CE351: Transportation Planning and Traffic Engineering

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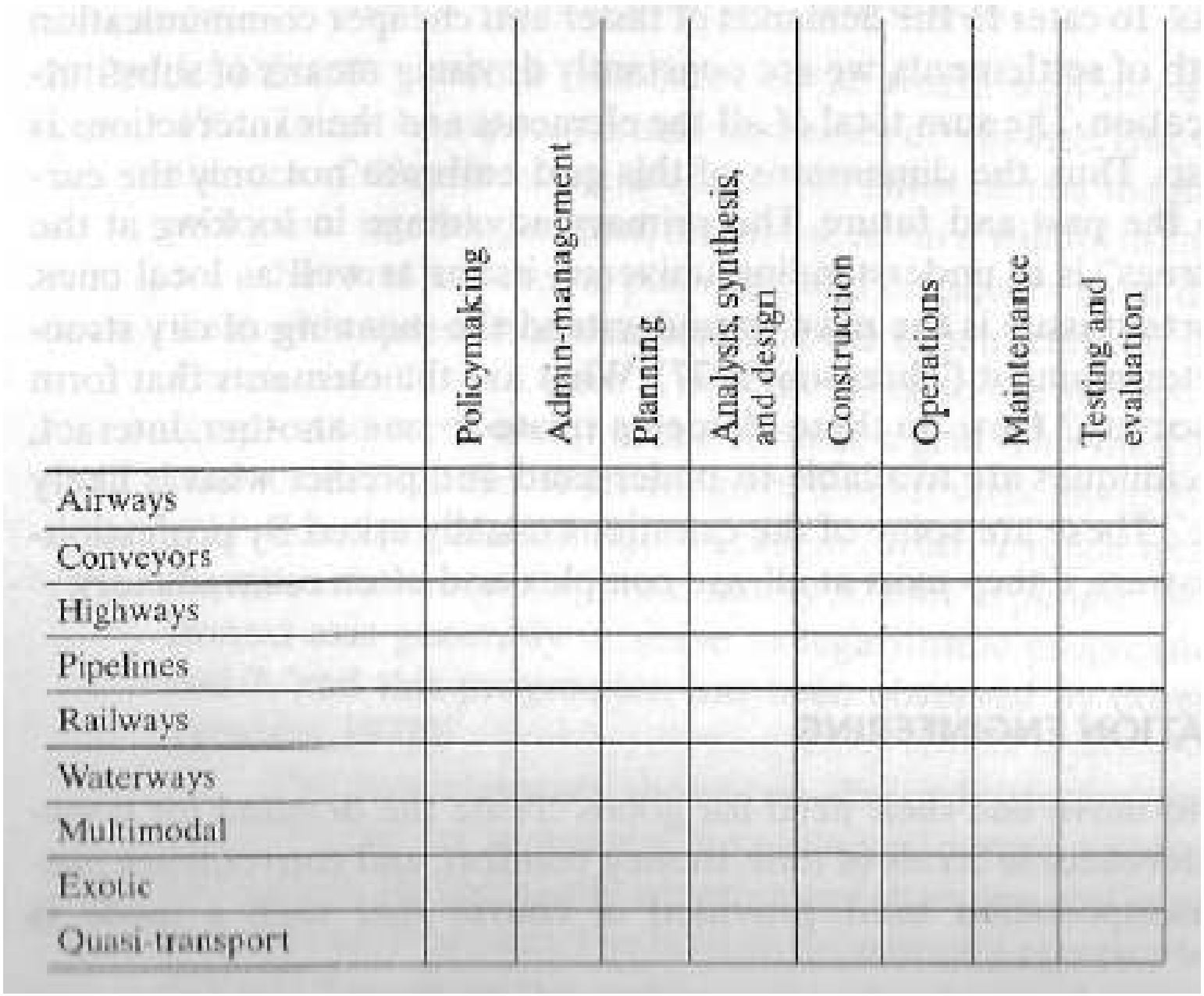
Topic: Transportation Engineering, Transportation Functions, Transportation Systems, Functional Components, Factors in Transportation Development, Transportation Modes, Public Transportation, Emerging Modes, ITS: Components and Applications; Transportation In Bangladesh: Modes and Networks, Constraints and challenges, Transport demand and modal share, road classification, and design standards.

Transportation Engineering

"the application of technological and scientific principles to the planning, functional design, operation, and management of facilities for any mode of transportation in order to provide for the safe, rapid, comfortable, convenient, economical and environmentally compatible movement of people and goods."

Figure: Transportation as a System



	Policymaking	Admin-management	Planning	Analysis, synthesis, and design	Construction	Operations	Maintenance	Testing and evaluation
Airways								
Conveyors								
Highways								
Pipelines								
Railways								
Waterways								
Multimodal								
Exotic								
Quasi-transport								

Figure: The System Approach

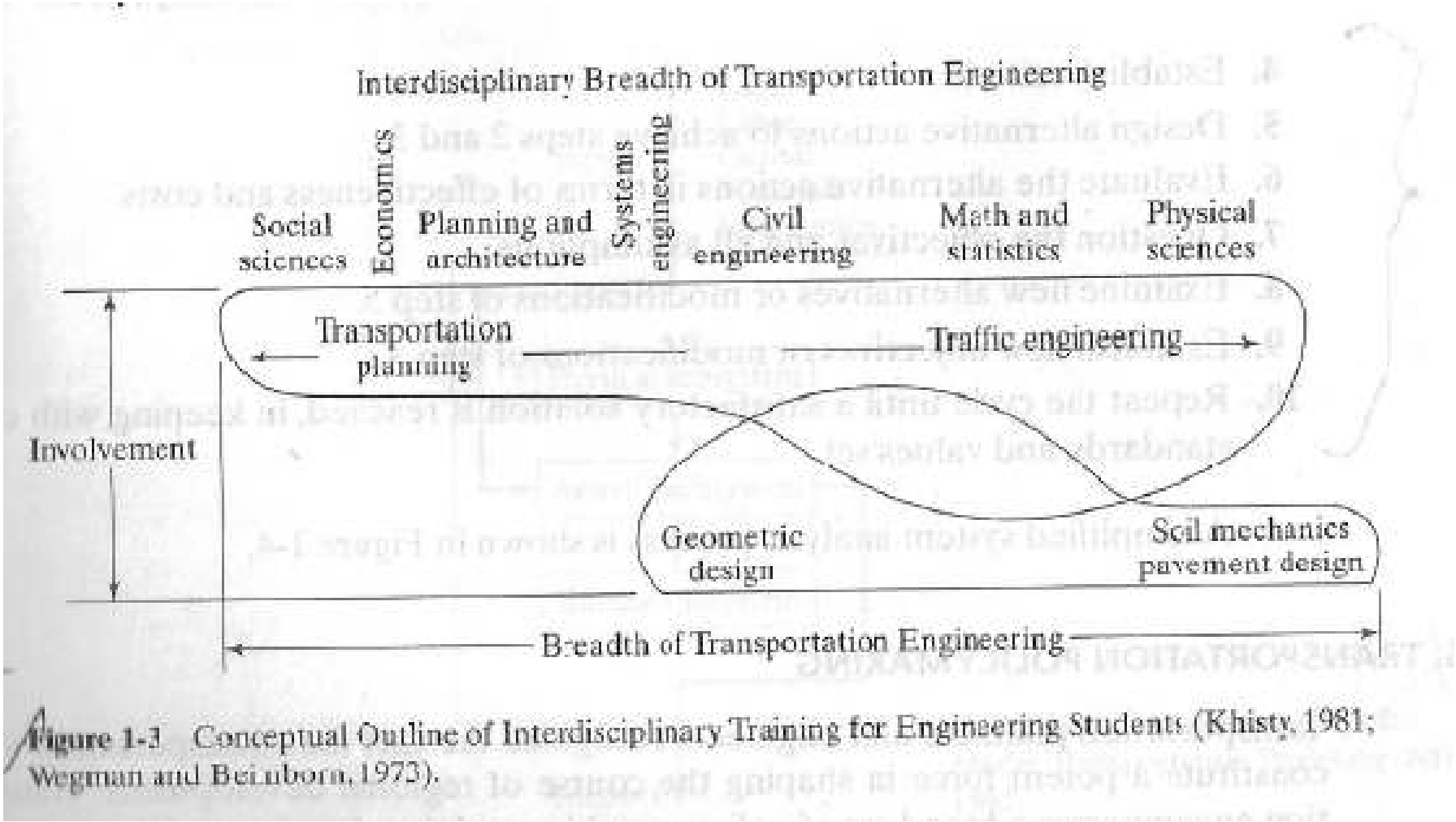


Figure 1-3 Conceptual Outline of Interdisciplinary Training for Engineering Students (Khisty, 1981; Wegman and Beaubois, 1973).

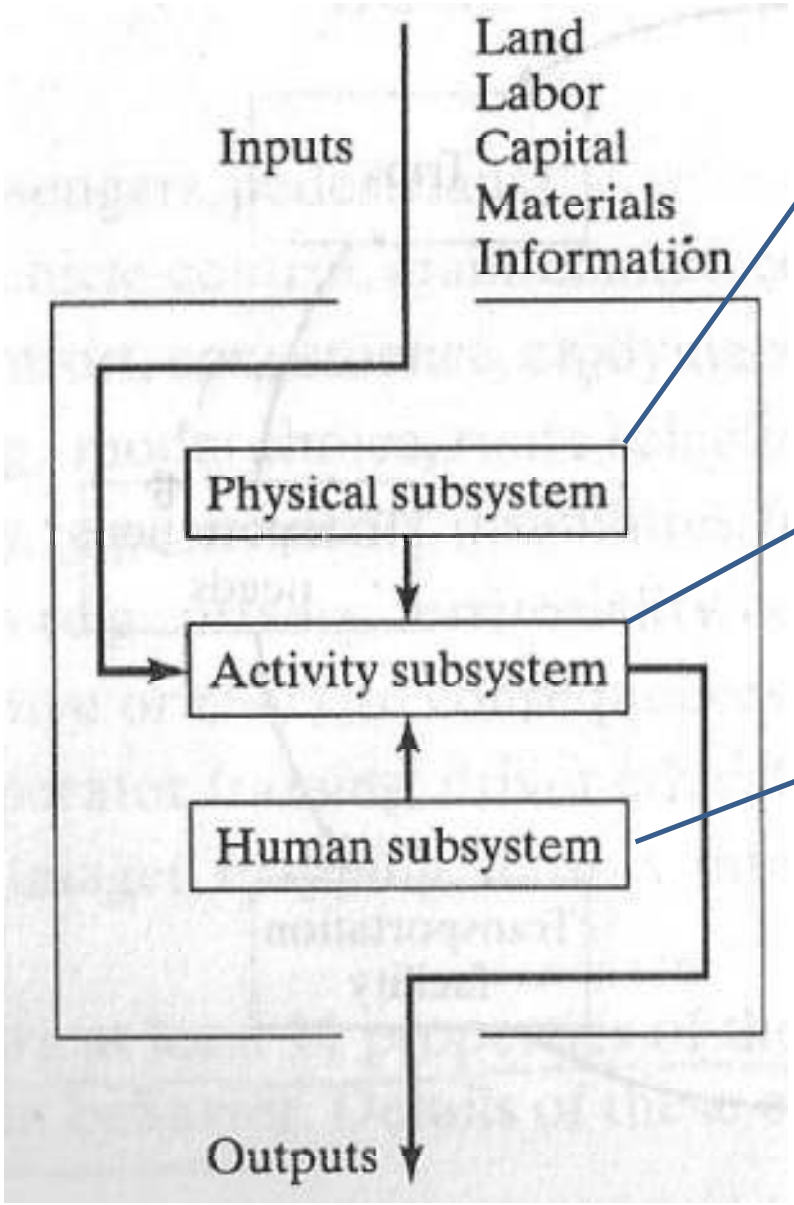
Steps in System Analysis

1. Recognize community problems and values.
2. Establish goals.
3. Define objectives.
4. Establish criteria.
5. Design alternative actions to achieve steps 2 and 3.
6. Evaluate the alternative actions in terms of effectiveness and costs.

Cont.

7. Question the objectives and all assumptions.
8. Examine new alternatives or modifications of step 5.
9. Establish new objectives or modifications of step 3.
10. Repeat the cycle until a satisfactory solution is reached, in keeping with criteria, standards and values set.

Figure: Transportation System Model

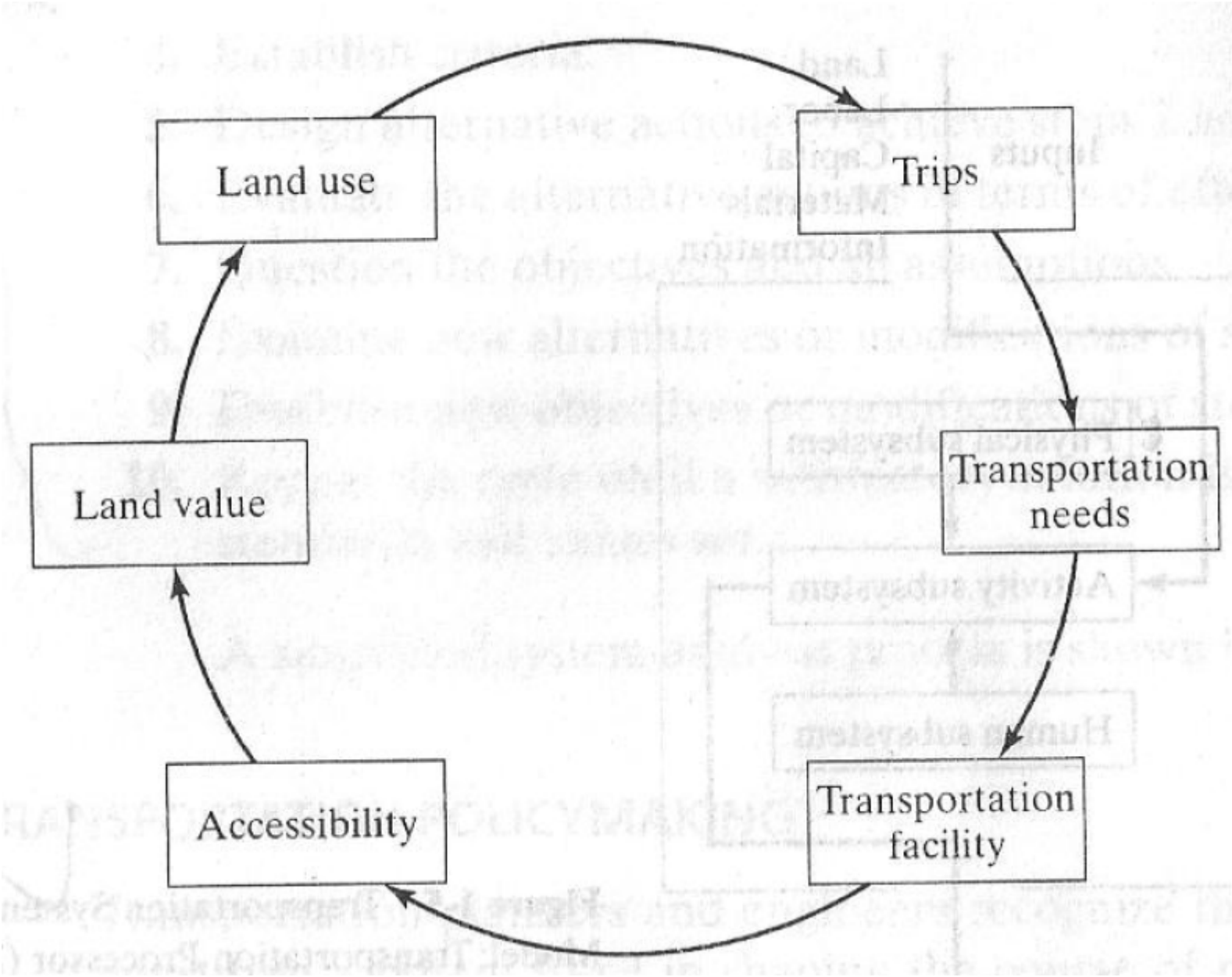


Vehicle
Pavement
Tracks
Right of way
Terminal, etc.

Riding Driving & Traffic Control.

Individuals , Agency and group of people responsible for the above two

Figure: Land Use/ Transportation Cycle



Overview of Transportation Systems Characteristics

1. ***Links:*** the roadways or tracks connecting two or more points. Pipes, beltways, Sea-lanes, and airways can also considered as links.
2. ***Vehicles:*** the means of moving people and goods from one node to another along a link. Motorcars, buses, ships, airplanes, belts and cables are example.
3. ***Terminals:*** the nodes where travel and shipment begins or ends. Parking garages, off-street parking lots, loading docks, bus stops, airports, and bus terminal are example.
4. ***Management and labor:*** the people who construct, operate, manage and maintain the links, vehicles, and terminals.

Cont.

Nine categories of human behavior that are affected by transportation:

1. **Locomotion** (passengers, pedestrians)
2. **Activities** (e.g., vehicle control, maintenance, community life)
3. **Feelings** (e.g., comfort, convenience, enjoyment, stress, likes, dislikes)
4. **Manipulation** (e.g., modal choice, route selection, vehicle purchase)

Cont.

5. **Health and Safety** (e.g., accidents, disabilities, fatigue)
6. **Social Interaction** (e.g., privacy, territoriality, conflict, imitation)
7. **Motivation** (positive or aversive consequences, potentiating)
8. **Learning** (e.g., operator training, driver education, merchandising)
9. **Perception** (e.g., images, mapping, sensory thresholds)

Cont.

There are at least 11 properties of the physical environment that have a direct impact on human behavior:

1. ***Spatial organization:*** This dimension often includes the shape, scale, definition, bounding surfaces, internal organization of objects and society, and connections to other spaces and settings.
2. ***Circulation and movement:*** This property includes people, goods, and objects used for their movement – cars, trains, highways and rails- and also the forms of regulating them.

Cont.

3. ***Communication:*** Both explicit and implicit signals, signs, or symbols communication, required behavior, Reponses, and meanings are covered by this dimension.
4. ***Ambience:*** This dimension usually includes such items as microclimate, light, sound and odor.
5. ***Visual Properties:*** This includes color, shape, and other visual modalities.
6. ***Resource:*** the physical components and amenities of a transportation system- paths, terminals and vehicles could be included.

Cont.

7. ***Symbolic Properties:*** The social values, attitudes, and cultural norms that are represented or expressed by the environment fall into this category.
8. ***Architectonic properties:*** This refers to the sensory or aesthetic properties of the environment.
9. ***Consequation:*** Measures of consequation include such items as costs, risks, and congestion.
10. ***Protection:*** Safety factors in general are implied in this category.
11. ***Timing:*** All the items mentioned before are scheduled in time and some of them fluctuate with various cyclical rhythms, such as daily, weekly, or hourly timings.

Cont.

Transportation systems can be evaluated in terms of three basic attributes:

1. ***Ubiquity:*** the amount of accessibility to the system, directness of routing between access points, and the system's flexibility to handle a variety of traffic conditions. Highways are very ubiquitous compared to railroads.
2. ***Mobility:*** the quantity of travel that can be handled. The capacity of a system to handle traffic and speed are two variables connected with mobility. Here again, a freeway has high mobility, whereas a local road has low mobility.

Cont.

3. ***Efficiency:*** the relationship between the cost of transportation and the productivity of the system. Direct cost of system are composed of capital and operating costs, indirect costs comprise adverse impacts and unquantifiable costs, such as safety. Each mode is efficient in some aspects and inefficient in others.

TABLE 1.1 Overview of Major Transportation Systems

System	Ubiquity	Mobility	Efficiency	Mode	Passenger Service	Freight Service
Highways	Very high: land owners have direct access to a road or street. Direct routing limited by terrain and land use.	Speeds are limited by human factors and speed limits. Capacity per vehicle is low, but many vehicles are available.	Not high as regards safety, energy, and some costs.	Truck	Negligible	Intercity, local, farm to processing and market centers. Small shipments; containers
				Bus	Intercity and local	Packages (intercity)
				Automobile	Intercity and local	Personal items only
				Bicycle	Local; recreational	Negligible
Rail transport	Limited by large investment in route structure. Also constrained by terrain.	Speed and capacity can be higher than for highway modes.	Generally high, but labor costs may result in low cost efficiency.	Railroads	Mostly < 300 miles and suburban commuters	Intercity. Mostly bulk and oversized shipments; containers
				Rail transit	Regional, intracity	None
Air transport	Airport costs reduce accessibility. Excellent opportunity for direct routing.	Speeds are highest, but capacity per vehicle is limited.	Fairly low as regards energy and operating costs.	Air carriers	Mostly > 300 miles and across bodies of water	High-value freight (no bulk) on long hauls; containers
				General aviation	Intercity; business, recreation	Minor
Water transport	Direct routing and accessibility limited by availability of navigable waterways and safe ports.	Low speed. Very high capacity per vehicle.	Very high: low cost, low energy use. Safety varies.	Ships	Cruise traffic. Ferry service	Bulk cargos, especially petroleum; containers
				Barges	None	Bulk cargos, especially petroleum; containers
				Hovercraft	Ferry service	Minor
Continuous-flow systems	Limited to few routes and access points.	Low speeds. High capacity.	Generally high: low-cost energy use.	Pipelines	None	Liquids, gases, and slurries on short and long hauls
				Belts	Escalators and belts for short distances	Bulk materials handling, mostly < 10 miles
				Cables	Lifts and tows for short distances in rough terrain	Materials handling in rough terrain

Source: Hamburger and Kell, 1988.

Transportation systems, Hierarchies, and Classification

- The classification of transportation modes into different operational systems or functional classes is useful in understanding the complexity of the total transportation system.
- A series of distinct travel movements are recognizable in most trips.

- On a highway system:
  - main movement along a free-way, a transition to an arterial via a freeway off-ramp,
  - then further movement along an arterial where traffic is distributed and
  - later collected via a collector, finally accessing a terminal (a garage or on-street parking lot).
  - Further movement of the passenger may be as a pedestrian on a sidewalk of a local street, and finally to his or her destination.

- The urban principal arterials serve the major activity centers, such as universities, shopping centers, and stadiums, and also the highest-traffic-volume corridors.

Figure: Hierarchy of Movement

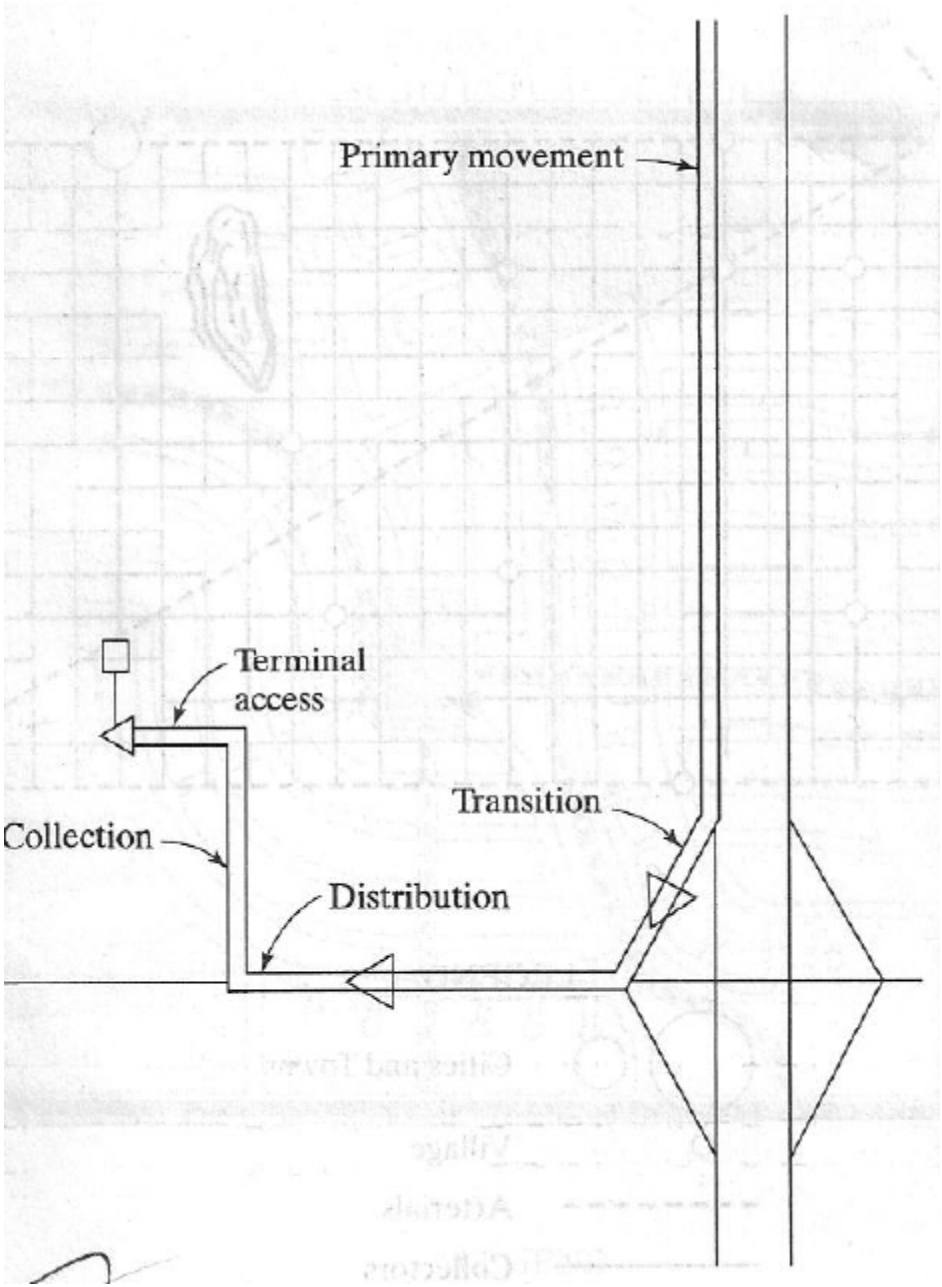


Figure: Relationship of Functionally Classified Systems in Service Traffic Mobility and Land Access

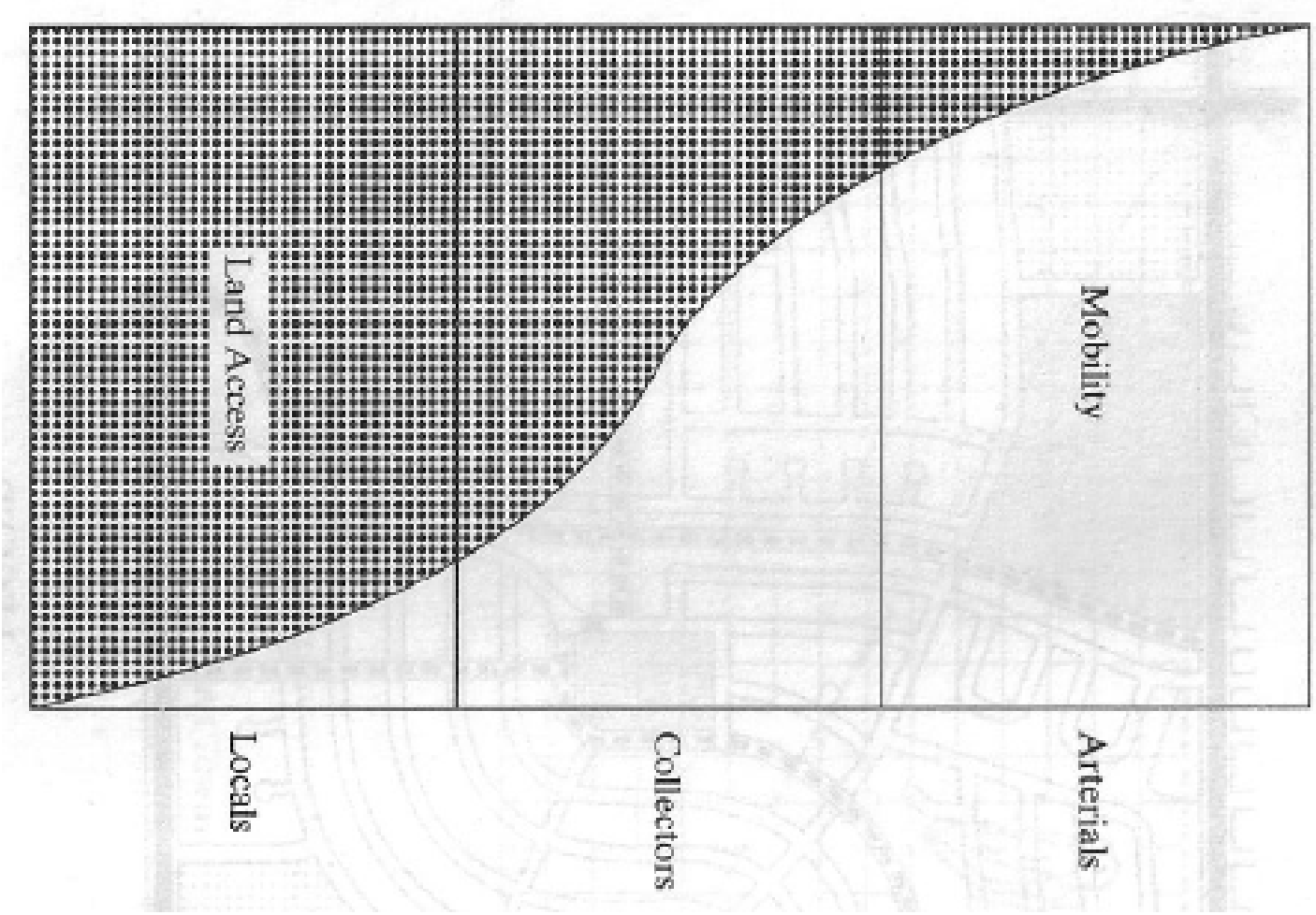


Figure: Vehicle-Miles of Travel by Street Class

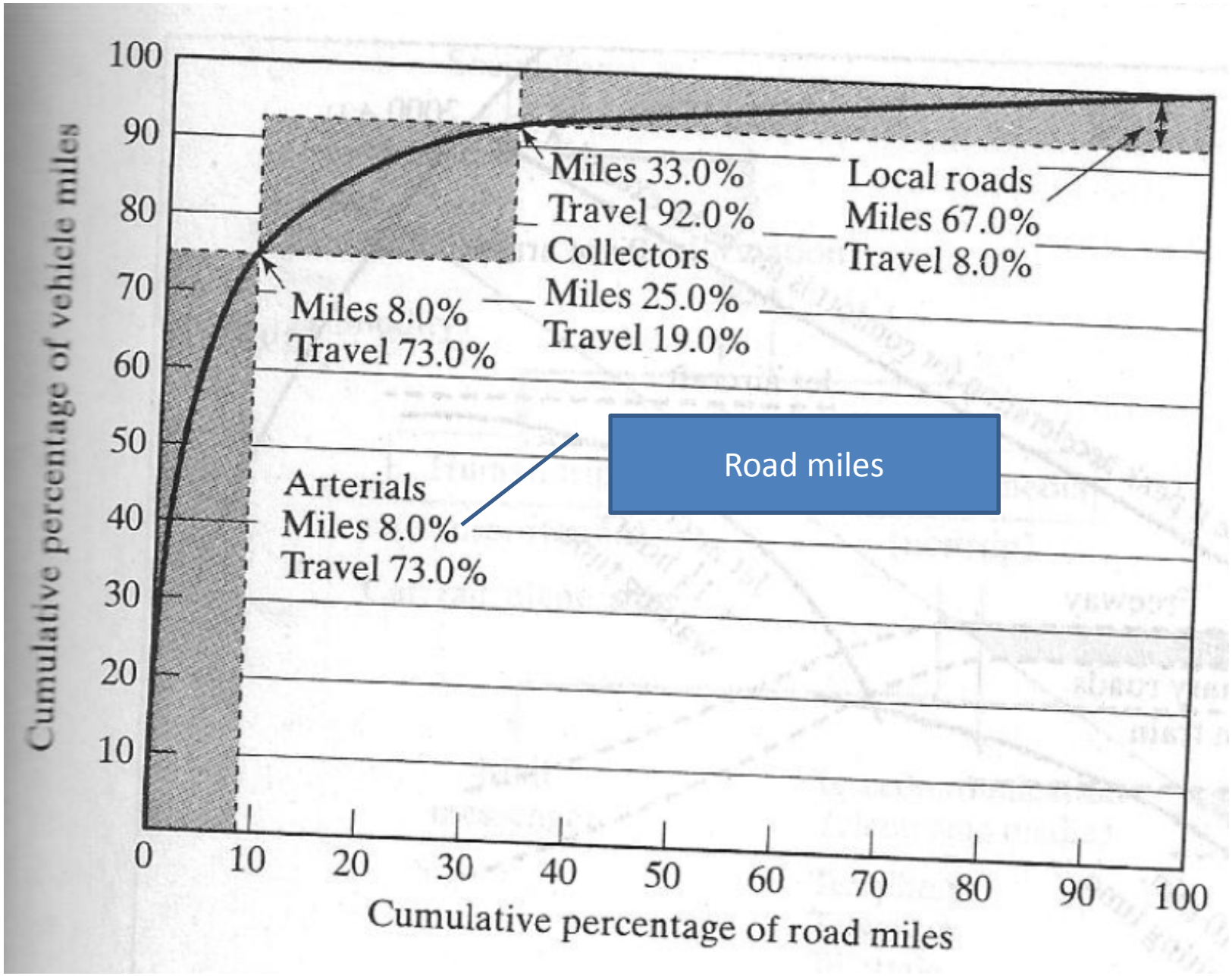
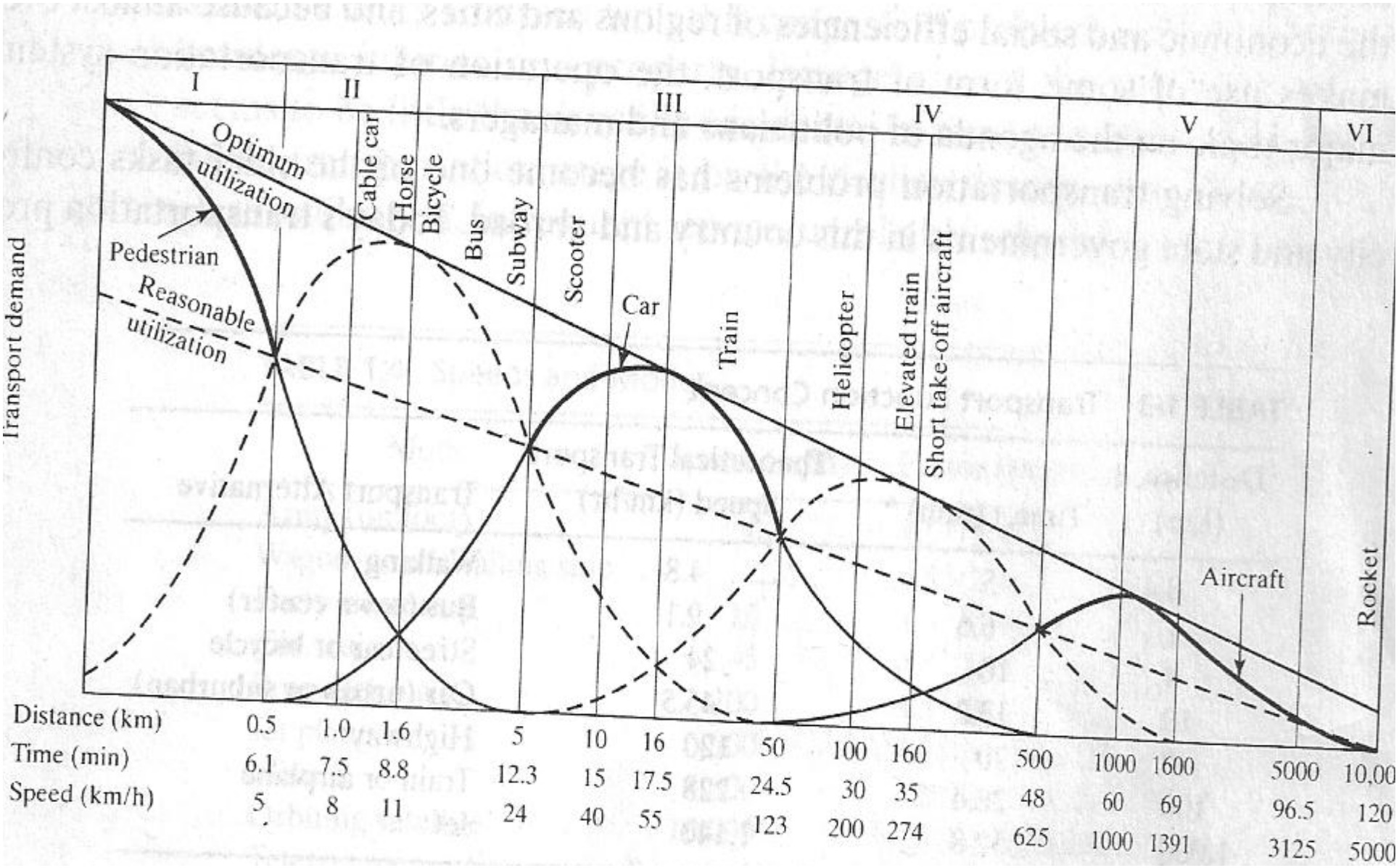
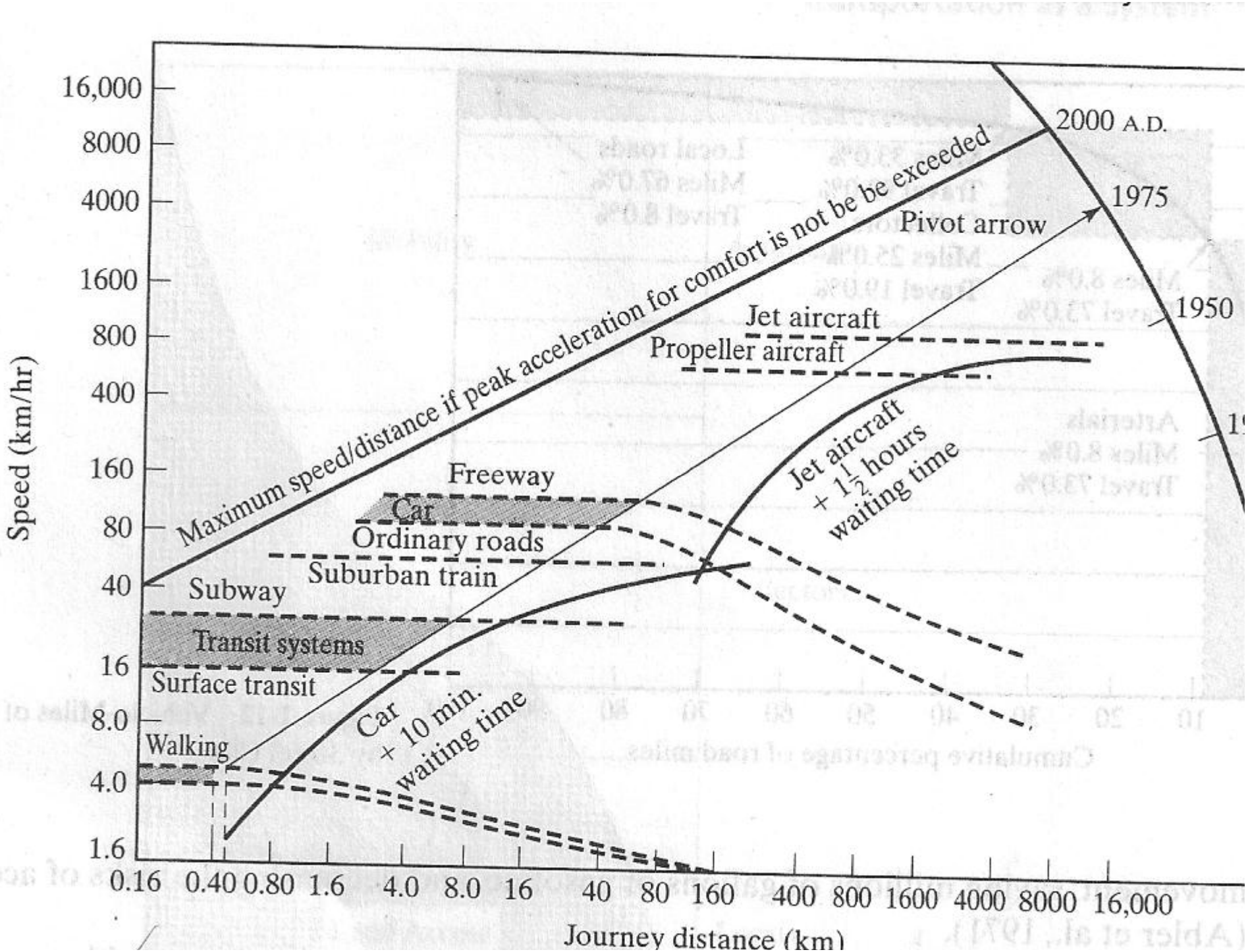


Figure: Transportation Gaps




16,000
8000
4000
1600
800
400
160
80
40
16
8.0
4.0
1.6
Speed (km/hr)
0.16
0.40
0.80
1.6
4.0
8.0
16
40
80
160
400
800
1600
4000
8000
16,000
Journey distance (km)
2000 A.D.
1975
1950
Maximum speed/distance if peak acceleration for comfort is not be be exceeded
Pivot arrow
Jet aircraft
Propeller aircraft
Jet aircraft
+ 1½ hours
waiting time
Freeway
Car
Ordinary roads
Suburban train
Subway
Transit systems
Surface transit
Walking
Car
+ 10 min.
waiting time

Transportation and Transportation related Problems

- The tremendous dependence on the automobile and relation of this dependency to urban form and the location of people and their jobs.
- The evolution of a public transportation system capable of serving the entire urban area effectively.
- The capability of government and its policies to provide a transportation system that is equitable to both car owners and the carless.
- The combination of new technologies and effort to design a more satisfying urban environment in the long run.
- Complexities of new problems due to the uncertainty of energy supplies.
- Solving urban transportation problems through the public and private sectors; and the cost implications of alternative federal policies.

Transportation System:

Key point 1: Behavior- people and organization alter behavior based on transport service

Key point 2: is a part of broader system- economic, social and political in nature

Key point 3: Competition- among operators for better service availability

Key point 4: the vehicle cycle- traffic flow and network analysis

Key point 5: Queuing and storage- queuing for service and storage for vehicles/freight/passengers

Key point 6: Transfers- Intermodal and intramodal transfer number and ease

Key point 7: Operating policy- affects LOS

Key point 8: Capacity- a complex system characteristics

Key point 9: Supply- ensures LOS

Key point 10: Availability of information

Transportation System:

Key point 11: Infrastructure shape- affects geo-economic shape

Key point 12: Costs, prices and LOS- they may not be consistent

Key point 13: Cost of service estimation

Key point 14: Costs/LOS trade-offs

Key point 15: Demand consolidation-may reduce costs for like demands

Key point 16: Peaking- design capacity trade off

Key point 17: Different time scales- long, short, medium and infrastructure plan

Key point 18: Equilibrium- between demand and supply

Key point 19: Transport, development and land-use- relation among transportation, economic development and location of activities

Key point 20: Performance measures

Urban transport system

- Factors influencing urban transport pattern
  - Infrastructure investment choices: expressway/LRT/Metro/Busway
  - Income changes and economic development (Income and car ownership)
  - Interaction of transport and urban form and the influence of urban planning policy
  - Prices and economic instruments (car/fuel price/tax; KL vs. Singapore)
  - Technology choice (NMT/MC/car/rail vs. expressway)
  - Transport patterns and infrastructure influence the urban form that evolves in any particular city and, conversely, the urban form of a city influences its transport patterns and further infrastructure investments.

City and transport

- Walking City
  - High density
  - Mixed use
  - Short distance origin and destination patterns highly dispersed throughout the city
- Transit city
  - High density city centre with mixed use
  - Short distance origin and destination patterns within city centre
  - Long distance and radial origin-destination pattern with satellite/suburb township
- Automobile city
  - High density commercial use core
  - Commercial, retail and industrial landuse separated and dispersed throughout the city
  - Long distance origin-destination pattern highly dispersed throughout the city

Emerging Transportation Technologies

1. Smart traffic signal control systems sense heavy traffic flows at road intersections and adjust the timing of signals automatically to accommodate the flow.
2. Freeway management systems meter vehicles entering freeways with signals on on-ramps. Although this technology has been in use for a long time, the system is being refined by linking it with other detection systems- for example, accident surveillance systems.
3. Transit management systems help managers to control and monitor the movements of transit vehicles and adjust schedules accordingly.

Cont.

4. Incident management systems (IMS) detect and manage nonrecurring traffic congestion caused by random unpredictable incidents, such as traffic accidents, lane blockages, and hazardous material spills resulting in major traffic congestion for considerable time periods. IMS has been in practice for quite some time.
5. Electronic toll collection on bridges and roads has been in operation on over a dozen sites.
6. Electronic fare payment systems have also been in practice for a long time but have to be refined further.

Cont.

7. Emergency response allows emergency vehicles to control traffic lights at intersections. The emergency vehicle driver can hold the green phase until the inter-section is cleared.
8. Travel information systems provide traffic information to users so that they can adjust their travel plans based on what they learn.
9. Route guidance systems are based on Global Positioning System (Satellite) technology and assist motorists with distance and direction information to selected destinations.

Intelligent Transport System (ITS): Encompassing Emerging Technologies

National ITS Architecture: The National ITS Architecture defines the components of the surface transportation system, how they interact and work together, and what information they exchange to provide ITS user services.

SIX ITS SUB SYSTEMS

ATMS (ADVANCED Transportation Management Systems): Network management, Incident management, traffic signal control, ETC, Congestion management

ATIS (Advanced Traveller Information System): Pre-trip, during trip information in real time

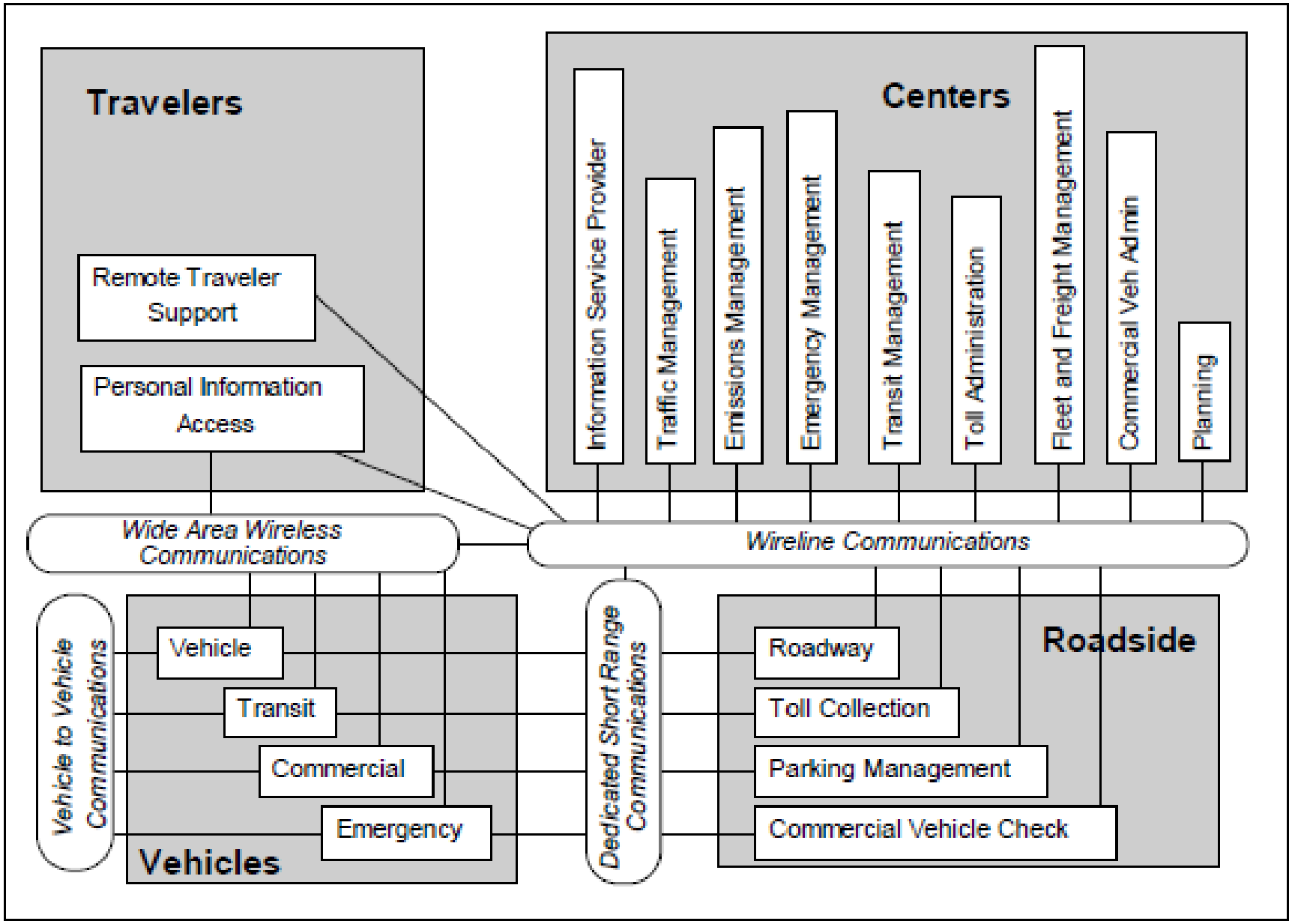
AVCS (Advanced Vehicle Control System): Driver aid, safety devices, AHS

CVO (Commercial vehicle operation): Fleet management, WIM, Routing, scheduling

APTS (Advanced public transport system): System operation, fare collection, matching transfer, scheduling, headway control

ARTS(Advanced rural transport system): safety, route guidance, security

ITS subsystems and Communications



Intelligent Transport System (ITS): Encompassing Emerging Technologies

User Service Bundle	User Service
Travel and Transportation Management	En-Route Driver Information Route Guidance Traveler Services Information **Traffic Control** **Incident Management** Emissions Testing and Mitigation **Highway-Rail Intersection**
Travel Demand Management	Pre-Trip Travel Information Ride Matching and Reservation Demand Management and Operations
Public Transportation Operations	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment Services	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes Hazardous Material Incident Response Commercial Fleet Management
Emergency Management	Emergency Notification and Personal Security Emergency Vehicle Management
Advanced Vehicle Control and Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Highway Systems

ITS market packages

Traffic Management
Network Surveillance
Probe Surveillance
Surface Street Control
Freeway Control
HOV and Reversible Lane Management
Traffic Information Dissemination
Regional Traffic Control
Incident Management System
Traffic Network Performance Evaluation
Dynamic Toll/Parking Fee Management
Emissions and Environmental Hazards Sensing
Virtual TMC and Smart Probe Data
Standard Railroad Grade Crossing
Advanced Railroad Grade Crossing
Railroad Operations Coordination

Transit Management
Transit Vehicle Tracking
Transit Fixed-Route Operations
Demand Response Transit Operations
Transit Passenger and Fare Management
Transit Security
Transit Maintenance
Multi-modal Coordination

Traveler Information
Broadcast Traveler Information
Interactive Traveler Information
Autonomous Route Guidance
Dynamic Route Guidance
Information Service Provider (ISP) Based Route Guidance
Integrated Transportation Management/Route Guidance
Yellow Pages and Reservation
Dynamic Ridesharing
In-Vehicle Signing

Advanced Vehicles
Vehicle Safety Monitoring
Driver Safety Monitoring
Longitudinal Safety Warning
Lateral Safety Warning
Intersection Safety Warning
Pre-Crash Restraint Deployment
Driver Visibility Improvement
Advanced Vehicle Longitudinal Control
Advanced Vehicle Lateral Control

Intersection Collision Avoidance
Automated Highway System

Commercial Vehicles
Fleet Administration
Freight Administration
Electronic Clearance
Commercial Vehicle Administrative Processes
International Border Electronic Clearance
Weigh-In-Motion
Roadside CVO Safety
On-board CVO Safety
CVO Fleet Maintenance
HAZMAT Management

Emergency Management
Emergency Response
Emergency Routing
MAYDAY Support

ITS Planning
ITS Planning

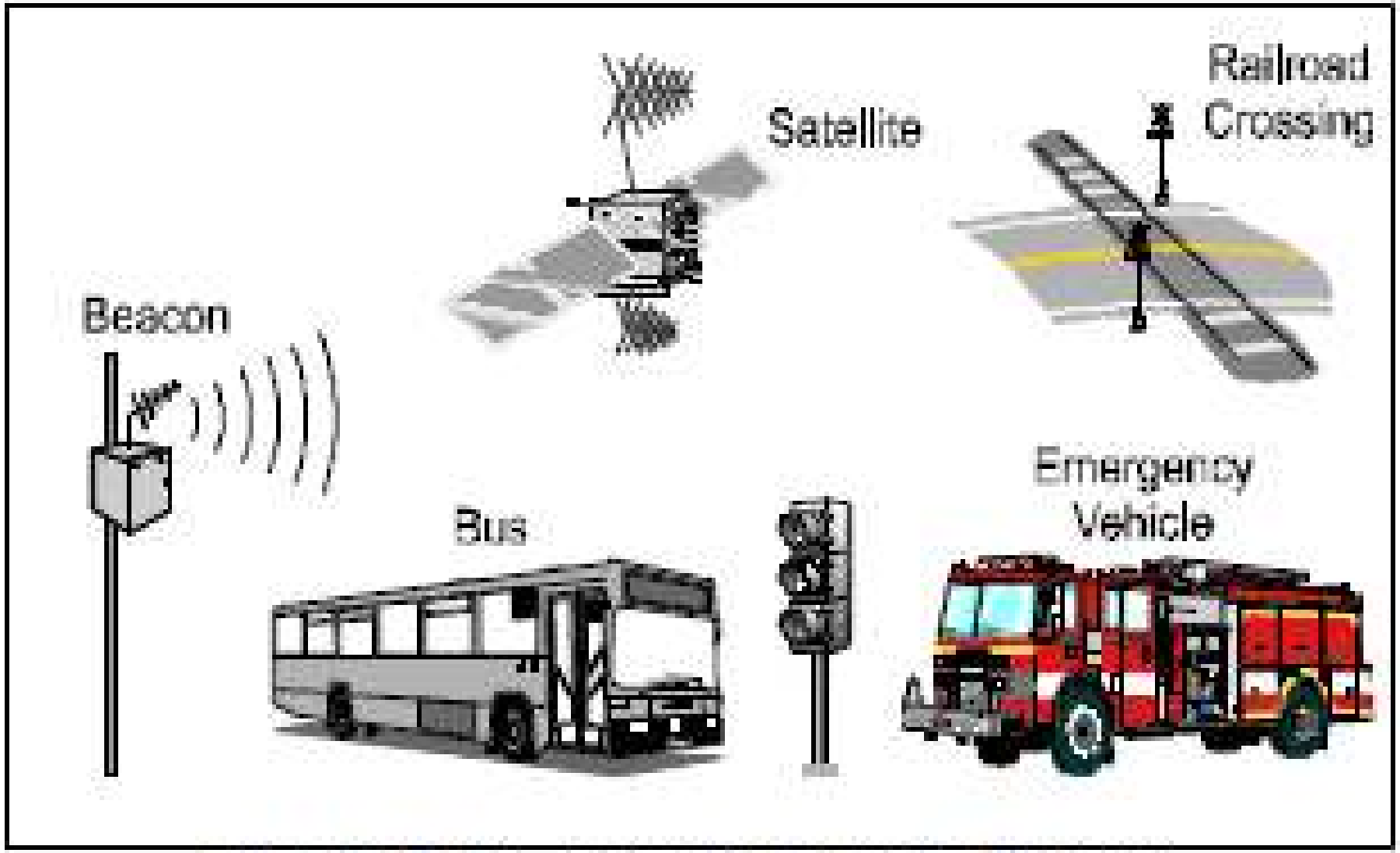


Figure 1.2-2. Intermodal Coordination

New Technology/Tools

- GPS location technology
- RFID
- Microwave sensor
- Induction loop vehicle/speed detection
- Mobile/dedicated Internet communication
- Image processing for vehicle/registration plate/speed detection
- Adaptive signal control, UTC, TMC
- Navigator technology- mobile internet/traffic master, VMS board
- Trip planner
- E-ticket/E-card for payment

URBAN Public Transport Technologies

Available Systems:

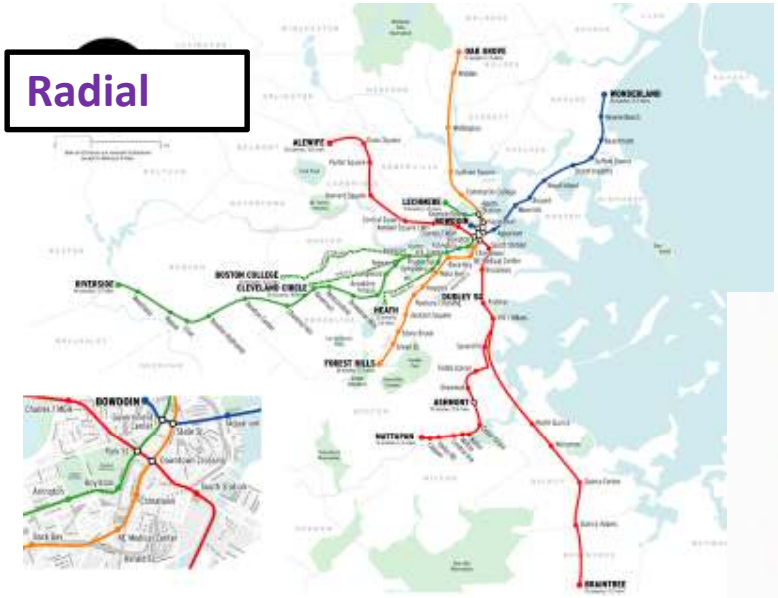
- **Non-motorised paratransit**
- **Motorised paratransit**
- **Conventional bus**
- **Improved Bus/Buslane/Busways**
- **Bus Rapid transit**
- **Tram/ street car**
- **Commuter/Conventional Rail**
- **Light rail transit**
- **Subway/ Metro on Road**
- **Demand Responsive System**

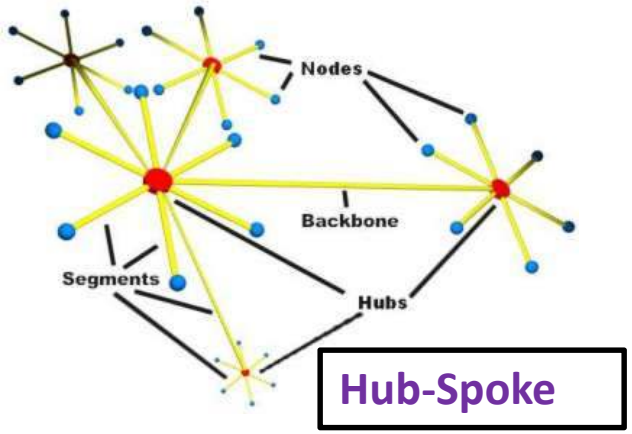
URBAN Public Transport Technologies

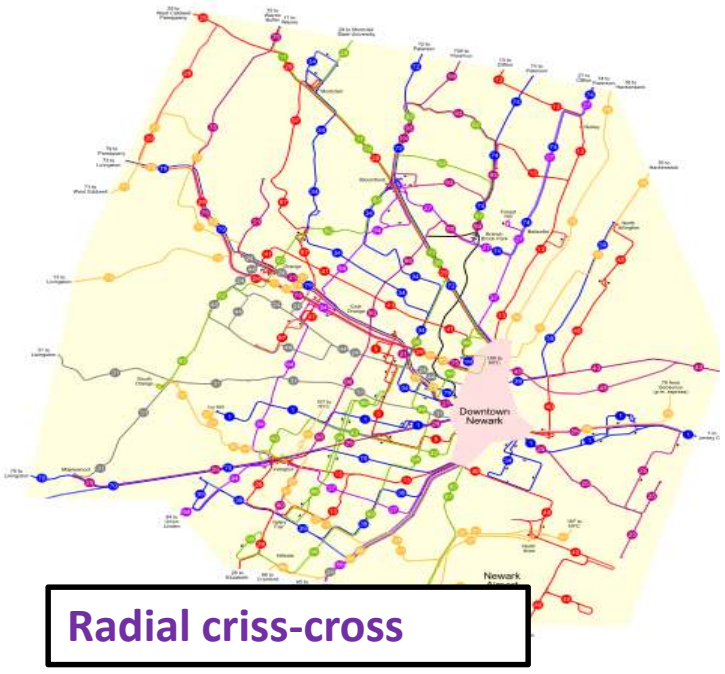
Service design:

- **Route/ Network**
- **Vehicles/ Fleet**
- **Frequency of Service**
- **Hours of service**
- **Level and Structures of fare**
- **Support Services**

- NETWORK STRUCTURE: Radial, Grid, radial criss-cross, trunk-feeder







Vehicle Cycle: Travel time for a return trip in a route

Fleet Size = VC/Headway

Frequency = 1/Headway

Dwell time: Amount of time the bus spends at the stop; proportional to number of people getting on and off

Boarding time

Alighting time

Public Transport Issues

- City size and population
- Large cities need larger PT modal split
- Need public agency to look after
- May need public subsidy
- Private investment needs careful monitoring and regulation
- Planning should be demand oriented

Public Transport Technologies

Key technological characteristics:

(a) Support - contact between vehicle and surface
- rubber tire on concrete
- steel wheel on steel rail
- others

(b) Guidance - lateral control:
- steered by driver
- guided by track
- others

(c) Propulsion:
- diesel ICE: conventional or clean
- LNG, CNG
- electric motor
- Hybrid, others

(d) Control
- manual/visual
- manual/signal
- automatic: ATO, ATC

Guidance and Control Technology

- Lateral kerbs and side rollers (O-BAHN)
- An optical guidance (steering linked to a video-monitoring system and a road marking recognition system : CIVIS of Irisbus and Matra Transport International,
- A single centrally embedded rail (of tram type) with disconnectable steering bogies (GLT) or arms supporting tilting rollers in V form (TRANSLOHR),
- An inductive cable guidance system (electronic steering by means of inductive cables embedded in the roadway) (Cegelec-AEG system),
-A magnetic guidance system under design (magnetic steering servitude to an electric cable embedded in the roadway) which has been envisaged for STREAM.
- The TVR and the TRANSLOHR can both run on a single wire light electric supply of the tramways type as the return current travels via the guiding rail,
- The CIVIS uses electric wheel motor, which means an integral low floor between the wheels,
- The STREAM power system consists of an electric contact line embedded in a roadway which has been adapted for urban purposes as voltage is only achieved beneath the vehicle.

Bus: vehicles operating individually with rubber tires, with manual lateral and longitudinal control

Key decisions:

Vehicles size: minibus (20 passengers)
up to bi-articulated (165+ passengers)

Vehicle design: high floor or low floor

Right-of-way: all options are available

Guidance: is guided operation appropriate
at some locations?

Propulsion: all options available

Fare payment: on-vehicle or off-vehicle

Light Rail: vehicles operating individually or in short trains with electric motors and overhead power collector, steel wheel on steel rail with manual or automatic longitudinal control

Key decisions:

Vehicle design: high floor or low floor, articulated or rigid body

Right-of-way: all options available

Operating arrangements: automated or manually driven

Heavy Rail/Metro: vehicles operating in trains with electric motors on fully separated rights-of-way with manual signal or automatic longitudinal control; level boarding, off-vehicle fare payment

Key decisions:

Train length: affects station cost

Right-of-way: at-grade, elevated, or tunnel

Station spacing

Operating arrangements: degree of automation

Commuter Rail: vehicles operating in trains with long station spacing, serving long trips into central city, large imbalance between peak hour and other period ridership.

Example: KTM

Traditional Transit Services

- Bus on shared right-of-way
- Streetcar on shared right-of-way
- Heavy rail on exclusive right-of-way
- Commuter/Regional rail on semi-exclusive right-of-way

New/Recent Service Concepts

- Bus Rapid Transit
- Light Rail on exclusive right-of-way

Increasing Diversity

- Driver arrangements: part-timers, 10-hour days, pay by vehicle type
- Routing and scheduling: fixed, flexible, advance booking
- Vehicle types: minibuses, articulated buses and railcars, bi-level railcars, low-floor
- Control options: fixed block, moving block, manual, ATO, ATC
- Priority options: full grade separation, semi-exclusive right-of-way, signal pre-emption
- Dual mode operations: bus, light rail

What is Bus Rapid Transit?

BRT systems have some or all of the following elements; many of these also can make a valuable contribution to improving regular bus service:

- Dedicated bus corridors with strong physical separation from other traffic lanes.

- Modern bus stops that are more like bus "stations", with pre-board ticketing and comfortable waiting areas.

- Multi-door buses that "dock" with bus stations to allow rapid boarding and alighting.
- Large, high capacity, comfortable buses, preferably low-emission.

- Differentiated services such as local and express buses.

- Bus prioritization at intersections either as signal priority or physical avoidance (e.g., underpasses).

BRT SYSTEM

- Add passing lane and multiple stop bays to increase capacity
- Passing lane required only at station
- Bus start to queue if bus stop time at stop bay more than 40% i.e. 1440 sec in a hour
- Operational capacity = (Nsb*1440) / ((To/Bc)+(Ren*T1))
- Nsb = Number of stop bays
- To = Bus dwell time
- Bc = Bus capacity
- Ren = Bus stop boarding ratio (% of all passengers)
- T1 = average boarding time per passenger

Rail advantages:

- High capacity
- Lower operating costs
- Better service quality
- Stronger land use influence
- Fewer negative externalitites

Bus advantages:

- Low capital costs
- Wide network coverage
- Single vehicle trips
- Flexibility
- “Dual mode” nature

Quito BRT underpass

Thank You