), to be transformed into a structure like "microcomputer networks?" or even a "cloud-computing" architecture.
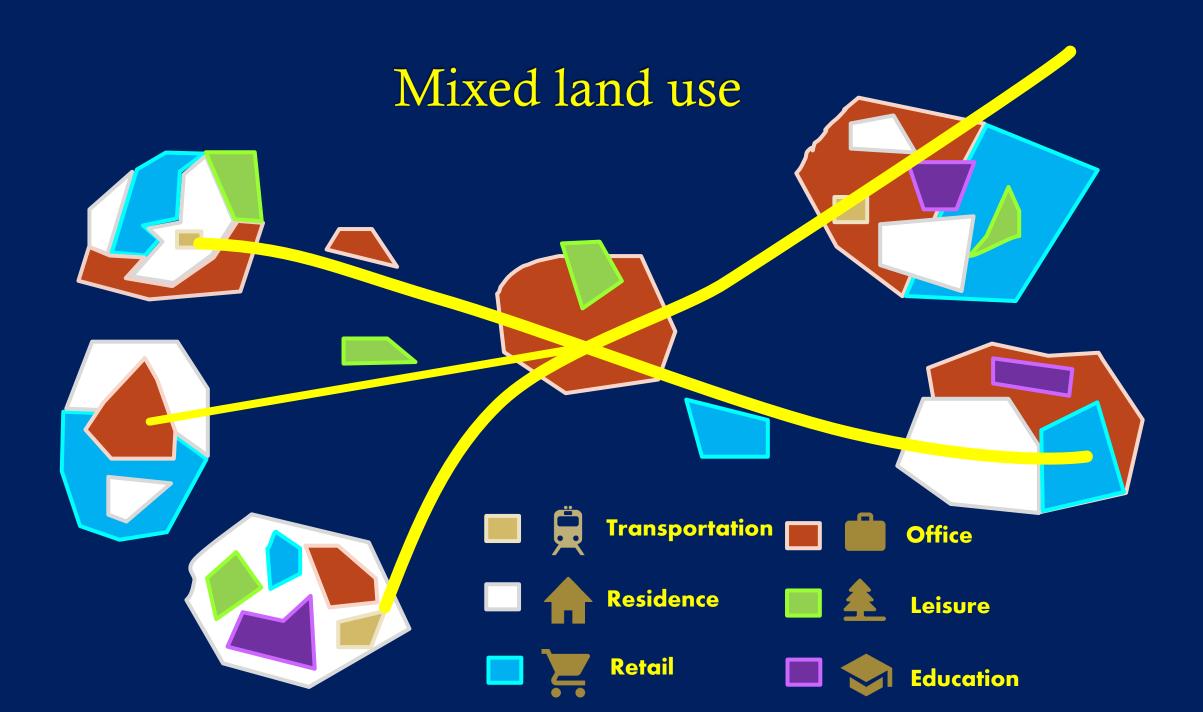
Decrease the Travel Demand

Reduced Trip Generation

- **Reshape urban structure**
- **Promote mixed-land use**

Reduced Peak-hour Trip Demand

Mixed land use

Transportation
Residence
Retail
Office
Leisure
Education

Information Highway/ Satellite Office Complex

HEAD OFFICE

Manager

Working at Home

Reginal office

Home

Home

Home

Decrease the Travel Demand

Reduced Trip Generation
- Reshape urban structure
- Promote mixed-land use
- Information highway/satellite office complex
- Promoting new culture

Reduced Peak-hour Trip Demand
- Dynamic working hours(8hr/day)
- Individual-based departure time/route/mode advisory system

Personal-based departure time/route/mode advisory system

Decrease the Travel Demand

Reduced Trip Generation

- **Reshape urban structure**
- **Promote mixed-land use**
- **Information highway/satellite office complex**
- **Promoting new culture**

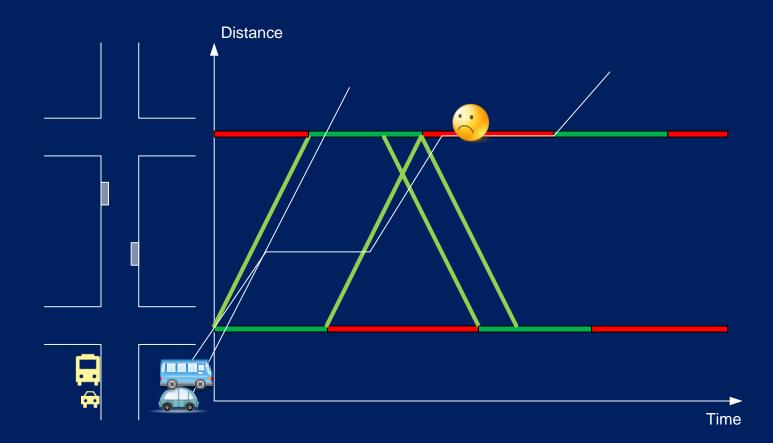**Reduced Peak-hour Trip Demand**

- **Dynamic working hours(8hr/day)**
- **Individual-based departure time/route/mode advisory system**
- **Dynamic working loads (bi-weekly 80hr)**

Convert to non-auto trips

1 Bus-based signal progression

2 Bus-service reliability system

3 Dynamic car-pool system

4 Responsive transit system

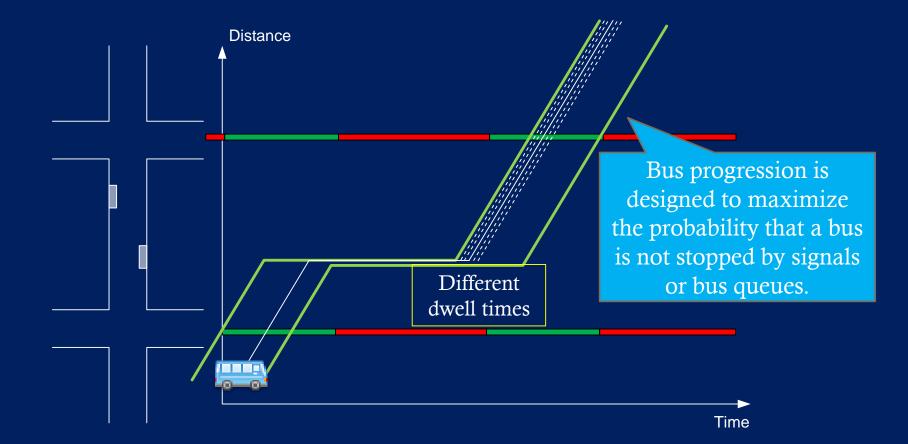5 Integrated multimodal community system (bus/car; subway/bus/bike)
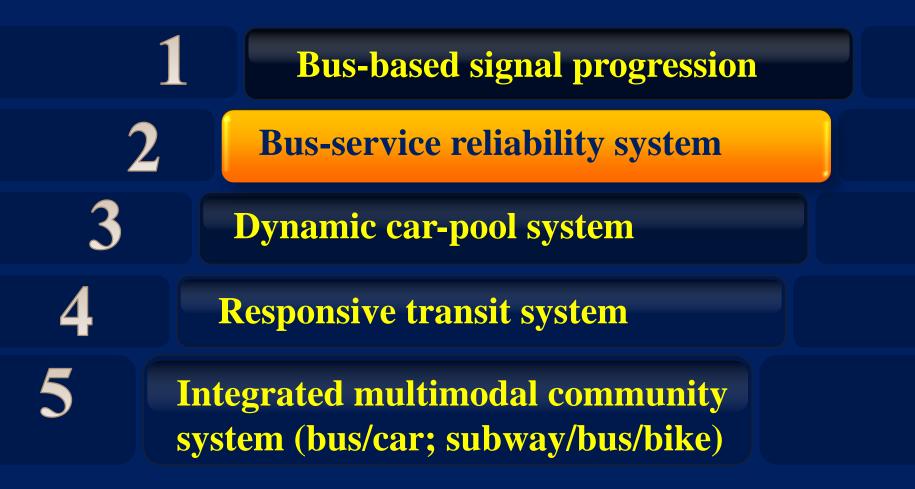
Impact of signals on bus operations

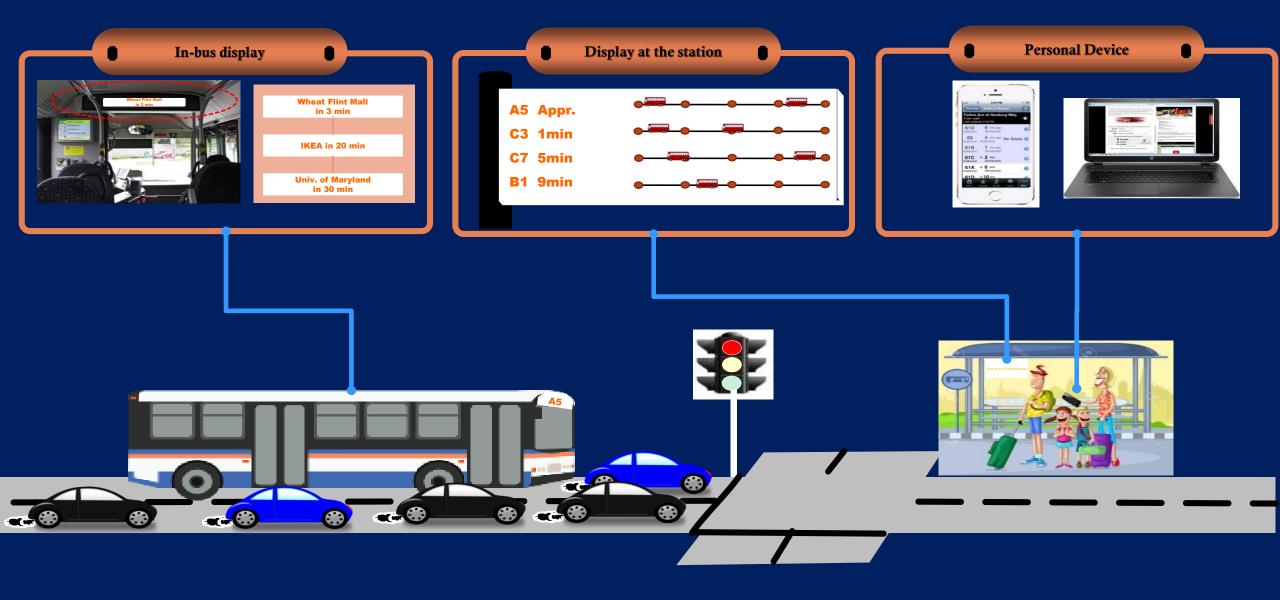◇ **Transit vehicles, impacted by the dwell time at stops, may not stay in the green band.**
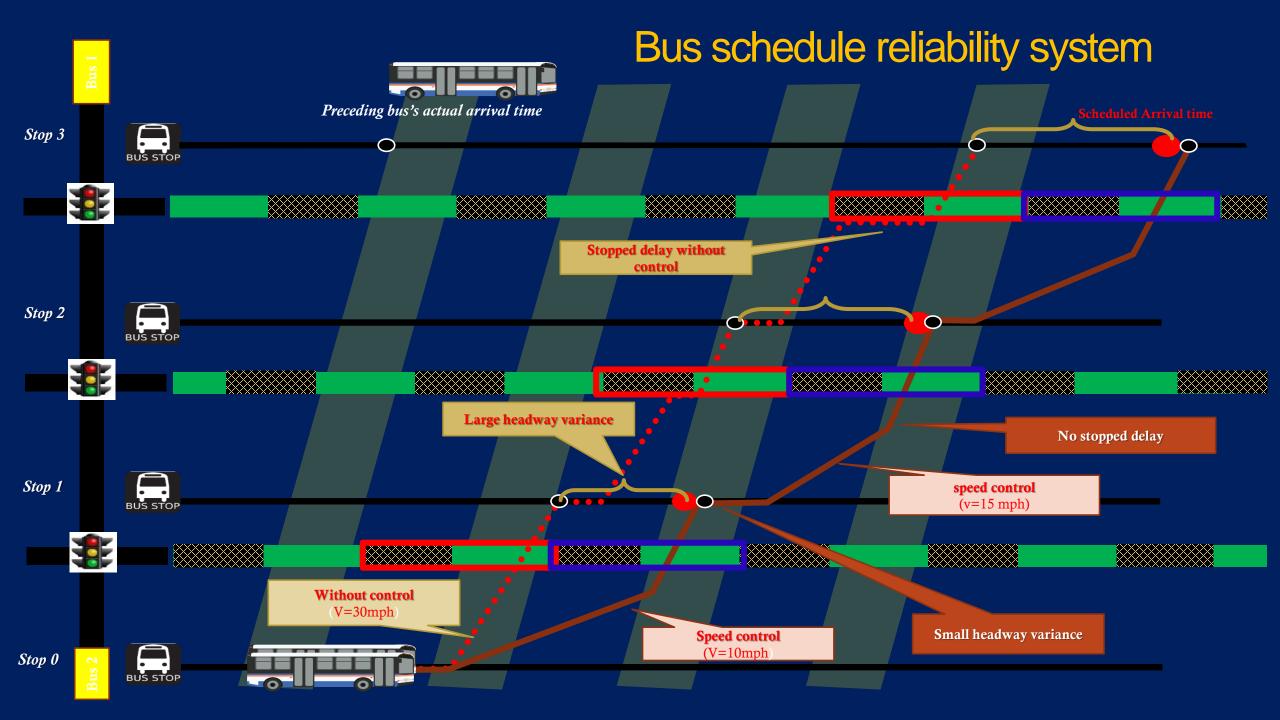
Bus progression

Different dwell times

Bus progression is designed to maximize the probability that a bus is not stopped by signals or bus queues.

Convert to non-auto trips

1 Bus-based signal progression

2 Bus-service reliability system

3 Dynamic car-pool system

4 Responsive transit system

5 Integrated multimodal community system (bus/car; subway/bus/bike)
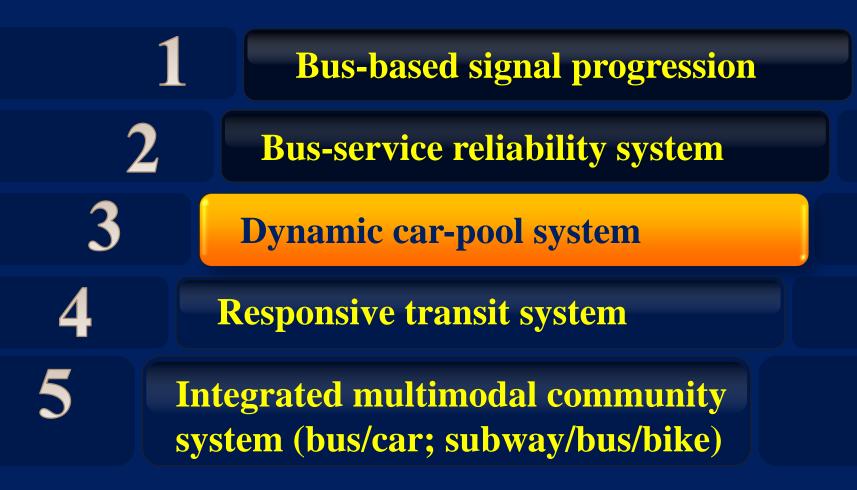
Bus Arrival Time Information

In-bus display

Wheat Flint Mall in 3 min
IKEA in 20 min
Univ. of Maryland in 30 min

Display at the station

A5 Appr.
C3 1min
C7 5min
B1 9min

Personal Device

Bus schedule reliability system

Convert to non-auto trips

1 Bus-based signal progression

2 Bus-service reliability system

3 Dynamic car-pool system

4 Responsive transit system

5 Integrated multimodal community system (bus/car; subway/bus/bike)

Split is *Smarter Shared Rides* - "a whole new way to get around town" —A dynamic car-pooling system

How does it work?

- Passengers request and pay for ride on our **mobile app**

- Split uses **open data** to ID thousands of safe, legal and non-disruptive pickup/drop-off points in a service area

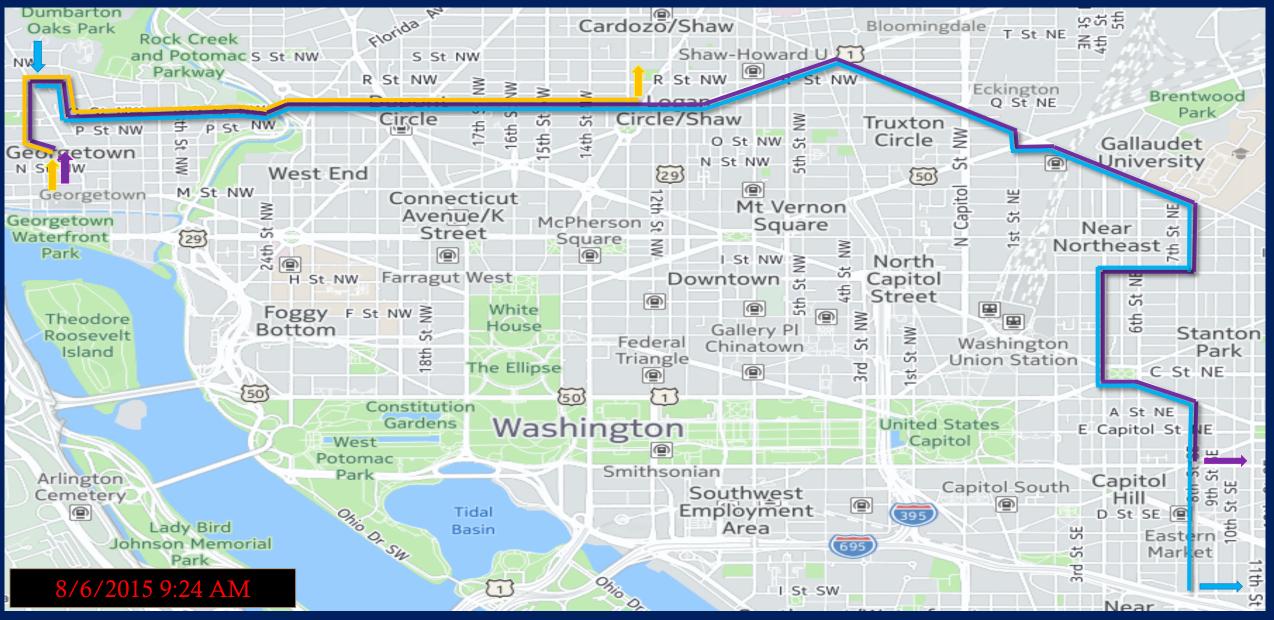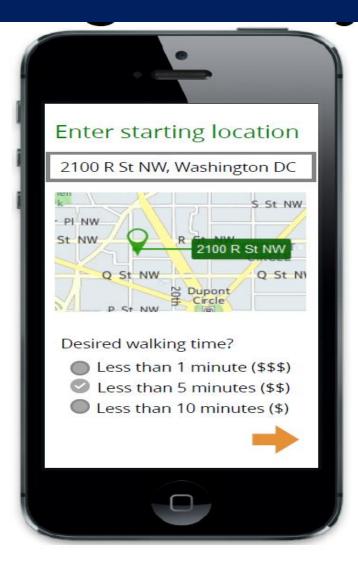- A **proprietary routing algorithm** instantly combines overlapping rides into a single vehicle

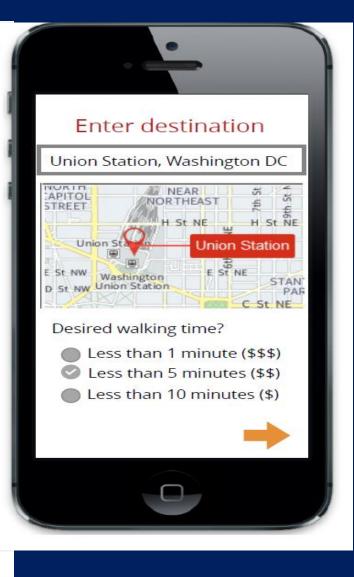- **independent contractors** use their personal vehicles to deliver our service

- **Convenient**
- **Affordable**
- **Sustainable**

A real shared ride example

8/6/2015 9:24 AM

Enter starting location

2100 R St NW, Washington DC

2100 R St NW

Desired walking time?
- Less than 1 minute ($$$)
- ✓ Less than 5 minutes ($$)
- Less than 10 minutes ($)

Enter destination

Union Station, Washington DC

Union Station

Desired walking time?
- Less than 1 minute ($$$)
- ✓ Less than 5 minutes ($$)
- Less than 10 minutes ($)

confirmation

Pickup at 10:07 AM

Arrival between 10:33-10:48

2100 R St NW

Pickup stop

Fare: $3.75

Highway Congestion Control & Management

PHOTO BY DON BARTLETTI/LOS ANGELES TIMES/MCT
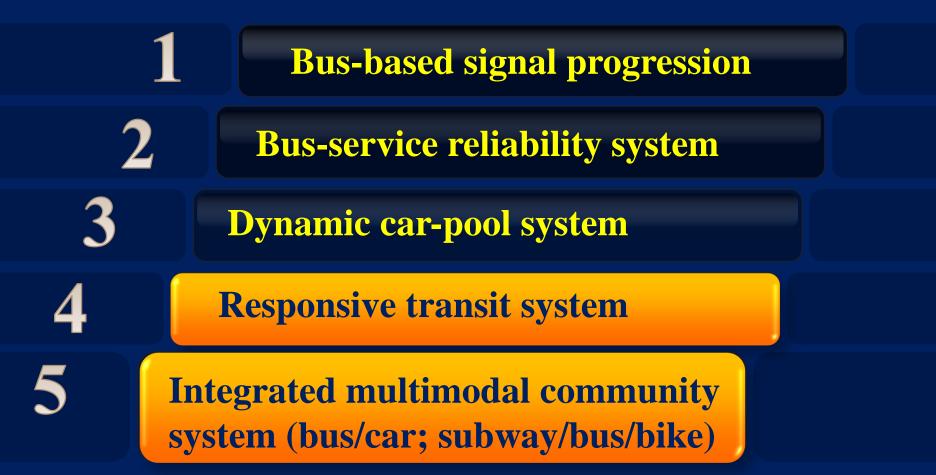
Congestion Patterns on Highway Corridors

1. On-ramp weaving bottlenecks
2. Off-ramp queue spillback
3. Recurrent congestion
4. Incidents or work zones
5. Highway/arterial mutual blockage

Congestion Contributing Factors

◈ **On Ramp Weaving**

RECURRENT CONGESTION DUE TO WEAVINGS
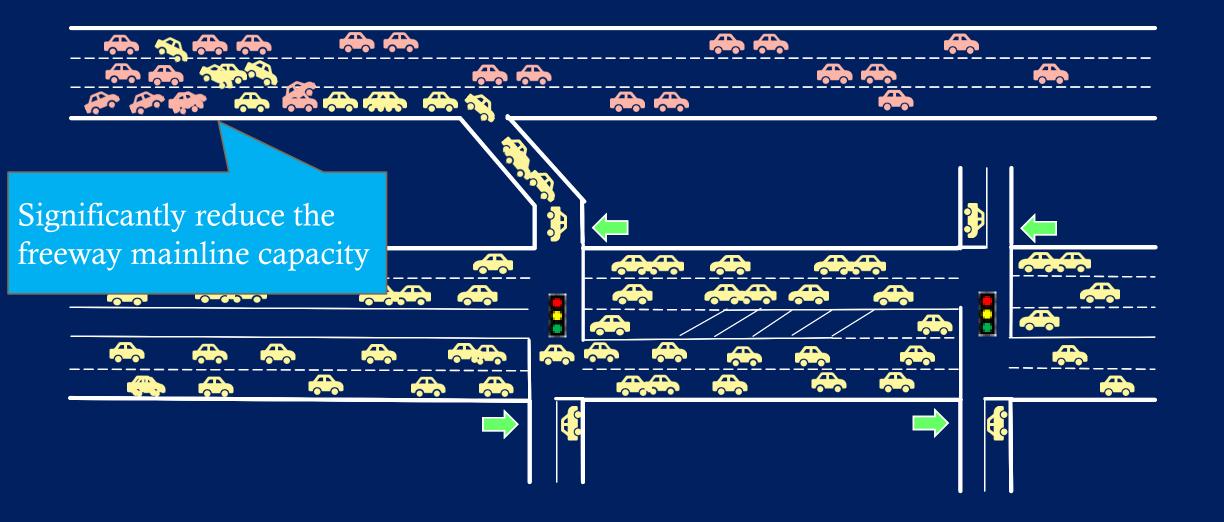
- ◇ MD 100
  - ◇ Two-lane highway in each direction
  - ◇ Speed limit 55 MPH
  - ◇ Changes in geometric features
  - ◇ High accident frequency (39 in 2008)
  - ◇ High and dynamic traffic demand during peak hours
  - ◇ Volume surge at merging areas
  - ◇ Rapid speed drop at merging areas

Location Map

Free flow: 180 sec
Congested: 600 sec

PROJECT LOCATION

On-ramp Spillback Congestion

Freeway Arterial Mutual Blockage

Congestion Contributing Factors to non-recurrent congestion

◈ **Lane Reduction**

Congestion due to accidents

Congestion Contributing Factors –Non-recurrent congestion
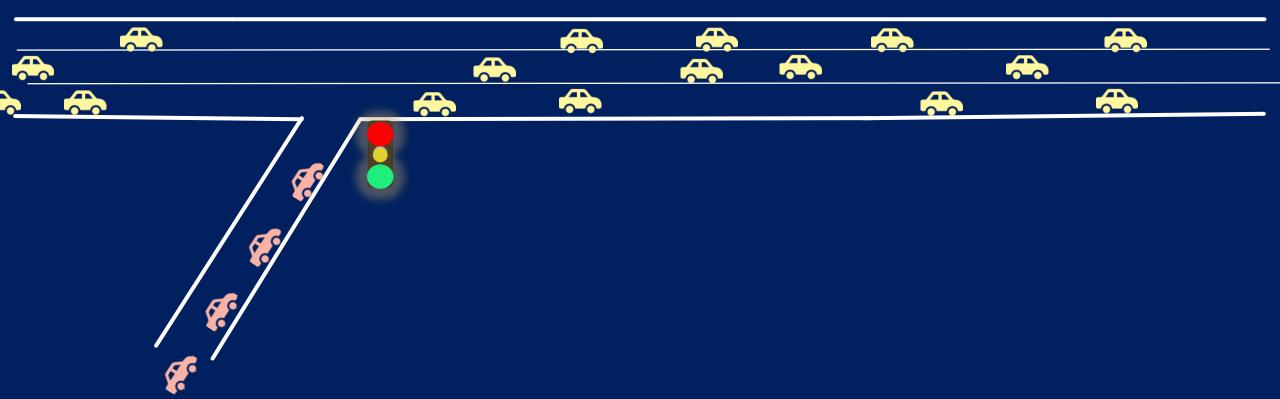
⬦ **Incidents / Work Zones**

Control Strategies

1. Ramp metering

2. off-ramp control

3. variable speed control

4. Integrated control (ramp metering/off-ramp/signal/travel time)

5. Non-recurrent congestion control (WZ, incidents)

Response strategies

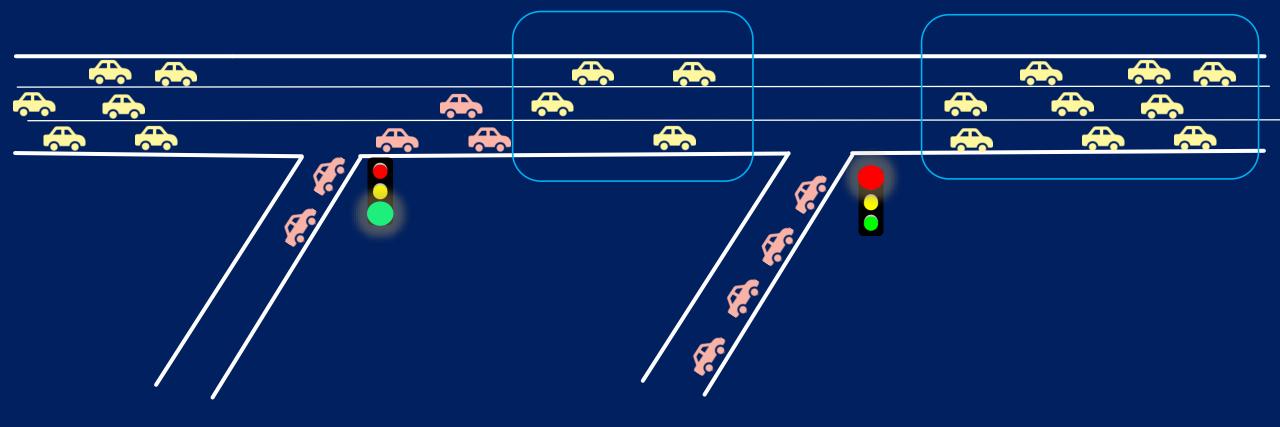◈ **Local Metering control**

Control on-ramp vehicles
    -To reduce impact to the vehicles on the freeway
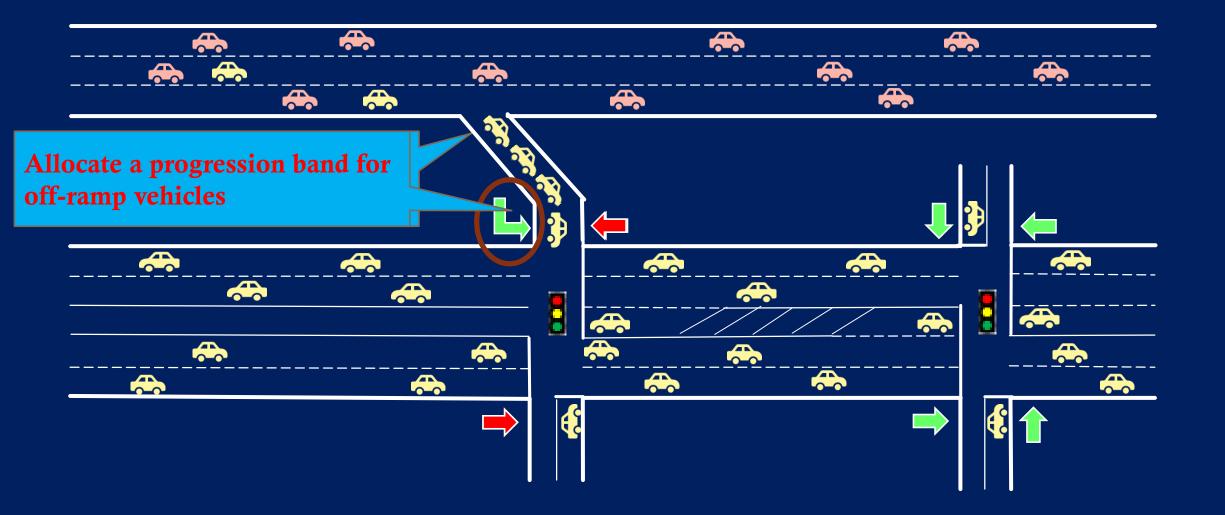
Response strategies

◈ **Coordinated Metering control**
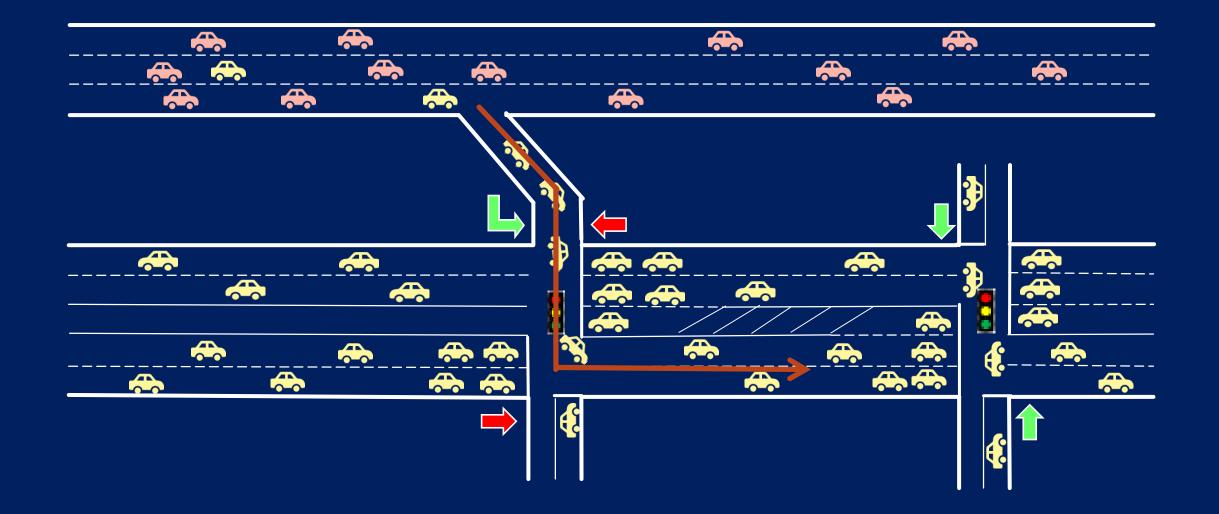
Control on-ramp vehicles
-To reduce impact to the vehicles on the freeway

Off-ramp Dynamic Control

Allocate a progression band for off-ramp vehicles
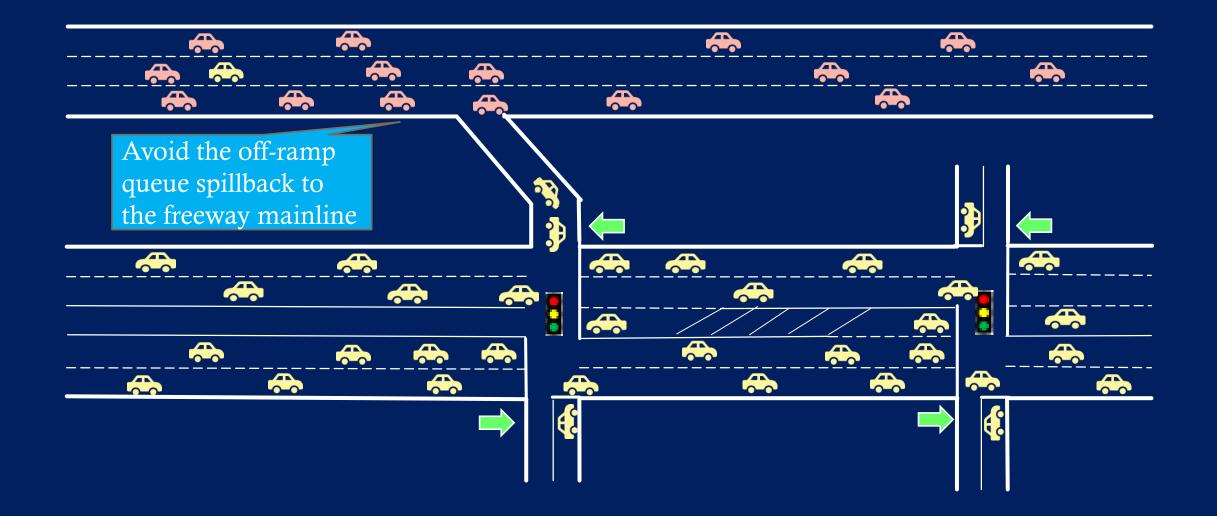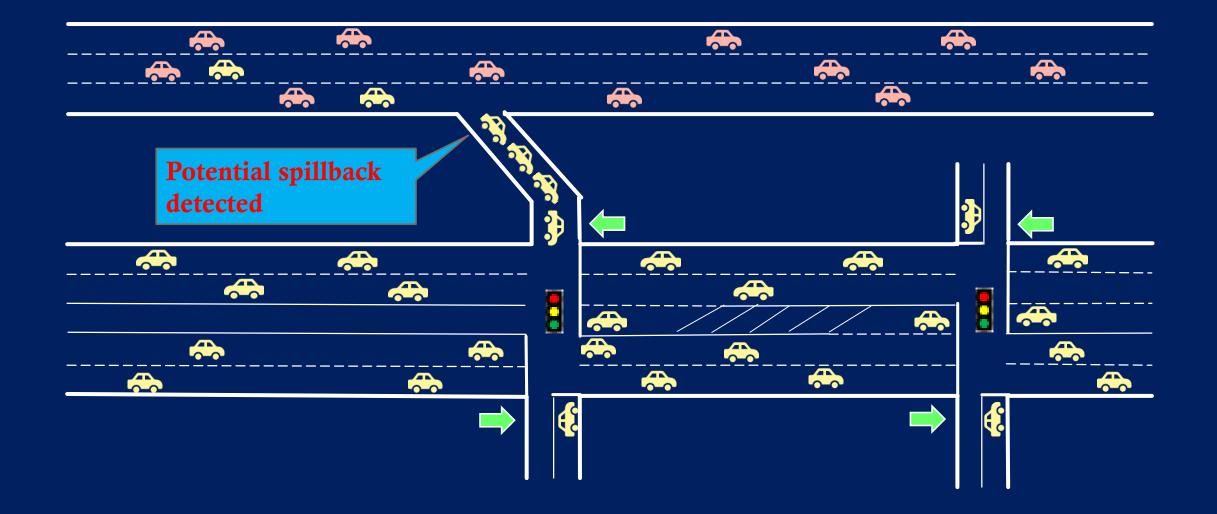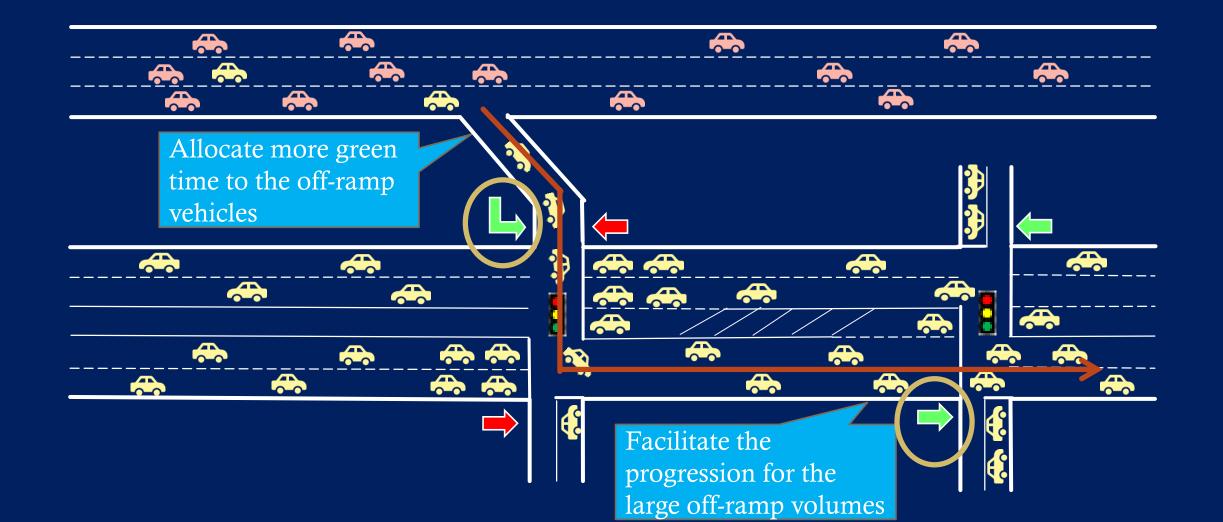
Off-ramp Dynamic Control

Off-ramp Dynamic Control
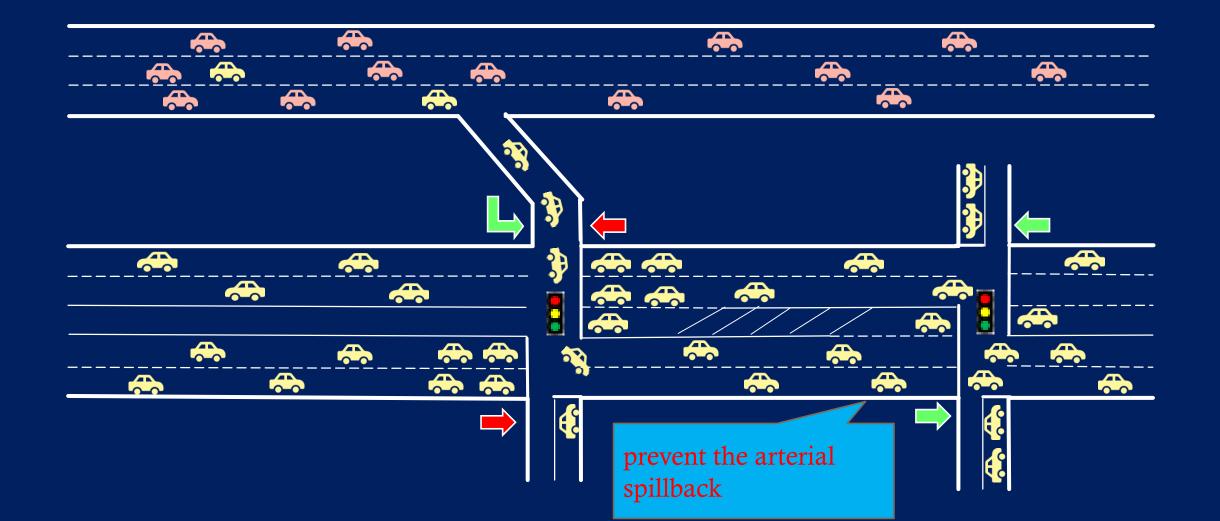
Avoid the off-ramp queue spillback to the freeway mainline

Off-ramp Control + Multi-path Progression

Potential spillback detected

Off-ramp Control + Multi-path Progression

Allocate more green time to the off-ramp vehicles

Facilitate the progression for the large off-ramp volumes

Off-ramp Control + Multi-path Progression

prevent the arterial spillback

On-ramp Metering +Off-ramp Dynamic Control

Reduce the off-ramp queue length

On-ramp Metering +Off-ramp Dynamic Control

Control the on-ramp volume, maintain the freeway capacity
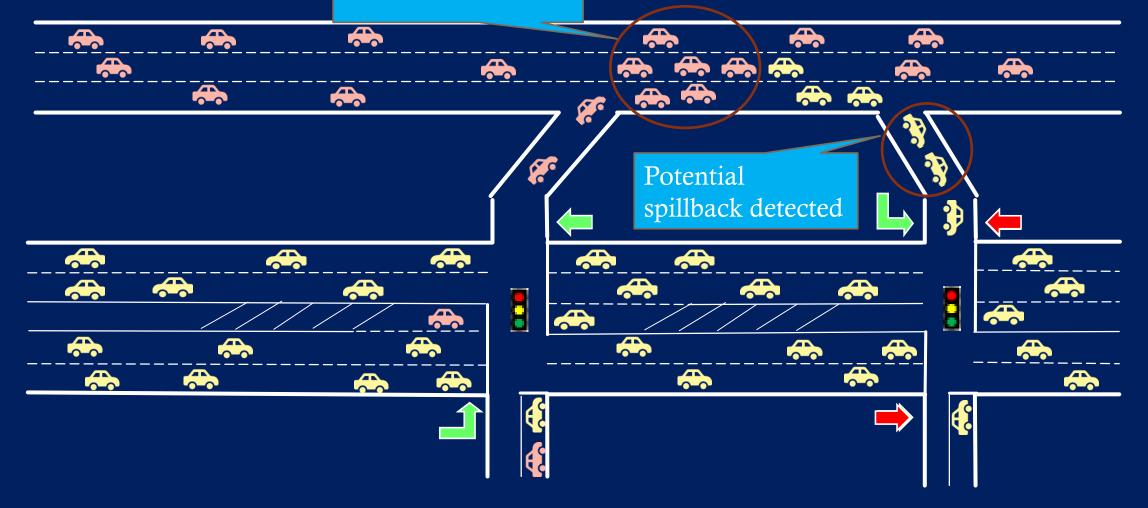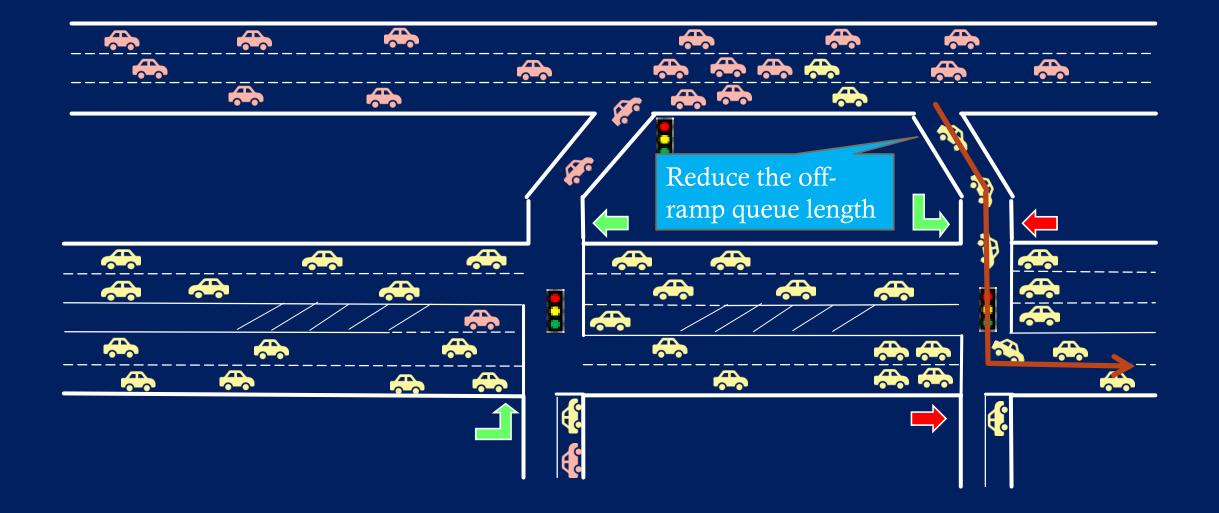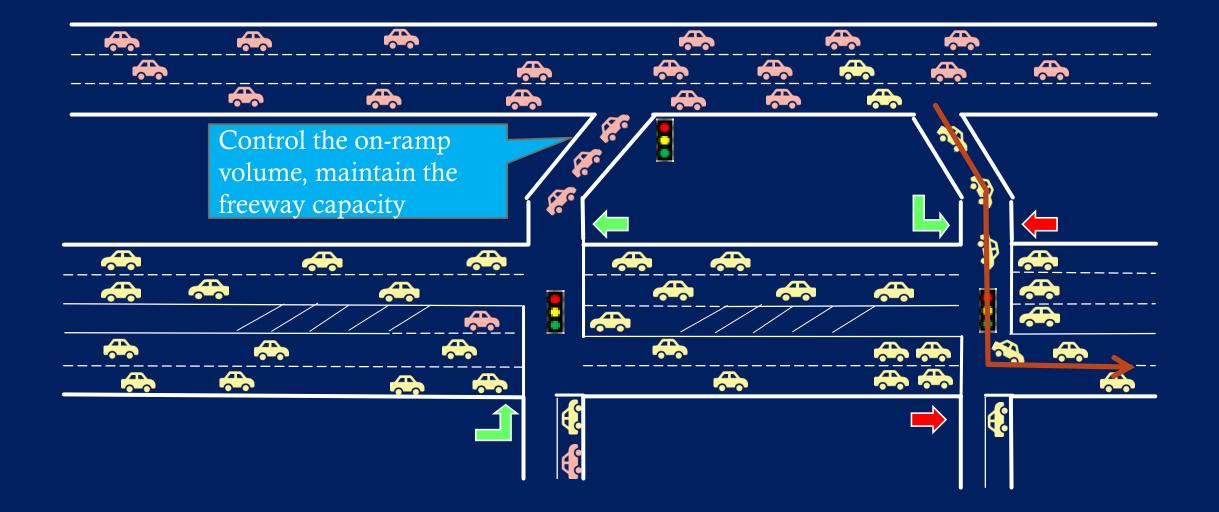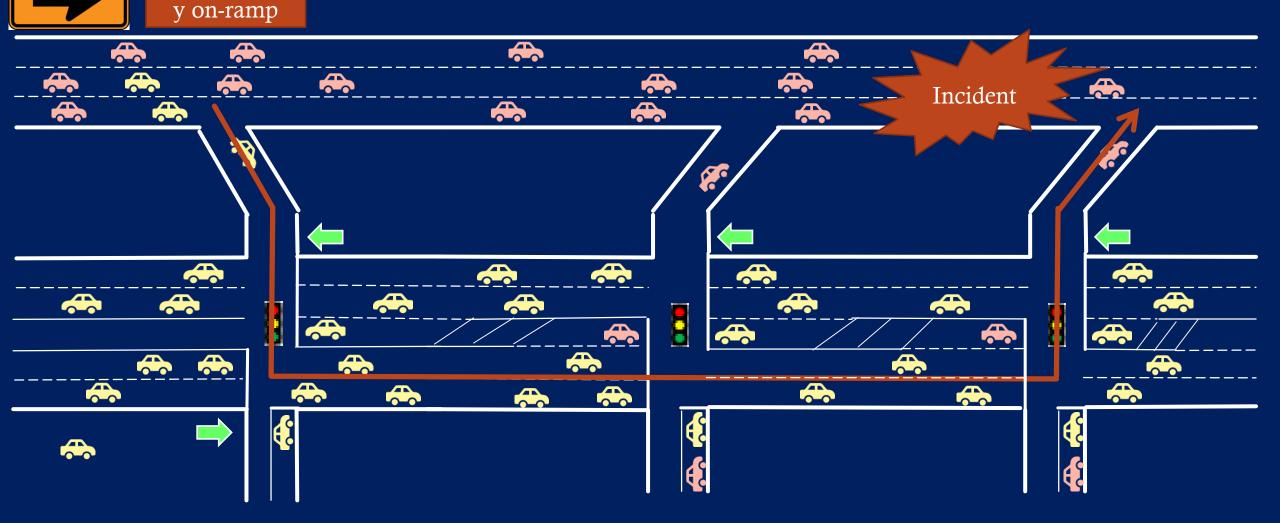
Detour Operations + Route Guidance + On-ramp Metering +Off-ramp Dynamic Control + Signal Optimization

Merge Control Strategies

◈ SEM and SLM controls
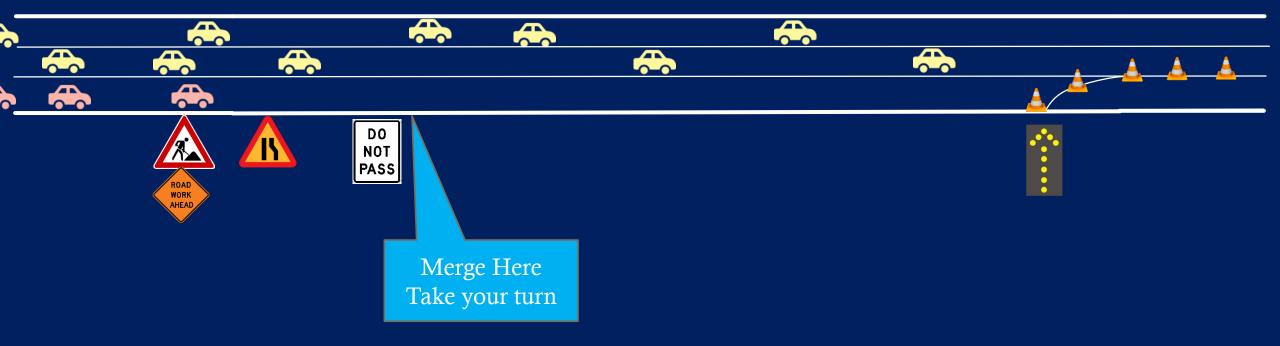
◈ Dynamic late merge (DLM) control

    ◇ To dynamically activate a early (or conventional) merge or late merge, based on the pre-determined control threshold.

← Early merge (or Convent.) under free and moderate traffic conditions

Late merge

under the congested traffic conditions ➔

Response strategies

◈ **Work Zone Control**

Early Merge

DO NOT PASS

Merge Here
Take your turn

Response strategies
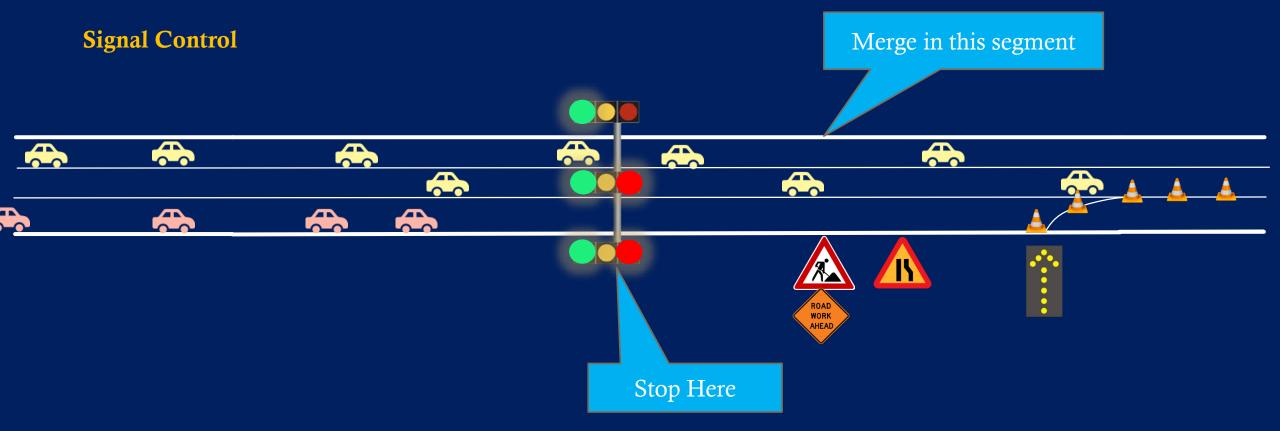
◈ **Work Zone Control**

Late Merge

ROAD WORK AHEAD

Merge Here
Take your turn

Response strategies

◈ **Work Zone Control**

Signal Control

Merge in this segment

Stop Here

ROAD WORK AHEAD

OTHER **VSL** APPLICATIONS (TIME-OF-DAY CONTROL)

Netherland

Spain

Germany

M25 Motorway (UK)

University of Maryland College Park

Speed Control Strategies

◈ Posted speed limit (PSL) control

◈ Speed monitor display (SMD) and Speed advisory sign (SAS)

   ◈ Focused on improving traffic safety based on the PSL
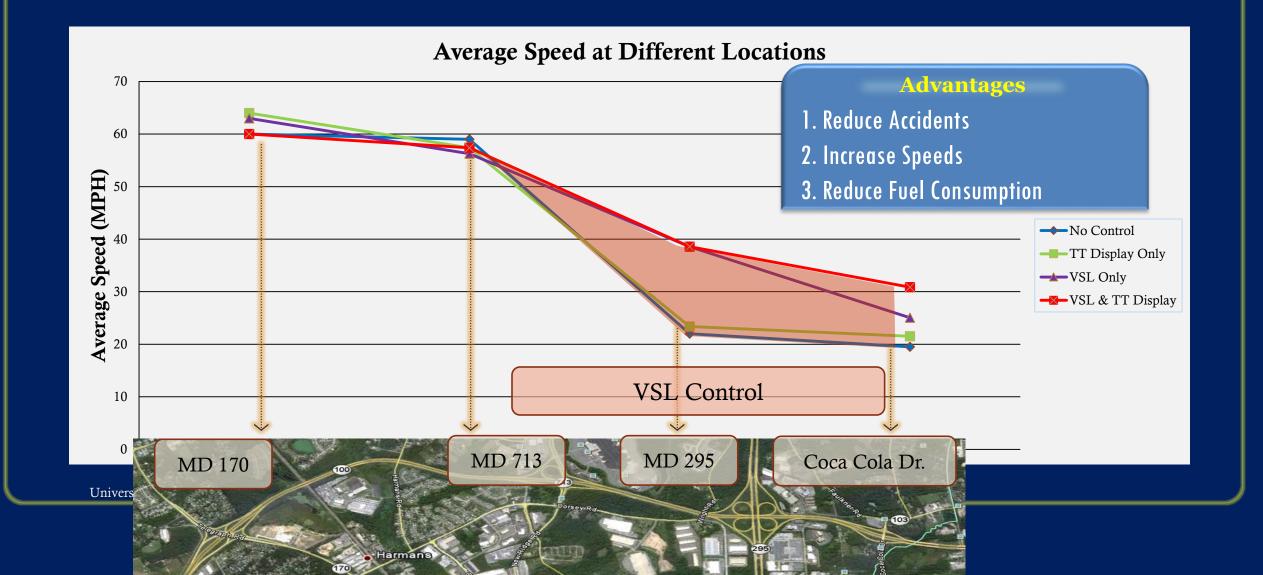
● Variable speed limit (VSL) control

   ● To effectively respond to traffic conditions and to increase the compliance rate of drivers

   ● Most systems have been applied in highway segments plagued by the bad weathers and recurrent congestion.

SAS

PART Ⅰ. What and Why VSL?

VSL CONTROL SPEED PROFILE

Average Speed at Different Locations

Advantages
1. Reduce Accidents
2. Increase Speeds
3. Reduce Fuel Consumption

Legend:
- No Control
- TT Display Only
- VSL Only
- VSL & TT Display

VSL Control

MD 170   MD 713   MD 295   Coca Cola Dr.

Y-axis: Average Speed (MPH), scale from 0 to 70

Coordinated Highways Action Response Team

- An incident response/management system

Dr. Gang-Len Chang

Department of Civil Engineering
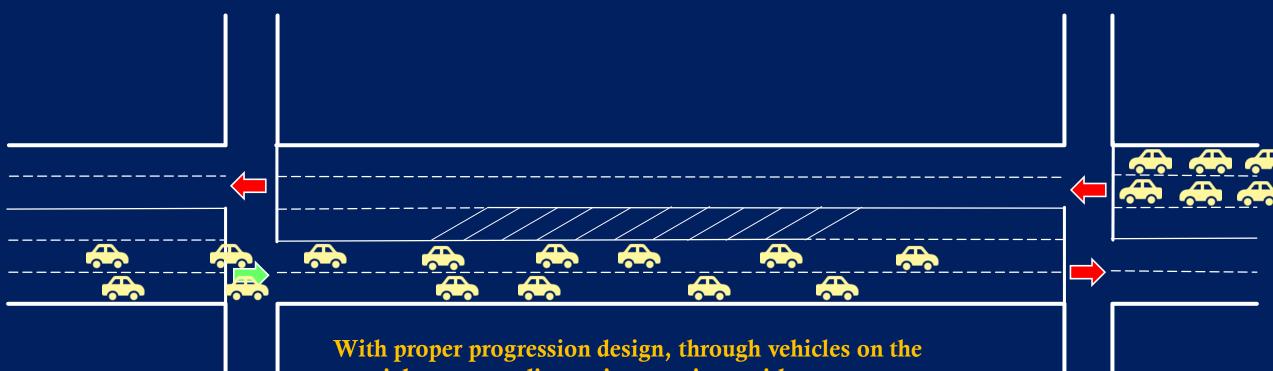
University of Maryland

February, 2012

Potential benefits

◈ Delay

◈ Fuel consumption

◈ Emission

◈ Secondary incidents

◈ Risks at primary incident sites

◈ **Driver assistance**

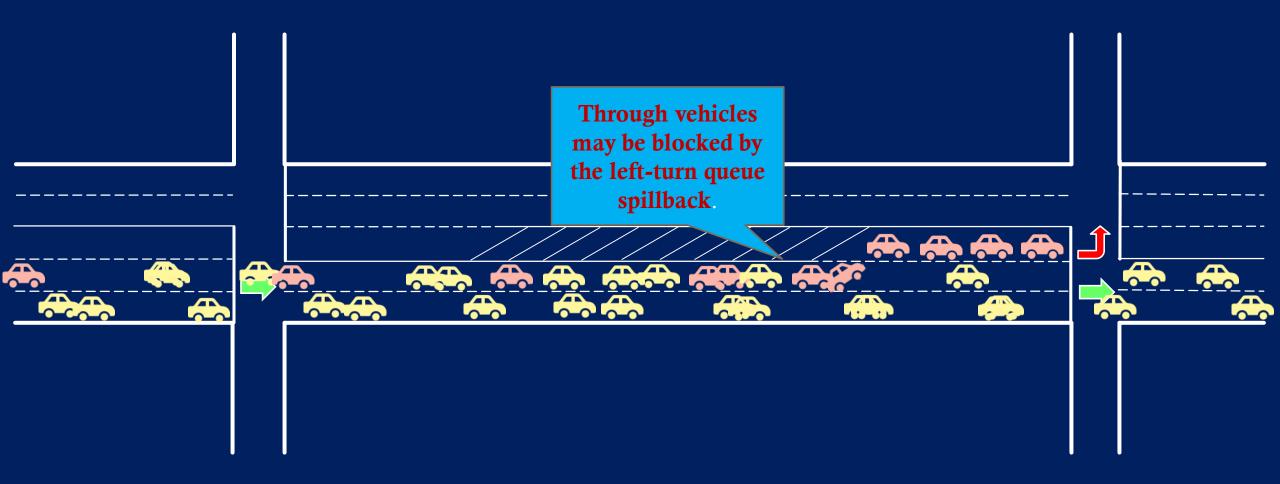# Control strategies for Urban traffic networks

1. **Two-way progression**

2. **Two-way, leading /lagging progression**

3. **Dual-band progression**

4. **Multiband progression**
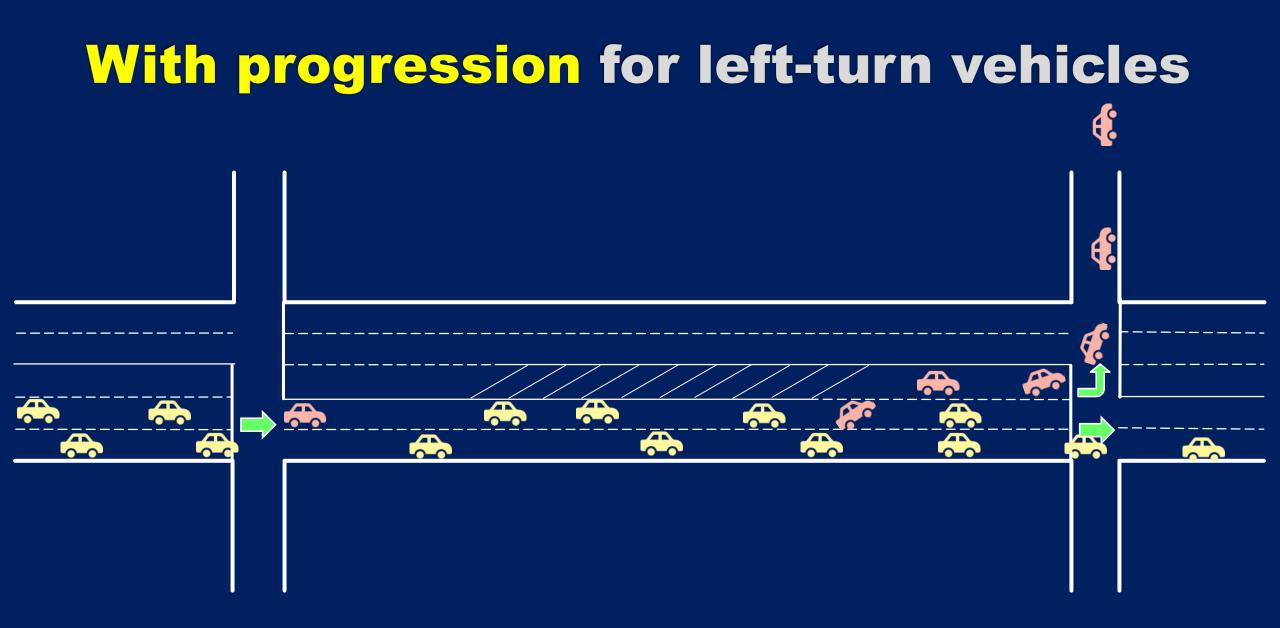
Progression only for through movements

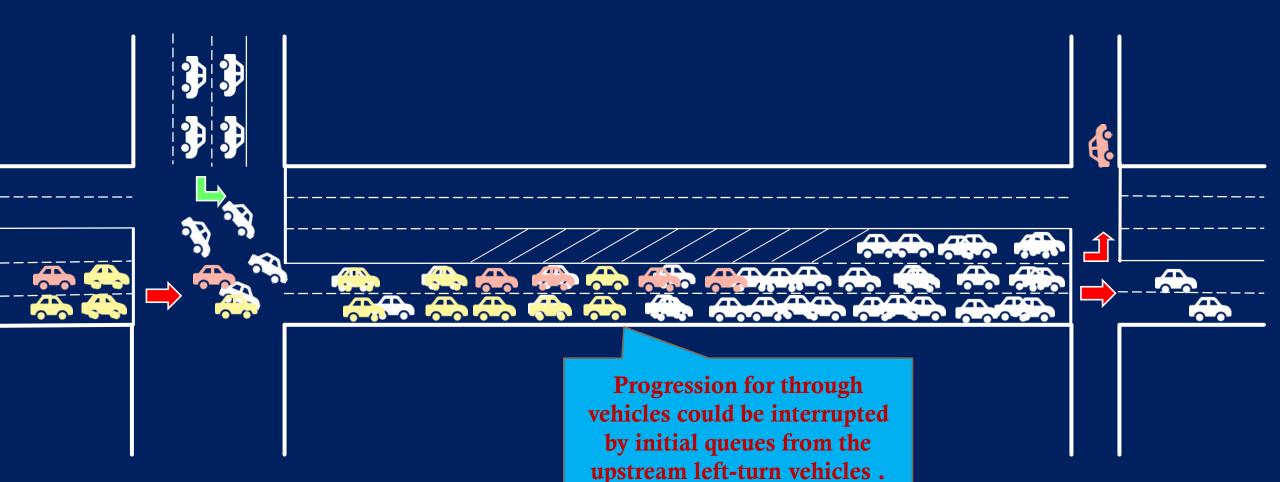With proper progression design, through vehicles on the arterial can pass adjacent intersections without stop.

With progression for left-turn vehicles

No progression for left-turn vehicles from the upstream intersection
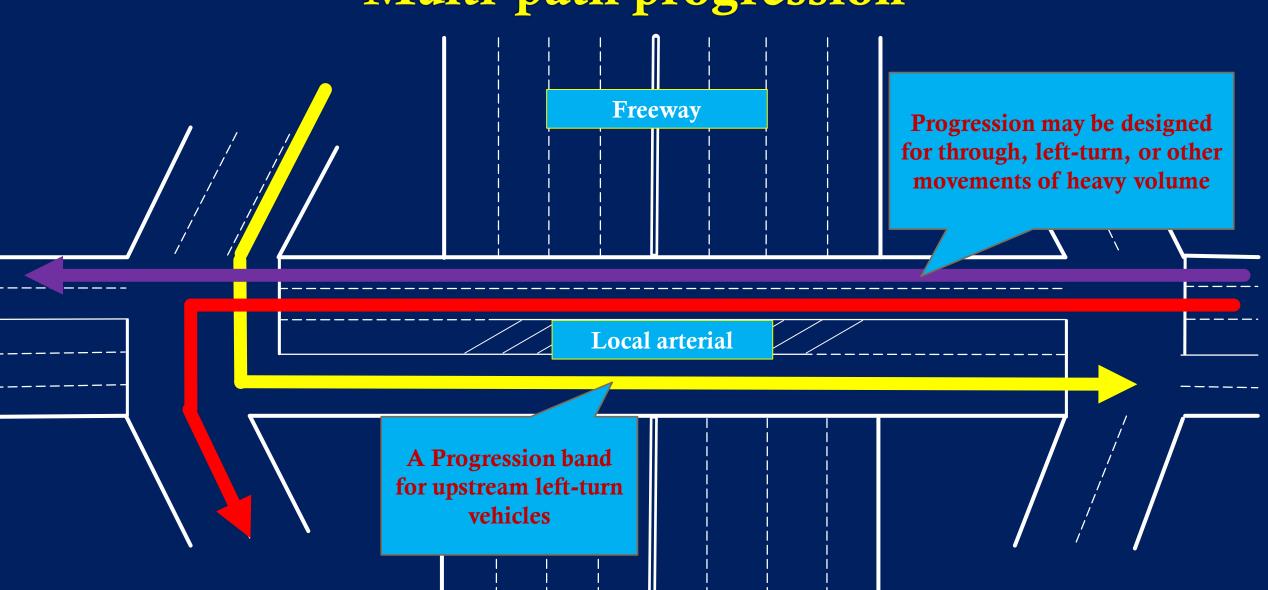
Progression for through vehicles could be interrupted by initial queues from the upstream left-turn vehicles .

With progression (dual-band progression)
for left-turn vehicles from the upstream intersection

Vehicles from the upstream cross street are able to pass through the intersection during the green band, and minimize the likelihood of generating residual queues.

With progression (dual-band progression) for left-turn vehicles from the upstream intersection

Vehicles from the upstream cross street are able to pass through the intersection during the green band, and minimize the likelihood of generating residual queues.
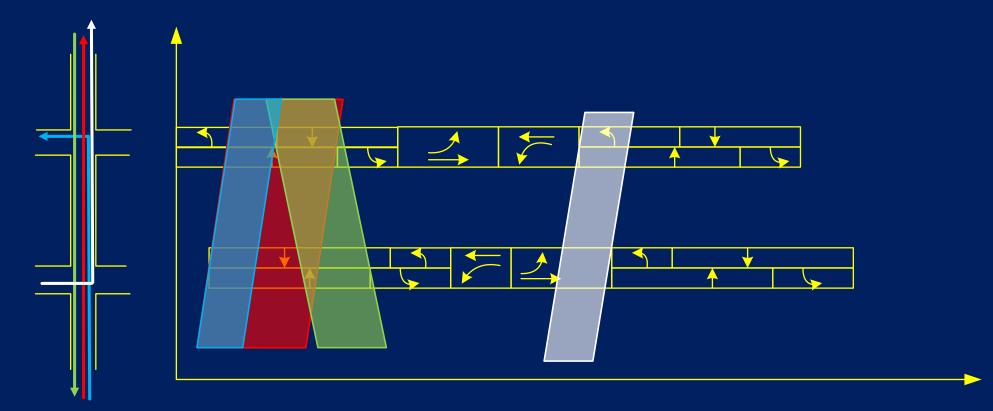
Multi-path progression

Freeway

Local arterial

Progression may be designed for through, left-turn, or other movements of heavy volume

A Progression band for upstream left-turn vehicles
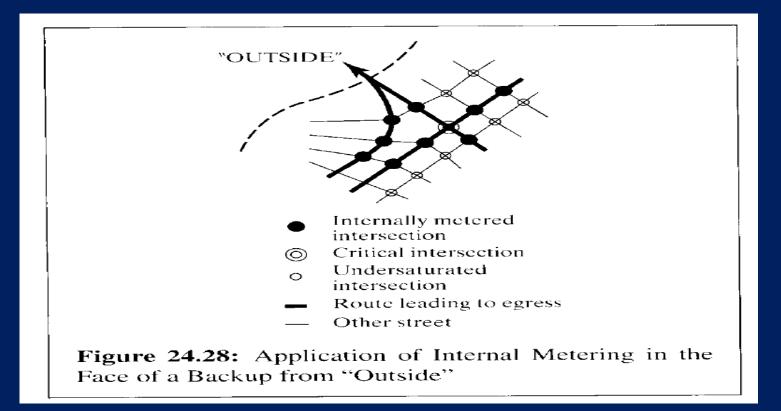
A sample time-space diagram for multi-path progression
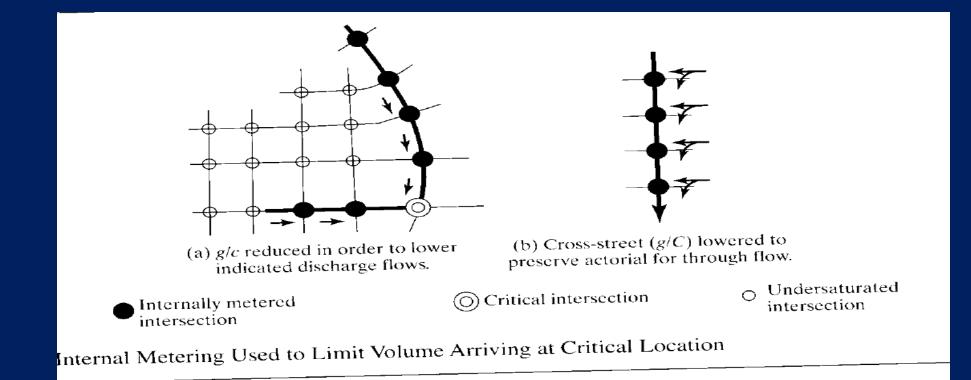
Internal metering for overstaurated networks

"OUTSIDE"

- ● Internally metered intersection
- ◎ Critical intersection
- ○ Undersaturated intersection
- — Route leading to egress
- — Other street

Figure 24.28: Application of Internal Metering in the Face of a Backup from "Outside"

Signal metering plans

⬦ **Internal metering**: the use of control strategies within a congested network so as to influence the distribution of vehicles arriving or departing from a critical location.

(a) g/c reduced in order to lower indicated discharge flows.

(b) Cross-street (g/C) lowered to preserve actorial for through flow.

● Internally metered intersection

◎ Critical intersection

○ Undersaturated intersection

Internal Metering Used to Limit Volume Arriving at Critical Location

Closure

- Can automation & technology effectively contain the "congestion expansion?"

- Need to re-shape the "urban culture"

◈

◈ Convert the "self-center" mentality to "cooperative attitude" of sharing space.

◈ Design the urban infrastructure to facilitate "PEOPLE", not "passenger cars".

◈ Integrated information and cooperative operations between institutions

- **Recognizing "congestion" as a "cancer", not "inconvenience", to the society**

- **Sustainable support and investment to contend with congestion**