SAFE MOBILITY IN EGYPT

التنقل الآمن في مصر

Road Safety School

Safe Mobility in Egypt & Road Safety School-UK

Intelligent Transportation Systems (ITS)

Lecture 3 & 4

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About the Instructor

- **د. يارة إسماعيل علي بسيوني**
- حاصل على دكتوراه هندسة النقل – نظم نقل ذكية ٢٠١٨
- أستاذ مساعد في هندسة النقل والمرور في عدد من الجامعات المصرية
- مهندس محترف أول في مكتب طلعت وإمام للاستشارات الهندسية
- مؤلف ومراجع للعديد من الأبحاث في أشهر مجلات نظم النقل الذكية العالمية
- مؤسس التنقل الآمن في مصر – **Safe Mobility in Egypt**

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للحصول على الشهادة

- للحصول على الشهادة، يشترط الالتزام الكامل بالمتطلبات التالية:
  - إتمام التسجيل الرسمي في المنصة باستخدام بيانات صحيحة.حضور جميع المحاضرات، مع السماح بالغياب عن محاضرة واحدة كحد أقصى فقط.
  - استكمال مشاهدة جميع المحتويات التعليمية المعتمدة داخل المنصة.حل جميع الأسئلة والاختبارات والواجبات المطلوبة دون استثناء.
  - تحقيق مستوى تفاعل فعّال من خلال المشاركة في النقاشات والتعليقات والأنشطة الاجتماعية داخل المنصة.
  - الالتزام التام بالمواعيد النهائية المحددة لتسليم كافة الأنشطة والمهام.

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2. ITS Applications & Data Science
3. Benefit & Cost Analysis for ITS Applications

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II. ITS Applications & Data Science

Questions?

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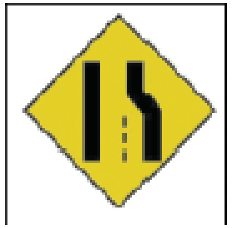
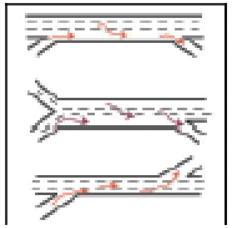
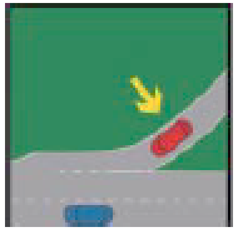
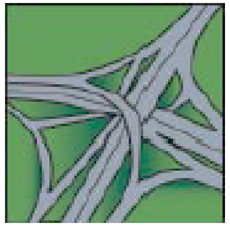
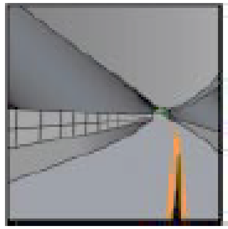
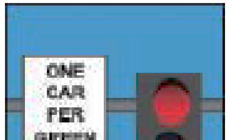
Review

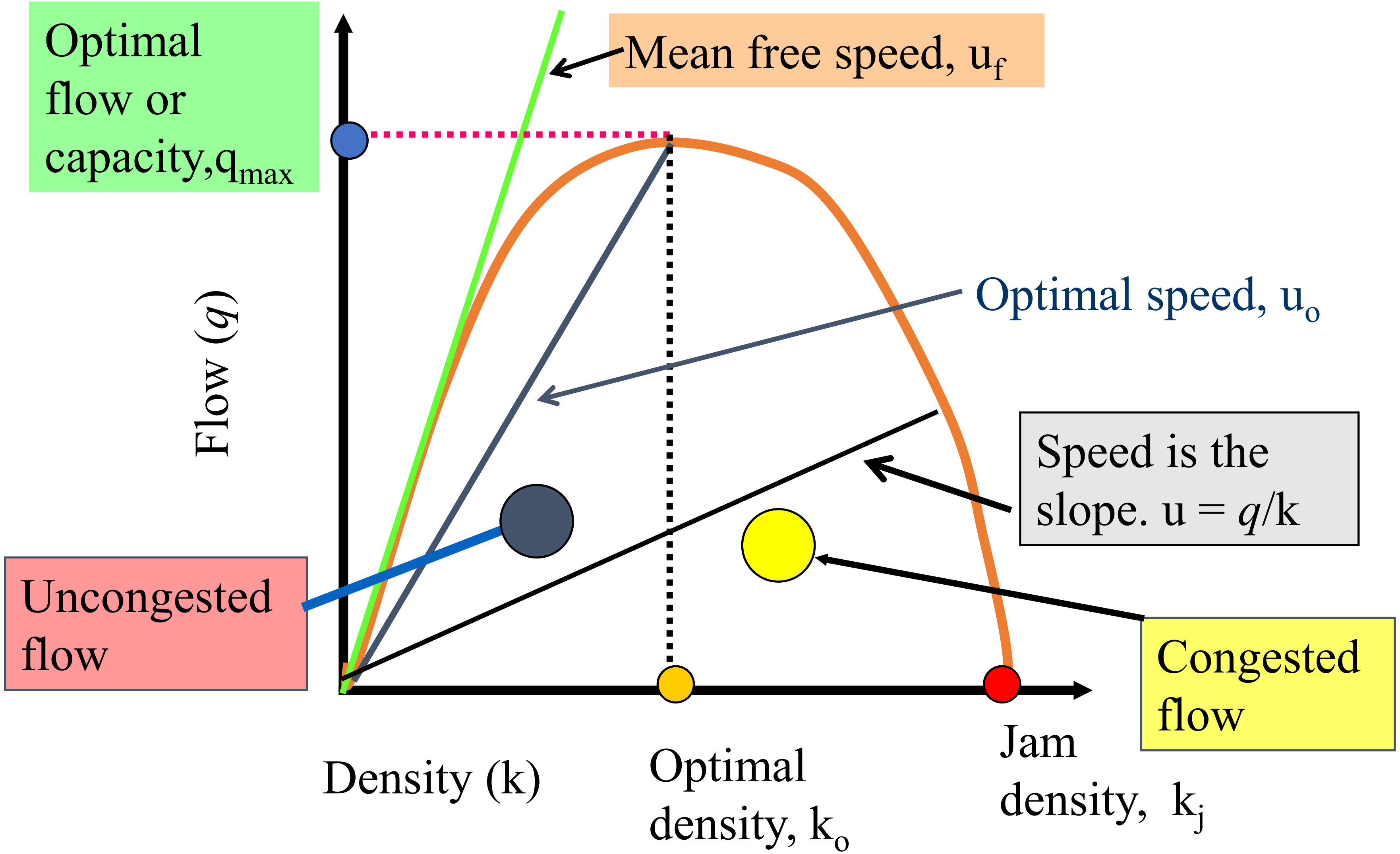
Common Locations for Localized Bottlenecks

Location	Symbol	Description
Lane Drops		Bottlenecks can occur at lane drops, particularly midsegment where one or more traffic lanes ends or at a low-volume exit ramp. They might occur at jurisdictional boundaries, just outside the metropolitan area, or at the project limits of the last megaproject. Ideally, lane drops should be located at exit ramps where there is a sufficient volume of exiting traffic.
Weaving Areas		Bottlenecks can occur at weaving areas, where traffic must merge across one or more lanes to access entry or exit ramps or enter the freeway main lanes. Bottleneck conditions are exacerbated by complex or insufficient weaving design and distance.
Freeway On-Ramps		Bottlenecks can occur at freeway on-ramps, where traffic from local streets or frontage roads merges onto a freeway. Bottleneck conditions are worsened on freeway on-ramps without auxiliary lanes, short acceleration ramps, where there are multiple on-ramps in close proximity and when peak volumes are high or large platoons of vehicles enter at the same time.
Freeway Exit Ramps		Freeway exit ramps, which are diverging areas where traffic leaves a freeway, can cause localized congestion. Bottlenecks are exacerbated on freeway exit ramps that have a short ramp length, traffic signal deficiencies at the ramp terminal intersection, or other conditions (e.g., insufficient storage length) that may cause ramp queues to back up onto freeway main lanes. Bottlenecks could also occur when a freeway exit ramp shares an auxiliary lane with an upstream on-ramp, particularly when there are large volumes of entering and exiting traffic.

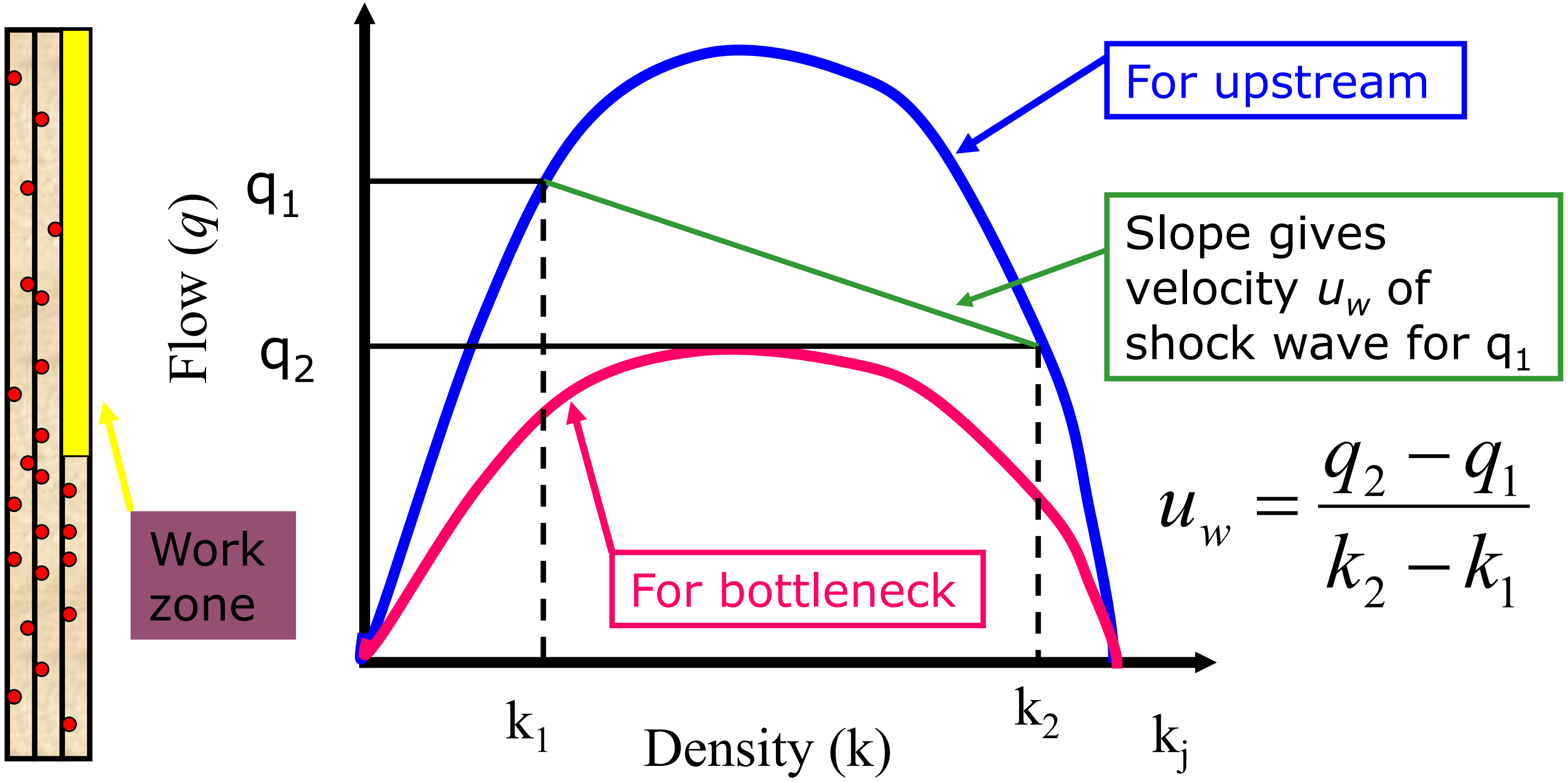
Common Locations for Localized Bottlenecks

Freeway-to-Freeway Interchanges		Freeway-to-freeway interchanges, which are special cases on on-ramps where flow from one freeway is directed to another. These are typically the most severe form of physical bottlenecks because of the high traffic volumes involved.
Changes in Highway Alignment		Changes in highway alignment, which occur at sharp curves and hills and cause drivers to slow down either because of safety concerns or because their vehicles cannot maintain speed on upgrades. Another example of this type of bottleneck is in work zones where lanes may be shifted or narrowed during construction.
Tunnels/ Underpasses		Bottlenecks can occur at low-clearance structures, such as tunnels and underpasses. Drivers slow to use extra caution, or to use overload bypass routes. Even sufficiently tall clearances could cause bottlenecks if an optical illusion causes a structure to appear lower than it really is, causing drivers to slow down.
Narrow Lanes/Lack of Shoulders		Bottlenecks can be caused by either narrow lanes or narrow or a lack of roadway shoulders. This is particularly true in locations with high volumes of oversize vehicles and large trucks.
Traffic Control Devices		Bottlenecks can be caused by traffic control devices that are necessary to manage overall system operations. Traffic signals, freeway ramp meters, and tollbooths can all contribute to disruptions in traffic flow.

Fundamental diagram of traffic flow (flow vs. density)



Fundamental diagram of traffic flow and shock wave



$$u_w = \frac{q_2 - q_1}{k_2 - k_1}$$

Queue forms upstream of the bottleneck. So we use the diagram of the upstream section

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Identifying Study Locations

Step 7 – Refine High-Priority Corridors

Identify Safety and Congestion Hot Spots

- Conduct preliminary safety and congestion assessment
- Field inspection
- Analyze crash trends
- Utilize internal tools
  (Integrator, ROW images, 1/4 mile crash densities, etc.)

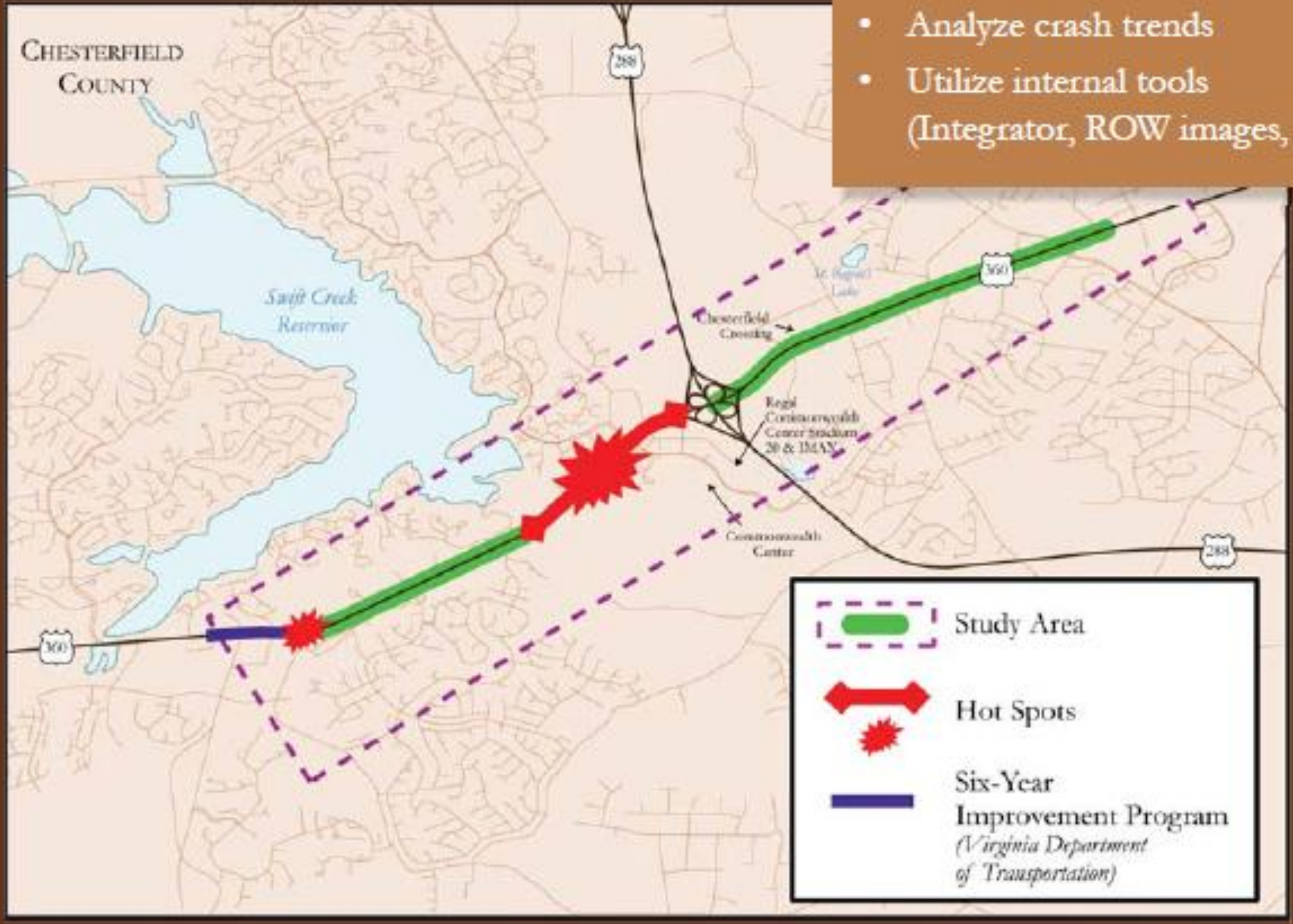
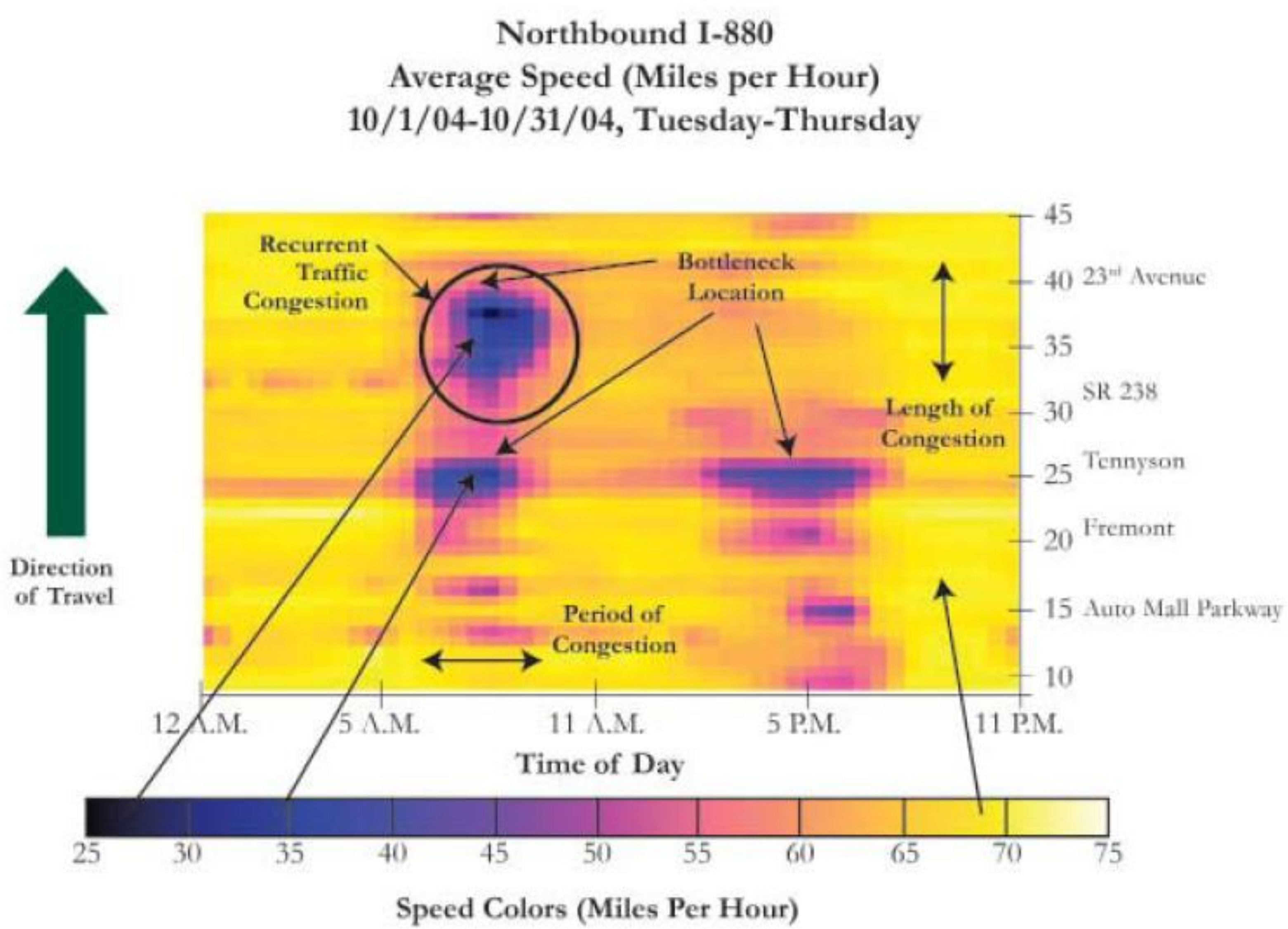
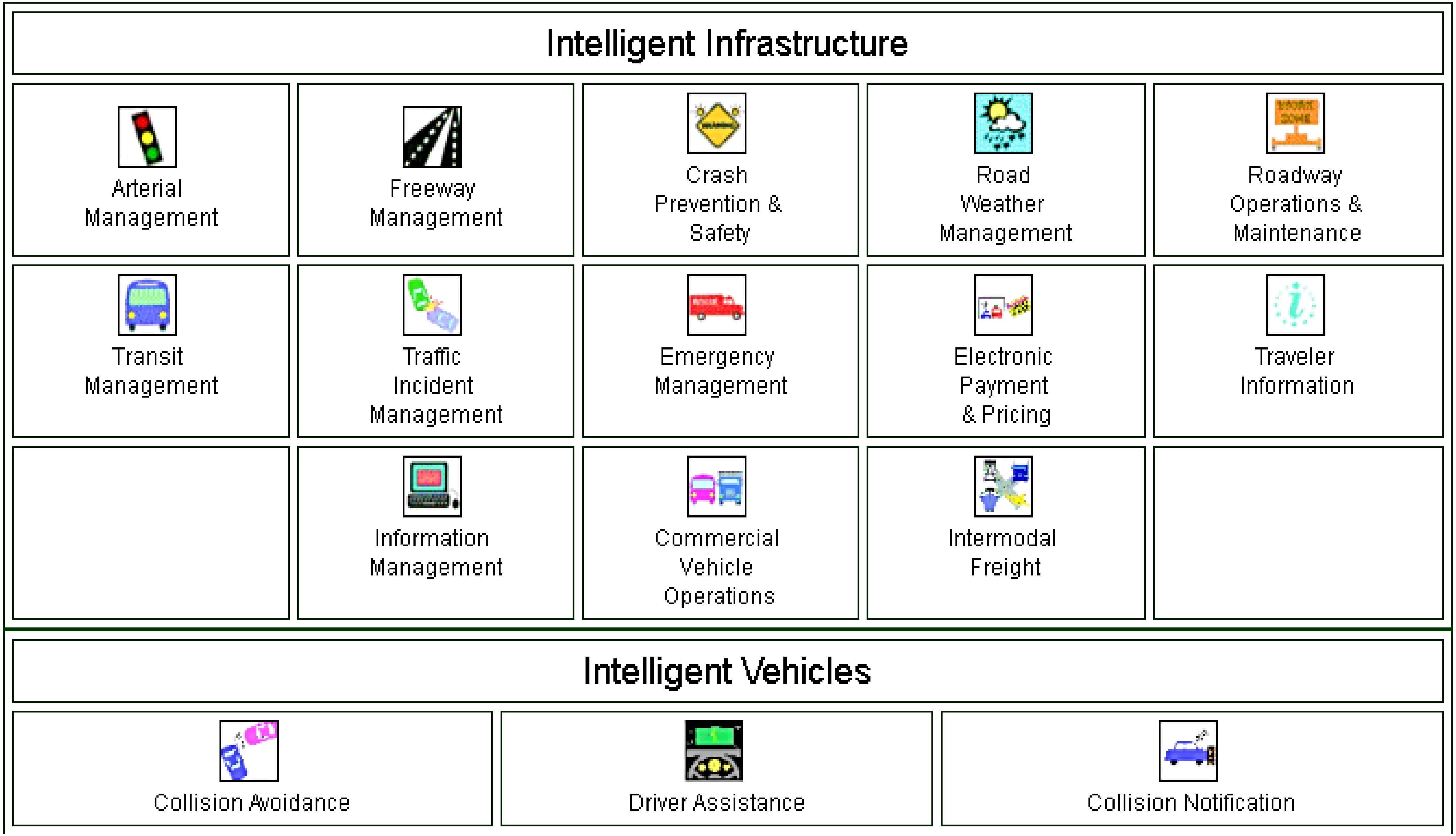


Exhibit 6. Using Freeway Detector for Bottleneck Analysis

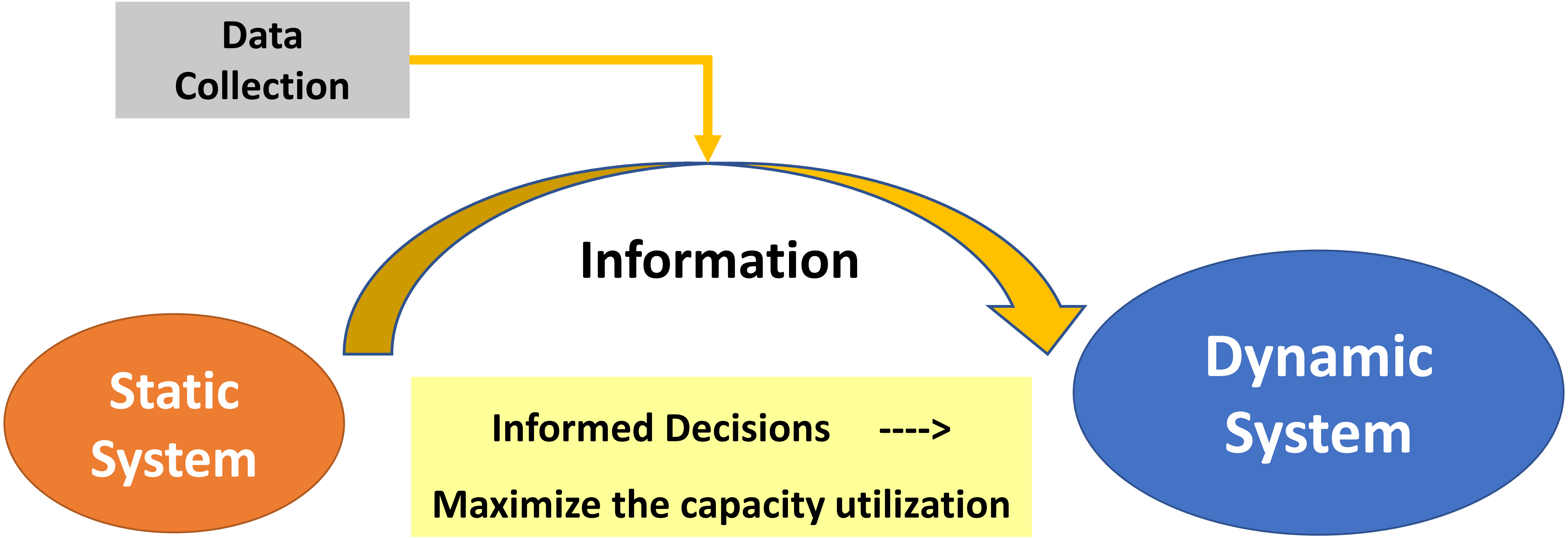




Intelligent Infrastructure
Arterial Management
Freeway Management
Crash Prevention & Safety
Road Weather Management
Roadway Operations & Maintenance
Transit Management
Traffic Incident Management
Emergency Management
Electronic Payment & Pricing
Traveler Information
Information Management
Commercial Vehicle Operations
Intermodal Freight
Intelligent Vehicles
Collision Avoidance
Driver Assistance
Collision Notification

Impact of ITS on the Transport System

• Converts the **Static** Control Systems into **Dynamic** Control Systems



When to think about ITS

- **Solve** an existing traffic problem: congestion, reliability, … etc
- **Improve** traffic services
- **Operate** the traffic system more reliably and more effectively
- **Store** and evaluate archived **data** collected from the operating system

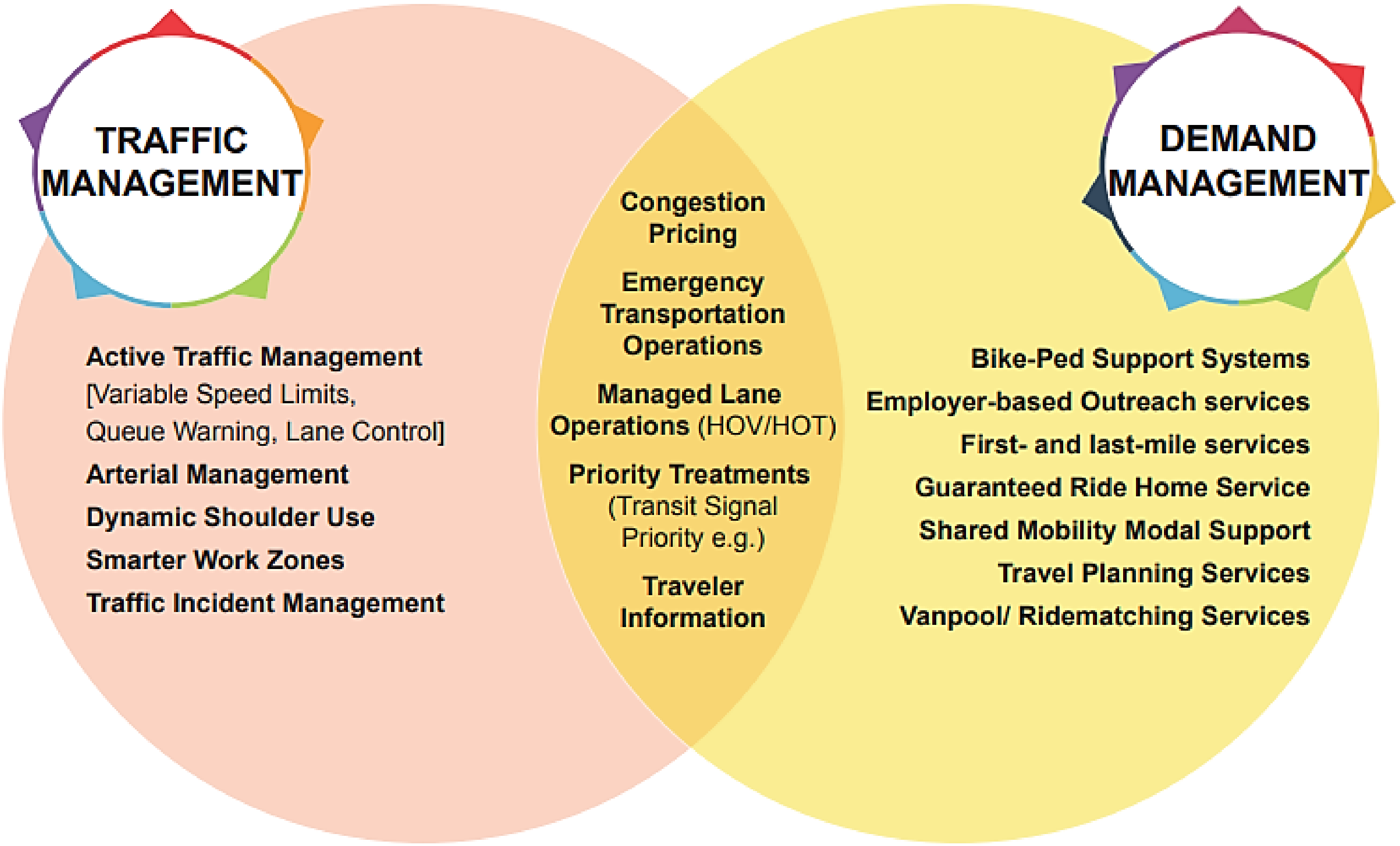


Figure 2. Illustration. The nexus between traffic management and demand management.

https://ops.fhwa.dot.gov/publications/fhwahop18072/fhwahop18072.pdf

Active Traffic Management (ATM) Strategies

- Active Traffic Management (ATM) strategies focus on influencing travel behavior **during a trip** with respect to operations and lane and facility choices.
- ATM is the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions.
- Focusing on trip reliability, ATM maximizes the effectiveness and efficiency of the facility, while also increasing safety and throughput by using integrated systems with new and automated technologies.
  - Adaptive Ramp Metering (ARM)
  - Adaptive Traffic Signal Control (ATSC)
  - Dynamic Junction Control (DJC)
  - Dynamic Lane Assignment (DLA)
  - Dynamic Lane Reversal (DLR)
  - Dynamic Merge Control (DMC)
  - Dynamic Shoulder Lanes (DShL)
  - Dynamic Speed Limits (DSpL)
  - Queue Warning (QW)
  - Transit Signal Priority (TSP)

Active Traffic Management (ATM)

- Active traffic management (ATM) is the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility.
- ATM approaches seek to increase throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without delay that occurs when operators must deploy operational strategies manually.
- ATM includes dynamic routing, dynamic junction control, adaptive signal control, and transit signal priority.

Active Traffic Management (ATM)

- Dynamic lane use/shoulder control: the dynamic opening of a shoulder lane to traffic or dynamic closure of travel lanes on a temporary basis in response to increasing congestion or incidents.
- Dynamic speed limits: the dynamic change in speed limits based on road, traffic, and weather conditions.
- Queue warning: the dynamic display of warning signs to alert drivers that congestion and queues are ahead.
- Adaptive ramp metering: the dynamic adjustment of traffic signals at ramp entrances to proactively manage vehicle flow from local-access roads.
- Dynamic rerouting: the dynamic provision of alternate route information in response to increasing congestion at bottlenecks/incidents.
- Dynamic junction control: the provision of lane access based on highway traffic present and merging/diverging traffic to give priority to the facility higher volume to minimize the impact of the merging/diverging movement.
- Adaptive traffic signal control: the optimization of signal timing plans based on prevailing conditions to increase throughput along an arterial.

Benefits of ATM

- A **decrease in primary incidents** by alerting drivers to congested conditions and promoting more uniform speeds;
- A **decrease in secondary incidents** by alerting drivers to the presence of queues or incidents and proactively managing traffic in and around incidents;
- **Increased throughput** by reducing the delay associated with the number of primary and secondary incidents reducing speed differential in traffic flow, and reducing the shockwave effects of excessive breaking.
- **Increased overall capacity** by adding shoulder use during congested periods when it is needed most;
- Overall **improvement in speed uniformity** during congested periods; and
- **Increased trip reliability** by increasing capacity and throughput and reducing incident delay and improving vehicle throughput.

Identifiers to use ATM Strategies

- High traffic volumes;
- Changes in prevailing conditions;
- A high prevalence of crashes;
- Capacity bottlenecks;
- Adverse weather;
- Adverse environmental impacts;
- Variability in trip reliability;
- Construction impacts;
- Financial constraints and priorities; and,
- Limitation in capacity expansion.

Potential measures to evaluate system performance and ATDM deployments

• Average Travel Time	• Travel Delay	• Bike/Ped Accessibility
• Travel Time Reliability	• Non-Recurring Delay	• Transit Use
• Travel Time Buffer Index	• Average System Speed	• Transit vs Auto Travel Time
• Travel Time x^{th} Percentile	• Incident Info. Dissemination	• Transit On-Time Performance
• Planning Time Index	• Incident Severity	• Mode Share
• Vehicle Miles Traveled	• Incident Clearance Time	• Parking Occupancy
• Congestion Level	• Road Weather Clearance Time	• Number of Citations
• Traffic Density	• Queue Length	• Customer Satisfaction
• Traffic Volume	• Occupancy	• Reduced Trips

Information

Data Collection ---> Processing ---> Analysis ---> Information

Daily

- Speed
- Flow
- Travel Time
- Weight
- Departure Time
- Trip Duration
- Accidents

Hourly

- Speed
- Flow
- Travel Time
- Weight
- Departure Time
- Trip Duration
- Accidents

Real-time

- **Speed**
- **Flow**
- **Travel Time**
- **Weight**
- **Departure Time**
- **Trip Duration**
- **Accidents**

Predictions

- **Predicted Speed**
- **Predicted Flow**
- **Expected Time of Arrival**
- **Alternative Routes**
- **En-route Information**

Before Implementing ITS

- Nation-wide Vision
- ITS Architecture
- Feasibility Studies … Cost – Benefit Analysis
- ITS Applications should be:
  1. Integrated: major elements of the ITS Taxonomy are linked
  2. Compatible:
  3. Expandable:
  4. Standardized:

Integration in ITS

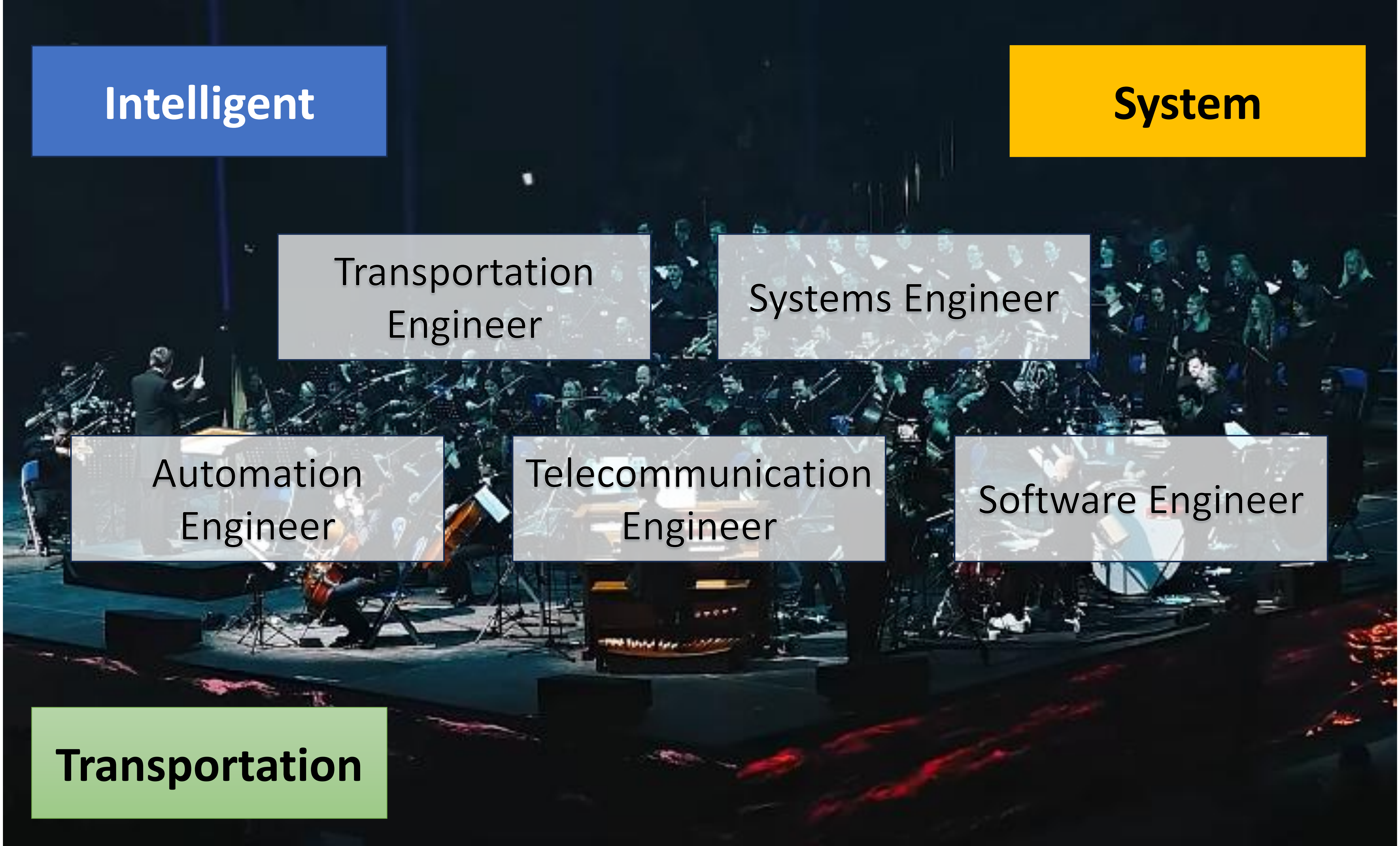
- Sharing of information between agencies
  - when arterial traffic data are shared with transit agencies so they can improve service
- Equipment interoperability
  - when emergency vehicles communicate with traffic signals to preempt signal timing to improve incident response
- Coordinate control actions between different agencies
  - when arterial management agencies coordinate signal timing on a corridor

Standardization in ITS

Regional standards or utilized from other regions. Standards lead to faster and more reliable systems development according to the governmental goals.

- To have a consistent & expectable product behavior
- To improve the interfaces between parts of complex systems
- Help users to expect at least minimum product performance
- Help public agencies and other organizations to cooperate and interact successfully.
- Offer manufacturers and vendors easier entry to markets
- Offer buyers a greater choice of suppliers, at lower risk and lower cost.


Intelligent
System
Transportation



Intelligent

System

Transportation Engineer

Systems Engineer

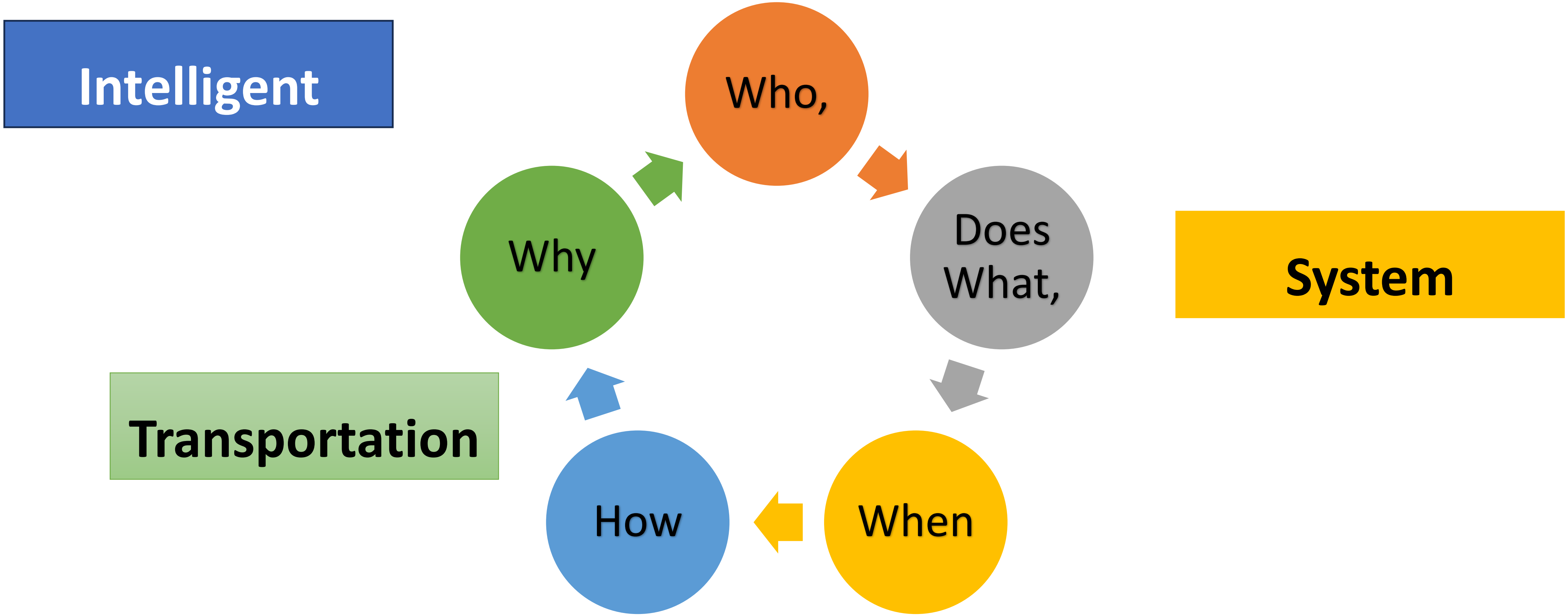
Automation Engineer

Telecommunication Engineer

Software Engineer

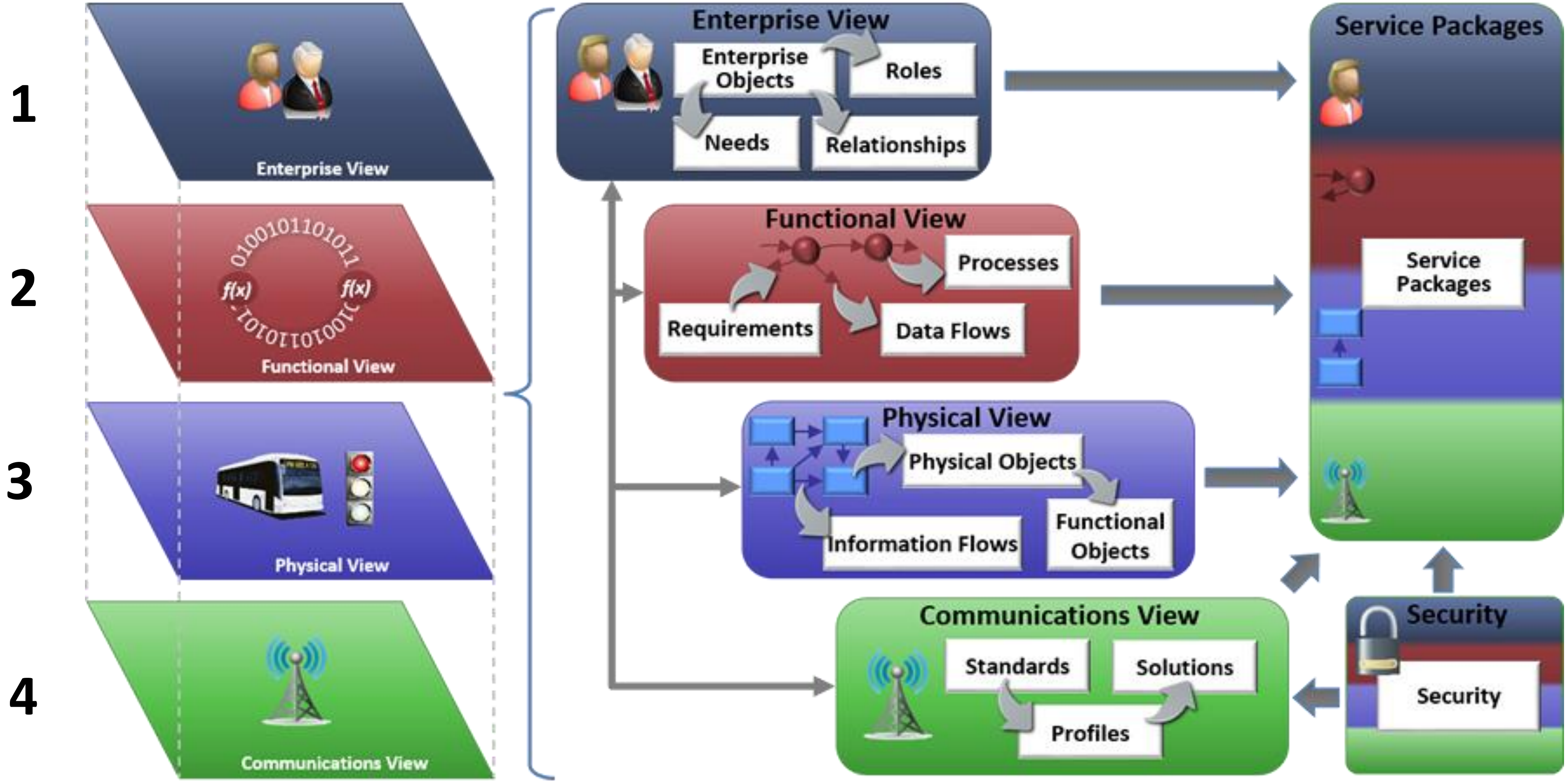
Transportation

Application in ITS



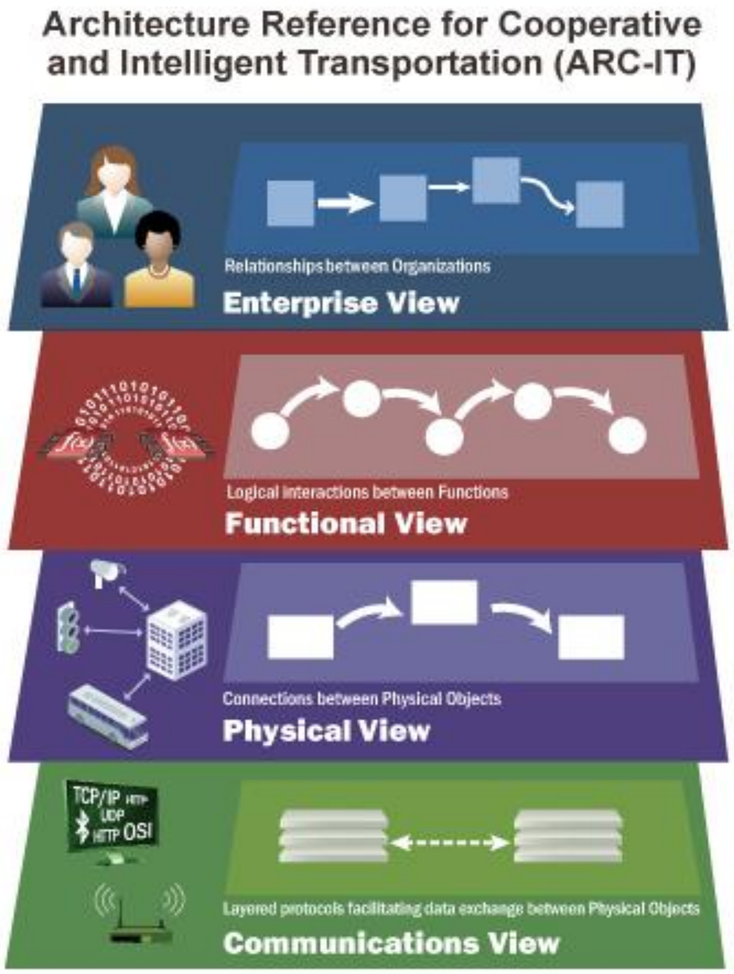
Architecture

4 Types of ITS Architecture:



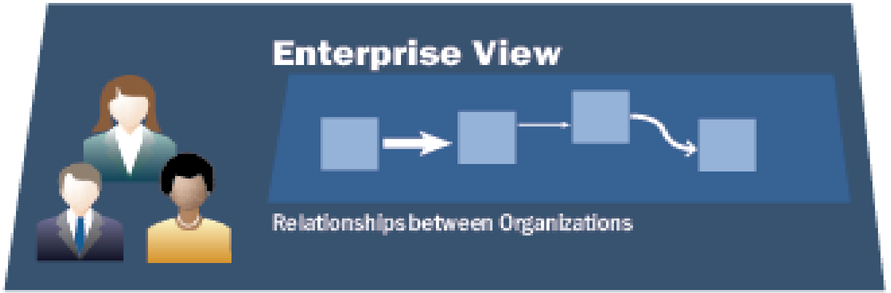
Architecture Reference

- The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) provides a common framework for planning, defining, and integrating intelligent transportation systems.
- ARC-IT is a reference architecture: it provides common basis for planners and engineers with differing concerns to conceive, design and implement systems using a common language as a basis for delivering ITS, but does not mandate any particular implementation.
- ARC-IT includes artifacts that answer concerns relevant to a large variety of stakeholders, and provides tools intended for transportation planners, regional architects and systems engineers to conceive of and develop regional architectures, and scope and develop projects.



Enterprise View

- The Enterprise View addresses the relationships between organizations and users, and the roles those entities play in the delivery and consumption of ITS services. Relationships between entities are dependent on the roles those entities take in the delivery of user services.



Functional View

- The Functional View addresses the analysis of abstract functional elements and their logical interactions.
- Processes are organized hierarchically, each in a set.
- These Processes (activities and functions) trace to a set of Requirements derived from source documents.
- The data flows that move between processes and the data stores where data may reside for longer periods are all defined in a Data Dictionary.

Questions

4. The data flows in the ITS Architecture in …….. view

   a. Physical view
   b. Data view
   c. Functional view
   d. Communication view
   e. Enterprise view

Data Flows

Data that is exchanged between logical processes in the Functional View of ARC-IT. Data flows in the Functional are related to information flows in the Physical by way of process allocation to physical objects. As functional processes are allocated to physical objects, data flows are similarly related to the information exchanged between physical objects that encapsulate related processes. The tabs below contain the Data Flows that comprise the Functional View of ARC-IT.

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

- actual_border_wait_time
- actual_border_wait_time_for_info
- actual_border_wait_time_for_traffic
- actuator_commands
- admin_catalog_request
- admin_check_specification
- admin_cleansing_parameters
- admin_data_format_parameters
- admin_data_product_request
- admin_permission_update
- admin_quality_metrics
- admin_schema_update
- admin_status_request
- administration_archive_schema
- administration_archive_status
- advanced_charge_transactions
- advanced_charges
- advanced_charges_billing_needed
- advanced_charges_confirm

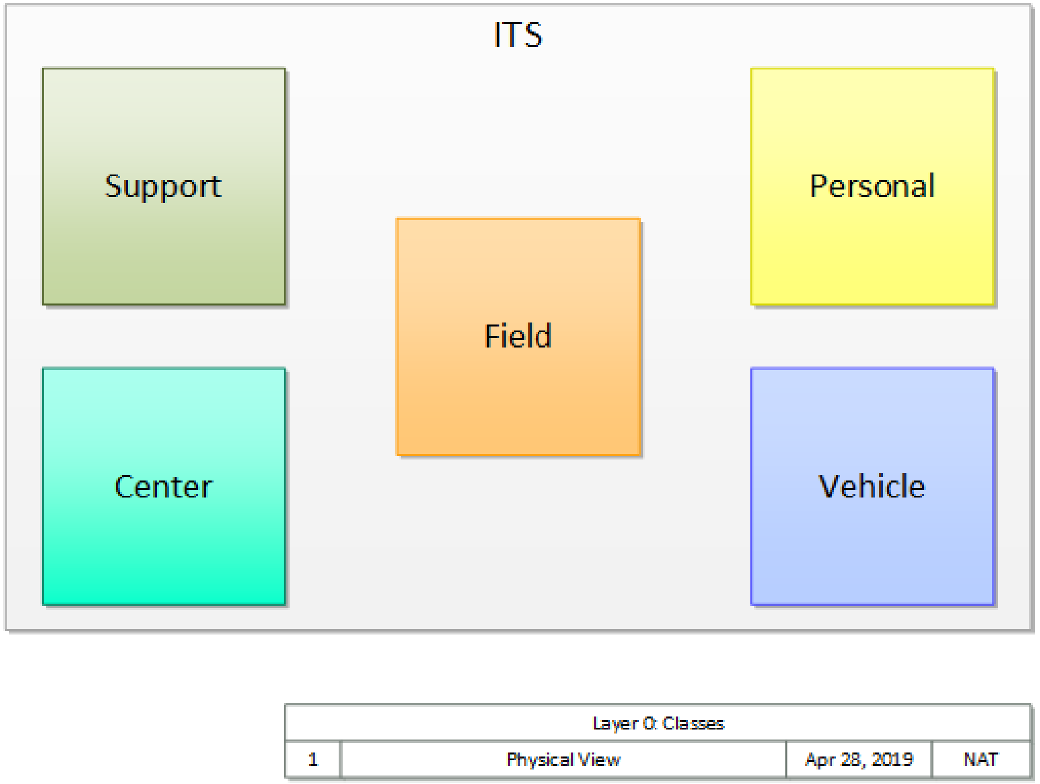
- variable_speed_limit_control
- variable_speed_limit_control_from_traffic_personnel
- variable_speed_limit_control_request
- variable_speed_limit_data_for_signage
- variable_speed_limit_equip_status_for_m_and_c
- variable_speed_limit_info
- variable_speed_limit_status
- vehicle_accel_decel_data
- vehicle_accel_decel_profile
- vehicle_acceleration
- vehicle_access_instructions
- vehicle_access_permission
- vehicle_action_requests
- vehicle_actuator_feedback_for_crash_avoidance
- vehicle_actuator_feedback_for_safety
- vehicle_ad_hoc_message_application
- vehicle_ad_hoc_message_data
- vehicle_advisory_information
- vehicle_alert_subscriptions
- vehicle_and_driver_safety_status
- vehicle_attitude_data
- vehicle_average_emissions
- vehicle_average_fuel_consumption
- vehicle_border_alert
- vehicle_border_alert_subscriptions
- vehicle_braking_status
- vehicle_broadcast_automated_lane_control
- vehicle_broadcast_border_data
- vehicle_broadcast_electric_charging_data
- vehicle_broadcast_event_information
- vehicle_broadcast_incident_information

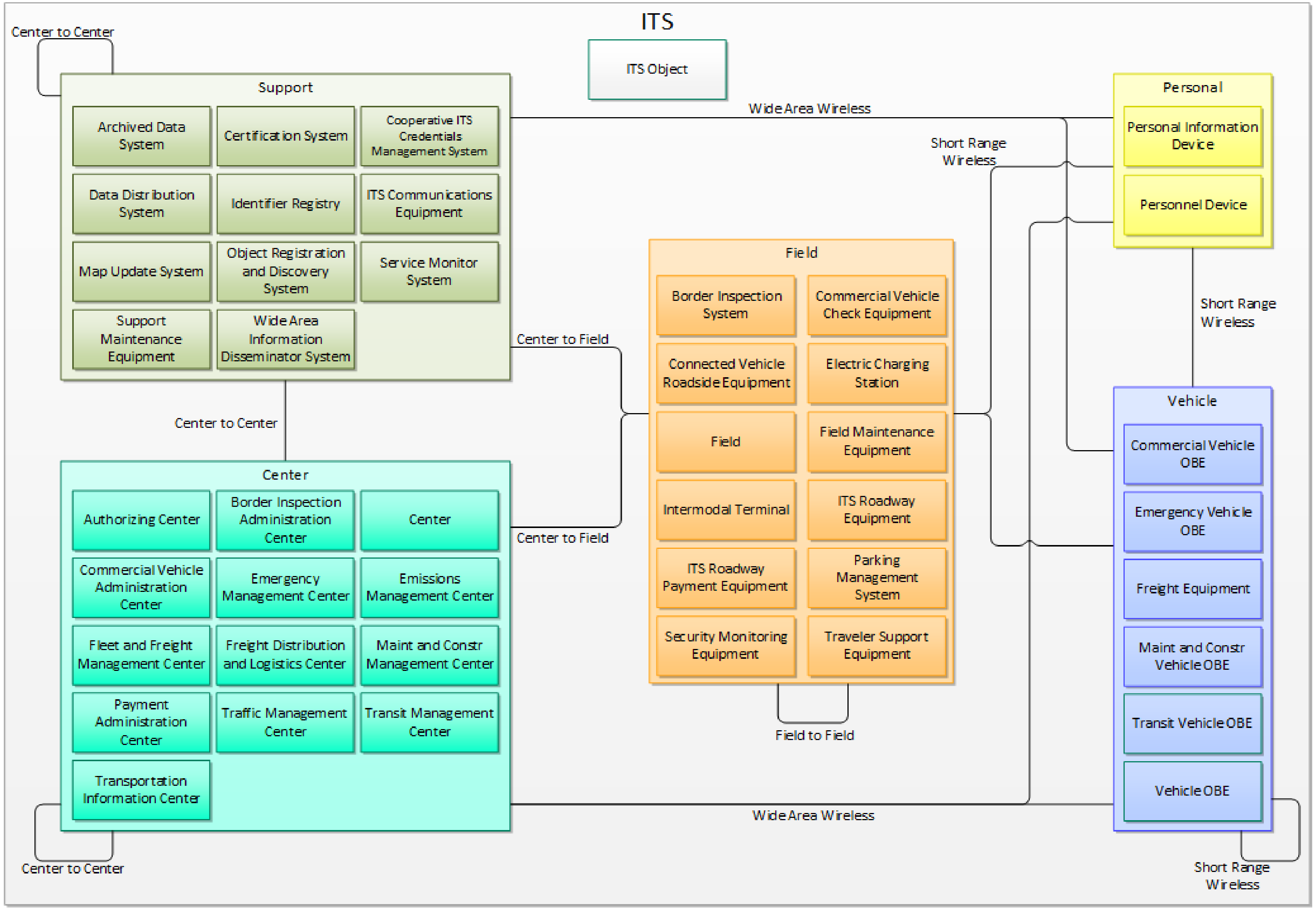
- walkway_information
- wayside_status
- weather_advisories
- weather_alert
- weather_and_env_data_archive_catalog
- weather_archive_catalog_request
- weather_archive_data_request
- weather_data
- weather_data_attributes
- weather_data_for_alerts
- weather_data_for_archive
- weather_data_for_broadcast
- weather_data_for_centers
- weather_data_for_interactive
- weather_data_for_route_guidance
- weather_data_for_trip_planning
- weather_data_request
- weather_data_request_for_alerts
- weather_data_request_from_interactive
- weather_data_request_from_route_guidance
- weather_data_request_from_trip_planning
- weather_forecast_details
- weather_forecasts
- weather_observation_attributes
- weather_observations
- weather_scale_forecast_data_attributes
- weather_service_emergency_information
- weather_service_information
- weather_service_information_request
- weather_warnings
- weather_watches

https://local.iteris.com/cvria/html/dataflows/dataflows.html

Physical Architecture

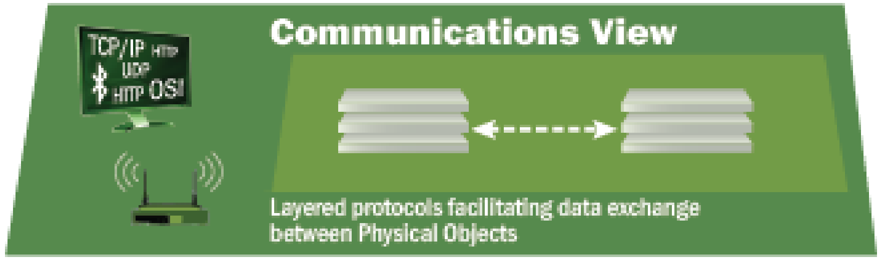
- The physical view describes the transportation systems and the information exchanges that support ITS

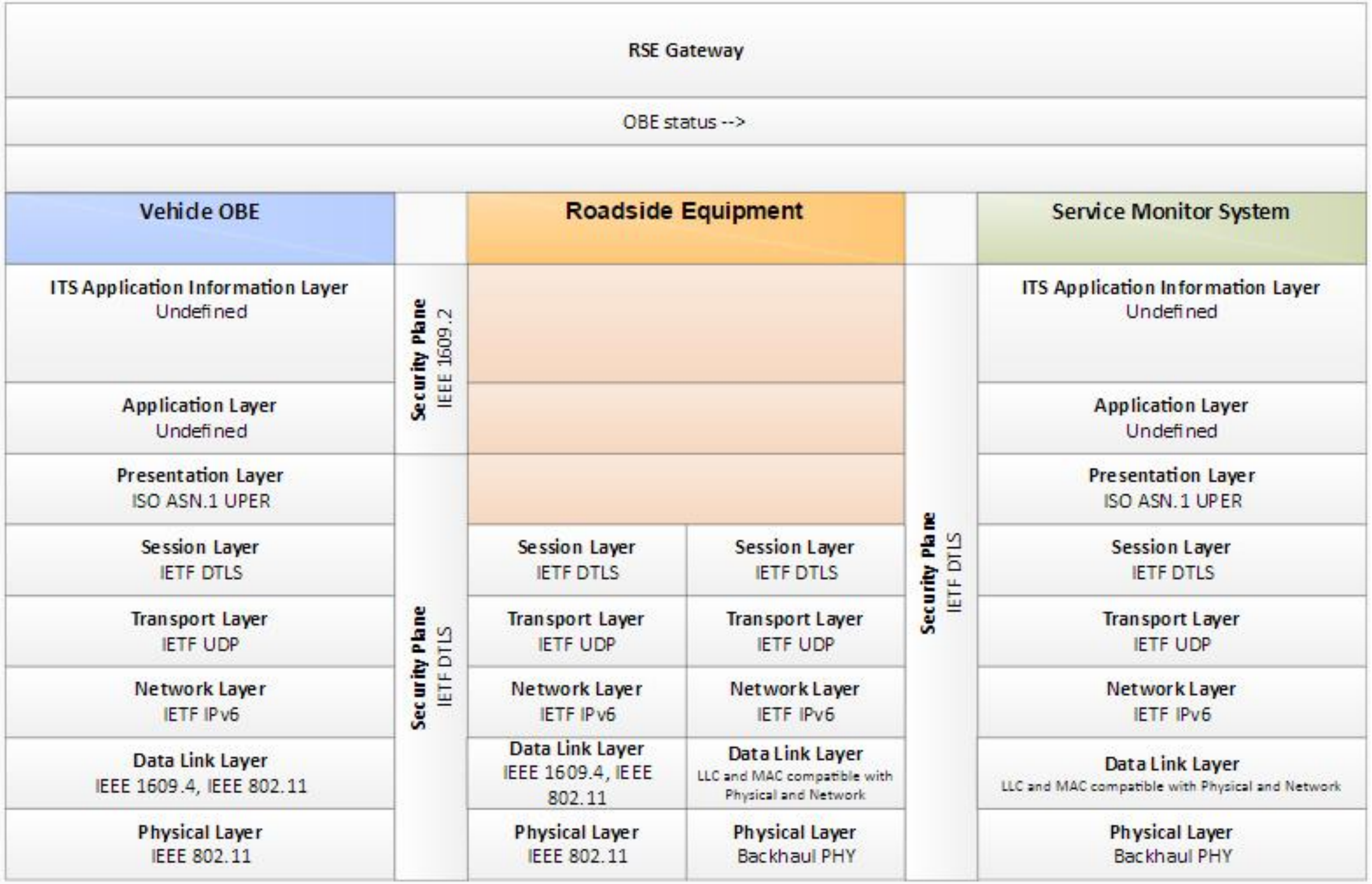




ARC-IT Subsystem Diagram			
7	Physical View	May 9, 2019	NAT

Communication View





Questions

5. Vehicles exist in the ITS Architecture in .... view

   a. Physical view
   b. Data view
   c. Functional view
   d. Communication view
   e. Enterprise view

ITS Examples

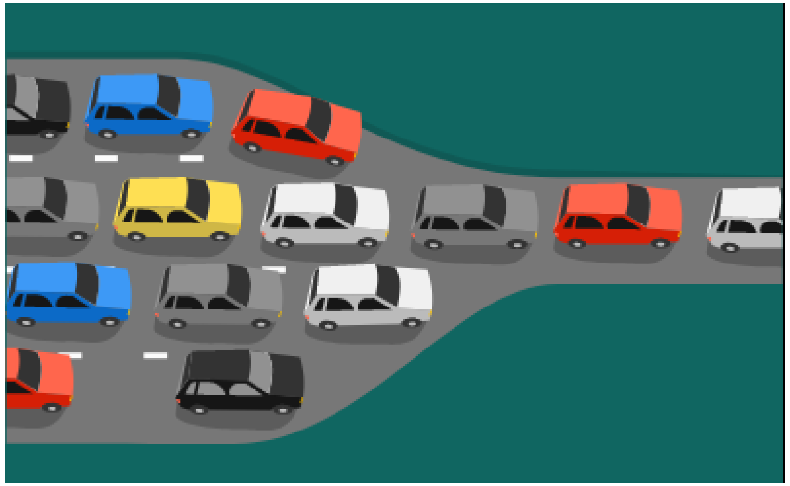
Examples of ITS Solutions

Urban Streets	Freeways
1- Coordinated & Adaptive Traffic Signals	2- Variable Speed Limits (VSL)

Highways Bottleneck

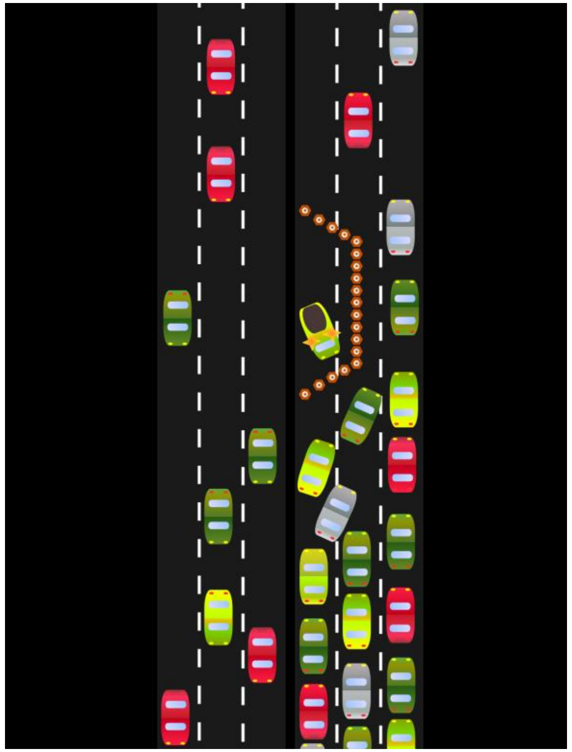
merge point

Physical Bottleneck



lane drop

Physical Bottleneck



incident lane blockage

Physical Bottleneck

+ Work Zones

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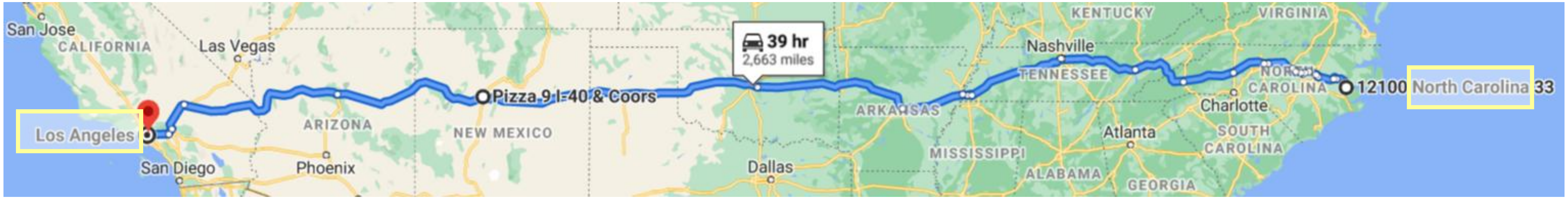
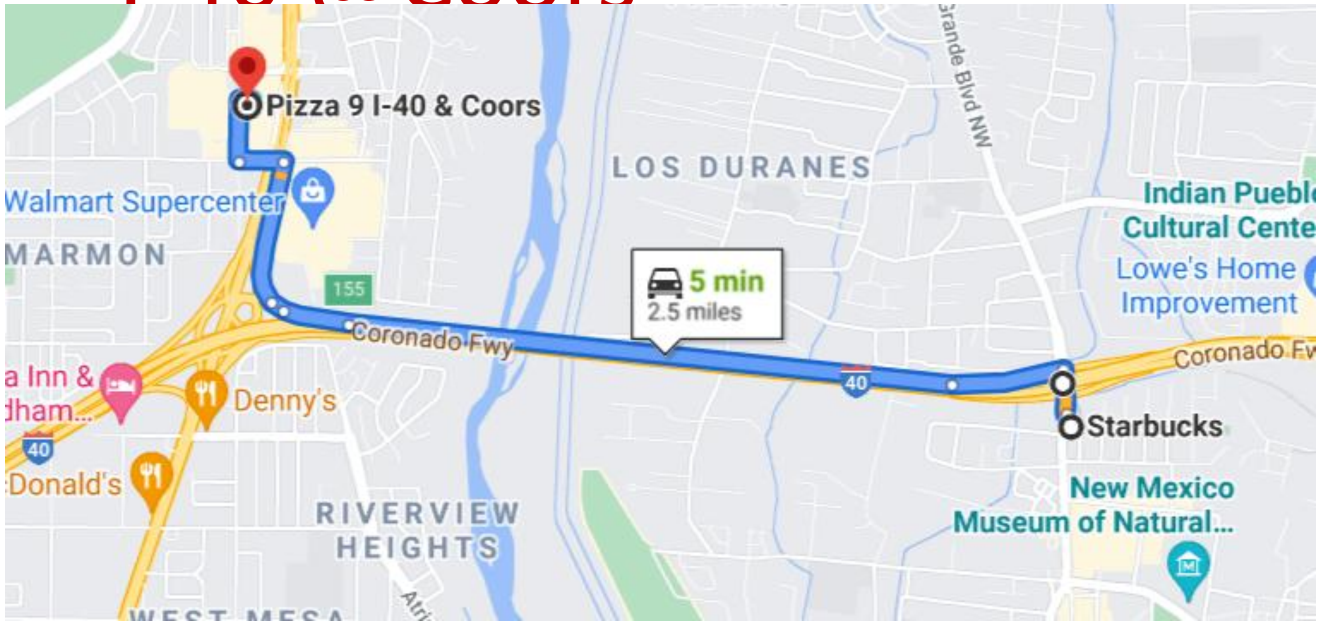
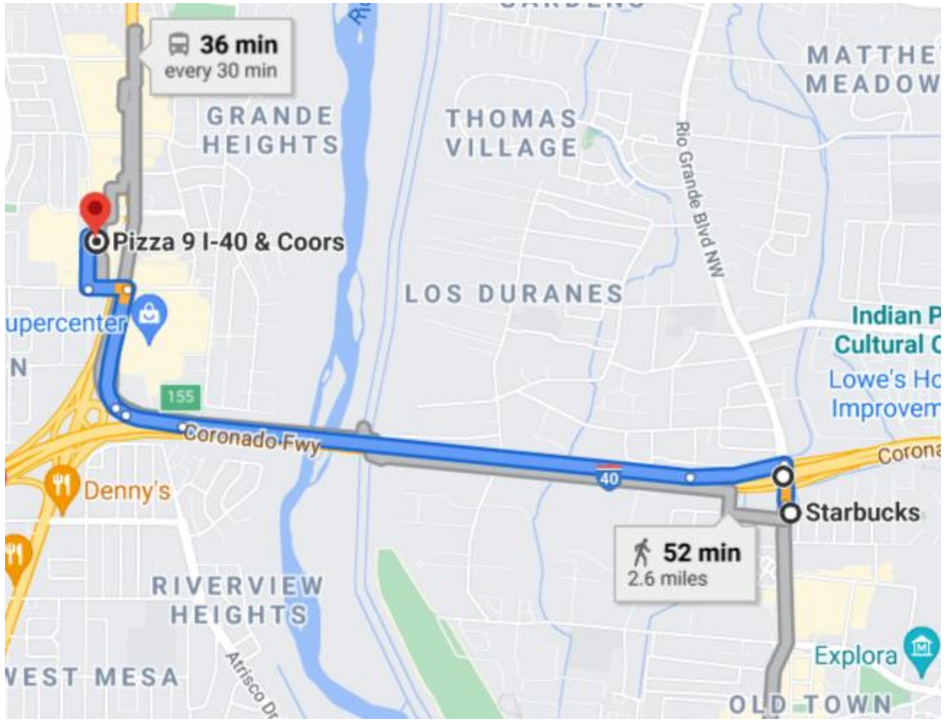
VSL Example

Example: I-40 Interstate (between states)



- I-40 @Coors

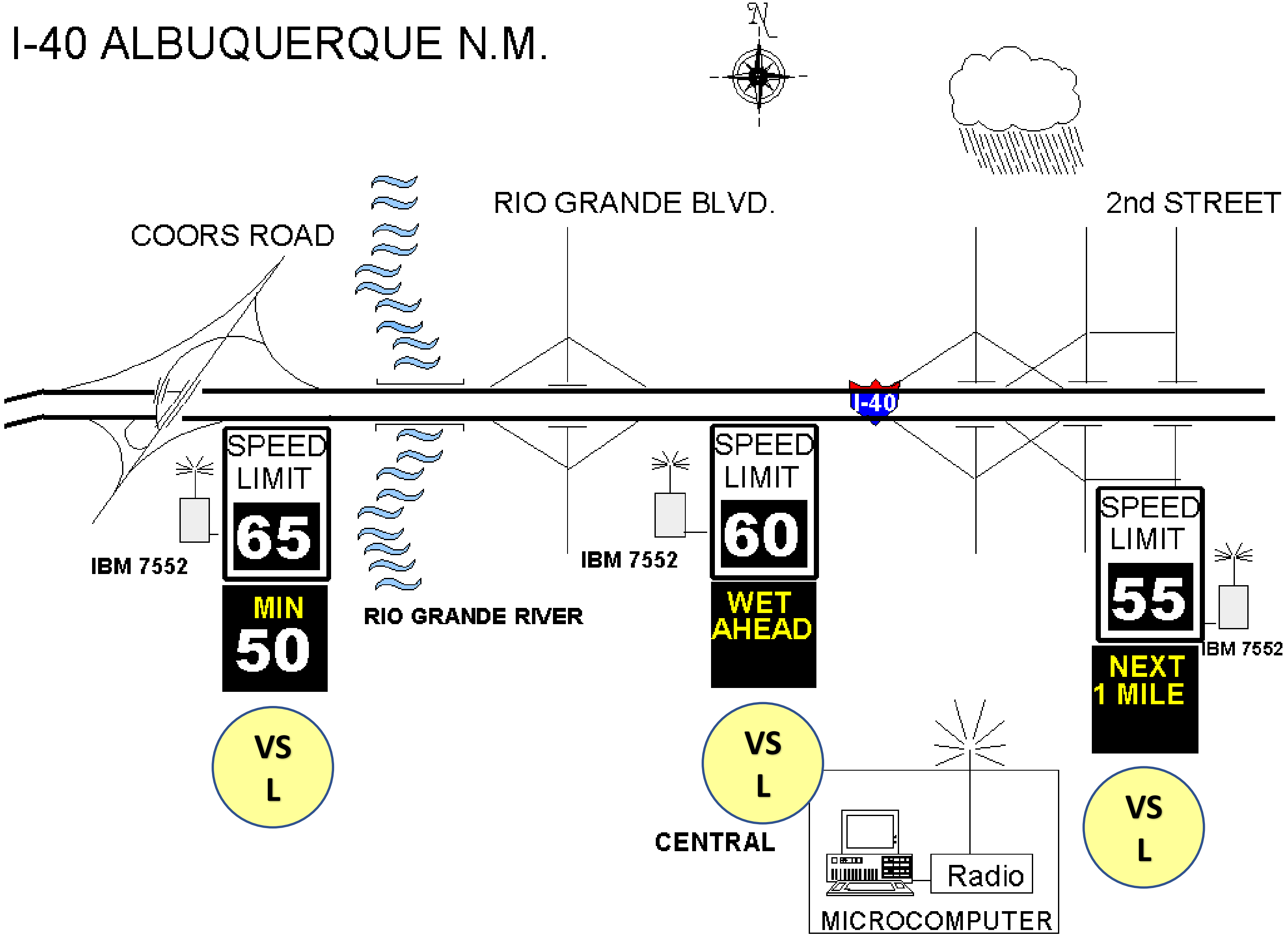




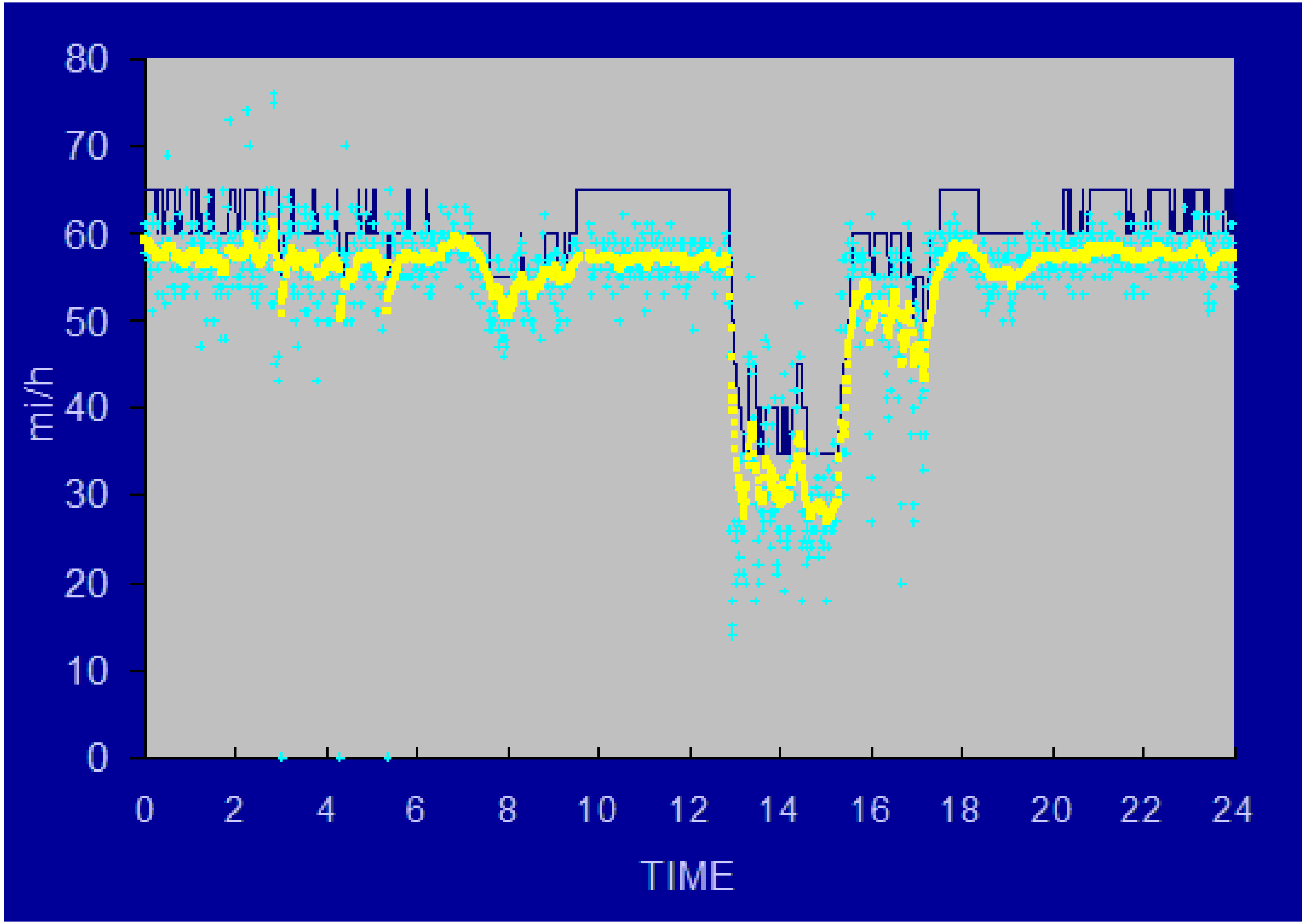
Solution: Variable Speed Limit (VSL)

- VSL Types:
  - Advisory
  - Mandatory

Project Layout

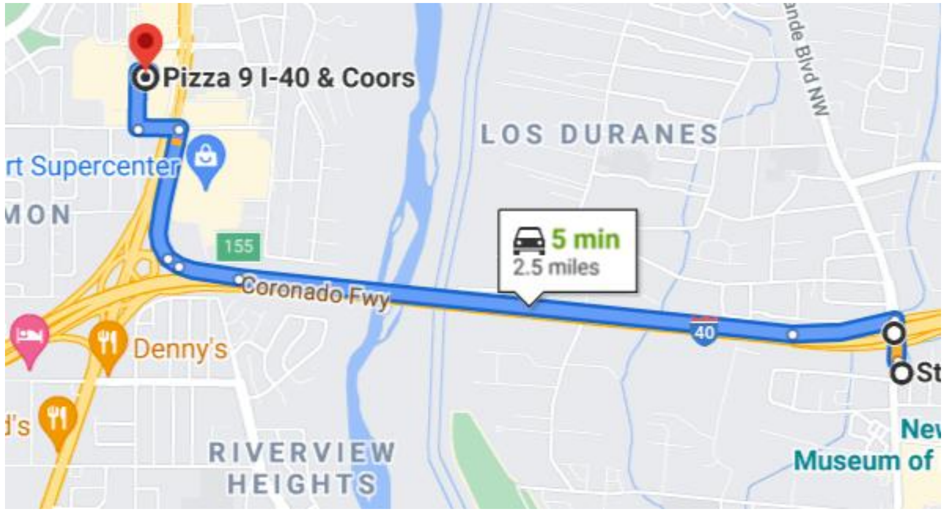


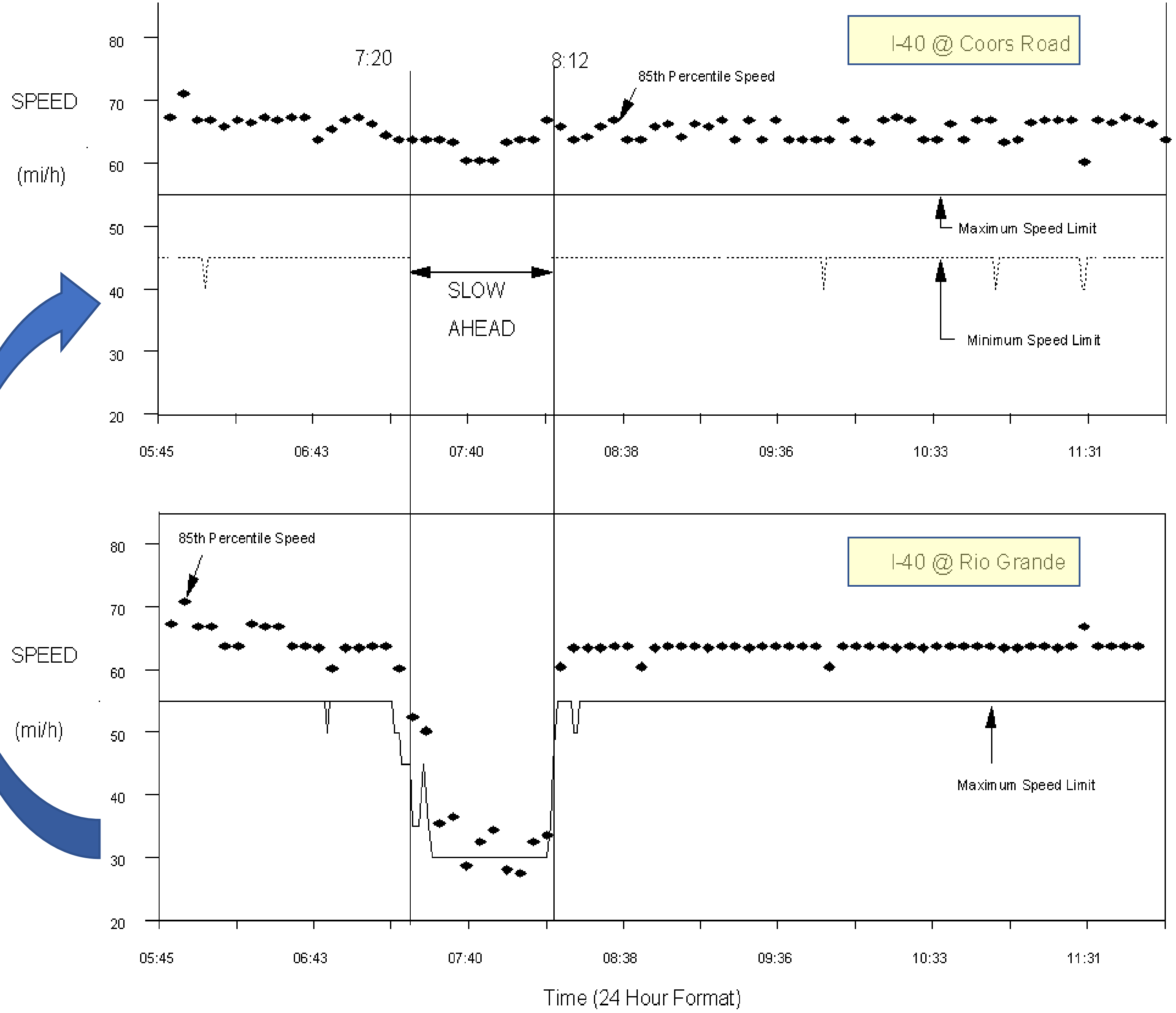
Smooth Mean Speed



System Performance

- Observe the following case ….





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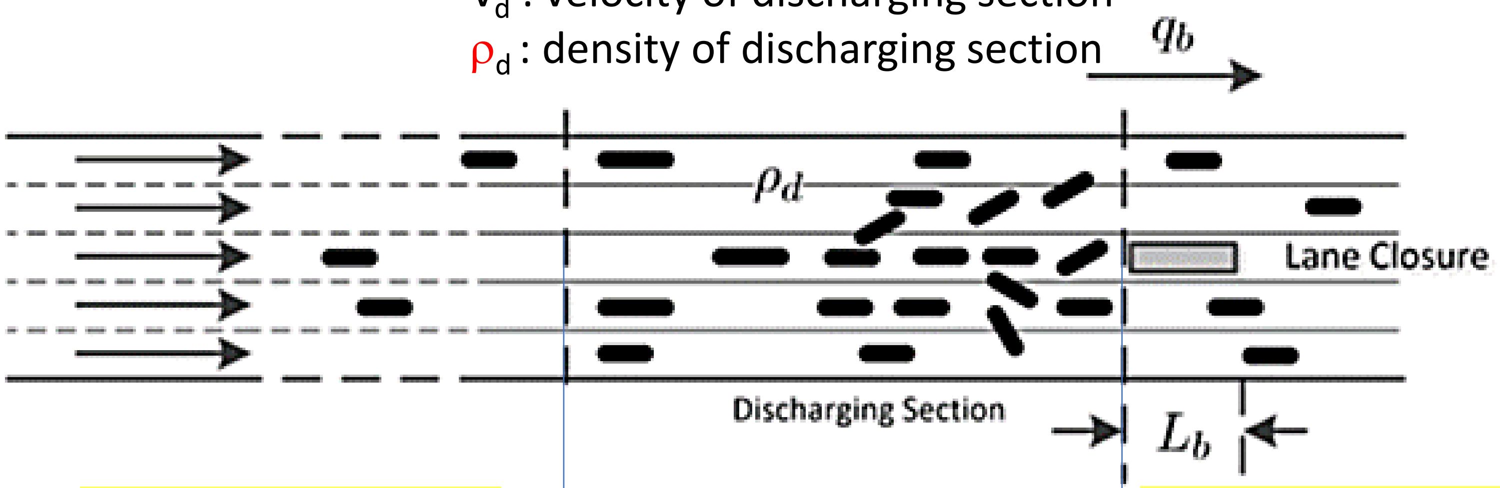
Questions?

VSL Concept

Bottleneck

A bottleneck is the point with lowest flow capacity along the road.

q_d : flow of discharging section
V_d : velocity of discharging section
ρ_d : density of discharging section



Normal Section

C or C_n : capacity of normal section
n_n : number of lanes in normal section
q_n : flow of normal section
V_n : velocity of normal section
ρ_n : density of normal section

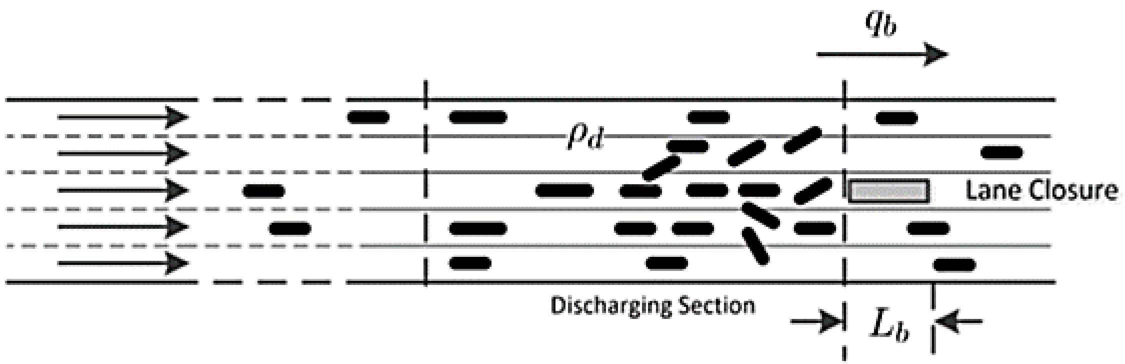
Discharging Section

Lane Changing ---

Bottleneck Section

C_b : capacity of bottleneck
n_b : number of lanes in bottleneck section
q_b : flow of bottleneck
L_b : length of bottleneck

Bottleneck



- disordered behaviour
- density increases at bottleneck (more than critical value)
- queue forms upstream of bottleneck
- capacity decreases at bottle neck (capacity drop phenomenon)
- the maximum achievable traffic flow rate decreases when queues are formed
- Unstable flow
- Vehicles in queue force the speed of vehicles in open lanes to reduce

Model of Highway Bottleneck

- C_b : capacity of the bottleneck
- Ideal capacity of the bottleneck after the incident should be $C_b = n_b : n_n$ C

  $4/5 = n_b : n_n$
- L_b : length of the bottleneck
- **Assume Triangular Fundamental Diagram**

$q_b = v_f \rho_d$,

critical value $\rho_{d,c}$

$$q_b = \begin{cases} v_f \rho_d, & \rho_d \leq \rho_{d,c} \\ (1-\epsilon) C_b, & \rho_d > \rho_{d,c} \end{cases} \quad (1)$$

where $C_b = v_f \rho_{d,c}$, $\epsilon \in (0, 1)$.

Drop in capacity

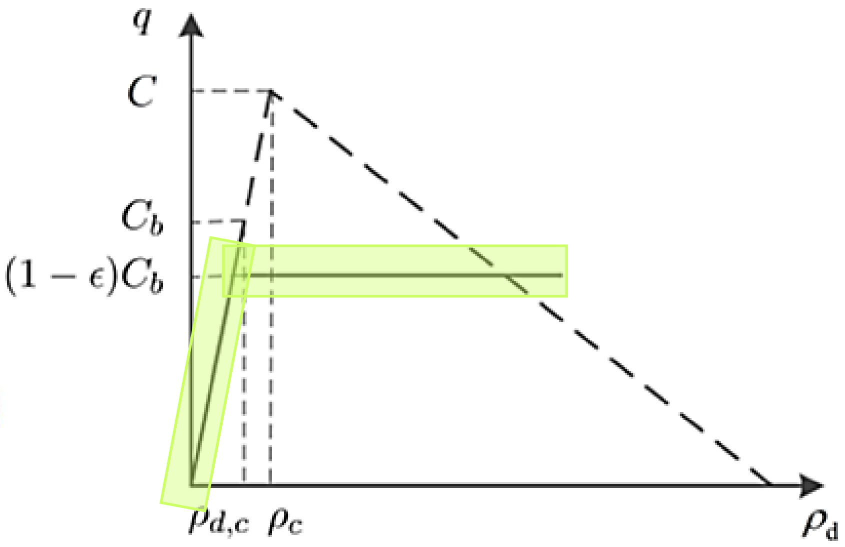
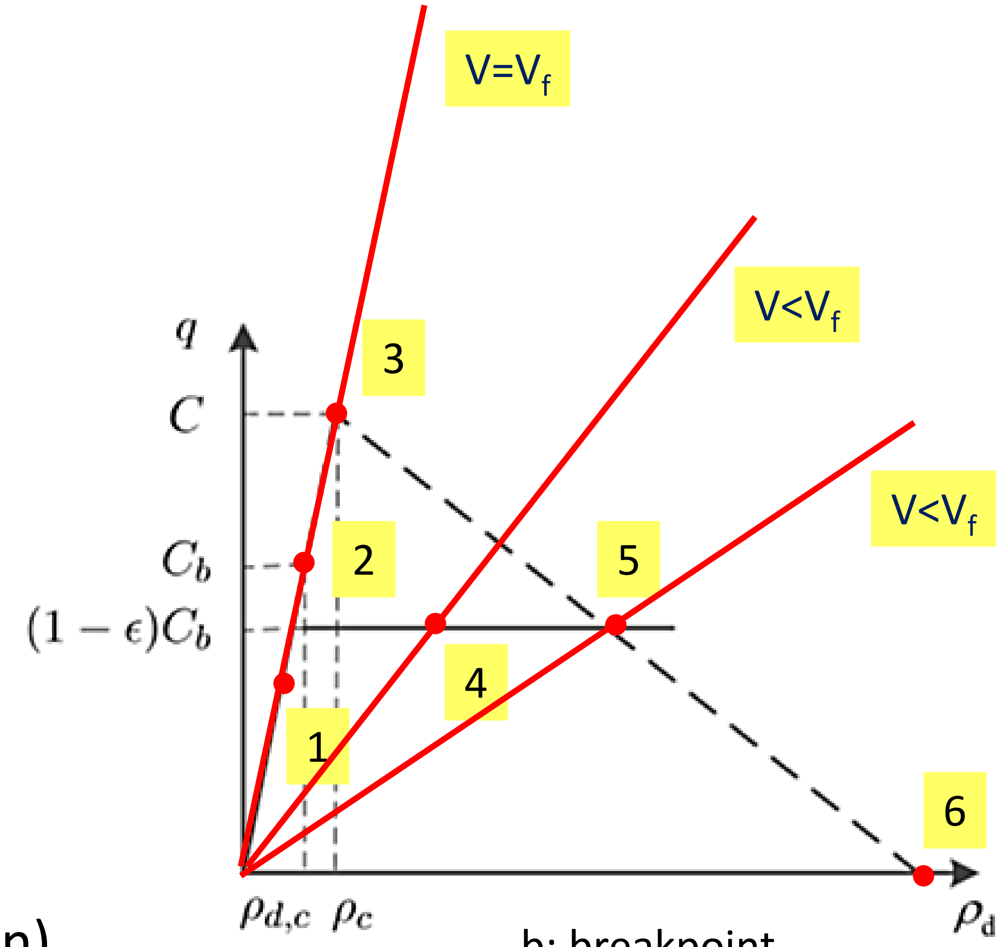


Fig. 2: Triangular Fundamental Diagram

Model of Highway Bottleneck

- 1 : $q_1 < (1-\varepsilon)C_b$, $\rho < \rho_c$
- 2 : $q_2 = C_b$, $\rho < \rho_c$
- 3 : $q_3 = C$, $\rho = \rho_c$
- 4 : $q_4 = (1-\varepsilon)C_b$, $\rho > \rho_c$
- 5 : $q_5 = (1-\varepsilon)C_b$, $\rho > \rho_c$
- 6 : $q_6 = 0$, $\rho = \rho_d$

- As flow is under capacity, traffic stream is expected to operate normally



$\rho_{d,c}$: critical density at section d (discharge section)

b: breakpoint
c: capacity

Model of Highway Bottleneck

- C_b : capacity of the bottleneck
- Ideal capacity of the bottleneck after the incident should be:
  - $C_b = (n_b : n_n) \times C$
- L_b : length of the bottleneck

- **Assume Triangular Fundamental Diagram**

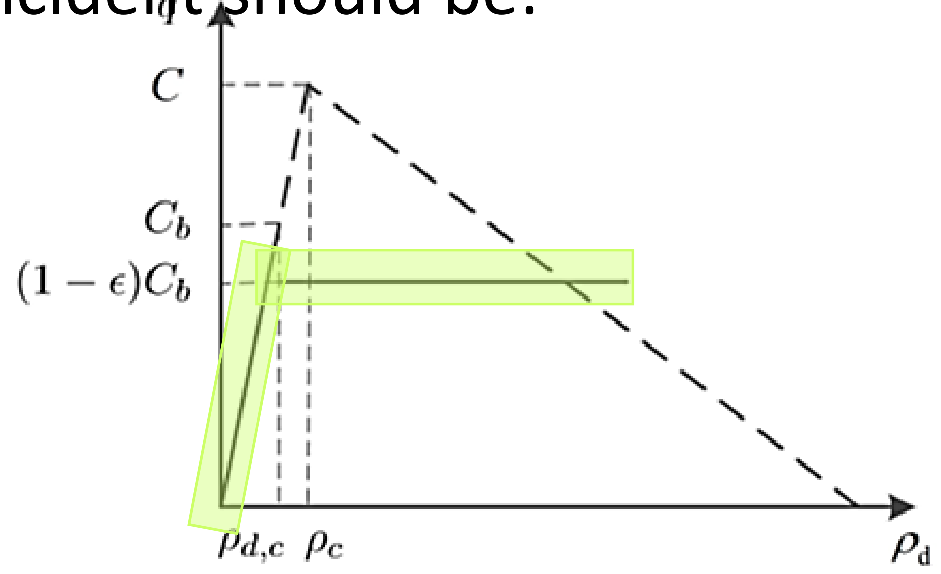


Fig. 2: Triangular Fundamental Diagram

critical value $\rho_{d,c}$

Model of Highway Bottleneck

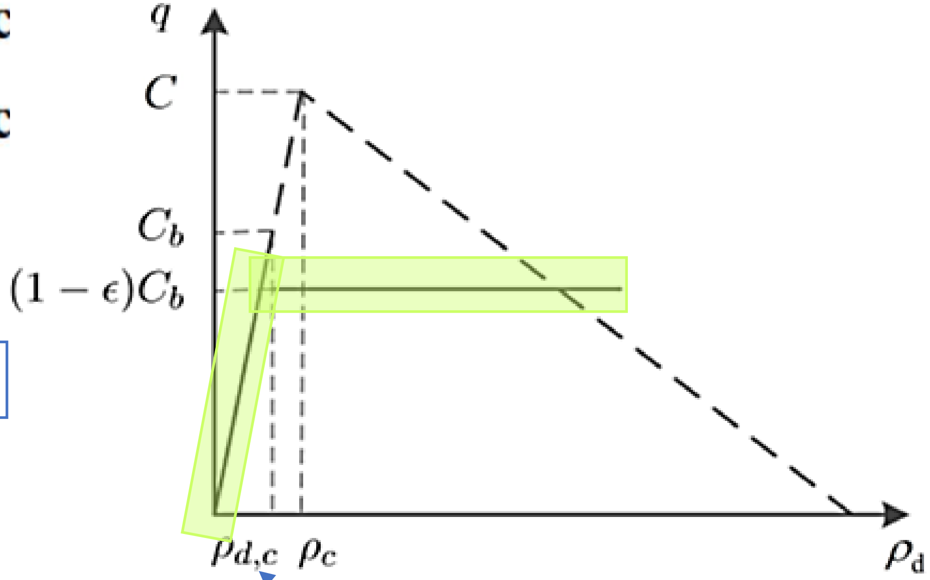
Assume Triangular Fundamental Diagram

$$q_b = \begin{cases} v_f \rho_d, & \rho_d \le \rho_{d,c} \\ (1-\epsilon) C_b, & \rho_d > \rho_{d,c} \end{cases}$$

where $C_b = v_f \rho_{d,c}, \ \epsilon \in (0,1).$

Drop in capacity

$C' = (1-\varepsilon)C_b$



critical value $\rho_{d,c}$

$\rho_{d,c}$: critical density at section d (discharge section)

Bottleneck

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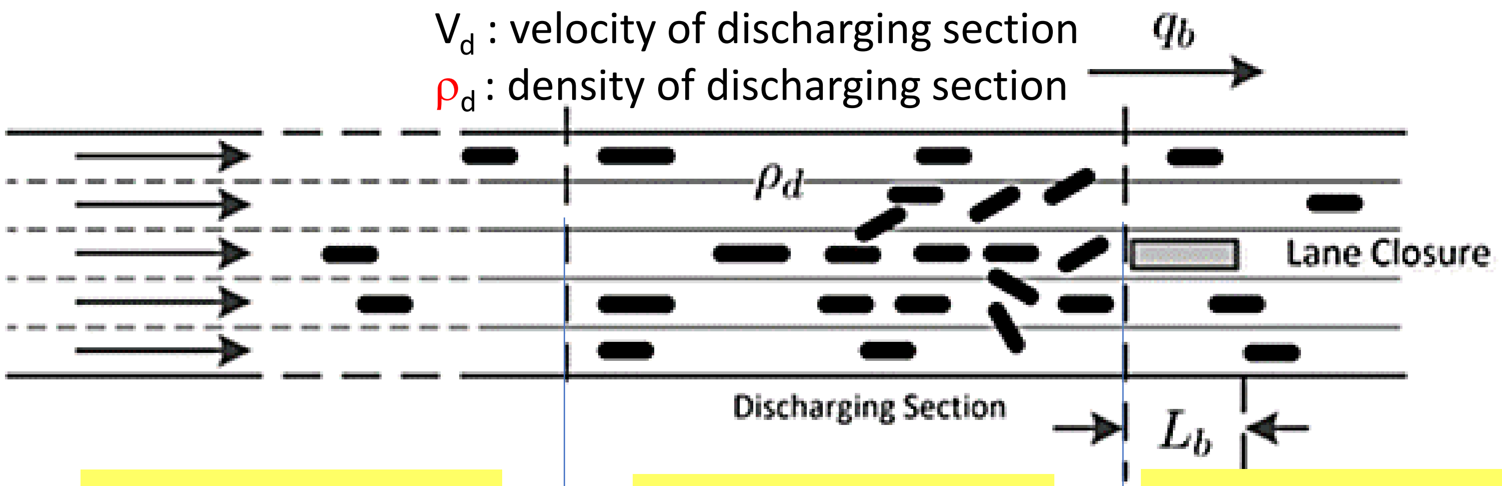

Normal Section | **Discharging Section** | **Bottleneck Section**

C or C_n : capacity of normal section
n_n : number of lanes in normal section
q_n : flow of normal section
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Lane Changing ---

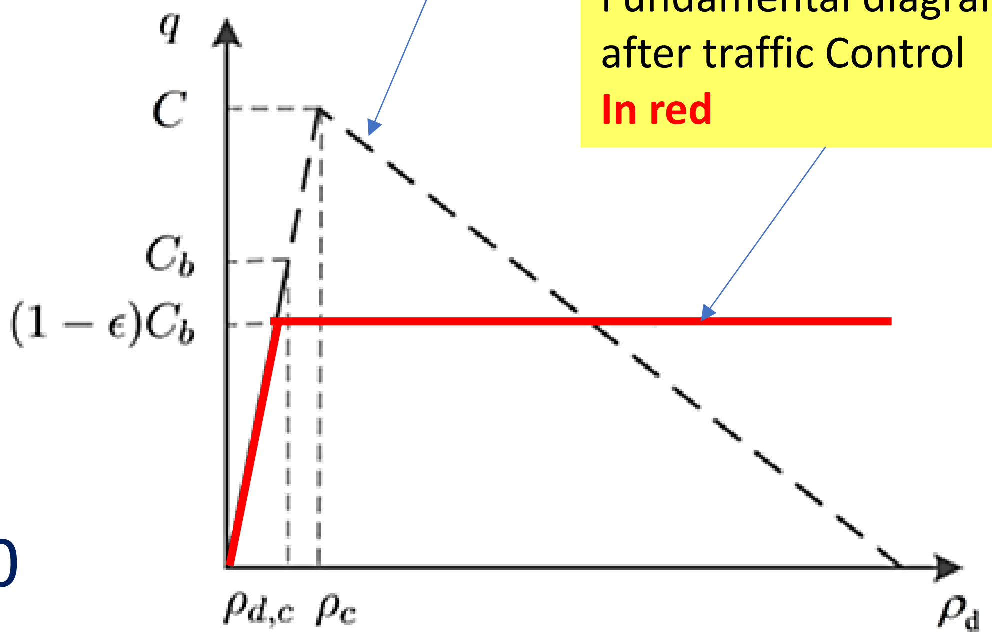
C_b : capacity of bottleneck
n_b : number of lanes in bottleneck section
q_b : flow of bottleneck
L_b : length of bottleneck

Model of Highway Bottleneck

- C_b = 6000 x 4/5 = 4800 vph & Q = 60 x 100 = 6000 vph > C_b
- Can we control/manage flow to be less than the capacity at the bottleneck
- For Q < C_b -----> Q = V x K
- To decrease Q, either decrease V or K or both ----> K can't be controlled
- If V is decreased from 60 kph to 40 kph
- Q = 40 x 100 = 4000 vph < C_b , (C_b = 4800 vph)

Assumed Fundamental diagram without control
Dotted

Fundamental diagram after traffic Control
In red



Model of Highway Bottleneck

- As flow is under capacity, traffic stream is expected to operate normally
- Reducing speed along highways during travel is possible through an Intelligent Transportation System (ITS) named Variable Speed Limits (VSL)

- V = 60, K=100, **Q=60 x 100 = 6000 vph**
- N = 5, n_b= 4 ($n-n_{closed}$)
- Q_b= 4/5 x 6000 = 4800 vph
- V = 40 kph
- Q = 40 x 100 = 4000 vph

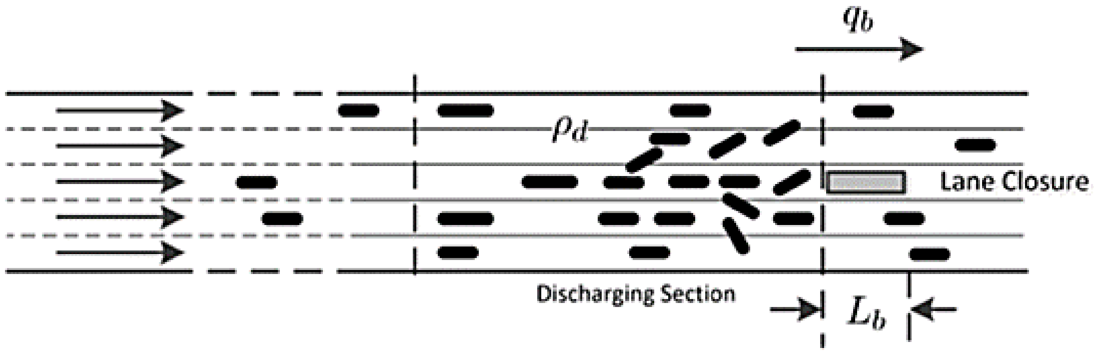
Questions

The fundamental diagram can be simplified to a … diagram

a. linear
b. **triangular**
c. parabolic
d. microscopic
e. Any of the above

Questions

If C = 6000 vph, V = 60 vph, K = 100 vpkm, no. of lanes = 5, only one lane is closed



<u>Solution:</u>

- $Cb = C \times (n_b : n_n)$
- One lane is blocked ----> $n_b = n_n - 1 = 5 - 1 = 4$
- $C_b = 6000 \times 4/5 = 4800$ vph
- $Q = V \times K$ -----> $k = \rho$
- Then $Q = 60 \times 100 = 6000$ vph > C_b (However in normal conditions, flow is at capacity)
- Queues will form at this section due to over capacity (flow is greater than available road capacity)

Questions

If the total road capacity is 12,000 vph. The bottleneck caused a drop in capacity to 8,000 vph (critical capacity)

- In normal conditions:
  - k = 100 vpkm & v=100 kph
  - q = 100 x 100 = 10,000 vph > 8,000, which is over capacity (shortage)
- If speed is lowered from 100 kph to 60 kph:
  - k = 100 vpkm & v=**<u>60</u>** kph
  - q = 100 x **<u>60</u>** = 6,000 vph < 8,000, which is less than capacity

Do we need VSL in Country?

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Thank You!