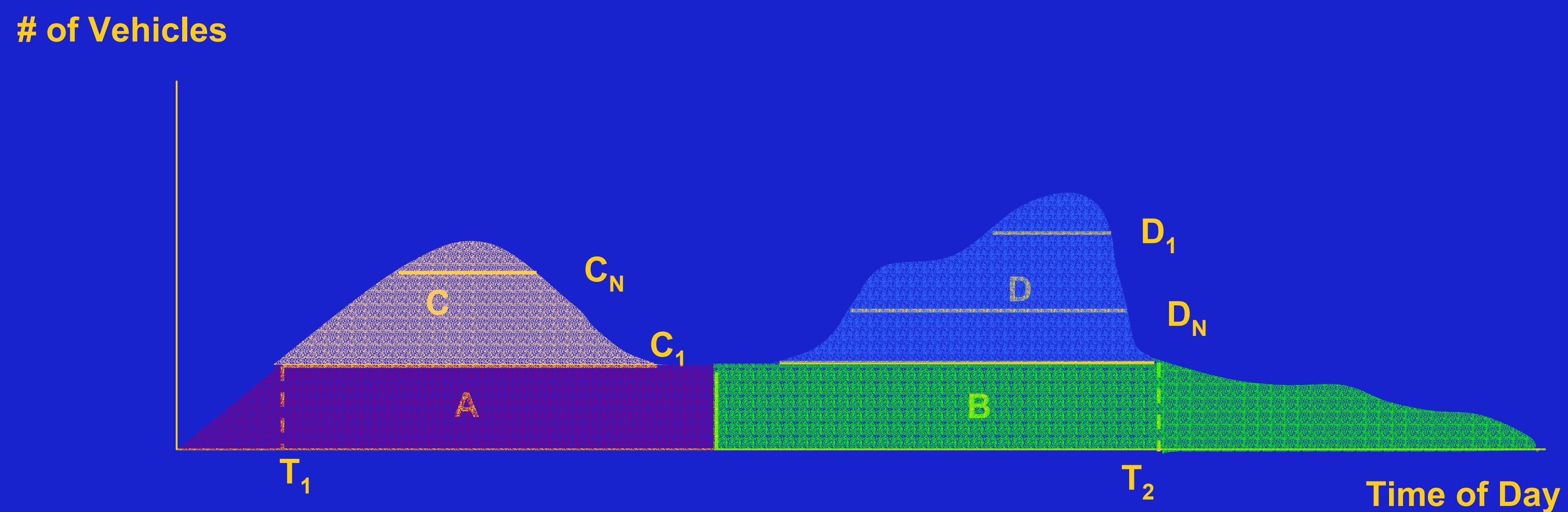
Transit Crew Scheduling and Corridor Analysis

Outline

- Crew Scheduling (wrap-up)
- Express
- Local
- Deadhead

Crew Scheduling: Manual Techniques



T_1 is earliest AM pullout which can still serve PM peak

T_2 is latest PM pullback which can still serve AM peak

A are AM straights (or short split runs)

B are PM straights (or short split runs)

C and D are long split runs

Typical Sequence

1. Based on total vehicle hours estimate total operators required
2. Determine # operators required in AM and PM peaks
3. Determine B based on # of pull-ins after time T_2.
4. Determine # split runs
   (# of PM Peak Vehicles - B)
5. Determine A based on
   # of AM Peak Vehicles - split runs
6. Combine earliest pullouts in C with earliest pull-ins in D to produce minimum spread splut runs C_1D_1. Iterate until all split runs are matched C_ND_N.

Example

Time Period	# Vehicles	Period Length	# Vehicle Hours
AM Peak	8	3	24 →AM duties = 4
Base	4	6	24
PM Peak	8	3	24 →split duties = 4
Evening	4	6	<u>24</u> →PM duties = 4
			96, or 12 FTOs

Experience with Automated Crew Scheduling Systems

- Virtually universally used in medium and large operators world-wide
- Two most widely used commercial packages are HASTUS (by GIRO Inc in Montreal) and Trapeze (by Trapeze Inc in Toronto), each with over 200 customers world-wide
- Typical cost ranges from $100K to $2 mill for the software
- Benefits of automated scheduling are:
  - scheduling process time reductions
  - improved accuracy
  - modest improvements in efficiency (typically 0-2%)
  - provides a key database for many other IT applications

Experience with Automated Crew Scheduling Systems

- Evolution of software has been from “black box” optimization/heuristics to highly interactive and graphical tools
- Current systems allow much greater ability to “shape” the solution to the needs of specific agencies
- One implication however is a profusion of these “soft” parameters which means greater complexity and it is very hard to get full value out of systems.

Selection of Minimum Cost Set of Runs

- Usually built around mathematical programming formulation

Problem Statement:

Given a set of *m* trips and a set of *n* feasible driver runs, find a sub-set of the *n* runs which cover all trips at minimum cost

Mathematical Model for Crew Scheduling Problem

A. Basic Model: Set Partitioning Problem

Notation:

- P = set of trips to be covered
- R = set of feasible runs
- c_j = cost of run j
- δ_i^j = binary parameter, if 1 means that trip i is included in run j, 0 o.w.
- x_j = binary decision variable, if 1 means run j is selected, 0 o.w.

$$\text{Min} \quad \sum_{j \in R} c_j x_j$$

$$\text{Subject to:} \quad \sum_{j \in R} x_j \delta_i^j = 1 \qquad \forall i \in P$$

$$x_j \in \{0,1\}, \qquad \forall j \in R$$

Mathematical Model for Crew Scheduling Problem

Problem size:

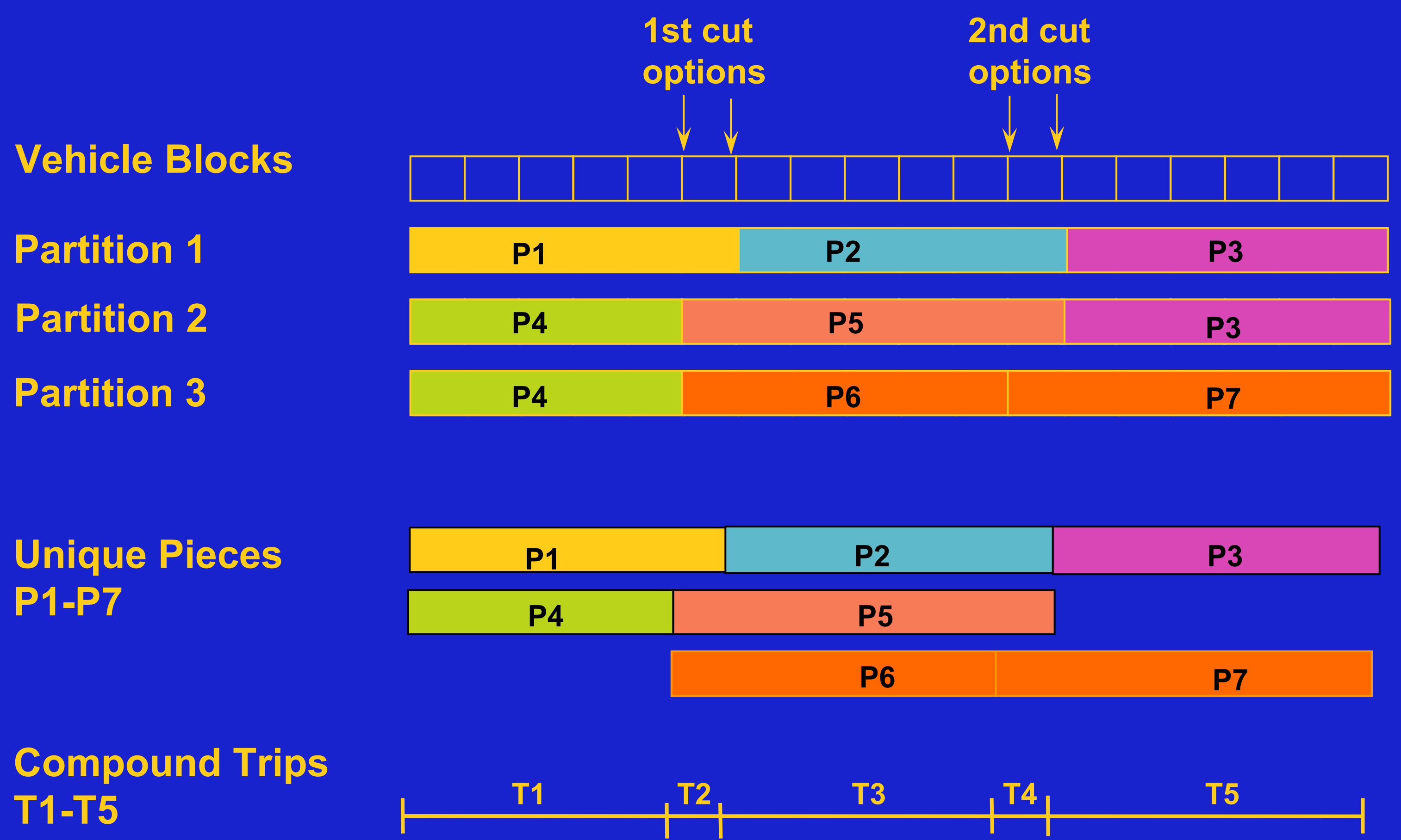
R decision variables (likely to be in millions)

P constraints (likely to be in thousands)

Problem size reduction strategy:

- replace individual trips with compound trips consisting of a sequence of vehicle trips which will always be served by a single crew.

Partitions of Vehicle Block, Pieces of Work and Compound Trip



May reduce the # of constraints but by less than one order of magnitude

Variations of Set Partitioning Problem

1. Set R consists of all feasible runs given all feasible partitions for all vehicle blocks
   - size of model, specifically # of columns, explodes with problem size
   - only possible for small problems
2. Set R consists of a subset of all feasible runs
   - not guaranteed to find an optimal solution
   - effectiveness will depend on quantity and quality of runs included
3. Column generation based on starting with a subset of runs and generating additional runs which will improve the solution as part of the model solution process.

Model with Side Constraints

Often the number (or mix) of crew types is constrained in various ways which can be formulated as side constraints

Example: Suppose total tripper hours are constrained to be less than 25% of timetable time.

Let:

Let:	WT	=	**total timetable time**
	R^T	=	**set of tripper runs**
	t_j	=	**work time for tripper run *j***

Then the additional constraint is:

$$\sum_{j \in R^T} t_i x_i \leq 0.25\, WT$$

Corridor Design Objectives

1. To reduce cost for providing existing level of service, or
2. To improve the level of service without increasing resources

Operational Objectives:

- Increase the operating speed
- Reduce the vehicle miles of service
- Reduce unnecessary slack time at terminals
- Maintain high, uniform vehicle loadings on all segments

Issues are:

Service Quality Impacts:

- Changes in wait time, walk distance, and need to transfer

Ridership Changes:

- What ridership changes will result from level of service impacts?

Strategies

A. Express Service

- -- Downtown orientation
- -- Zonal Express
- -- Limited Stops on Express Segment

B. Local Service

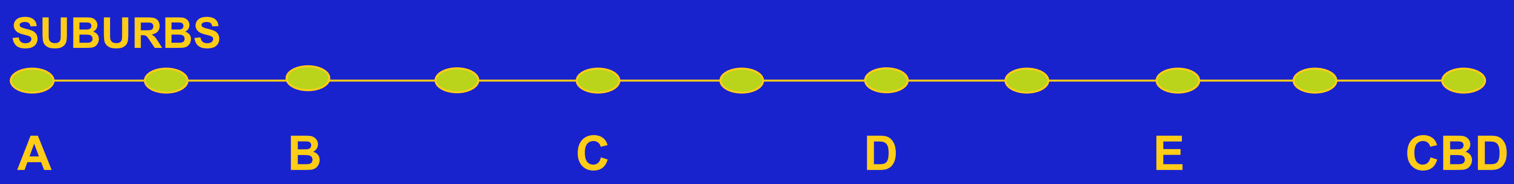
- -- Short Turns/Lines
- -- Restricted Zonal
- -- Semi-Restricted Zonal
- -- Limited Stop Zonal

C. Light Direction Strategies

- -- Complete Deadheading
- -- Partial Deadheading

Local and Express Service Symbols and Example Schedules

1. <u>Local Service, Route 1</u>

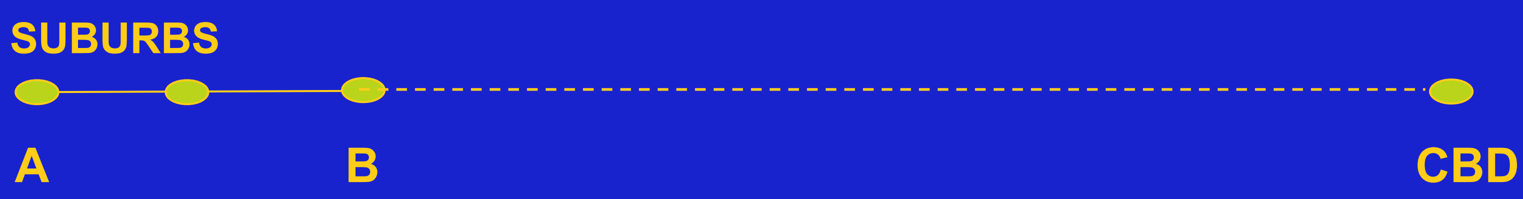


SCHEDULE Route 1

A	B	C	D	E	CBD
7:00 A.M.	7:08	7:15	7:25	7:32	7:45
7:10	7:18	7:25	7:35	7:42	7:55
7:20	7:28	7:35	7:45	7:52	8:05
7:30	7:38	7:45	7:55	8:02	8:15
7:40	7:48	7:55	8:05	8:12	8:25
7:50	7:58	8:05	8:15	8:22	8:35
8:00	8:08	8:15	8:25	8:32	8:45

Local and Express Service Symbols and Example Schedules (cont'd)

1. <u>Express Service, Route 1E</u>



SCHEDULE Route 1E					
A	B	C	D	E	CBD
7:10 A.M.	7:18	----	----	----	7:35
7:30	7:38	----	----	----	7:55
7:45	7:53	----	----	----	8:10
8:00	8:08	----	----	----	8:25
8:15	8:23	----	----	----	8:40
8:30	8:38	----	----	----	8:55

Issues In Designing Express Services

Downtown Routing: Minimize time on local streets

Adding Stops to Express Portions: Minimize impact on capacity and running time

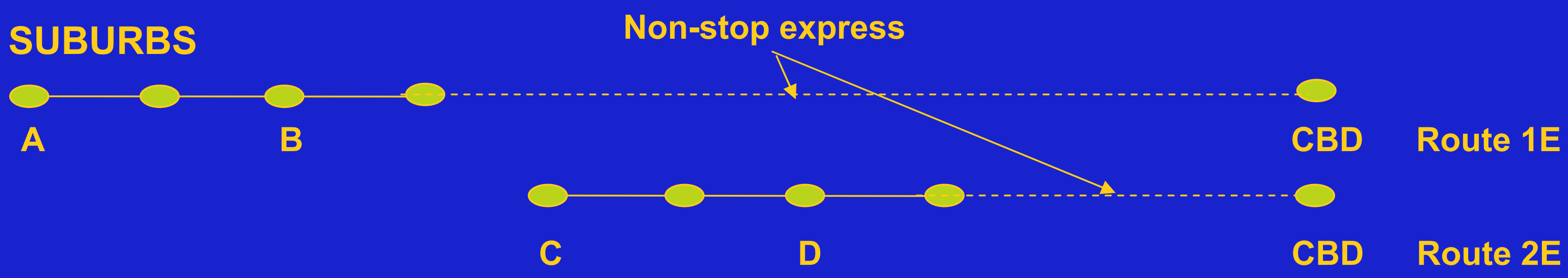
Reverse Commuting: Maximize potential for reverse commuting traffic

Fares: What fare premium is appropriate?

Local Service Interaction:

- Is parallel local service viable?
- Is express time advantage sufficient to attract (almost) all downtown riders?

Zonal Express Service

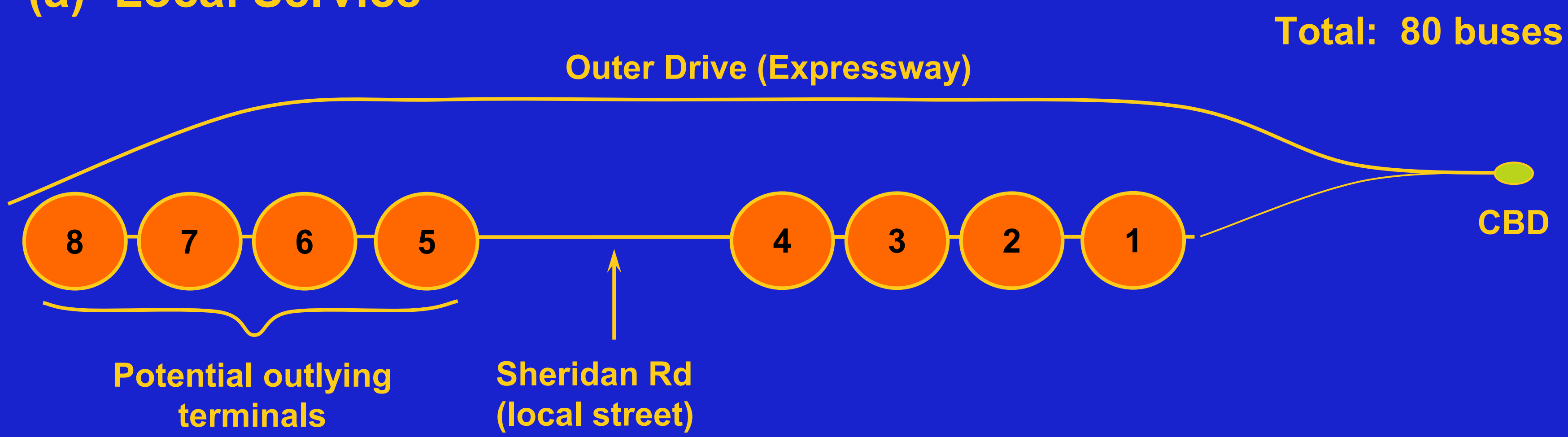


SCHEDULE - Route 1E					
A	B	C	D	E	CBD
7:00 A.M.	7:08	----	----	----	7:32
7:20	7:28	----	----	----	7:52
7:40	7:48	----	----	----	8:12
8:00	8:08	----	----	----	8:32

SCHEDULE - Route 2E					
A	B	C	D	E	CBD
----	----	7:05	7:13	----	7:45
----	----	7:20	7:28	----	7:45
----	----	7:35	7:43	----	8:00
----	----	7:50	7:58	----	8:15
----	----	8:05	8:13	----	8:30

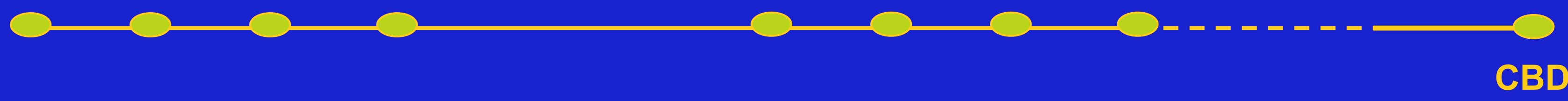
Zonal Express Service in the Sheridan Road corridor (simplified)

(a) Local Service

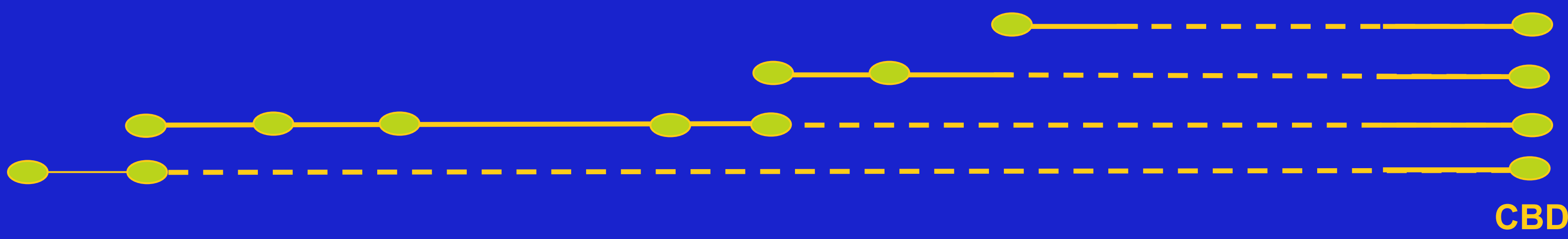


Zonal Express Service in the Sheridan Road corridor (simplified)

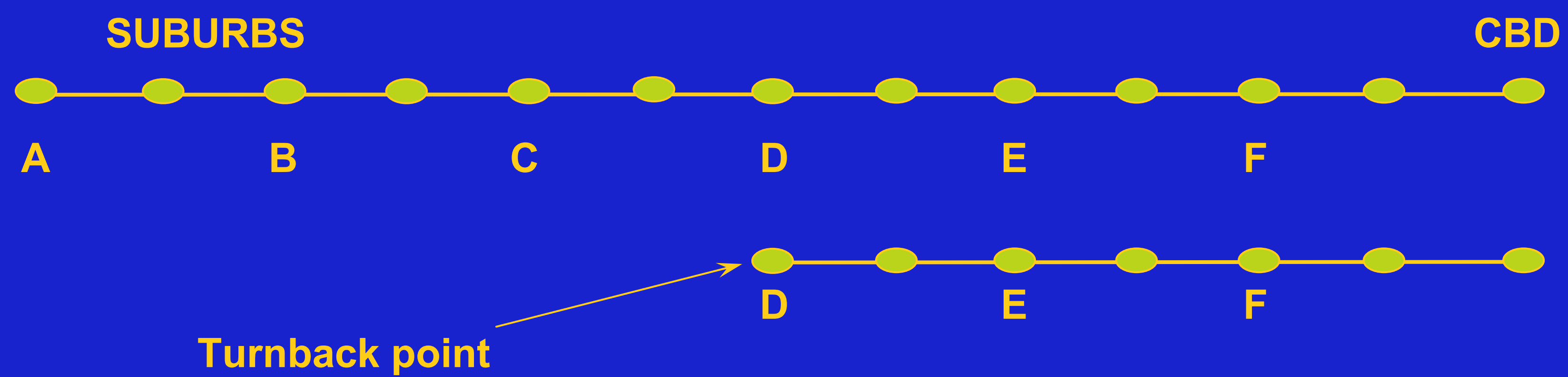
(b) Conventional Express Service — Total: 72 buses



(c) Zonal Express Service — Total: 47 buses



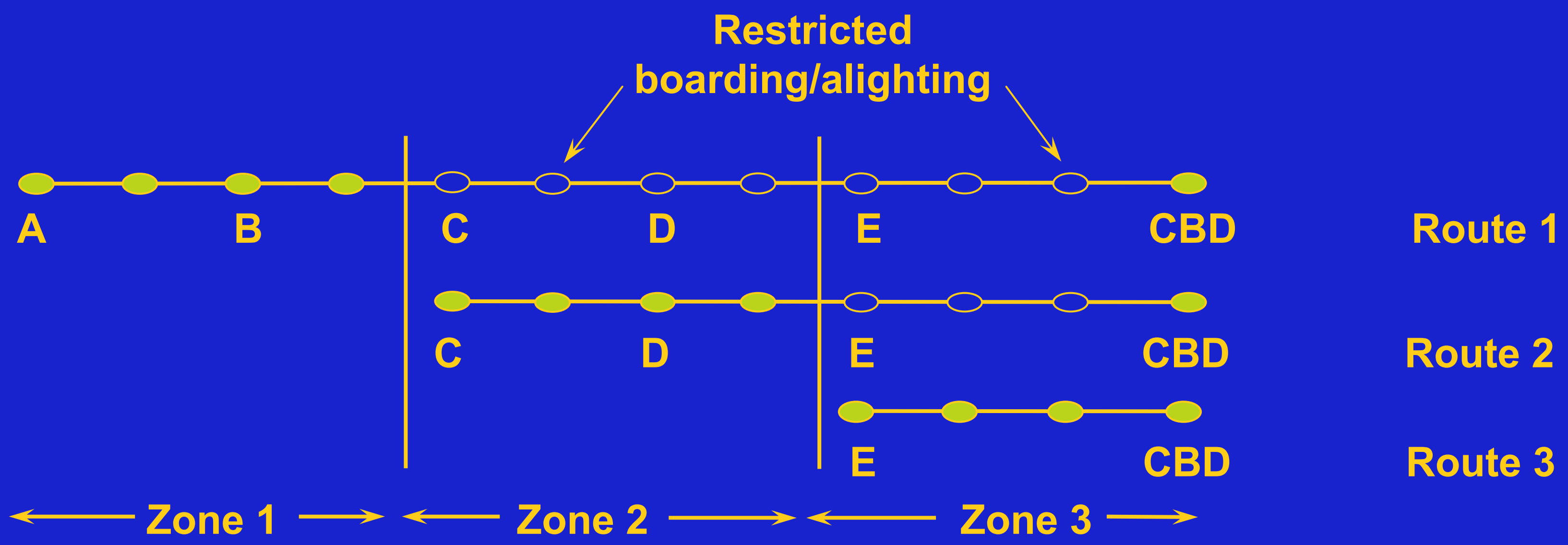
Short-Turning Local Service



SCHEDULE - Inbound

A	B	C	D	E	F	CBD
7:00 A.M.	7:08	7:15	7:18	7:25	7:32	7:45
			7:25	7:32	7:39	7:52
7:15	7:23	7:30	7:33	7:40	7:47	8:00
			7:40	7:47	7:54	8:07
7:30	7:38	7:45	7:48	7:55	8:02	8:15
			7:55	8:02	8:09	8:22

Restricted Zonal Local Service



- Inbound buses do not stop except to let passengers alight; boarding prohibited. Outbound buses do not stop except to let passengers board; alighting prohibited.

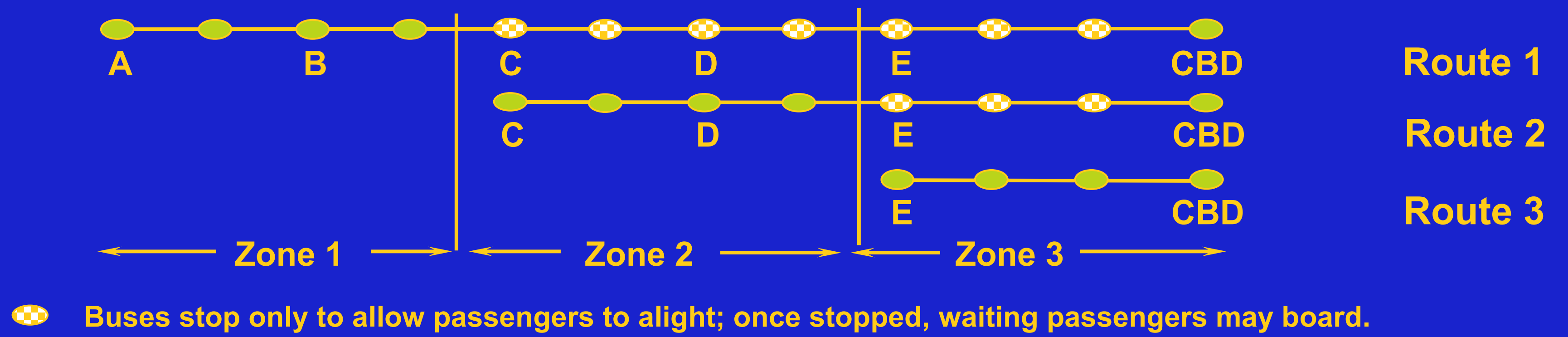
Restricted Zonal Local Service

SCHEDULE - Route 1					
A	B	C	D	E	CBD
7:00	7:08	(7:15)*	(7:24)	(7:30)	7:42
7:15	7:23	(7:30)	(7:39)	(7:45)	7:57
7:30	7:38	(7:45)	(7:54)	(8:00)	8:12

SCHEDULE - Route 2					
A	B	C	D	E	CBD
		7:10	7:20	(7:27)*	7:39
		7:22	7:32	(7:39)	7:51
		7:34	7:44	(7:51)	8:03

SCHEDULE - Route 3					
A	B	C	D	E	CBD
				7:25	7:39
				7:35	7:49
				7:45	8:59

Semi-Restricted Zonal Local Service
(Inbound only)

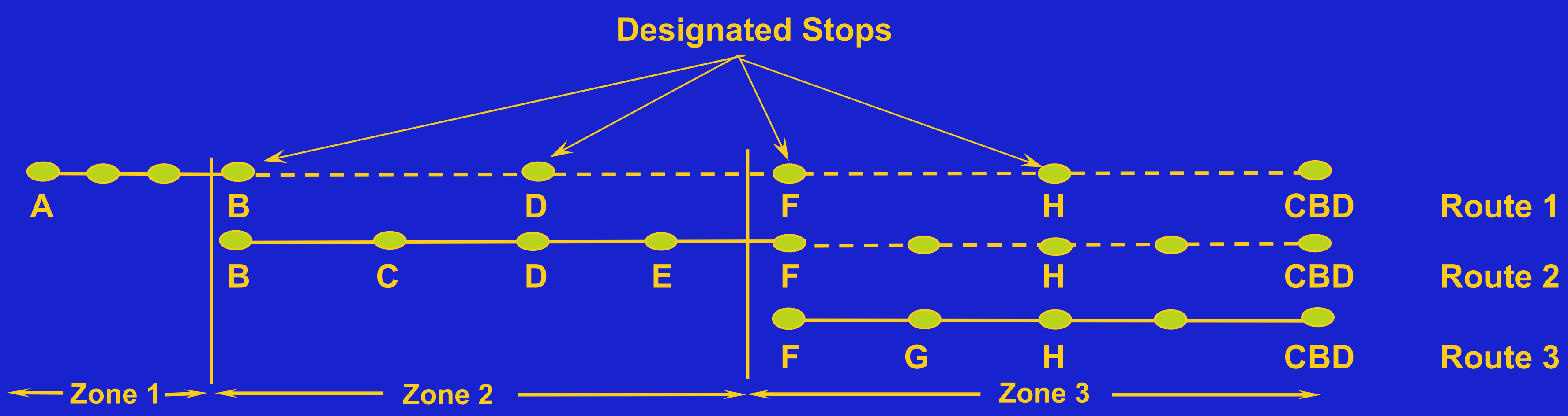


SCHEDULE - Inbound

A	B	C	D	E	CBD	
				7:25	7:39	Route 3
		7:10	7:20	(7:27)*	7:39	Route 2
7:00	7:08	(7:15)*	(7:24)	(7:30)*	7:42	Route 1
				7:35	7:49	Route 3
		7:22	7:32	(7:39)*	7:51	Route 2
7:15	7:23	(7:30)*	(7:39)*	(7:45)*	7:57	Route 1
				7:45	8:59	Route 3
		7:34	7:44	(7:51)*	8:03	Route 2
				7:55	8:09	Route 3
7:30	7:38	(7:45)	(7:54)	(8:00)*	8:12	Route 1

* ( ) means on-board passengers may alight; waiting passengers may board only if bus stops to let someone alight.

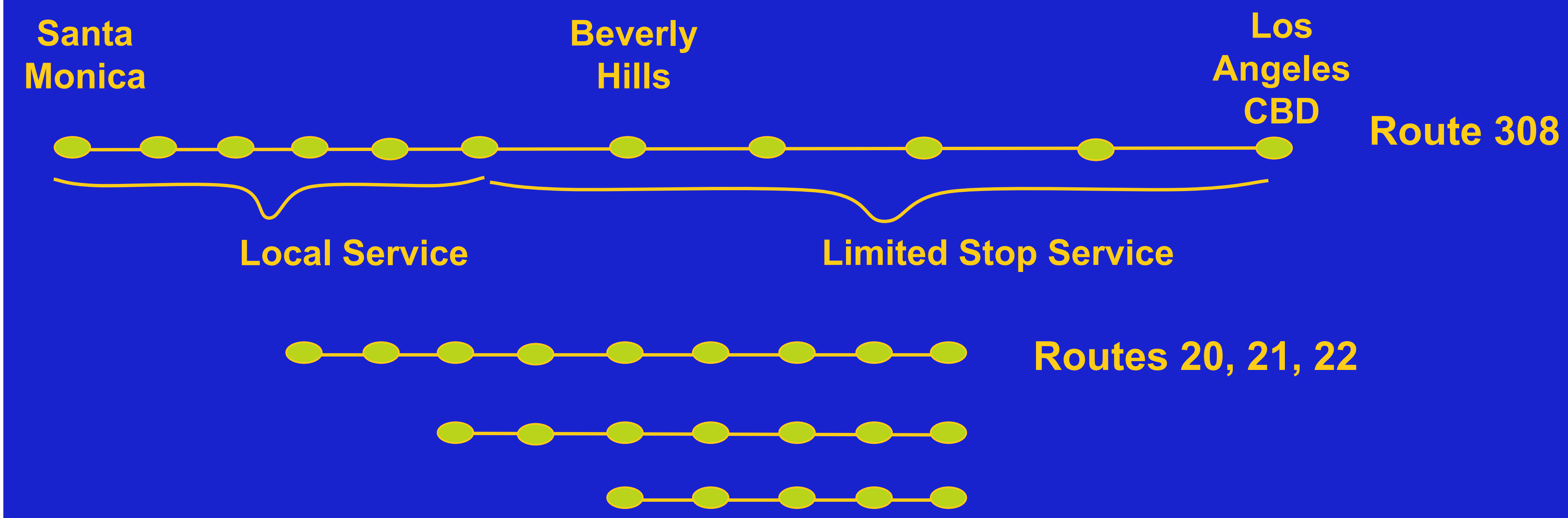
Limited-Stop Zonal Local Service



SCHEDULE - Inbound

A	B	C	D	E	F	G	H	I	CBD	
7:00 AM	7:12	-----	7:19	-----	7:26	-----	7:33	-----	7:40	Route 1
	7:13	7:17	7:22	7:27	7:31	-----	7:38	-----	7:45	Route 2
					7:30	7:35	7:40	7:45	7:50	Route 3
7:15	7:27	-----	7:34	-----	7:41	-----	7:48	-----	7:55	Route 1
	7:28	7:32	7:37	7:42	7:46	-----	7:53	-----	8:00	Route 2
					7:45	7:50	7:55	8:00	8:05	Route 3

Bus Service in Wilshire Boulevard Corridor



Deadheading Strategies

A. Deadhead all vehicles on route:

Possible with one (or more) routes of short turn or zonal route system

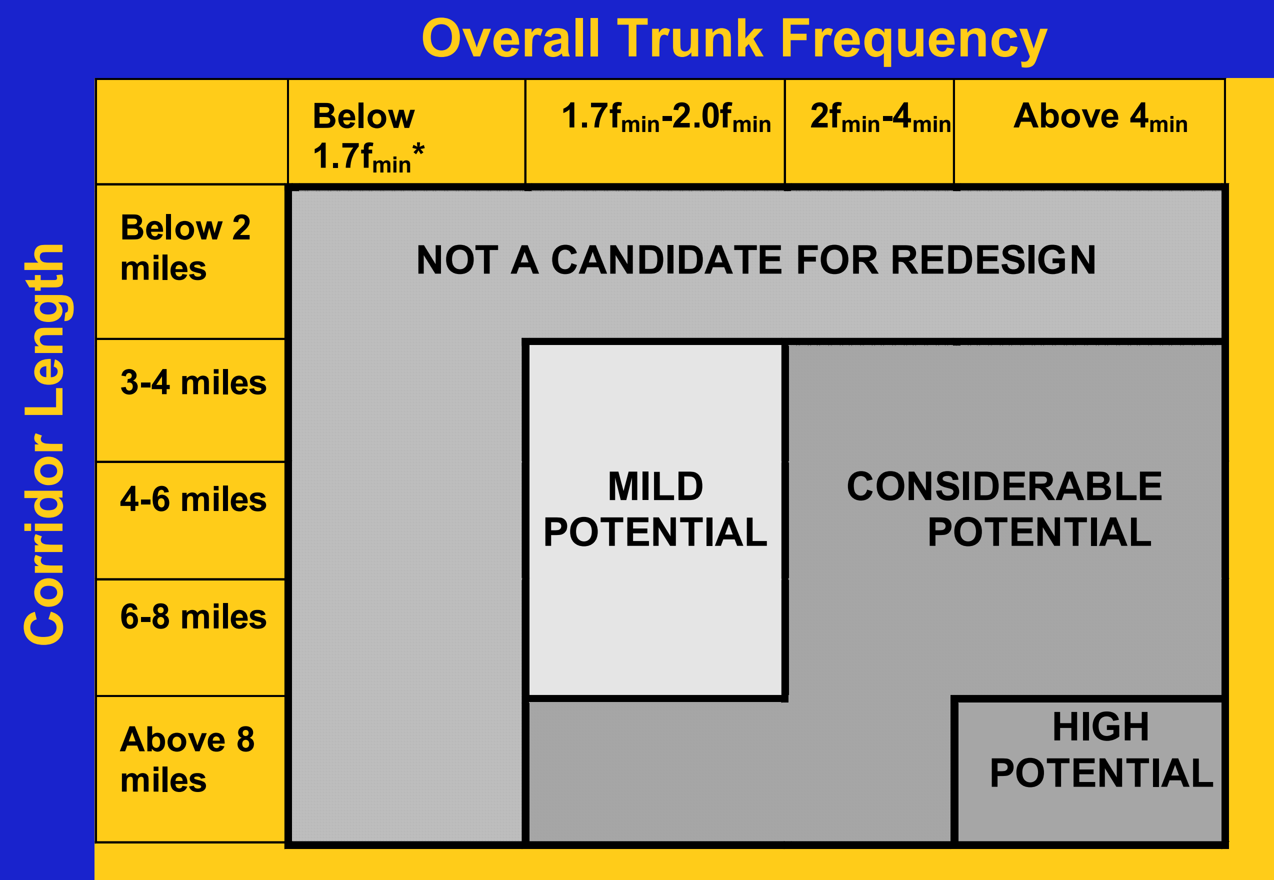
B. Deadhead some vehicles on route:

Deadhead every other bus (or 2 out of every 3) with remainder in service

<u>Issues:</u>

1. Can a vehicle be saved by deadheading?
2. Will there be adverse public reaction?

Key Factors in Determining the Potential Benefit of Route Redesign of a Corridor



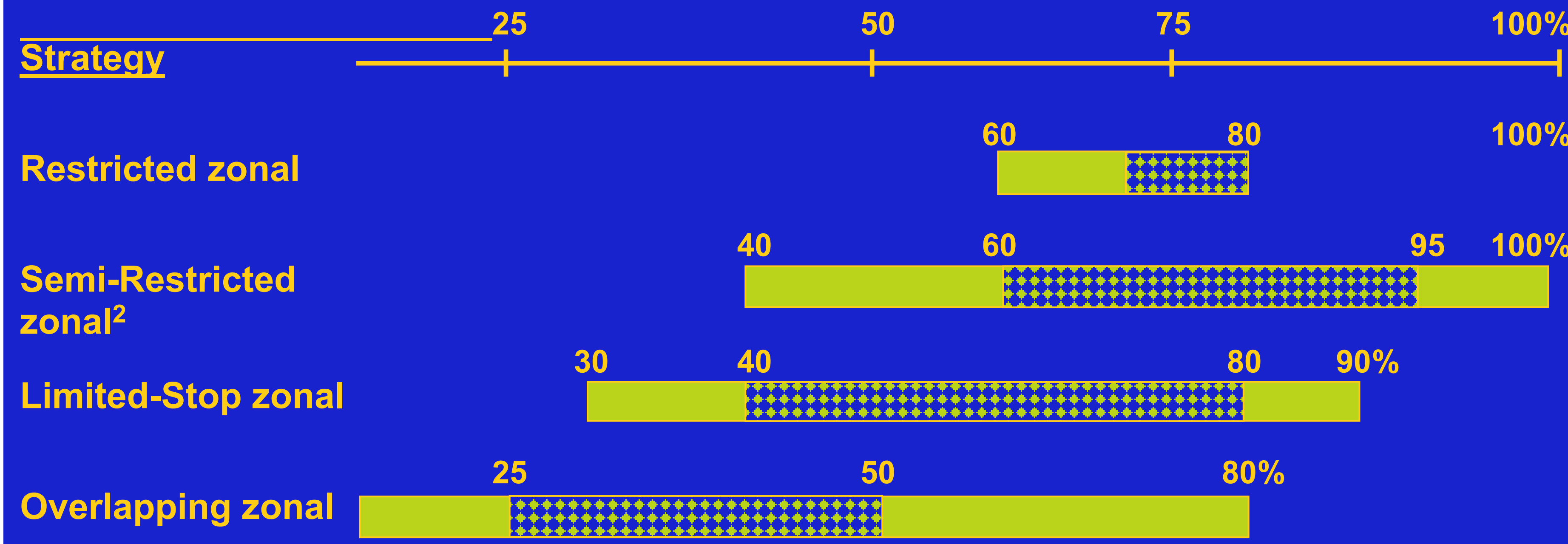
*f_{min} = minimum acceptable frequency for a peak period radial route

Advantages and Disadvantages of Local Service Operating Strategies

	Short-Turn	Restricted Zonal	Semi-Restricted Zonal	Limited-Stop Zonal
Need for schedule coordination and strict adherence	valuable in a.m. vital in p.m.	none	none	unnecessary in a.m. valuable in p.m.
Reliance on overtaking	none	strong	moderate	strong
Wait time impact*	up by 90% in outer segment, by 20% in inner segment	up by 90% throughout	up by 90% in outer segment, by 20% in inner segment	up by 90% in outer segment, by 20% in inner segment
In-vehicle time reduction	none	considerable	moderate	considerable
Walk-distance impact*	none	none	none	up by 0.2 mi. for some outer segment passengers
Difficulty in public comprehension	little	considerable	considerable	moderate
Most favorable conditions for vehicle savings:				
Corridor length	short	long	any	long
Fraction of local (non-CBD) travel	moderate to high	small	moderate	moderate to high
Outer segment volume	low	low	low	any

* Average impact to peak direction travelers in typical application

Strategies Best Suited to Different Ratios of Peak Volume to Uptown Boardings[1]



Legend

- range in which strategy can be effectively operated
- range in which strategy is likely to be most promising

1 For inbound direction. When the peak direction is outbound, use the ratio of peak volume to uptown alightings (PV/UA). The same figures apply.

2 Can be operated inbound only.

Effect of Corridor Length on Choice of Local Operating Strategy

Strategy	4 mi. or less	4-6 mi.	6-9 mi.	9 mi. or more
Restricted Zonal	😐	😐	😀	🙂
Semi- Restricted Zonal	😐	😐	🙂	🙂
Limited-Stop Zonal	☹	😐	🙂	😀
Overlapping Local	😐	😐	☹	☹
Skip-Stop	☹	😐	🙂	😀

Legend

☹ discourages use of strategy

😐 neutral

🙂 encourages use of strategy

😀 strongly encourages use of strategy