TRANSIT SCHEDULING: ADVANCED MANUAL

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CHAPTER 1

SERVICE POLICIES AND SCHEDULE DEVELOPMENT

Advanced Section

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I. Introduction

Responsive schedule making is a dynamic process, evolving along with the ridership trends, service demands and funding opportunities of the community. As ridership patterns change, schedulers are often faced with the complex task of making adjustments to schedules while keeping costs as low as possible. Sound decisions necessarily require timely and accurate information. Historically, a number of methods have been utilized to provide this information, taking advantage of a wide variety of data collection and analysis techniques.

Many of the elements of scheduling and schedule adjustments can be performed with the assistance of commercially available automated scheduling software. Some systems have customized software for specific scheduling applications. Even general spreadsheet and database software can provide a valuable resource for schedulers, in particular, for keeping track of data, evaluating alternative approaches and producing scheduling forms. The "metaphors" or guiding theories behind scheduling software design, input to output, is typically consistent with the principles covered in the manual approach.

II. Types of Data

Using various kinds of transit operating data is a fundamental part of effective schedule making. Two types of data are particularly important for making efficient and effective schedules. They are as follows:

> **Passenger traffic data** provides information about ridership volumes and distribution necessary to support decisions about route design and service level issues. Primary passenger traffic information sources include boardings and alightings by vehicle stop, maximum load data collected at high volume points along each route and individual trip counts collected by bus operators, on-board checkers or on-board automatic passenger counters (APCs).
>
> **Vehicle running time data** provides information needed to determine route cycle time, create timed transfers and ensure schedule reliability. Primary running time information sources include scheduled running times, schedule adherence checks, automated vehicle location (AVL) system data, vehicle stop inventory information, and extended dwell time requirements (e.g., time allotted to board wheelchair users, provide for mid-route timed transfers to other routes, and so forth).

A. Passenger traffic data

Sources for passenger traffic data vary from system to system. Examples of typical passenger traffic data collected are 1) Boardings/Alightings by Stop, 2) Maximum Load Points and 3) Trip Counts.

1) Boardings/alightings by stop

Extremely useful to the schedule maker is knowing where and how many passengers board, alight or ride past particular stops or segments on a route. These data are generally collected with *ride checks*. Ride checks involve the systematic placement of people, called checkers, on revenue vehicles. Checkers record information on stop location, number of passengers boarding and alighting, number of passengers on the vehicle as it departs each stop and schedule adherence. Checkers often remain on a particular vehicle for an entire set of trips. Ride check information can be recorded manually or electronically.

Manual ride check information may be recorded on a form similar to the one shown below. The information on the form may then be entered into a computer spreadsheet or database program which allows the scheduler to summarize the data by direction, time period, route segment, individual trip or total route.

Checkers may also enter their data into small programmable calculators or palmtop computers. Other systems use APCs which consist of infrared or pressure sensors at the bus door(s). These sensors, used in conjunction with vehicle locator systems, automatically record boarding and alighting information which can be subsequently linked to location. Data are then downloaded into system computers for further analysis and report generation.

In either case, the ability to access and evaluate the data allows the scheduler much greater flexibility in maintaining system efficiency. For example, when ridership is low on a particular route, the scheduler may investigate the possibility of adjusting spacing between trips, adding or removing vehicles from the line and short-turning trips to adjust service to meet the demand over the length of the route.

POINT CHECK FORM

Day: Monday Date: 10/12/xx Weather: Clear & Sunny, 72°

Route: 32 Traffic: Light

Direction: Westbound Vehicle #: 8501

Scheduled Trip Start Time: 6:26a Scheduled Trip End Time: 7:04a

Actual Trip Start Time: ________ Actual Trip End Time: ________

	Stop		Passengers On	Off	Lob*	Time Scheduled	Actual	Variance
1.	Comanche @	Big Sky	6	0	6	6:26a	6:27a	-1
2.		El Rio	2	0	8		6:27	
3.		Portola	5	0	13		6:27	
4.		Louisiana	2	0	15		6:28	
5.		Davis	3	0	18		6:29	
6.		Alta	1	1	18		6:31	
7.		Cordoba	4	0	22		6:32	
8.		Denali	6	0	28		6:34	
9.	Comanche @	Wyoming	2	12	18	6:35	6:35	0

* Left on Board

Example of a partially completed ride check data collection form

2) Maximum load points (MLPs)

Passenger loading, departing and left-on-board (LOB) data provides a relationship between passenger loads and location. The location(s) where the number of passengers is greatest is called the maximum load point (MLP).

Once the MLP for a route has been determined by a ride check, the ongoing verification of that stop (and the number of passengers on board at that stop) can be confirmed with a *point check* (also called load checks) taken at the MLP. Point checks differ from ride checks because the checker is stationary at the location and not a rider on the revenue vehicle.

Note: Point checks can be used to monitor service at any important or active location along a route. Often, point checks are conducted at locations where routes overlap or intersect. This way, one checker can record data for more than one route. The point check data are often recorded on a form similar to the one shown below.

POINT CHECK FORM

Day: Monday
Road Surface: Clear
Date: April 1, XXXX
Traffic: Moderate
Direction: Westbound
Location: 4GR-4th @ Griegos
Type: Arriving _____ Leaving ______

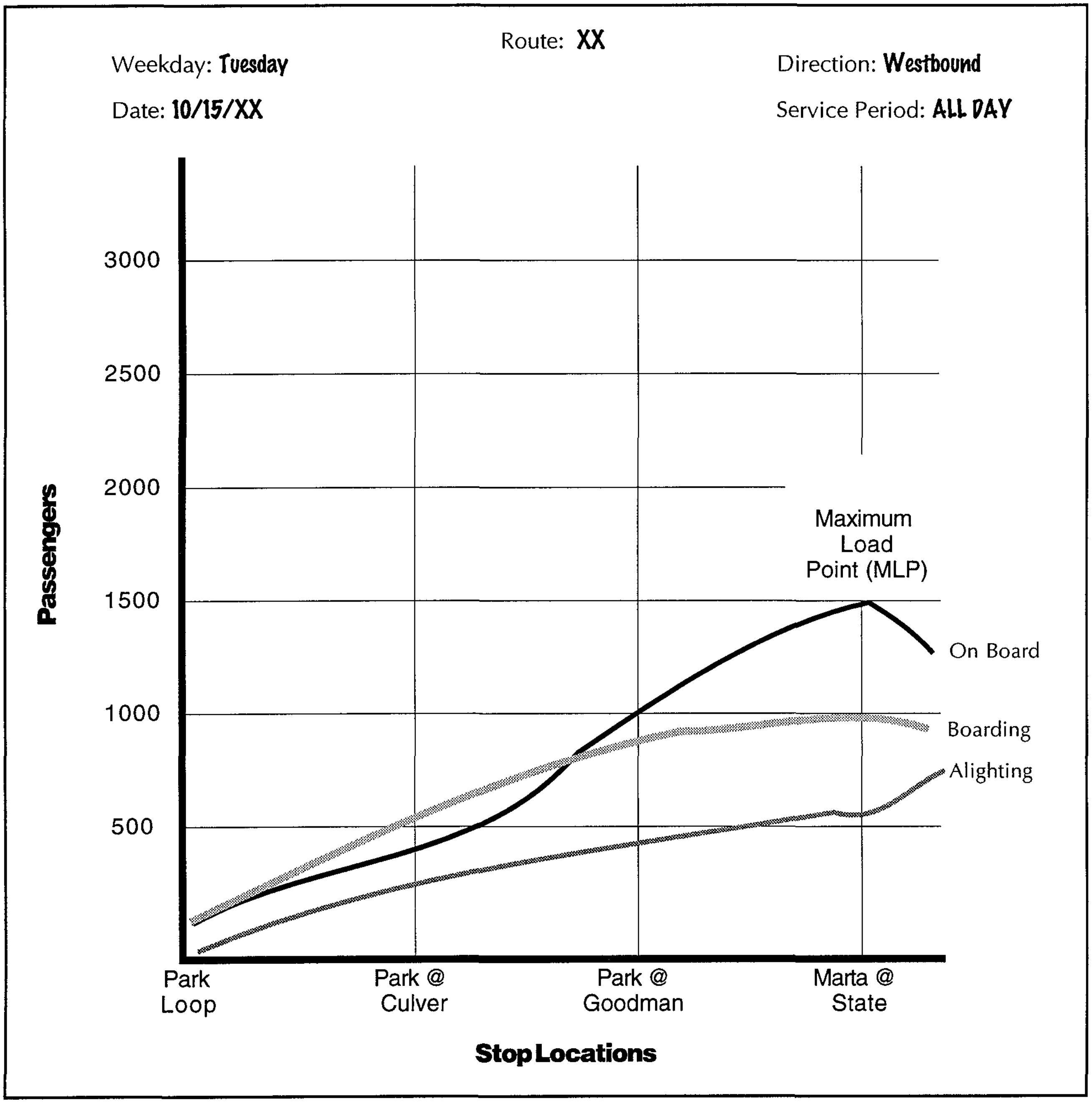
		Passengers	Time		
Route	Vehicle #	On Board	Scheduled	Actual	Variance
14	8005	38	6:15a	6:18a	-3
20	7656	51	6:30	6:32	-2
30	8063	25	6:40	6:44	-4
14	8021	44	6:45	6:45	0
32	8014	16	6:55	6:53	+2
20	7609	21	7:00	7:08	-8

Example of a point check form

In the example shown above, a negative variance is noted when a revenue vehicle passes the check location late (6:15a scheduled vs. 6:18a actual, recorded as -3). A positive variance is recorded when a revenue vehicle passes the check point early (6:55a vs. 6:53a, recorded as +2). Some systems will note the reverse, i.e., a positive variance when a vehicle passes late and a negative variance when a vehicle passes early.

Boarding/alighting data may also be arranged graphically into a **route profile diagram** (as shown on the next page). The route profile is a graph that shows the accumulated load (total number of passengers on board) at any point along the route on a single trip, multiple trips, a time period or all day. It may also display total boardings and alightings at each stop. The boardings and alightings data allow identification of individual stops with significant passenger activity.

The highest point on the graph represents the MLP. Some routes may have more than one MLP.



Example of a route profile diagram

3) Passenger trip counts

Passenger trip counts are the total passenger boardings on each one-way trip. Depending on how the information is collected, it may also show a distribution of passengers by fare type. It is the least specific form of passenger traffic data because it shows total boardings and not the distribution of passengers over the entire trip. It can, however, be a good indicator of possible overcrowding or underutilization of resources and is the simplest, most direct way to determine ridership growth trends on a particular route.

B. Vehicle running time data

1) Calculated running times

Calculated running times are used primarily when developing new routes or segments. In these cases, no actual running time history is usually available. Running times between nodes are developed in several steps, usually beginning with calculations based on average operating speed or data collected in an automobile check, which may be followed by simulated operation using an out-of-service vehicle or training vehicle. A "mileage wheel" may also be used to calculate distance. This hand-held device is run along a map of the route and factored with the map distance scale. Applying a speed factor yields route segment running time estimates.

2) Schedule adherence data

Schedule adherence data consists of comparisons between existing scheduled running times and actual running times measured through field checks. It is useful either to validate the accuracy of current schedules or to indicate fine tune adjustments that may be required due to changing traffic conditions, passenger loads or other factors. Schedule adherence data are usually collected by on-board (ride check) or roadside (point check) field checkers either manually or electronically. Another method involves the National Transit Database Collection (formerly called Section 15) random trip samples. The reliability of the data, however, increases with the number of incidences observed for each trip.

3) Automatic vehicle location (AVL) data

AVL data are available to scheduling personnel in some larger transit systems that have acquired reliable AVL technology. AVL technology is based on one of several locating techniques, including "global positioning" (GPS), "dead-reckoning" and "triangulation" or alternatively, on a network of wayside signpost transponders that communicate with on-board transmitters to estimate vehicle location and provide a corresponding time stamp. Running time data are stored temporarily in on-board computer memory and periodically downloaded or transmitted via radio to a site computer.

4) Vehicle stop inventory

A vehicle stop inventory is a reference document containing information such as the location of bus stops, the position of stops relative to intersections (near side - this side of intersection, far side - across the intersection, or mid-block), the distance between stops, the routes that serve that stop, and a list of street "furniture" (shelters, benches, signs, etc.). The number and location of vehicle stops along the route directly affects the amount of running time needed to travel from one time point to another. Often, the following guidelines are used to estimate the number of stops on a given route segment.

- **Urban settings:** Locate six (6) to eight (8) stops per directional mile, or one every two (2) to three (3) city blocks.
- **Suburban settings:** Locate four (4) to six (6) stops per mile, depending on the availability of intersections, continuity of property development, availability of sidewalks, safe stopping locations and other relevant information.
- **Rural settings:** Posted stops may be infrequent. Flag stops often exist, whereby a passenger is able to signal the vehicle to stop at a location deemed safe for boarding.

5) Extended dwell requirements

Schedules may need to be adjusted to accommodate timed transfer locations, predicted use of a wheelchair lift or bicycle rack equipment, and other activities that may require the vehicle to dwell (stay) at a stop longer than usual.

III. Data Collection Techniques

A variety of collection techniques have been utilized to obtain passenger traffic and vehicle running time data. Many of these techniques allow the field checker to collect both types of information at once. Eight common techniques are presented below.

A. Calculated running time estimates

In cases where field service is proposed, running times are often estimated by projecting average operating speed or driving the proposed service via automobile. Reliability of the estimates can be made by simulating the new service alignment utilizing an out-of-service revenue or training vehicle. Checks can be made to determine if other service alignments overlap the area and running time files are available. Once new service has begun, monitoring running times for accurancy is a good idea to evaluate the accuracy of the original estimates.

B. Point checks

Point checks are an effective way to identify passenger loads and schedule adherence of transit vehicles passing a particular time point(s). The data collected are useful when considering changes in headways on relatively high frequency routes, reallocating running time between time points, or similar schedule fine tuning. The data may be recorded manually on forms or on hand-held data collection devices.

C. Ride checks

Ride checks provide passenger traffic data by stop and running time for an entire trip or set of trips. These data are collected by a checker who rides the vehicle and records passenger boardings and alightings at each stop, as well as on-time performance. The data may be recorded manually on forms or on hand-held programmable calculators.

D. National Transit Database (NTD) checks (formerly Section 15)

NTD checks are special ride checks designed to collect data on one-way trips which are selected at random to comply with Federal grant administration requirements. Although otherwise identical to ride checks, NTD checks are based on random sampling–statistically valid at the system level but not at the route or trip level. Therefore, this information is best used to supplement other data collection efforts.

E. Trail checks

Trail checks are usually conducted by supervisors or checkers in company vehicles that follow the revenue service vehicle in order to observe running times, passenger loading or related issues. The major benefit of a trail check is that the schedule maker or supervisor can observe actual conditions on the street without drawing conclusions from data alone. Trail checks are especially benefical for observing contingent issues such as bus stop conditions and pedestrian access.

F. Farebox and operator counts

Trip counts are collected either with registering fareboxes or denominator button counts taken by vehicle operators while in revenue service. These counts provide general information on passenger traffic, such as total passengers per trip and a distribution of passengers by fare type. In some systems, depending on work rules, operators may also conduct occasional or daily boarding counts.

G. Automated passenger counters and automated vehicle location

APCs, when included as a component of AVL systems, can provide comprehensive ride check and running time data faster than manual methods. APCs are often installed on a limited number of electronically equipped "data buses" that are moved throughout the system to collect data on specific routes, runs or blocks. APCs generally count passengers using either pulse beams mounted in the door stepwells or step treadles. APCs can be used without AVL, although the specific location of each stop and route segmentation can be difficult to ascertain.

H. Operator interviews

Although not always an accurate method of obtaining precise quantitative data, operator interviews are especially helpful for obtaining information necessary for proper schedule adjustment. Operators familiar with a route are a valuable source of information on route safety issues, locations where extended dwell requirements are called for, large volume passenger stops, and transfer needs.

IV. Using Data as a Diagnostic Tool

To maintain schedule reliability and service quality, every schedule, regardless of how well constructed, will require periodical fine tuning. It is generally considered good practice to revisit new or substantially revised schedules after 6 to 12 months of operation. Some schedules may require more timely attention. Cost considerations, passenger complaints and suggestions from operators and supervisors are factors that may prompt more immediate schedule analysis.

The most desirable way to understand how well a schedule is working is by analyzing ridership and running time data over as many days as practical and including personal observations in the field whenever possible. Multi-day analysis helps minimize the chance for improper schedule adjustments resulting from an evaluation based on an unusual event on that route.

A. Example schedule analysis using Route 32

Recap: Route 32 is a peak-only local bus route that operates a 30-minute headway. No midday service is provided. A ride check is conducted to determine ridership and running time on all 18 westbound and 16 eastbound trips. This is done by ride checkers on each of the three A.M. and three P.M. blocks. The data are collected on ride check forms (see earlier example), then transferred into an electronic spreadsheet (see following example of a partially completed summary spreadsheet).

Route 32 / Westbound

TRIP DEPARTS			**6:26a**					**6:56a**						
Stop	Sched	Actual	On	Off	LOB	Sched	Actual	On	Off	LOB	.	.	**Total**	
Comanche @ Big Sky	6:26a	**6:26**	2	0	2	6:56a	**6:57**	1	0	1				
El Rio			1	0	3			1	0	2				
Portola			5	0	8			1	0	3				
Louisiana			1	0	9			3	0	3				
Davis			1	0	10			2	1	4				
Alta			0	1	9			1	0	5				
Cordoba			1	0	10			3	0	8				
Denali			2	0	12			3	0	11				
Wyoming			0	1	11			4	1	14				
Jones			4	2	13			2	0	16				
.														
.														
TOTAL			**37**	**37**	**0**			**26**	**26**	**0**			**192192**	**0**

Example ride check summary spreadsheet

1) Compiling and viewing ride check data

The primary reason to compile ride checks into a summary spreadsheet format is to be able to view, analyze and summarize the data in ways that produce a clear picture of passenger traffic volumes and distributions. The previous spreadsheet presented passenger traffic data and schedule variance by trip and summarized total boardings, alightings and LOBs. Viewing these data by **route segment** allows the scheduler to see

- Where maximum loads occur (LOB data).
- Whether the number of scheduled trips is appropriate for rider demand. (Does the average LOB exceed policy?)
- How passenger loading affects running time and on-time performance. (Does schedule variance increase at high passenger boardings or alightings?)

Viewing these data by **time period** allows the scheduler to see

- Whether the service span is adequate. (Do high passenger volumes exist at the beginning or end of a service period?)
- Whether headways are appropriate for ridership volumes at various hours of the day. (Does the average LOB exceed policy load standards?)

Average schedule variance is a useful method of organizing schedule adherence data collected over a number of days. It is the total number of minutes ahead or behind schedule divided by the number of trips checked. Average schedule variance is often used to analyze a time period, route segment or similarly defined set of trips.

Direction: Westbound
Time Period: A.M. Peak

Route Segment	Number of Trips	Passengers On	Passengers Off	Passengers LOB	Average Schedule Variance: Segment	Average Schedule Variance: Cumulative
1. CBS to COW	8	76	0	76	-1	-1
2. COW to CSM	8	52	23	105	-1	-2
3. CSM to COC	8	66	47	124	-2	-4
4. COC to 4GR	8	70	72	122	+1	-3
5. 4GR to RGM	8	8	130	0	0	-3
Total	8	272	272		-3	-3

Direction: Eastbound
Time Period: A.M. Peak

Route Segment	Number of Trips	Passengers On	Passengers Off	Passengers LOB	Average Schedule Variance: Segment	Average Schedule Variance: Cumulative
1. RGM to 4GR	8	41	5	36	0	0
2. 4GR to COC	8	28	9	55	0	0
3. COC to CSM	8	47	21	81	-2	-2
4. CSM to COW	8	23	27	77	-1	-3
5. COW to CBS	8	14	91	0	-1	-4
Total	8	153	153		-4	-4

Example schedule variance summary by route segment - Route 32 A.M. peak east- and westbound

Direction: Westbound
Time Period: P.M. Peak

	Route Segment	Number of Trips	Passengers On	Passengers Off	LOB	Average Schedule Variance Segment	Average Schedule Variance Cumulative
1.	CBS to COW	10	38	1	37	-1	-1
2.	COW to CSM	10	34	6	65	0	-1
3.	CSM to COC	10	50	39	76	-3	-4
4.	COC to 4GR	10	32	41	67	+1	-3
5.	4GR to RGM	10	15	82	0	-1	-4
	Total	10	169	169		-4	-4

Direction: Eastbound
Time Period: P.M. Peak

	Route Segment	Number of Trips	Passengers On	Passengers Off	LOB	Average Schedule Variance Segment	Average Schedule Variance Cumulative
1.	RGM to 4GR	8	161	15	146	0	0
2.	4GR to COC	8	67	30	183	-1	-1
3.	COC to CSM	8	48	52	179	-2	-3
4.	CSM to COW	8	16	105	90	0	-3
5.	COW to CBS	8	4	94	0	-1	-4
	Total	8	296	296		-4	-4

Example schedule variance summary by route segment - Route 32 P.M. peak east- and westbound

2) Evaluating the data

The schedule maker can make a number of observations from viewing the data in this manner.

- The primary passenger flow is westbound in the morning and eastbound in the afternoon. Morning peak flow trips average 34 total boardings (272 total boardings divided by 8 trips), while afternoon trips average 37 boardings (296 total boardings divided by 8 trips).

- The segment summary data indicate the central transfer point RGM is a significant trip generator, meaning that the accuracy of scheduled arrivals and departures at that point is very important.

- The MLP occurs between the time points COC and CSM in both directions.

- Running time allowed in the current schedule is 3 to 4 minutes too little to ensure 100% on-time performance. At least 2 more minutes are required between COC and CSM. One additional minute is needed between COW and CBS in both directions and during all time periods. Other adjustments appear to be needed in one direction or the other as well as in the A.M. or P.M. peak.

- The data on average passenger loads, starting and ending loads and the presence of significant ridership in both directions suggests that midday service may be justified on this route. (Many transit systems have guidelines and standards on which to base increases or decreases in service).

B. Revising the master schedule for Route 32

It appears that adjustments to Route 32 are in order. The scheduler intends to adjust running times and add base service in accordance with the data collected.

1) Adding base service

The agency has decided to add three midday (base) trips in each direction. It has been determined that these three midday trips will operate on a 1-hour headway. Although the current running times are tight for the peak periods, they appear to be adequate for the midday or base period when demand is not as high.

2) Adjusting running times

The chart below illustrates the adjustments made to the running times for Route 32 Revised. The running time has been increased in both directions during both A.M. and P.M. peak periods. When running time and cycle time are increased, it is important to ensure that layover requirements have not been compromised.

ROUTE 32 (Revised running time file)

Service Day: Weekday

Direction: Westbound

Time Point	A.M. Peak	**Base**	P.M. Peak
Comanche @ Big Sky	-	-	-
Comanche @ Wyoming	~~9~~ **10**	**9**	~~9~~**10**
Comanche @ San Mateo	~~6~~ **7**	**6**	~~6~~ **6**
Comanche @ Carlisle	~~4~~ **6**	**4**	~~4~~ **7**
N. 4th @ Griegos	~~10~~ **9**	**10**	~~10~~**9**
Rio Grande @ Montano	~~7~~ **7**	**7**	~~7~~ **8**
TOTAL	~~36~~**39**	**36**	~~36~~**40**

ROUTE 32 (Revised running time file)

Service Day: Weekday

Direction: Eastbound

Time Point	A.M. Peak	**Base**	P.M. Peak
Rio Grande @ Montano	-	-	-
N. 4th @ Griegos	~~7~~ **7**	**7**	~~7~~ **7**
Comanche @ Carlisle	~~10~~**10**	**10**	~~10~~**11**
Comanche @ San Mateo	~~4~~ **6**	**4**	~~4~~ **6**
Comanche @ Wyoming	~~6~~ **7**	**6**	~~6~~ **6**
Comanche @ Big Sky	~~9~~ **10**	**9**	~~9~~ **10**
TOTAL	~~36~~**40**	**36**	~~36~~**40**

Revised running time file for Route 32

CHAPTER 1: EXERCISES

#1 Given the new running time file, revise the master schedule below for Route 32. For this exercise, assume trips starting between 6:00 a.m. and 10:00 a.m. use A.M. peak running times. Trips starting between 10:01 a.m. and 1:00 p.m. use base running times and trips starting after 1:00 p.m. require P.M. peak running times.

The start times for each A.M., Base and P.M. trip in each direction are already shown on the schedule. (Answer on next page)

ROUTE 32 (Revised running time file)

Service Day: Weekday

Direction: Westbound

Time Point	A.M. Peak	Base	P.M. Peak
Comanche @ Big Sky	-	-	-
Comanche @ Wyoming	10	9	10
Comanche @ San Mateo	7	6	6
Comanche @ Carlisle	6	4	7
N. 4th @ Griegos	9	10	9
Rio Grande @ Montano	7	7	8
TOTAL	39	36	40

ROUTE 32 (Revised running time file)

Service Day: Weekday

Direction: Eastbound

Time Point	A.M. Peak	Base	P.M. Peak
Rio Grande @ Montano	-	-	-
N. 4th @ Griegos	7	7	7
Comanche @ Carlisle	10	10	11
Comanche @ San Mateo	6	4	6
Comanche @ Wyoming	7	6	6
Comanche @ Big Sky	10	9	10
TOTAL	40	36	40

Westbound / Eastbound

Westbound: Comanche & Big Sky	Comanche & Wyoming	Comanche & San Mateo	Comanche & Carlisle	N. 4th & Griegos	Rio Grande & Montano		Eastbound: Rio Grande & Montano	N. 4th & Griegos	Comanche & Carlisle	Comanche & San Mateo	Comanche & Wyoming	Comanche & Big Sky
							6:10					6:50
							6:40					
6:26					7:05	A	7:10					
6:56						M	7:40					
7:26							8:10					
7:56							8:40					
8:26							9:10					
8:56							9:40					10:20
9:26												
9:56							10:40					11:16
10:26							11:40					
11:26							12:40					
12:26							1:40					2:20
1:26					2:06		2:10					
1:56						P	2:40					
2:26						M	3:10					
2:56							3:40					
3:26							4:10					
3:56							4:40					
4:26							5:10					5:50
4:56												
5:26												
5:56					6:36							

Revised Master Schedule for Route 32

Comanche & Big Sky	Comanche & Wyoming	Comanche & San Mateo	Comanche & Carlisle	N. 4th & Griegos	Rio Grande & Montano		Rio Grande & Montano	N. 4th & Griegos	Comanche & Carlisle	Comanche & San Mateo	Comanche & Wyoming	Comanche & Big Sky
							6:10	6:17	6:27	6:33	6:40	6:50
							6:40	6:47	6:57	7:03	7:10	7:20
6:26	6:36	6:43	6:49	6:58	7:05	A	7:10	7:17	7:27	7:33	7:40	7:50
6:56	7:06	7:13	7:19	7:28	7:35	M	7:40	7:47	7:57	8:03	8:10	8:20
7:26	7:36	7:43	7:49	7:58	8:05		8:10	8:17	8:27	8:33	8:40	8:50
7:56	8:06	8:13	8:19	8:28	8:35		8:40	8:47	8:57	9:03	9:10	9:20
8:26	8:36	8:43	8:49	8:58	9:05		9:10	9:17	9:27	9:33	9:40	9:50
8:56	9:06	9:13	9:19	9:28	9:35		9:40	9:47	9:57	10:03	10:10	10:20
9:26	9:36	9:43	9:49	9:58	10:05							
9:56	10:06	10:13	10:19	10:28	10:35		10:40	10:47	10:57	11:01	11:07	11:16
10:26	10:35	10:41	10:45	10:55	11:02		11:40	11:47	11:57	12:01	12:07	12:15
11:26	11:35	11:41	11:45	11:55	12:02		12:40	12:47	12:57	1:01	1:07	1:16
12:26	12:35	12:41	12:45	12:55	1:02		1:40	1:47	1:58	2:04	2:10	2:20
1:26	1:36	1:42	1:49	1:58	2:06		2:10	2:17	2:28	2:34	2:40	2:50
1:56	2:06	2:12	2:19	2:28	2:36	P	2:40	2:47	2:58	3:04	3:10	3:20
2:26	2:36	2:42	2:49	2:58	3:06	M	3:10	3:17	3:28	3:34	3:40	3:50
2:56	3:06	3:12	3:19	3:28	3:36		3:40	3:47	3:58	4:04	4:10	4:20
3:26	3:36	3:42	3:49	3:58	4:06		4:10	4:17	4:28	4:34	4:40	4:50
3:56	4:06	4:12	4:19	4:28	4:36		4:40	4:47	4:58	5:04	5:10	5:20
4:26	4:36	4:42	4:49	4:58	5:06		5:10	5:17	5:28	5:34	5:40	5:50
4:56	5:06	5:12	5:19	5:28	5:36							
5:26	5:36	5:42	5:49	5:58	6:06							
5:56	6:06	6:12	6:19	6:28	6:36							

#2 Re-block the revised master schedule for Route 32. The ORIGINAL blocking scheme is shown below as reference. (Answer on the next page)

Westbound

Block/Trip#	Comanche & Big Sky	Comanche & Wyoming	Comanche & San Mateo	Comanche & Carlisle	N. 4th & Griegos	Rio Grande & Montano
3203-01	6:26	~~6:35~~	~~6:41~~	~~6:45~~	~~6:55~~	~~7:02~~◍
3201-02	6:56	~~7:05~~	~~7:11~~	~~7:15~~	~~7:25~~	~~7:32~~●
3202-02	7:26	~~7:35~~	~~7:41~~	~~7:45~~	~~7:55~~	~~8:02~~○
3203-03	7:56	~~8:05~~	~~8:11~~	~~8:15~~	~~8:25~~	~~8:32~~◍
3201-04	8:26	~~8:35~~	~~8:41~~	~~8:45~~	~~8:55~~	~~9:02~~●
3202-04	8:56	~~9:05~~	~~9:11~~	~~9:15~~	~~9:25~~	~~9:32~~○
3203-05	9:26	~~9:35~~	~~9:41~~	~~9:45~~	~~9:55~~	~~10:02~~◍
3201-06	9:56	~~10:05~~	~~10:11~~	~~10:15~~	~~10:25~~	~~10:32~~●
3204-01	1:26	~~1:35~~	~~1:41~~	~~1:45~~	~~1:55~~	~~2:02~~●
3206-01	1:56	~~2:05~~	~~2:11~~	~~2:15~~	~~2:25~~	~~2:32~~◍
3205-02	2:26	~~2:35~~	~~2:41~~	~~2:45~~	~~2:55~~	~~3:02~~○
3204-03	2:56	~~3:05~~	~~3:11~~	~~3:15~~	~~3:25~~	~~3:32~~●
3206-03	3:26	~~3:35~~	~~3:41~~	~~3:45~~	~~3:55~~	~~4:02~~◍
3205-04	3:56	~~4:05~~	~~4:11~~	~~4:15~~	~~4:25~~	~~4:32~~○
3204-05	4:26	~~4:35~~	~~4:41~~	~~4:45~~	~~4:55~~	~~5:02~~●
3206-05	4:56	~~5:05~~	~~5:11~~	~~5:15~~	~~5:25~~	~~5:32~~◍
3205-06	5:26	~~5:35~~	~~5:41~~	~~5:45~~	~~5:55~~	~~6:02~~○
3204-07	5:56	~~6:05~~	~~6:11~~	~~6:15~~	~~6:25~~	~~6:32~~●

Eastbound

Rio Grande & Montano	N. 4th & Griegos	Comanche & Carlisle	Comanche & San Mateo	Comanche & Wyoming	Comanche & Big Sky	Block/Trip#
6:10	~~6:17~~	~~6:27~~	~~6:31~~	~~6:37~~	~~6:46~~●	3201-01
6:40	~~6:47~~	~~6:57~~	~~7:01~~	~~7:07~~	~~7:16~~○	3202-01
7:10	~~7:17~~	~~7:27~~	~~7:31~~	~~7:37~~	~~7:46~~◍	3203-02
7:40	~~7:47~~	~~7:57~~	~~8:01~~	~~8:07~~	~~8:16~~●	3201-03
8:10	~~8:17~~	~~8:27~~	~~8:31~~	~~8:37~~	~~8:46~~○	3202-03
8:40	~~8:47~~	~~8:57~~	~~9:01~~	~~9:07~~	~~9:16~~◍	3203-04
9:10	~~9:17~~	~~9:27~~	~~9:31~~	~~9:37~~	~~9:46~~●	3201-05
9:40	~~9:47~~	~~9:57~~	~~10:01~~	~~10:07~~	~~10:16~~○	3202-05
1:40	~~1:47~~	~~1:57~~	~~2:01~~	~~2:07~~	~~2:16~~○	3205-01
2:10	~~2:17~~	~~2:27~~	~~2:31~~	~~2:37~~	~~2:46~~●	3204-02
2:40	~~2:47~~	~~2:57~~	~~3:01~~	~~3:07~~	~~3:16~~◍	3206-02
3:10	~~3:17~~	~~3:27~~	~~3:31~~	~~3:37~~	~~3:46~~○	3205-03
3:40	~~3:47~~	~~3:57~~	~~4:01~~	~~4:07~~	~~4:16~~●	3204-04
4:10	~~4:17~~	~~4:27~~	~~4:31~~	~~4:37~~	~~4:46~~◍	3206-04
4:40	~~4:47~~	~~4:57~~	~~5:01~~	~~5:07~~	~~5:16~~○	3205-05
5:10	~~5:17~~	~~5:27~~	~~5:31~~	~~5:37~~	~~5:46~~●	3204-06

Block	Comanche & Big Sky	Comanche & Wyoming	Comanche & San Mateo	Comanche & Carlisle	N. 4th & Griegos	Rio Grande & Montano		Rio Grande & Montano	N. 4th & Griegos	Comanche & Carlisle	Comanche & San Mateo	Comanche & Wyoming	Comanche & Big Sky
3201								6:10	6:17	6.27	6:32	6:40	6:50
3202								6:40	6:47	6:57	7:03	7:10	7:20
3203	6:26	6:36	6:43	6:49	6:58	7:05	A	7:10	7:17	7:27	7:33	7:40	7:50
3201	6 56	7:06	7:13	7:19	7:28	7:35	M	7:40	7:47	7:57	8:03	8:10	8:20
3202	7:26	7:36	7:43	7:49	7:58	8:05		8:10	8:17	8:27	8·33	8:40	8:50
3203	7:56	8:06	8:13	8:19	8:28	8:35		8:40	8:47	8:57	9:03	9:10	9:20
3201	8:26	8:36	8:43	8:49	8:58	9:05		9:10	9:17	9:27	9:33	9:40	9·50
3202	8:56	9:06	9:13	9·19	9:28	9:35		9:40	9:47	9:57	10:03	10:10	10.20
3203	9:26	9:36	9:43	9:49	9:58	10:05							
3201	9:56	10:06	10:13	10:19	10:28	10:35		10:40	10:47	10:57	11.01	11:07	11:16
3202	10:26	10:35	10:41	10:45	10:55	11:02		11:40	11:47	11:57	12 01	12:07	12:15
3201	11·26	11:35	11:41	11:45	11:55	12·02		12:40	12:47	12:57	1·01	1:07	1:16
3202	12.26	12.35	12:41	12 45	12·55	1:02		1:40	1:47	1:58	2:04	2:10	2:20
3201	1 26	1:36	1:42	1:49	1:58	2:06		2:10	2:17	2:28	2:34	2:40	2:50
3204	1:56	2:06	2:12	2:19	2:28	2:36	P	2:40	2:47	2:58	3:04	3:10	3:20
3202	2:26	2:36	2:42	2:49	2:58	3:06	M	3:10	3:17	3:28	3:34	3:40	3 50
3201	2:56	3:06	3:12	3:19	3:28	3:36		3:40	3:47	3:58	4:04	4:10	4:20
3204	3:26	3:36	3·42	3 49	3·58	4:06		4:10	4:17	4:28	4:34	4.40	4:50
3202	3·56	4:06	4:12	4:19	4:28	4:36		4.40	4:47	4:58	5.04	5;10	5:20
3201	4·26	4:36	4:42	4:49	4:58	5:06		5.10	5:17	5:28	5:34	5 40	5:50
3204	4:56	5:06	5:12	5:19	5:28	5:36							
3202	5:26	5:36	5:42	5:49	5:58	6:06							
3201	5:56	6:06	6:12	6:19	6:28	6:36							

New blocking configuration for revised Route 32

With the addition of the midday service, the original Route 32 A.M. blocks 3201 and 3202 remain in service and hook into the midday trips. A.M. block 3203 remains a peak only block with the same start and end times.

Extended blocks 3201 and 3202 (now referred to as base or all day blocks) are shown continuing into the P.M. peak and hooking into former P.M. blocks 3204 and 3205 respectively. Original P.M. block 3206 still begins and ends at the same times, however is renumbered as 3204 in the revised Route 32 schedule in order to maintain a pattern of consecutive block numbering.

Finally, note that since the midday service operates hourly, considerable excess layover exists at Rio Grande & Montano at the midday hooks.

Notes:

CHAPTER 2

TRIP GENERATION

Advanced Section

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I. Introduction

A number of factors influence the complexity of a schedule, including the number of vehicles on the route; changes in the headway between peak, base, evening and night service; route branches; short turns; timed transfers; changes in the controlling time point(s) and travel direction(s); special trips; school trippers, interlined trips and agency work rules and stipulations.

To address these and other scheduling considerations, a variety of intermediate and advanced scheduling techniques are presented in this chapter on trip generation. For illustration, a hypothetical Route 110, considered a complex local route, will serve as a model. The development of Route 110, along with newly revised Route 32, will continue as models for subsequent chapters on Blocking (Chapter 3), Runcutting (Chapter 4) and Rostering (Chapter 5).

The process for trip generation presented in this chapter will generally follow these steps:

- Understanding how route design relates to service area characteristics
- Defining route patterns
- Calculating and optimizing cycle time
- Investigating branch interlining
- Drafting a route diagram
- Calculating running times and number of vehicles
- Determining and transitioning between controlling time points
- Pull-on and pull-off points and strategies
- Optimizing
- Developing the master schedule

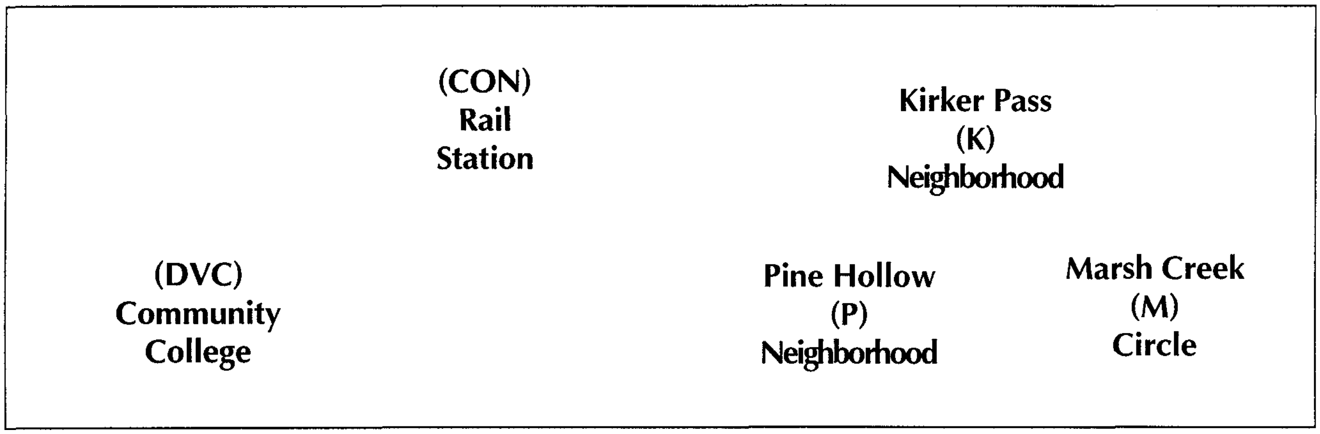
II. Route Design and the Master Schedule

Service Area The functional role of Route 110 is to connect several miles of residential neighborhoods and subdivisions that stretch along the main road (Clayton) at the eastern end of the service area, with numerous local commercial destinations, a commuter rail station and a community college campus (DVC), all of which are concentrated in the western end of the service area.

Both a high school and a middle school are located in the eastern neighborhoods. However, there is no strong commercial anchor to serve as the eastern terminal, making looping through these major subdivisions the most apparent option. The three neighborhood areas (and their branch definition) are

1) Kirker Pass (K),
2) Pine Hollow (P), and
3) Marsh Creek (M).

The commuter rail station (CON) is located mid-route. The community college campus (DVC) is the logical choice for western terminus, at which transfers to other routes are possible.



Service area planned for Route 110

Service Design Guidance

Route 110 has substantial peak period ridership potential due primarily to the large number of neighborhood commuters needing to access the rail station before 7:30 a.m. Service on the trunk is therefore planned to operate every 10 minutes during peak hours, every 20 minutes during off-peak hours and every 30 minutes at night. Up to three branches may be used to serve the residential subdivisions at the eastern end of the route.

III. Route Pattern

As complexities are planned into a new or restructured route, the scheduler is challenged to create a route pattern which ensures that vehicle hours and miles are distributed as effectively as possible. The Route 110 pattern above defines how each of the three planned branches will be served. Passengers tend to be better served when the pattern generates predictable "through-service connections" in both directions.

Before beginning the trip building process, the scheduler must decide which vehicles from the trunk line will operate over which branch. Based on the available information, the preliminary decision is made to alternate the trips evenly across the three branches.

IV. Optimizing Cycle Time

When the branches are of different lengths and running times, the scheduler can investigate the option of hooking long and short trips together to achieve more balanced cycle times. Otherwise, a vehicle making two long trips could result in maximum cycle time while a vehicle making two shorter trips could lead to minimum cycle time.

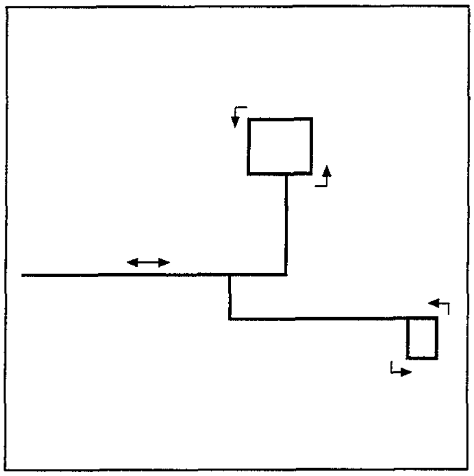
For example: When route branches are of unequal length, the following combination of trips may help balance the cycle time:

First vehicle:	Trunk + Long Branch + Trunk + Short Branch
Second vehicle:	Trunk + Short Branch + Trunk + Long Branch

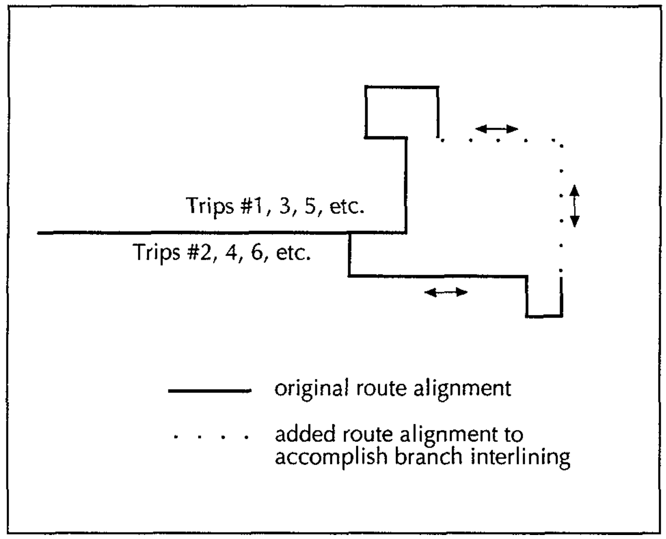
Other strategies could also optimize cycle time, such as combining all short trips together as well as combining all long trips together to produce more efficent blocks.

V. Branch Interlining

Branch interlining is often employed as an alternative to one-way looping through residential areas in order to "end" a route. In many cases, two route branches that serve adjacent residential neighborhoods can be interlined through a common outer time point. This means that the outbound trip of one branch is hooked to the inbound trip of another branch, rather than turned back on itself (on the same branch) at the terminal time point.



Route branches using one-way terminating loop operation



Route branches using branch interlining

Interlining the two branches creates a single, larger loop serving both directions on most segments of the branches. This has three distinct advantages when considered for Route 110.

1) It tends to balance the running times required to maintain service on each branch.

2) Operating vehicles in both directions along the same neighborhood streets provides opportunities for local circulation within the neighborhoods. Independent one-way loops would not provide that opportunity.

3) It allows for more efficient spacing of vehicles. Turning buses back at an arbitrary point and following the same route back to the trunk line would not provide that opportunity.

The area covered by the eastern segment of Route 110 is dominated by residential subdivisions linked by minor arterials and collector streets. There is little commercial development or other land use conducive to vehicle layovers.

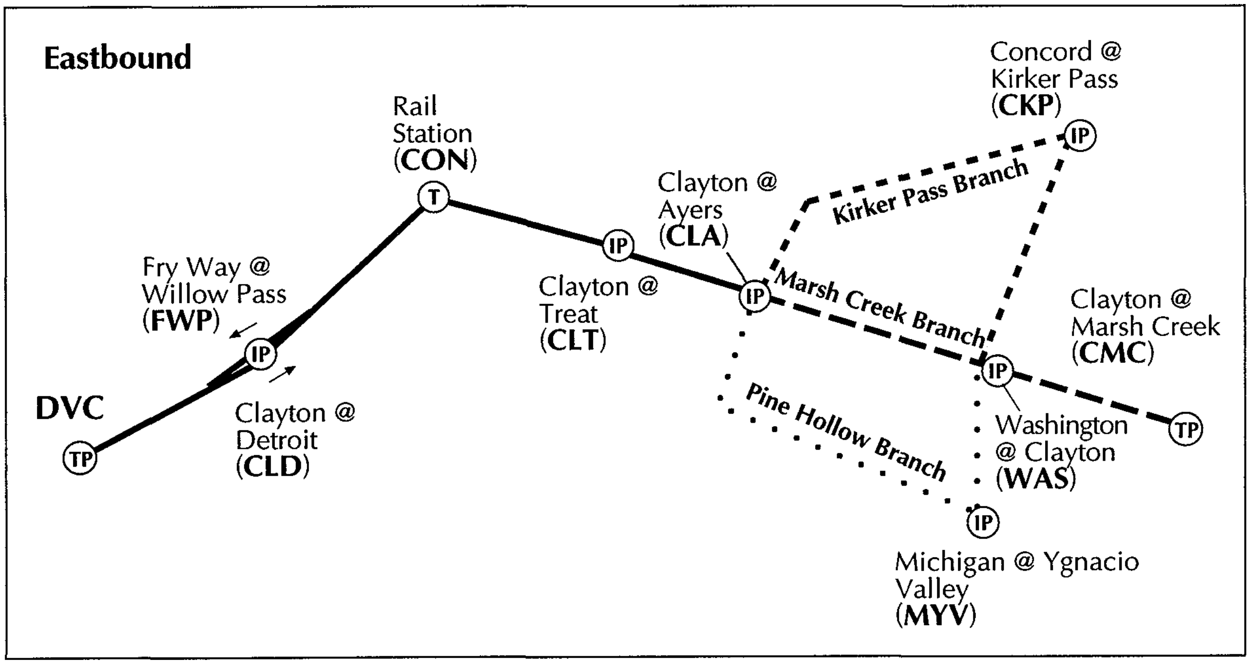
Interlining outbound K and inbound P trips, and outbound P and inbound K trips generates effective internal circulation between adjacent residential subdivisions. This linkage is particularly useful to students attending the middle and high schools located along the Pine Hollow branch.

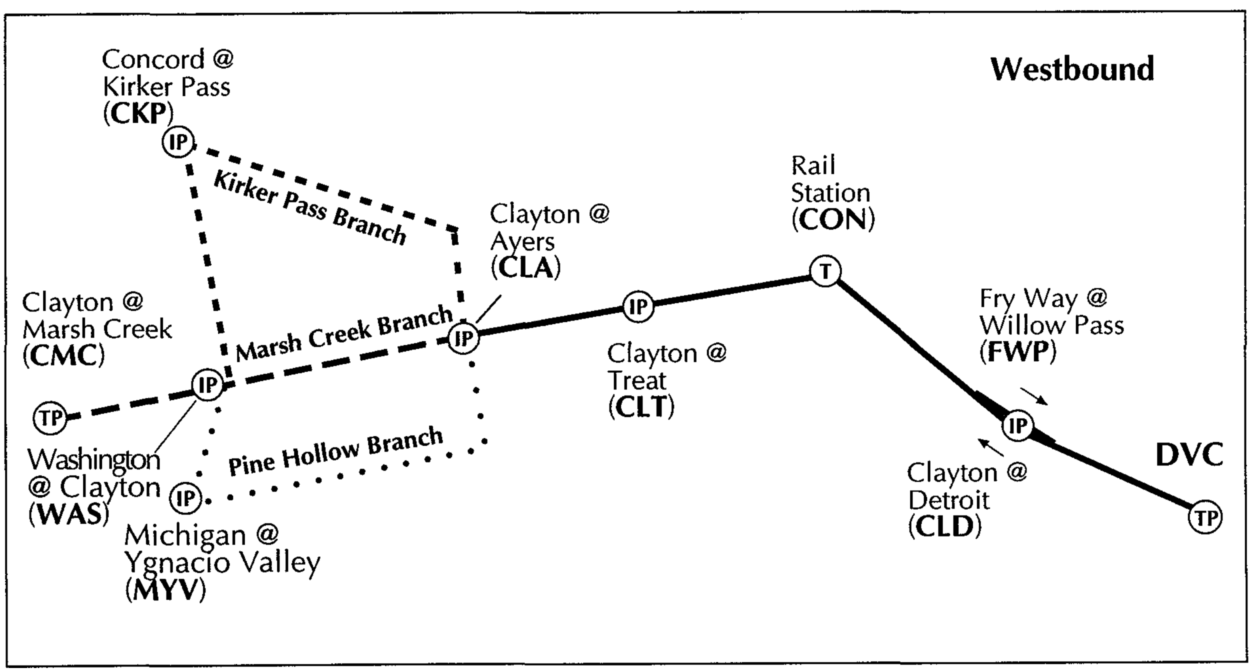
Branch interlining appears to be an effective way to handle two of the three neighborhoods at the eastern end of Route 110.

VI. Using Route Diagrams

Many schedulers find it useful to create a diagram of the trunk and branches of complex routes. This usually helps when laying out the time points in the master schedule.

Sample route diagrams of Route 110 in the eastbound and westbound directions are provided below.





Route diagrams for Route 110 by direction

IP	Intermediate Point
TP	Terminal Point
T	Timed Transfer Terminal

The route diagrams show timed transfer terminals (T), terminal time points (TP), intermediate time points (IP), and the trunk and branches of the route. Running time between time points can also be added, and controlling time point(s) can be noted as well.

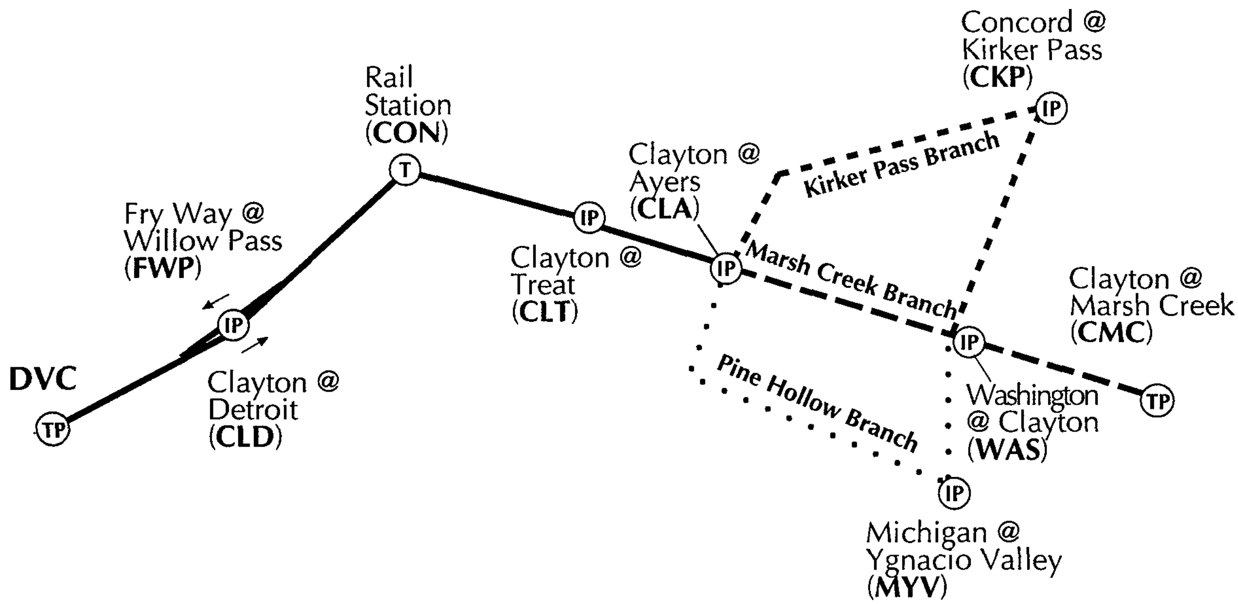
The diagrams indicate that there is a trunk (DVC to Clayton @ Ayers) and three branches at the eastern end of the route:

Kirker Pass (K)
Pine Hollow (P)
Marsh Creek (M)

Both the K and P branches are designed to use the same terminal end point at the intersection of Washington @ Clayton (WAS). This allows for branch interlining as follows:

- Eastbound Kirker Pass (K) trips return as westbound Pine Hollow (P) trips
- Eastbound Pine Hollow (P) trips return as westbound Kirker Pass (K) trips

The third branch serving Marsh Creek (M) runs two-way service along a linear alignment into Marsh Creek Circle.



Three defined patterns for Route 110

Interlining two of the three branches means that three route patterns are now defined as follows:

Combination Number	Round Trip Trunk/Branch Combinations
1	Eastbound trunk + eastbound K branch + westbound P branch + westbound trunk
2	Eastbound trunk + eastbound P branch + westbound K branch + westbound trunk
3	Eastbound trunk + eastbound M branch + westbound M branch + westbound trunk

VII. Cycle and Running Times

Cycle time is the total number of minutes needed to make a round trip in revenue service, plus any layover and recovery time at both ends of the line. For Route 110, cycle time is the time required for a vehicle to travel from DVC eastbound to Clayton @ Ayers, continue on one of the three branches to an eastern terminal, layover, and then return to DVC and layover again.

To determine round trip running time for Route 110, it is important to first understand the various patterns that will be used in the development of the master schedule.

The running time files that follow illustrate running times between time point pairs for each of ***seven defined time periods.*** Time periods are customized to the needs of the local transit agency. Note that running times vary not only by time period, but also by branch. To calculate maximum cycle time, the longest combination of eastbound and westbound one-way trips must be used for each time period. As expected, the longest cycle time occurs during the morning and afternoon peak periods when transit ridership and general traffic volumes are highest.

ROUTE 110 EASTbound
Running Time File

Service Day: Weekday
Direction: Eastbound

Time Period/Point	***Early A.M.***	***A.M. Peak***	***Base***	***School***	***P.M. Peak***	***Evening***	***Night***
From:	4:30a	5:31a	8:31a	2:01p	4:01p	7:01p	10:01
Until:	5:30a	8:30a	2:00p	4:00p	7:00p	10:00p	11:59p
ALL TRIPS							
DVC	-	-	-	-	-	-	-
Clayton@Detroit (CLD)	10	11	11	13	13	11	11
Rail Station (CON)	6	7	6	7	8	7	6
Clayton@Treat (CLT)	6	8	8	9	10	7	7
Clayton@Ayers (CLA)	4	5	5	6	7	5	5
VIA KIRKER PASS (K)							
Concord@Kirker Pass (CKP)	4	4	4	5	5	4	4
Washington@Clayton (WAS)	7	9	8	9	10	8	8
VIA PINE HOLLOW (P)							
Michigan@Ygnacio Valley (MYV)	4	5	4	5	5	4	4
Washington@Clayton (WAS)	7	8	7	9	8	7	7
VIA MARSH CREEK CIRCLE (M)							
Washington@Clayton (WAS)	3	4	3	4	3	3	3
Clayton@Marsh Creek (CMC)	8	8	8	8	14	12	12
Total via K	37	44	42	49	53	42	41
Total via P	37	44	41	49	51	41	40
Total via M	37	43	41	47	55	45	44

Running time file for eastbound Route 110

ROUTE 110 WESTbound
Running Time File

Service Day: Weekday
Direction: Westbound

Time Period/Point	*Early A.M.*	*A.M. Peak*	*Base*	*School*	*P.M. Peak*	*Evening*	*Night*
From:	4:30a	5:31a	8:31a	2:01p	4:01p	7:01p	10:01
Until:	5:30a	8:30a	2:00p	4:00p	7:00p	10:00p	11:59p
VIA KIRKER PASS (K)							
Washington@Clayton (WAS)	-	-	-	-	-	-	-
Concord@Kirker Pass (CKP)	9	9	9	9	9	9	8
Clayton@Ayers (CLA)	4	5	4	5	5	4	4
VIA PINE HOLLOW (P)							
Washington@Clayton (WAS)	-	-	-	-	-	-	-
Michigan@Ygnacio Valley (MYV)	7	8	7	9	8	7	7
Clayton@Ayers (CLA)	4	5	4	4	4	4	4
VIA MARSH CREEK CIRCLE (M)							
Clayton@Marsh Creek (CMC)	-	-	-	-	-	-	-
Clayton@Ayers (CLA)	14	14	12/11	8	8	8	8
ALL TRIPS							
Clayton@Treat (CLT)	5	6	5	6	6	5	5
Rail Station (CON)	8	9	9	10	10	8	8
Fry Way@Willow Pass (FWP)	5	6	6/5	5	6	5	5
DVC	11	12	13	13/12	13	11	11
Total via K	42	47	46	48	49	42	41
Total via P	40	46	44	47	47	40	40
Total via M	43	47	45	42	43	37	37

Running time file for westbound Route 110

The running time tables show that among eastbound Route 110 trips, the longest running time occurs during the P.M. peak period. Running times range from 51 minutes for trips on the P branch, to 53 minutes for K trips, to 55 minutes for the M trips.

Among westbound trips, the longest running times also occur during the P.M. peak. Running times range from 49 minutes for K trips, to 47 minutes for P trips, to 43 minutes for M trips.

Maximum round trip running time for P.M. peak trips that originate at DVC, operate eastbound via K, westbound via P and return to DVC is ***100 minutes*** (53 minutes eastbound and 47 minutes westbound).

For trips that follow P eastbound and K westbound, maximum round trip running time is also ***100 minutes*** (51 minutes eastbound and 49 minutes westbound).

For M trips in both directions, maximum round trip running time is ***98 minutes*** (55 minutes eastbound and 43 minutes westbound) during the P.M. peak.

VIII. Calculating the Number of Vehicles from the Cycle Time

In addition to round trip running time, cycle time includes layover and recovery time for the round trip. This agency has work rules that establish <u>target</u> layover and recovery time per round trip as follows:

Layover time (min.)	All	4
Recovery time (min.)	A.M. Peak	5
	P.M. Peak	6
	Base	9

The number of vehicles needed to operate service is determined by the equation on the right.

$$\text{\# of Vehicles} = \frac{\text{Cycle Time}}{\text{Headway}}$$

Using P.M. peak for the first computation: Cycle time is determined to be <u>110</u> minutes (100 minutes maximum running time plus 4 minutes layover plus 6 minutes recovery).

The headway for both A.M. and P.M. peak is <u>10</u> minutes. Base service is scheduled at 20 minute headways. Therefore <u>11</u> vehicles are needed to operate P.M. peak service.

$$\mathbf{11} = \frac{110}{10}$$

Calculating Required Number of Vehicles

Given maximum running times of <u>91</u> minutes for A.M. peak service (44 minutes P eastbound plus 47 minutes K westbound) and <u>87</u> minutes maximum running time for base service (41 minutes P eastbound plus 46 minutes K westbound), the number of vehicles is 10 and 5, respectively.

The table on the following page summarizes the calculation.

(minutes)	A.M. Peak	P.M. Peak	BASE
Running Time (RT)	91	100	87
Maximum Rail Layover	9	6	5
Maximum Recovery Time	0	4	8
Cycle Time	100	110	100
Trunk Headway	10	10	20
# of Vehicles Required	**10**	**11**	**5**

Route 110 - Maximum number of vehicles required by time period

IX. Controlling Time Points

It is the responsibility of the scheduler to decide not only *where* buses go, but *when* they go there as well. Determining the timing of one or a series of trips is accomplished with the aid of particular point(s) along the route appropriately called controlling time points. Controlling time points are especially important because arrival and departure times at these points can also affect the coordination of trips on one or more intersecting routes.

Controlling time points are usually major traffic generators where a significant number (or flow) of passengers require service at specific times. Office parks, factories and schools are examples of key locations that are often used as controlling time points. Timed transfer points and intermodal transfer facilities are also commonly used as controlling time points.

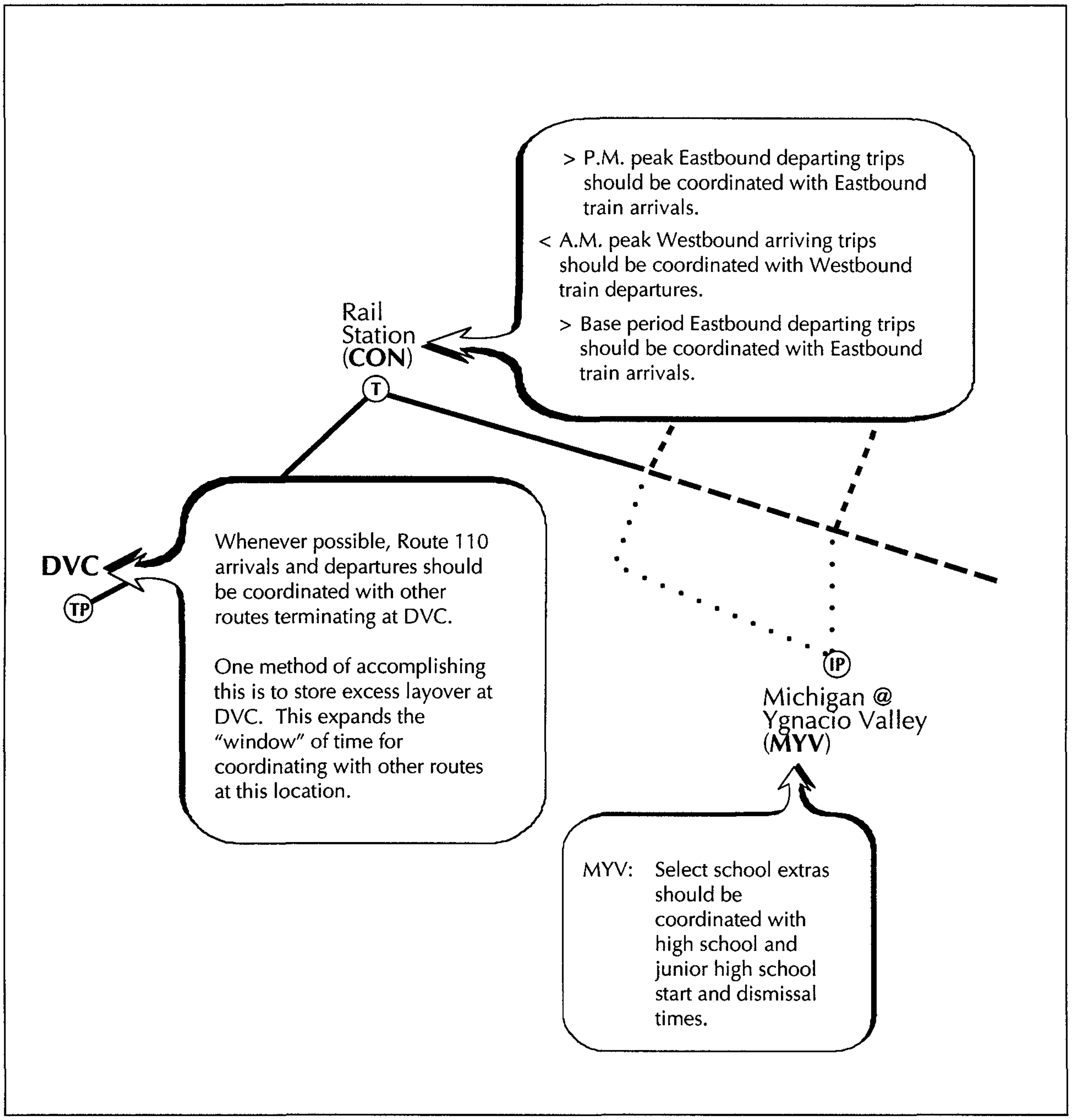
A route may contain one or more controlling time points. However, seldom can two be used at the same time (i.e., on the same trip). This is true because once an arrival or departure time is fixed at a given time point, the times at every other time point in the trip become fixed as well. Recovery time at the route terminal may be used to alter the schedule of the return trip by a few minutes, but often not enough to meet the requirements of a second controlling time point.

Route 110 is influenced by several controlling time points. A very significant controlling time point is the commuter rail station (CON). The regular scheduling practice of the transit agency is to coordinate bus and train arrival and departure times, in both directions whenever possible. Note that the rail station is an intermediate time point rather than a terminal point.

A secondary controlling time point for Route 110 is DVC, the western route terminal. Although it is desirable to schedule timed transfers with the arrivals and departures of other routes serving DVC, it may not be possible to achieve this throughout the day, assuming the dominant influence of the rail station on the Route 110 schedule.

One way to enhance the opportunity for schedule coordination at DVC is to concentrate recovery time at this point. This also expands the window of time during which other routes could meet and coordinate with Route 110 trips.

A third important controlling time point is relevant during morning and afternoon school bell hours. Route 110 serves significant high school and middle school traffic on the K and P branches of the route.



Controlling time points for Route 110

X. Pull-On/Off Points

One final piece of information is needed before beginning the process of generating trips–determining those points where buses *pull on* and *pull off* the route. One or more locations may be used to add or remove vehicles from scheduled service. These locations may be at either or both terminals or at an intermediate time point. The primary factors in determining pull on/off points are distance and travel time from the facility where the vehicles are stored. The desire is to minimize the deadhead time between the points.

In the example of Route 110, both the western terminal DVC and the rail station CON will be used to add and remove peak vehicles to the schedule, given their close proximity to the garage facility.

XI. Developing the Master Schedule

Service Design Guidance — The service day is planned to begin with a 15-minute trunk headway in the early A.M. and rapidly transition to 10-minutes for the A.M. peak. Each branch would have a 30-minute peak headway. The trunk headway spreads to 20 minutes during the base and much of the school period, and then back to 10 minutes for the P.M. peak. The trunk headway will return to 20 minutes during the evening hours and spread to 30 minutes near the end of the service day (night).

Schedulers can use one of several approaches to generating trips. A chronological approach is used in this example. This means that groups of trips will be built consecutively for each time period, by direction, starting with the first early A.M. and A.M. peak trips in the westbound direction.

A. Beginning the service day

The design objective is for five successive westbound arrivals at the rail station at 15-minute intervals between 5:30 a.m. until 6:30 a.m. During this hour, the headway is linked to morning train departures, which occur every 15 minutes.

By constructing trip 1W to leave Washington @ Clayton (WAS) at 5:04 a.m., this first westbound trip arrives at the rail station (CON) at 5:30 a.m. and arrives at the western terminal DVC at 5:49 a.m. (see running time files for computing time point arrival times). Four more westbound trips (two via P, one each from M and K) arrive at CON within the targeted time period. Trips 1W through 5W are consistent with the design objective.

NOTE: Completed Master Schedules, by direction, can be found at the end of this chapter.

Trip #	**Via**	Lv **MCC**	Lv **WAS**	**MYV**	**CKP**	**CLA**	**CLT**	Arr **CON**	Lv **CON**	**FRY**	Arr **DVC**
1W	K		5:04		5:13	5:17	5:22	**5:30**	5:33	5:38	5:49
2W	P		5:21	5:28		5:32	5:37	**5:45**	5:48	5:53	6:04
3W	K		5:31		5:40	5:45	5:51	**6:00**	6:03	6:09	6:21
4W	M	5:43	5:57			6:00	6:06	**6:15**	6:18	6:24	6:36
5W	P		6:02	6:10		6:15	6:21	**6:30**	6:33	6:39	6:51

The first five westbound trips meet the early morning design objective.

The **controlling time point** during this period of the day is the rail station (Arr CON). This corresponds to the prevailing flow of westbound commuters wanting service to the rail line.

Note that the first M branch trip is trip 4W rather than 3W. Although inconsistent with the plan to alternate trips between the three branches, the M branch is skipped in the early morning due to the determination that service to this area is not required during this time period. Modifications to the rotation of branch service are not uncommon when overall service can be enhanced.

B. Transition to A.M. peak

At 6:30 a.m., the planned headway reduces to 10 minutes between westbound arrivals at CON. However, westbound trains depart toward downtown every 7.5 minutes during this time period. Experienced schedulers recognize that this decision results in less that perfect schedule coordination. From a scheduling perspective, it would be preferable to either 1) reduce the bus headway from 15 minutes to 7.5 minutes (equal to the train station departures), or 2) leave the headway at 15 minutes to meet every other train.

However, the decision to reduce the headway to 10 minutes is a compromise to avoid the additional cost of a reduction all the way to 7.5 minutes and the desire to operate whole minute "clock" headways for customer convenience.

Observation Anticipating the impact of the schedule for a particular set of trips allows the scheduler an opportunity to address the possible consequences, including adverse passenger reaction. In this case, two questions are considered before the next set of trips is constructed:

1) After arriving at CON, how long will passengers wait for the next train?

2) Will passengers arrive just in time to see a train leaving and be frustrated?

Given a 10-minute clock headway, the following would occur:

Arrival #	Bus Arrives	Train Departs	Wait Time
1	6:30a	6:33a	3
2	6:40a	6:40.5a	0
3		6:48a	8
4	6:50a	6:55.5a	5
5	7:00a	7:03a	3
6	7:10a	7:10.5a	0
7		7:18a	8
8	7:20a	7:25.5a	5
9	7:30a	7:33a	3

Anticipating wait time for bus arrival and train departure

The scheduler knows that it takes approximately 3 minutes to comfortably alight the bus, move through the station and board the train. Arrival numbers 2 and 6 could likely generate complaints because arriving passengers observe trains departing before they can get there. Arrival numbers 1, 5 and 9 may also generate similar complaints if they repeatedly arrive behind schedule.

Conclusion Given the relatively high frequency of both bus arrivals (10 minutes) and train departures (7.5 minutes) during this time period, it is determined not to meet every train with a bus arrival. Given a maximum wait of 8 minutes, the decision is made to maintain the 10-minute headway.

Other options Delay the arrival times of 2 and 6 by 1 to 2 minutes
Accelerate arrivals 1 and 9 by 1 to 2 minutes.

Trips 6W through 12W are constructed to deliver the desired 10-minute headway through 7:40 a.m.

Trip #	**Via**	Lv **MCC**	Lv **WAS**	**MYV**	**CKP**	**CLA**	**CLT**	Arr **CON**	Lv **CON**	**FRY**	Arr **DVC**
6W	K		6:11		6:20	6:25	6:31	**6:40**	6:43	6:49	7:01
7W	M	6:18	6:32			6:35	6:41	**6:50**	6:55	7:01	7:13
8W	P		6:32	6:40		6:45	6:51	**7:00**	7:05	7:11	7:23
9W	K		6:41		6:50	6:55	7:01	**7:10**	7:15	7:21	7:33
10W	M	6:48	7:02			7:05	7:11	**7:20**	7:25	7:31	7:43
11W	P		7:02	7:10		7:15	7:21	**7:30**	7:35	7:41	7:53
12W	K		7:11		7:20	7:25	7:31	**7:40**	7:45	7:51	8:03

Second set of westbound trips

Some schedulers continue writing all trips in one direction before moving on to the opposite direction trips. Others prefer to write groups of trips in alternating directions by time period. The latter practice is used in this example.

Thus far, the first 12 westbound trips covering the early A.M. and A.M. peak periods have been built. The eastbound counterparts will be developed with consideration to "hooking" westbound trips to eastbound trips. This procedure will ensure that no more than the planned number of vehicles will be required to operate the schedule.

Hooking is the process of tying one-way trips together to form vehicle blocks. (Refer to Chapter 3 for more detailed discussion of blocking.) Hooking can be done after the entire master schedule has been developed or it can be done concurrent with master schedule development to help fine tune trips and ensure the efficient utilization of vehicles.

The timing of the first eastbound trip is affected by three considerations:

1) It is desirable to hook to trip 1W, which departs WAS at 5:04 a.m.

2) It should support the desired branch pattern described earlier in this segment.

   Note: Recall that pattern for the branches - westbound K trips return as eastbound P trips and eastbound K trips return as westbound P trips.

   Therefore, the first eastbound trip should follow P.

3) Since the trip will be operated by a vehicle pulling onto the line from the vehicle garage facility, it should enter revenue service efficiently at one of the two designated pull on points.

Trip 1E below satisfies these conditions.

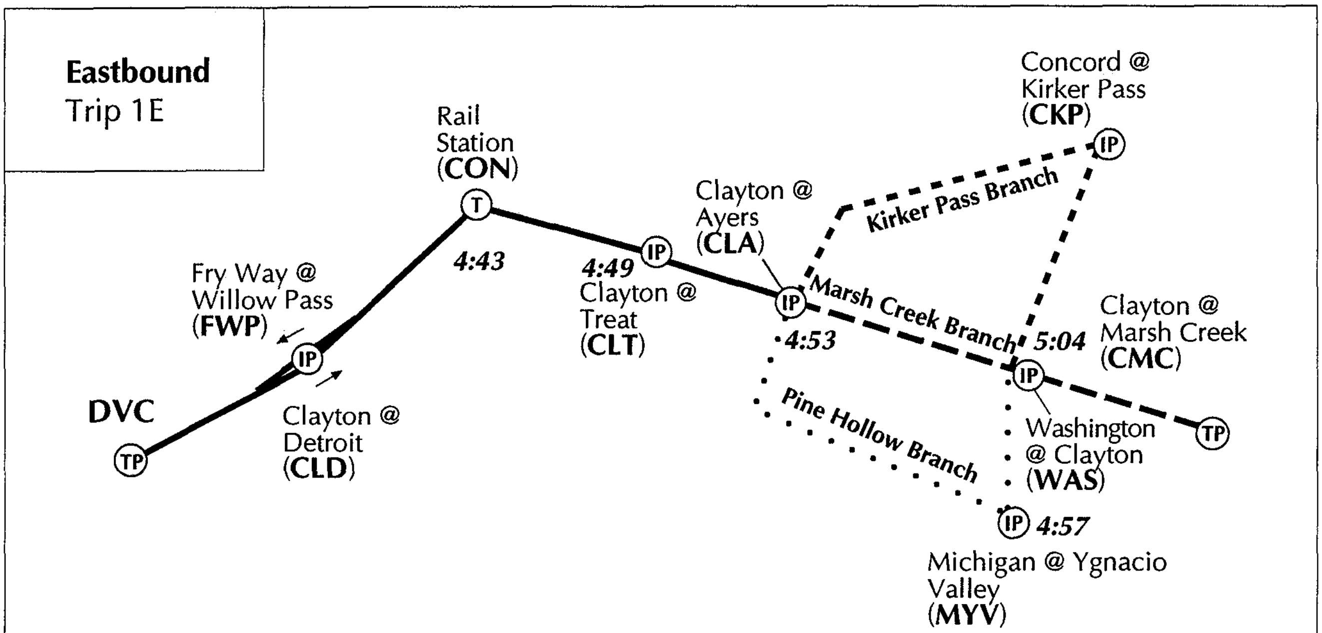
Trip #	**Via**	Lv **DVC**	**CLD**	Arr **CON**	Lv **CON**	**CLT**	**CLA**	**CKP**	**MYV**	Arr **WAS**	Arr **MCC**
1E	P				4:43	4:49	4:53		4:57	5:04	

Trip 1E arrives at WAS at 5:04 a.m. and immediately proceeds as (hooks to) trip 1W.

Trip #	***Via***	*Lv* ***MCC***	*Lv* ***WAS***	***MYV***	***CKP***	***CLA***	***CLT***	*Arr* ***CON***	*Lv* ***CON***	***FRY***	*Arr* ***DVC***
1W	*K*		*5:04*		*5:13*	*5:17*	*5:22*	***5:30***	*5:33*	*5:38*	*5:49*

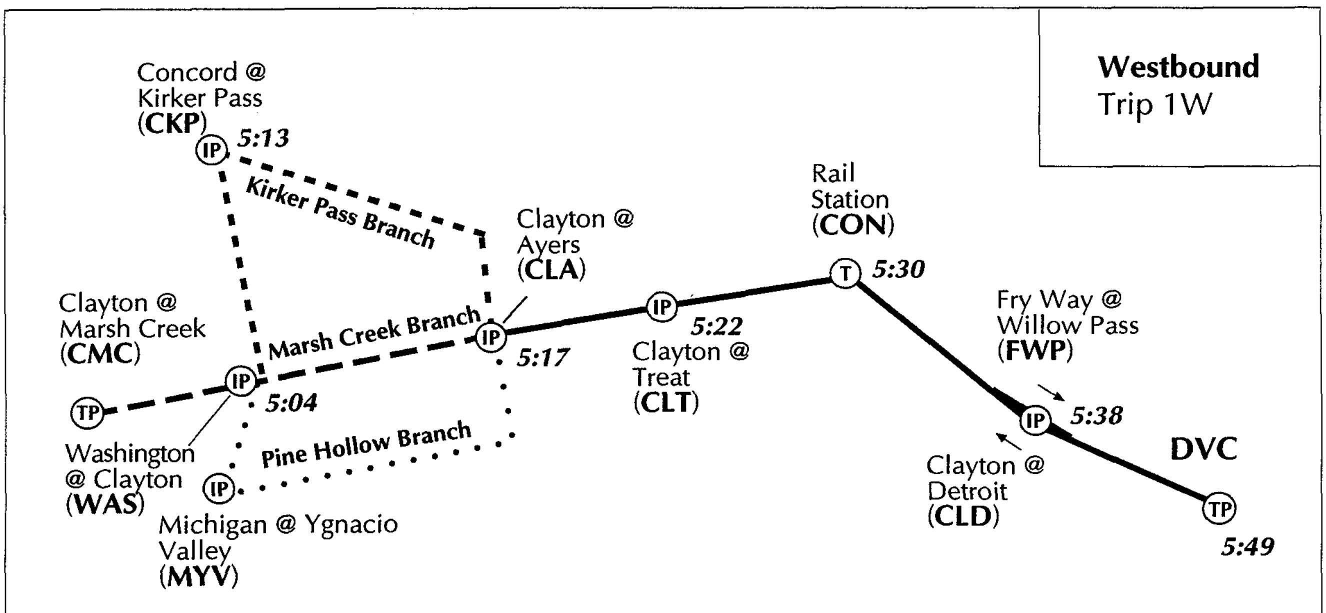
No layover or recovery time is provided at WAS. Since the vehicle will have only been in service for 17 minutes at a very early hour, the need for recovery time is minimal. Additionally, WAS is a residential intersection where idling vehicles during early morning hours could generate complaints from residents. Recovery time is alternatively stored at CON and DVC.

Note also that 1E follows the P branch and interlines to the K branch as trip 1W, as planned. The graphic on the following page illustrate the progression.



Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
1E	P				4:43	4:49	4:53		4:57	5:04	

The first eastbound trip 1E



Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
1W	K		5:04		5:13	5:17	5:22	**5:30**	5:33	5:38	5:49

The first westbound trip 1W

Given that trip 2W departs WAS in the westbound direction as a P trip at 5:21 a.m., the second eastbound trip (2E) is developed using the same pattern as used for trip 1E. Trip 2E departs CON at 4:59 a.m., operates eastbound as a K trip, and hooks to 2W at WAS at 5:21 a.m. Again, no recovery time is allowed.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
2E	K				4:59	5:05	5:09	5:13		5:21	

Trip #	*Via*	*Lv MCC*	*Lv WAS*	*MYV*	*CKP*	*CLA*	*CLT*	*Arr CON*	*Lv CON*	*FRY*	*Arr DVC*
2W	*P*		*5:21*	*5:28*		*5:32*	*5:37*	*5:45*	*5:48*	*5:53*	*6:04*

Although the route pattern dictates that trip 3E cover the M branch, it has been established that ridership demand on this segment does not require westbound service this early. In the interest of efficiency, the P branch will replace the M branch for this trip. Trip 3E hooks to 3W, which departs WAS at 5:31am.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
3E	P				5:05	5:11	5:15		5:19	5:27	

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
3W	K		5:31		5:40	5:45	5:51	**6:00**	6:03	6:09	6:21

Note that a 4-minute layover at WAS (from 5:27 a.m. until 5:31 a.m.) has been scheduled. This is necessary to fix the departure from CON at 5:05 a.m. to coordinate with the scheduled 5:00 a.m. train arrival, avoiding any negative perception of a "near miss" with the subsequent 5:10 a.m. train arrival. In this instance, the general interest in avoiding recovery time at the residential time point WAS is violated.

The next eastbound trip 4E provides coverage on the M branch and hooks to trip 4W, departing MCC at 5:43 a.m. One minute of recovery time is allowed at MCC.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
4E	M				5:21	5:27	5:31			5:34	5:42

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
4W	M	5:43	5:57			6:00	6:06	**6:15**	6:18	6:24	6:36

Trips 1E through 4E each will be operated by the first four vehicles pulled onto the route. All four vehicles are pulled on at CON, the preferred pull on point located nearest to the vehicle garage facility. Trips 5E and 6E hook to westbound trips 5W and 6W.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
5E	K				5:36	5:44	5:49	5:53		6:02	
6E	P				5:45	5:53	5:58		6:03	6:11	

Although pulling buses on and off Route 110 is most efficient at CON, it is common to use one or more secondary access points on a relatively long route. The secondary point on Route 110 is DVC. Ridership demand dictates that eastbound service from DVC begin at approximately 5:30 a.m. Since the first westbound trip (1W) is not scheduled to arrive at DVC until 5:49 a.m., another vehicle must pull onto the line at DVC to cover a 5:30 a.m. departure.

Trip #	**Via**	Lv **DVC**	**CLD**	Arr **CON**	Lv **CON**	**CLT**	**CLA**	**CKP**	Arr **MYV**	Arr **WAS**	Arr **MCC**
7E	M	5:30	5:40	**5:46**	**5:52**	6:00	6:05			6:09	6:17

Trip #	**Via**	Lv **MCC**	Lv **WAS**	**MYV**	**CKP**	**CLA**	**CLT**	Arr **CON**	Lv **CON**	**FRY**	Arr **DVC**
7W	M	6:18	6:32			6:35	6:41	**6:50**	6:55	7:01	7:13

The new trip 7E will hook with westbound trip 7W, which departs MCC at 6:18 a.m. Assuming 1 minute of recovery time at MCC, 7E should arrive at MCC at 6:17 a.m. Referring back to the running time table, this requires a departure from DVC no later than 5:36 a.m. to reach MCC by 6:17 a.m. By scheduling the departure from DVC 6 minutes earlier, at exactly 5:30 a.m., a 6 minute window is created at CON to ensure schedule coordination between arriving buses and departing trains.

Since 1W completes its westbound run at DVC at 5:49 a.m., this vehicle may be used to cover an eastbound trip leaving DVC just before 6:00 a.m.

The eastbound trips constructed to this point are as follows:

Trip #	**Via**	Lv **DVC**	**CLD**	Arr **CON**	Lv **CON**	**CLT**	**CLA**	**CKP**	**MYV**	Arr **WAS**	Arr **MCC**
1E	P				**4:43**	4:49	4:53		4:57	5:04	
2E	K				**4:59**	5:05	5:09	5:13		5:21	
3E	P				**5:05**	5:11	5:15		5:19	5:27	
4E	M				**5:21**	5:27	5:31			5:34	5:42
5E	K				**5:36**	5:44	5:49	5:53		6:02	
6E	P				**5:45**	5:53	5:58		6:03	6:11	
7E	M	5:30	5:40	5:46	5:52	6:00	6:05			6:09	6:17

Now that the pattern is well established, it is possible to complete the remaining eastbound t,rips which can be hooked to westbound trips 8W through 12W.

Trip #	**Via**	Lv **DVC**	**CLD**	Arr **CON**	Lv **CON**	**CLT**	**CLA**	**CKP**	**MYV**	Arr **WAS**	Arr **MCC**
8E	K	**5:44**	5:55	6:02	6:06	6:14	6:19	6:23		6:32	
9E	P	**5:54**	6:05	6:12	6:15	6:23	6:28		6:33	6:41	
10E	M	6:00	6:11	6:18	6:22	6:30	6:35			6:39	6:47
11E	K	6:14	6:25	6:32	6:36	6:44	6:49	6:53		7:02	
12E	P	6:23	6:34	6:41	6:45	6:53	6:58		7:03	7:11	

Note: Pull-out trips are shown in bold.

The schedule requires nine vehicles rather than ten as initially calculated on the basis of maximum cycle time. *Why wasn't a tenth vehicle required?*

Service was not required on the entire length of the route until 5:30 a.m., when eastbound service from DVC commenced. By not serving the segment west of CON in the early A.M., it was possible to extend the 10-minute headway into the A.M. peak without pulling out the tenth vehicle. This reduction would not have been possible if the 100-minute cycle time was required.

Also, recovery time was minimized during the first morning trips on the assumption that vehicles were not in revenue service long enough to fall behind schedule nor were operators behind the wheel long enough to require layover time.

Finally, the duration of the A.M. peak period was 70 minutes, which is less that the 100-minute cycle time.

C. Transition from A.M. peak to base time period

The transition from a 10-minute morning peak to the 20-minute base period is guided by three important objectives:

1) Achieving a smooth transition from 10 minutes on the trunk and 30 minutes on the branches to 20 minutes on the trunk and 60 minutes on the branches. In instances where the transition is to a longer headway (i.e., less frequent service) and/or where the change in headway is more than 5 minutes, it is generally considered good practice to spread out the transition over two, three or more consecutive trips.

2) Establishing a realignment of the schedule around a new controlling time point and direction. This is necessary because of the shift in the prevailing flow of Route 110 passenger traffic.

   As the morning peak transitions into the base period, the volume of rail feeder trips declines while the number of arriving rail passengers using the bus to reach the community college and shopping malls located at the western end of the route increases.

   Accordingly, the controlling time point changes from westbound bus arrivals at CON to westbound departures from CON.

3) Removing four of the nine peak buses from service as efficiently as possible, noting that the best place to pull a bus off the line is at CON.

Because westbound buses are arriving regularly to DVC during this period, no additional morning pull-outs will be required. The next four eastbound trips (13E through 16E) are subsequently constructed.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
13E	M	6:38	6:49	6:56	6:58	7:06	7:11			7:15	7:23
14E	K	6:53	7:04	7:11	7:13	7:21	7:26	7:30		7:39	
15E	P	7:08	7:19	7:26	7:29	7:37	7:42		7:47	7:55	
16E	M	7:14	7:25	7:32	7:34	7:42	7:47			7:47	7:55

Trip #	Via	MCC	Lv WAS	Lv MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
4W	*M*	*5:43*	*5:57*			*6:00*	*6:06*	***6:15***	*6:18*	*6:24*	*6:36*
5W	*P*		*6:02*	*6:10*		*6:15*	*6:21*	***6:30***	*6:33*	*6:39*	*6:51*
6W	*K*		*6:11*		*6:20*	*6:25*	*6:31*	***6:40***	*6:43*	*6:49*	*7:01*
7W	*M*	*6:18*	*6:32*			*6:35*	*6:41*	***6:50***	*6:55*	*7:01*	*7:13*

- Eastbound trip 13E hooks to trip 4W, which arrives at DVC at 6:36a.m.
- Eastbound trip 14E hooks to trip 5W, which arrives at DVC at 6:51a.m.
- Eastbound trip 15E hooks to trip 6W, which arrives at DVC at 7:01a.m.
- Eastbound trip 16E hooks to trip 7W, which arrives at DVC at 7:13a.m.

Recalling that the last westbound trip constructed during the morning peak was 12W:

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
12W	K		7:11		7:20	7:25	7:31	7:40	7:45	7:51	8:03

The first westbound trip in the base period (13W) has the following three objectives:

1) Maintain the alternating branch pattern already established.

2) Generate an arrival time at CON that is somewhere between the 10-minute morning peak headway and the desired base headway of 20 minutes.

3) Establish a recognizable pattern of departure times from CON toward DVC that will carry through the base period.

Trip 13W below meets those conditions:

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
13W	M	7:24	7:38			7:41	7:46	7:55	8:00	8:06	8:18

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
13E	M	6:38	6:49	6:56	6:58	7:06	7:11			7:15	7:23

Notes: Trip 13W follows the M pattern and allows 1 minute of recovery time (when hooked with 13E).
Arrival time at CON is 15 minutes later than the previous trip 12W. Departure time from CON occurs on the hour.

The next trip, 14W, follows the P pattern and maintains the headway at 15 minutes at the controlling time point Lv CON. It is hooked to eastbound trip 13E.

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
14W	P		7:39	*7:47*		7:52	7:58	8:07	*8:15*	8:21	8:34

Following these two consecutive westbound departures from CON at 8:00 a.m. and 8:15 a.m. (13W and 14W), the time is right to spread the next trip to the target base headway of 20 minutes. This requires a departure at 8:35 a.m. This means that one of the next two westbound trips must be truncated at CON and removed from service.

The next two westbound trips, 15W and 16W, follow the K and M branches, and arrive at CON at 8:24 a.m. and 8:32 a.m. respectively. Trip 16W is clearly the better of the two to maintain in service, since a 3-minute layover at CON allows an 8:35 a.m. departure exactly 20 minutes after trip 14W. This provides a good opportunity to establish the base 20-minute headway at 0:15, 0:35 and 0:55 minutes past the hour at Lv CON.

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
15W	K		7:55		8:04	8:09	8:15	8:24	**Out of service**		
16W	M	8:00	8:14			8:17	8:23	8:32	8:35	8:41	8:54

Meanwhile, the last eastbound trip constructed during the A.M. peak was 16E:

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
16E	M	7:14	7:25	7:32	7:34	7:42	7:47			7:47	7:55

At the DVC end of the route, westbound buses will continue to arrive at-10 minute intervals until 8:03 a.m. (trip 12E). Trips 17E through 21E below are hooked to westbound arrivals 8W through 12W. One to two minutes of recovery time are allowed at DVC.

Entering the base period, running time decreases slightly and allows for more recovery time at DVC. As noted earlier, the extra running time is stored as additional recovery time at DVC in order to expand the "window of dwell time" during which transfers to other routes can be achieved.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
17E	K	7:24	7:35	7:42	7:43	7:51	7:56	8:00		8:09	
18E	K	7:34	7:45	7:52	7:53	8:00	8:04	8:07		8:14	
19E	P	7:44	7:55	8:02	8:04	8:12	8:17		8:22	8:29	
20E	M	7:55	8:06	8:13	8:15	8:23	8:28			8:32	8:40
21E	K	8:10	8:21	8:28	8:30	8:38	8:43	8:47		8:55	

Note that trip 18E deviates from the established rotating pattern of service to the branches. The second K trip is scheduled instead of adding a school extra to serve the morning bell of the local high school located near the MYV time point.

Three of the next westbound trips must pull out of service. Because the desired effect is to cut the 10-minute headway in half, it makes sense that every other bus should be removed from service until the five buses needed to operate the desired base period headway remain on the line.

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
17W	P		8:09	8:17		8:23	8:29	8:38	**Out of service**		
18W	P		8:14	8:21		8:27	8:33	8:42	8:55	9:01	9:14
19W	K		8:29		8:38	8:42	8:47	8:56	**Out of service**		
20W	M	8:40	8:54			8:57	9:02	9:11	9:13	9:19	9:32
21W	P		9:00	9:07		9:11	9:16	9:25	**Out of service**		

Recap: Shown below are the 12 westbound trips arriving at CON from 7:30 a.m. until 9:38 a.m. During this period, the schedule transitions from an even 10-minute headway between arrivals at CON (until 7:40 a.m.) to 15 minutes and then to 20 minutes between departures from CON.

Four of nine buses operating in morning peak service are removed from service, leaving five base blocks to carry through the base time period.

Route 110 - Westbound (recap)
Morning Peak to Base Period Transition

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
11W	P		7:02	7:10		7:15	7:21	7:30	7:35	7:41	7:53
12W	K		7:11		7:20	7:25	7:31	7:40	7:45	7:51	8:03
13W	M	7:24	7:38			7:41	7:46	7:55	8:00	8:06	8:18
14W	P		7:39	7:47		7:52	7:58	8:07	8:15	8:21	8:34
15W	K		7:55		8:04	8:09	8:15	8:24	**Out of service**		
16W	M	8:00	8:14			8:17	8:23	8:32	8:35	8:41	8:54
17W	P		8:09	8:17		8:23	8:29	8:38	**Out of service**		
18W	P		8:14	8:21		8:27	8:33	8:42	8:55	9:01	9:14
19W	K		8:29		8:38	8:42	8:47	8:56	**Out of service**		
20W	M	8:40	8:54			8:57	9:02	9:11	9:13	9:19	9:32
21W	P		9:00	9:07		9:11	9:16	9:25	**Out of service**		
22W	K		9:11		9:20	9:24	9:29	9:38	9:40	9:46	9:59

Note that the departure time of trips 20W and 22W from CON are not exactly 20 minutes apart. These variations are made deliberately in order to create minimum 15-minute mid-run layovers that are required by labor agreement for full-time runs.

The figure below shows the 13 eastbound trips that comprise the morning peak to base period transition. Uneven headways result from the attention given to westbound arrivals and departures to and from the train station CON.

Route 110 - Eastbound (recap)
Morning Peak to Base Transition

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
10E	M	6:00	6:11	6:18	6:22	6:30	6:35			6:39	6:47
11E	K	6:14	6:25	6:32	6:36	6:44	6:49	6:53		7:02	
12E	P	6:23	6:34	6:41	6:45	6:53	6:58		7:03	7:11	
13E	M	6:38	6:49	6:56	6:58	7:06	7:11			7:15	7:23
14E	K	6:53	7:04	7:11	7:13	7:21	7:26	7:30		7:39	
15E	P	7:08	7:19	7:26	7:29	7:37	7:42		7:47	7:55	
16E	M	7:14	7:25	7:32	7:34	7:42	7:47			7:47	7:55
17E	K	7:24	7:35	7:42	7:43	7:51	7:56	8:00		8:09	
18E	K	7:34	7:45	7:52	7:53	8:00	8:04	8:07		8:14	
19E	P	7:44	7:55	8:02	8:04	8:12	8:17		8:22	8:29	
20E	M	7:55	8:06	8:13	8:15	8:23	8:28			8:32	8:40
21E	K	8:10	8:21	8:28	8:30	8:38	8:43	8:47		8:55	
22E	P	8:25	8:36	8:43	8:45	8:53	8:58		9:02	9:09	

D. Base period – pulse/timed transfer windows

During base period, both CON and DVC serve as pulse transfer points for Route 110 and other routes operating in the area. Bus schedules are designed to meet at the rail station once an hour.

A timed transfer window of approximately 10 minutes – from :55 minutes past the hour until :05 minutes past the hour – is designed around train arrivals and departures. All bus/rail connections are timed, and all possible bus/bus connections are timed as well. Ridership and passenger transfer data could be used to identify particular bus/bus connections that should be supported in the schedules.

The base period service design of Route 110 calls for a 20-minute base period headway. This means that every third arrival and departure at CON should fall within the timed transfer window. Every third bus in both directions should be timed to arrive at the top of the hour.

The base period schedule pattern is established by trip 22W, which arrives at CON 13 minutes after 21W, at 9:38 a.m. Two minutes of dwell time are allowed to produce a departure at :40 minutes past the hour, allowing the next trip (23W) to depart at the top of the hour.

This sets the pattern for the next 15 westbound trips that operate until after 2:00 p.m. when a transition to the school period becomes necessary. Base period westbound trips arrive at :18, :38 and :58 minutes past the hour and depart at :20, :40 and :00 minutes after the hour.

Route 110 - Westbound
Base Period Trips

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
22W	K		9:11		9:20	9:24	9:29	9:38	9:40	9:46	9:59
23W	M	9:29	9:41			9:44	9:49	9:58	10:00	10:06	10:19
24W	P		9:53	10:00		10:04	10:09	10:18	10:20	10:26	10:39
25W	K		10:11		10:20	10:24	10:29	10:38	10:40	10:46	10:59
26W	M	10:29	10:41			10:44	10:49	10:58	11:00	11:06	11:19
27W	P		10:52	10:59		11:03	11:09	11:18	11:20	11:25	11:37
28W	K		11:10		11:19	11:23	11:29	11:38	11:40	11:45	11:57
29W	M	11:29	11:40			11:43	11:49	11:58	12:00	12:05	12:17
30W	P		11:52	11:59		12:03	12:09	12:18	12:20	12:25	12:37
31W	K		12:10		12:19	12:23	12:29	12:38	12:40	12:45	12:57
32W	M	12:29	12:40			12:43	12:49	12:58	1:00	1:05	1:17
33W	P		12:52	12:59		1:03	1:09	1:18	1:20	1:25	1:37
34W	K		1:10		1:19	1:23	1:29	1:38	1:40	1:45	1:57
35W	M	1:29	1:40			1:43	1:49	1:58	2:00	2:05	2:18
36W	P		1:52	1:59		2:03	2:09	2:18	2:20	2:25	2:38
37W	K		2:09		2:18	2:23	2:29	2:39	2:40	2:45	2:58

Base period eastbound trips are shown below. Arrivals at CON occur at :03, :23 and :43 minutes past the hour (1 minute earlier after 10:00 a.m.). Two to three minutes of dwell time are allowed, resulting in departures at :05, :25 and :45 minutes past the hour.

Route 110 - Eastbound
Base Period Trips

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
22E	P	8:25	8:36	8:43	8:45	8:53	8:58		9:02	9:09	
23E	M	8:45	8:56	9:03	9:05	9:13	9:18			9:21	9:29
24E	K	9:05	9:16	9:23	9:25	9:33	9:38	9:42		9:50	
25E	P	9:25	9:36	9:43	9:45	9:53	9:58		10:02	10:09	
26E	M	9:45	9:56	10:03	10:05	10:13	10:18			10:21	10:29
27E	K	10:05	10:16	10:22	10:25	10:38	10:42	10:42		10:50	
28E	P	10:25	10:36	10:42	10:45	10:53	10:58		11:02	11:09	
29E	M	10:45	10:56	11:02	11:05	11:13	11:18			11:21	11:29
30E	K	11:05	11:16	11:22	11:25	11:33	11:38	11:42		11:50	
31E	P	11:25	11:36	11:42	11:45	11:53	11:58		12:02	12:09	
32E	M	11:45	11:56	12:02	12:05	12:13	12:18			12:21	12:29
33E	K	12:05	12:16	12:22	12:25	12:33	12:38	12:42		12:49	
34E	P	12:25	12:36	12:42	12:45	12:53	12:58		1:02	1:09	
35E	M	12:45	12:56	1:02	1:05	1:13	1:18			1:21	1:29
36E	K	1:05	1:16	1:22	1:25	1:33	1:38	1:42		1:49	
37E	P	1:25	1:36	1:42	1:45	1:53	1:58		2:02	2:09	
38E	M	1:45	1:56	2:02	2:05	2:13	2:18			2:21	2:29

Note that the timed trips follow the M pattern in both directions. This practice generates very competitive transit travel times for passengers making longer bus/rail trips. The M branch is selected because it generates the highest passenger volumes of the three branches during the base period. Offering the benefit to different branches in the morning and evening peak periods would tend to reduce the attractiveness of transit travel to a larger number of passengers.

E. School extras

A school extra is a trip (or series of trips) added to accommodate the impact of large numbers of students arriving to or departing from a school located along a regular route. School extras typically operate on school days only and often consist of a partial trip or trips as necessary to accommodate actual demand. While school extras may be added in the morning or afternoon, they are more commonly needed at the afternoon bell. School extras are available to students and to the general public just as any other trip.

Looking back to the morning peak schedule of Route 110, extra capacity was provided without the need for any extra vehicles. This was possible because the morning school bell occurred during the peak period when the trunk headway was 10 minutes. By interrupting the alternating branch pattern and running two consecutive trips via the K branch, it was possible to bring two regular route vehicles to the school within 10 minutes of each other.

Unfortunately, additional school capacity for the afternoon bell cannot be accomplished in the same manner. The school dismissal time occurs 90 minutes before the 10-minute afternoon peak headway is needed. The 20-minute interval between Route 110 buses during the base period makes it impractical to rely solely on the buses in regular service. Students are unlikely to wait 20 minutes for the second bus and accelerating the arrival time would create an unacceptable gap in service just before the transition to the peak service is initiated. Therefore, an extra trip must be added.

School Period Trips:
Route 110 - Westbound

Trip #	**Via**	Lv **MCC**	Lv **WAS**	**MYV**	**CKP**	**CLA**	**CLT**	Arr **CON**	Lv **CON**	**FRY**	Arr **DVC**
38W	M	2:32	2:40			2:43	2:49	2:59	3:04	3:09	3:22
39W	**K**		**2:44S**		**2:51S**						
40W	P		2:54	3:03		3:07	3:13	3:23	3:25	3:30	3:43
41W	K		3:12		3:21	3:26	3:32	3:42	3:47	3:52	4:05

Route 110 - Eastbound

Trip #	**Via**	Lv **DVC**	**CLD**	Arr **CON**	Lv **CON**	**CLT**	**CLA**	**CKP**	**MYV**	Arr **WAS**	Arr **MCC**
39E	K	2:01	2:14	2:21	2:24	2:33	2:39	2:44		2:54	
40E	P	2:20	2:33	2:40	2:43	2:52	2:58		3:03	3:12	
41E	M	2:40	2:53	3:00	3:03	3:12	3:18			3:22	3:36

Trips 38W, 39W and 40W all pass the local high school, which is located near the time point WAS (Washington @ Clayton). Afternoon dismissal occurs at 2:35 p.m.

Trip 38W is a regular trip that passes the school 5 minutes after bell time. Note that the same running time is allowed as for other westbound M branch trips, even though it can be assumed that this trip may run behind schedule on school days due to heavy passenger loadings. This is done so that the trip will not run early on non-school days when passenger volumes are likely to be much lower. To enable the operator to get back on schedule as soon as the impact of the student load is distributed, additional recovery time at CON is allowed before continuing westbound to DVC.

Trip 39W is the school extra. It enters revenue service at the school 4 minutes following the scheduled departure of trip 38W and 9 minutes after the dismissal bell. Note that this trip follows the K branch and departs the school in a northbound direction. It will remain on route until all passengers have alighted.

Trip 40W is a regular route trip that passes the school 19 minutes after bell time. It operates southbound from the school to the area served by the P branch. Given that the wait time will discourage some passengers from using the bus, it could be assumed that the number of potential riders on this branch is lower than on the others.

Trip 41W passes the high school 37 minutes after bell time, serving as a "clean-up" trip for those passengers who may have missed trip 39W.

In this example, only one school extra has been added. However, it is quite common to operate several school extras or trippers as necessary to accommodate demand. The use of higher capacity (i.e., articulated) vehicles could be considered to respond to the impact of school demand without adding additional vehicles to the route.

F. Transition from base/school to the P.M. peak

The transition from the base/school period to the P.M. peak is influenced by many of the same considerations that were encountered earlier in the service day:

- Reduce headway from 20 to 10 minutes.
- Bring additional buses from the vehicle garage facility into revenue service at the nearest time point (CON) whenever possible.
- Reset the controlling time point as appropriate to address the bus/rail scheduling connections.

As before, the headway should decrease smoothly over several consecutive trips. When to restore the peak period service level varies from route to route, but is generally determined by the volume of passenger traffic and service productivity objectives.

Route 110 covers suburban communities with access to a commuter rail line. Assuming one-way train trips of approximately 1 hour, many commuters do not reach CON until after 6:00 p.m. Therefore, the P.M. peak 10-minute headway is maintained until at least 6:30 p.m. or 6:45 p.m.

Local workers and students are likely to use bus service between 4:30 p.m. and 5:15 p.m. This means that the P.M. peak period will be longer than the A.M. peak - over 2 hours compared to just 70 minutes in the A.M.

Nine vehicles are required to generate a -0 minute trunk headway in the A.M. peak. Based on cycle time alone, 10 vehicles should have been required. However, one less vehicle was needed because the duration of the A.M. peak period (90 minutes) is shorter than the cycle time (100 minutes) of the A.M. peak period and because a number of vehicles were pulled on at CON without making full round trips.

The duration of the P.M. peak (120 minutes) is greater than (or equal to) the cycle time (110 minutes). Therefore, it can be projected that all 11 vehicles estimated to be needed for P.M. peak revenue service will be required in order to generate the desired 10-minute trunk headway on Route 110.

Five vehicles have been operating during the base period, and a sixth was added during the school period. A second objective of the scheduling transition into the P.M. peak is then to integrate five additional vehicles to the line as efficiently as possible. Vehicles pull onto the line in a similar manner as they were pulled off near the end of the morning peak.

A third objective during the transition into the afternoon peak is to reset the controlling time point. There are two significant passenger flows during this time period:

1) Rail commuters returning home to the residential neighborhoods served by the three route branches at the east end of the route; and

2) Students, shoppers and retail district employees returning to the rail station from the west end of the route.

To accommodate these passenger flows, the afternoon peak schedule will be developed around:

- Eastbound arrivals at CON,
- Eastbound departures from CON, and
- Westbound departures from CON.

While bus departures occur every 10 minutes, evening train arrivals occur at 7.5-minute intervals. Because the bus and rail headways are not even multiples of one another, they are not compatible for timed transfers. As with the morning peak, this is not a significant problem as both are relatively frequent and transfer wait times are consequently low.

The optimal strategy for intermodal transfers is to provide even intervals between bus departures and arrivals at the controlling time point, except as necessary to steer away from "near misses" in rail/bus transfers as perceived by customers.

The transition from base/school to P.M. peak begins with trip 45E in the eastbound direction. Trips 42E through 44E maintain the 20-minute base/school period headway, with departures from DVC evenly spaced at :00, :20 and :40 minutes past the hour and with arrivals at CON at :20, :40 and :00.

Route 110 - Eastbound

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
42E	K	3:00	3:13	3:20	3:24	3:33	3:39	3:44		3:54	
43E	P	3:20	3:33	3:40	3:44	3:53	3:59		4:04	4:13	
44E	M	3:40	3:53	4:00	4:02	4:11	4:17			4:21	4:35
45E	K		**Into service**		4:12	4:22	4:29	4:34		4:44	
46E	P	3:55	4:08	4:16	4:20	4:30	4:37		4:42	4:50	
47E	M	4:15	4:28	4:36	4:40	4:50	4:57			5:00	5:14

Route 110 - Westbound

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
42W	M	3:36	3:44			3:47	3:53	4:03	4:05	4:10	4:23
43W	P		3:54	4:03		4:07	4:13	4:23	4:25	4:30	4:43
44W	K		4:13		4:22	4:27	4:33	4:43	4:46	4:51	5:04
45W	M	4:36	4:44			4:47	4:53	5:03	5:05	5:10	5:23
46W	P		4:45	4:53		4:57	5:03	5:13	5:15	5:21	5:34

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
37W	K		2:09		2:18	2:23	2:29	2:39	2:40	2:45	2:58
38W	M	2:32	2:40			2:43	2:49	2:59	3:04	3:09	3:22

Trip 37W hooks to eastbound trip 42E, allowing 2 minutes of recovery time (2:58 p.m. until 3:00 p.m.) at DVC. Since the next westbound arrival at DVC does not occur until 3:22 p.m. (trip 38W), a vehicle must be added to cover trip 43E beginning at 3:20 p.m. This could be hooked to trip 39W on school days.

The addition of the 3:20 p.m. departure provides a drop-back through which additional layover can be provided between trips at DVC. This provides an opportunity for mid-run breaks of at least 15 minutes if required by contract. For example, if applied to Route 110, trip 38W could hook to eastbound trip 44E, allowing 18 minutes at DVC. This would consist of 3 minutes of recovery time (3:22 p.m. until 3:25 p.m.) and 15 minutes of layover (3:25 p.m. until 3:40 p.m.) for a total of 18 minutes.

The second afternoon pull-out enters revenue service at CON at 4:12 p.m. and makes trip 45E. Trip 40W hooks to 46E, allowing 12 minutes of recovery time (3:43 p.m. until 3:55 p.m.) at DVC. These trips absorb the service frequency transition from 20 to 10 minutes.

G. P.M. peak service

The 10-minute eastbound headway is established by trip 47E and continues through trip 58E with evenly spaced departures from CON. Note the two additional buses that enter revenue service to make trips 48E and 50E from CON. The result is that the 10-minute headway of departures from DVC does not begin until 5:15 p.m.

P.M. Peak Trips

Route 110 - Eastbound

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
48E	K			**Into service**	4:50	5:00	5:07	5:12		5:22	
49E	P	4:35	4:48	4:56	5:00	5:10	5:17		5:22	5:30	
50E	M			**Into service**	5:10	5:20	5:27			5:30	5:44
51E	K	4:55	5:08	5:16	5:20	5:30	5:37	5:42		5:52	
52E	P			**Into service**	5:30	5:40	5:47		5:52	6:00	
53E	M	5:15	5:28	5:36	5:40	5:50	5:57			6:00	6:14
54E	K	5:25	5:38	5:46	5:50	6:00	6:07	6:12		6:22	
55E	P	5:35	5:48	5:56	6:00	6:10	6:17		6:22	6:30	
56E	M	5:45	5:58	6:00	6:10	6:20	6:27			6:30	6:44
57E	K	5:55	6:08	6:16	6:20	6:30	6:37	6:42		6:52	
58E	P	6:05	6:18	6:26	6:30	6:40	6:47		6:52	7:00	

Since eastbound is the prevailing direction of passenger traffic during the P.M. peak, the westbound schedule simply accommodates the eastbound trips. The -0 minute interval between departures from CON is established by trip 45W at 5:05 p.m., and subsequent trips are evenly spaced. The schedule pattern will be maintained for 14 consecutive trips, until 7:25 p.m. The eleventh and final bus of the P.M. peak enters revenue service at 5:35 p.m. at CON and operates trip 48W.

Route 110 - Westbound

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
47W	K		4:50		4:59	5:04	5:10	5:20	5:25	5:31	5:44
48W	--						**Into service**		5:35	5:41	5:54
49W	M	5:15	5:23			5:27	5:33	5:43	5:45	5:51	6:04
50W	P		5:25	5:33		5:37	5:43	5:53	5:55	6:01	6:14
51W	K		5:33		5:42	5:47	5:53	6:03	6:05	6:11	6:24
52W	M	5:45	5:53			5:57	6:03	6:13	6:15	6:21	6:34
53W	P		5:55	6:03		6:07	6:13	6:23	6:25	6:31	6:44
54W	K		6:03		6:12	6:17	6:23	6:33	6:35	6:41	6:54
55W	M	6:15	6:23			6:27	6:33	6:43	6:45	6:51	7:04
56W	P		6:25	6:33		6:37	6:43	6:53	6:55	7:01	7:14
57W	K		6:33		6:42	6:47	6:53	7:03	7:05	7:11	7:24
58W	M	6:45	6:53			6:57	7:03	7:11	7:15	7:20	7:31
59W	P		6:55	7:03		7:07	7:13	7:21	7:25	7:30	7:41

H. Evening and night service

The level of service requirement drops substantially after the end of the P.M. peak. Prevailing traffic flows remain unchanged, however, so that the controlling time point for eastbound departures continues to be CON. Therefore, the major objective of the transition is to remove buses from service efficiently while preserving a recognizable headway and service pattern.

The eastbound trips are developed around the controlling time point CON. The 10-minute peak headway spreads to 15 minutes between eastbound departures after 6:30 p.m. (trips 59E through 61E), to 20 minutes after 7:30 p.m. (trips 62E through 65E), and 30 minutes after 8:30 p.m. until the end of the service day (trips 66E through 69E).

Evening and Night Period Service

Route 110 - Eastbound

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
59E	M	6:20	6:33	6:41	6:45	6:55	7:02			7:05	7:17
60E	P	6:35	6:48	6:56	7:00	7:07	7:12	7:16		7:24	
61E	K	6:50	7:03	7:11	7:15	7:22	7:27		7:31	7:38	
62E	M	7:10	7:21	7:27	7:30	7:37	7:42			7:45	7:57
63E	K	7:30	7:41	7:47	7:50	7:57	8:02	8:06		8:14	
64E	P	7:50	8:01	8:07	8:10	8:17	8:22		8:26	8:33	
65E	M	8:10	8:21	8:27	8:3C	8:37	8:42			8:45	8:57
66E	K	8:40	8:51	8:57	9:00	9:07	9:12	9:16		9:24	
67E	P	9:10	9:21	9:27	9:30	9:37	9:42		9:46	9:53	
68E	K	9:40	9:51	9:57	10:00	10:07	10:12	10:16		10:24	
69E	P	10:10	10:21	10:27	10:30	10:37	10:42		10:46	10:53	

Route 110 westbound service operates until 11:18 p.m. Because the westbound direction has lower passenger traffic, the decision is made to remove buses from revenue service after arriving at CON. This will inconvenience fewer passengers than truncated eastbound trips.

The basic approach is to remove every other bus arriving at CON after 7:30 p.m. Trips 60W, 62W, 64W and 67W pull to the garage.

Notice the headway transition of arrivals at the western terminal DVC. The-20 minute interval between trips 61W and 63W gives way to 30 minutes between trips 63W, 65W and 66W, and 40 minutes between 66W and 67W.

Evening and Night Period Service (con't)

Route 110 - Westbound

Trip #	Lv Via	Lv MCC	WAS	MYV	CKP	CLA	Arr CLT	Lv CON	CON	Arr FRY	DVC
60W	K		7:07		7:15	7:19	7:24	7:32	**Out of service**		
61W	M	7:23	7:31			7:34	7:39	7:47	7:50	7:55	8:06
62W	P		7:28	7:35		7:39	7:44	7:52	**Out of service**		
63W	K		7:42		7:50	7:54	7:59	8:07	8:10	8:15	8:26
64W	M	8:00	8:08			8:11	8:16	8:24	**Out of service**		
65W	P		8:14	8:21		8:25	8:30	8:38	8:40	8:45	8:56
66W	K		8:37		8:45	8:49	8:53	9:01	9:10	9:15	9:26
67W	M	9:00	9:08			9:11	9:16	9:24	**Out of service**		
68W	P		9:24	9:31		9:35	9:40	9:48	9:50	9:55	10:06
69W	K		9:53		10:01	10:05	10:10	10:18			
70W	P		10:24	10:31		10:35	10:40	10:48			
71W	K		10:53		11:01	11:05	11:10	11:18			

All trips for Route 110 have been generated and a completed master schedule is shown at the end of this section. The next step involves blocking the trips into vehicle assignments. The blocking process, using Route 110 and Revised Route 32 as models, is covered in Chapter 3.

XII. Rail Scheduling

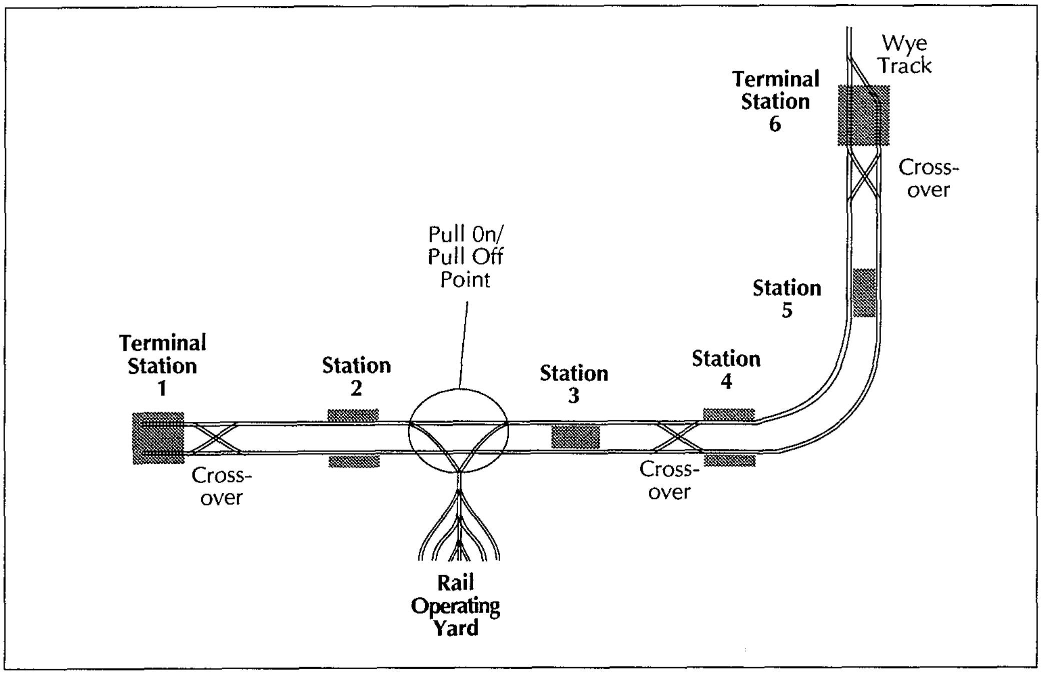
Generally, most scheduling principles apply to both rail and bus. However, schedulers face many unique issues and constraints emanating from the lack of flexibility that operating on fixed track presents. The impact of these issues on scheduling efficiency depends significantly on the physical layout of the rail network and the type of train control system used. Representative examples of those issues are presented in this section.

A. Example rail system layout

The simplest and most common layout of rail facilities is "double track." This configuration consists of two tracks lying side by side in the railbed. Double track provides for the unobstructed flow of trains operating in opposite directions. Stations located along double track segments are either "outside platform" or "center platform." Each station is generally a published time point.

"Crossover" tracks are often located near the terminating stations on the line. These crossovers are of concern to the scheduler because trains in both directions must use them in order to reverse direction at the end of the line. The "yard track" is a connecting spur between the main line and the rail maintenance and/or storage yard.

A simplified double track line serving two terminal stations and four intermediate stations is shown on the next page. Trains pull into and out of service from a yard line between Stations 2 and 3. The crossover between stations 3 and 4 is primarily for emergency use only.



Example layout of a simplified rail line with double track operation

B. Special considerations for rail

The limited flexibility of operating on fixed rail usually results in additional constraints for the scheduler, generally in addressing five typical areas:

1) Minimum spacing between trains
2) Pulling trains into and out of revenue service
3) Passing trains
4) Single track operations
5) Merging tracks and terminal point scheduling

1) Minimum spacing between trains

Spacing is a critical concern. Most systems require, as a matter of operating policy, a minimum time and/or distance between trains, both for safety considerations and to ensure a smooth flow of service. The specific operating policy for minimum spacing varies between systems, but is typically between 1 and 3 minutes. Factors that influence spacing include train volumes, length of train sets, safety, history and the sophistication of the train control system.

2) Pulling trains into and out of revenue service

The techniques for moving trains into and out of revenue service are similar to those used for bus scheduling. However, it is extremely important that trains entering and leaving the main track be coordinated with trains operating in revenue service.

The following table illustrates how trains would pull onto the example rail line given the following operating characteristics.

Cycle Time	60 Minutes
Frequency	15 Minutes, both directions
Number of Trains	4
First Pullout no earlier than	4:30a.m.

Eastbound (A.M.)

Train#	Station Pullout	1	2	3	4	5	6
101	**4:33**			4:35	4:41	4:46	4:51
103	**4:48**			4:50	4:56	5:01	5:06
102		4:55	5:01	5:05	5:11	5:16	5:21
104		5:10	5:06	5:10	5:26	5:31	5:36
101		5:25	5:31	5:35	5:41	5:46	5:51
103		5:40	5:46	5:50	5:56	6:01	6:06
102		5:55					
104		6:10					

Example schedule demonstrating A.M. pull-outs eastbound

Westbound (A.M.)

Train#	Station Pullout	6	5	4	3	2	1
102	**4:44**					4:46	4:50
104	**4:59**					5:01	5:05
101		4:55	5:01	5:06	5:12	5:16	5:20
103		5:10	5:16	5:21	5:27	5:31	5:35
102		5:25	5:31	5:36	5:42	5:46	5:50
104		5:40					
101		5:55					
103		6:10					

Example schedule demonstrating A.M. pullouts westbound

Trains leave the yard at 4:33, 4:44, 4:48 and 4:59 a.m. respectively. A deadhead time of 2 minutes is allowed to either Station 3 for eastbound trains or Station 2 for westbound trains.

3) Passing trains

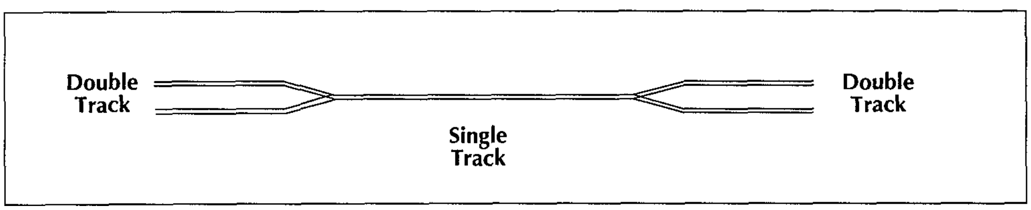
Buses operating on public streets are generally able to pass other buses as dictated by service requirements. However, rail operations do not share this flexibility. Trains operating in scheduled service on a double track configuration generally cannot pass other trains unless a parallel express track is available.

In some instances, trains operating in revenue service can pass an out-of-service train when a side track is available to momentarily store the out-of-service train or when a crossover track is available to divert the out-of-service train from the main track.

4) Single track operations

Train movements are highly constrained on segments where only one track is available for trains travelling in both directions. Single track operation creates a bottleneck that requires special consideration by the scheduler. The severity of the bottleneck is a function of the length of the one-way track segment, the frequency of trains and the reduced operating speeds that are typically required for single track operation.

For lower frequency operations such as commuter rail, it is possible that single track operations may prove adequate. However, in Heavy Rail Transit (HRT) or Light Rail Transit (LRT) systems with a higher volume of trains, single track operations are limited to short segments. Safety concerns dictate that train operating speeds be reduced on these sections and minimum spacing intervals be strictly enforced.



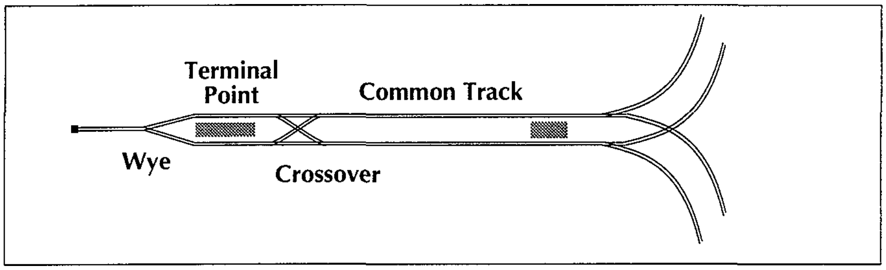
Example of a single track segment on a double track layout

In the example above, only one train at a time can enter and travel through a single track segment. The time a train requires to travel the single track will affect the level of service that can be provided. For example, a 3-minute requirement on the single track will dictate a minimum 7- to 10-minute service frequency, depending on minimum spacing requirements.

5) Merging tracks and terminal point scheduling

A number of unique scheduling issues arise when two or more rail lines merge onto a single alignment or "common track." Most important are safety considerations. For the passenger, common tracks can sometimes be confusing when multiple routes serve a common stop.

Perhaps the most significant potential bottleneck in the common track scenario is the terminal point. Terminal rail stations are typically equipped with crossover tracks that allow trains to enter, layover and depart the station without blocking one another. The crossover may be located either forward of the station on the active line track or beyond the station on a "Wye" or spur track. The configuration of the crossover track affects the number of trains that can be accommodated at the terminal point.



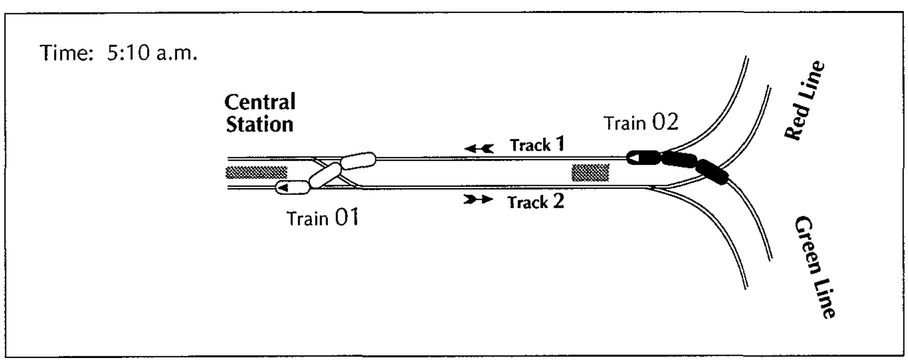
Typical rail terminal point crossover options involving common track

Example: Crossing Over Two Lines Operating the Same Frequency at a Terminal Point

In the following illustration two rail lines, the Red Line and the Green Line terminate at Central Station. Both lines share a common track for both the Central Station and one other station. The scheduler must determine the desired pattern and spacing between trips operating on the common track while maintaining a minimum policy spacing between trains of at least 2 minutes. Central Station consists of a center platform with a track on each side and a forward crossover ahead of the platform. The scheduler intends that all trains inbound to Central Station utilize Track 1, while outbound trains utilize Track 2.

The Red and Green Lines are intended to operate 15-minute headways during the day with a 10-minute layover at Central Station. A straight forward option would be to introduce alternating Red and Green Line trains onto the common track. Under optimal conditions, each would enter the common track at 7- and 8-minute intervals.

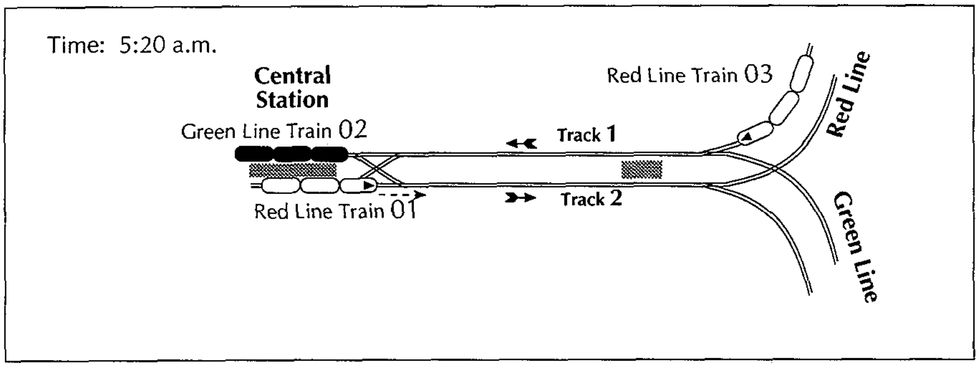
Red Line train 01 is scheduled to arrive at Central Station at 5:10 a.m. The scheduler opts to have this train cross over to Track 2 before entering Central Station for a 10-minute layover. Green Line train 02 is due to arrive at Central Station at 5:17 a.m.



Inbound Track 1 Red Line train 01 arrives at central station at 5:10 a.m.

At 5:17 a.m., train 01 will still be laying over at Central Station occupying Track 2. The scheduler determines that inbound Green Line train 02 can arrive at Central Station on Track 1 and remain on Track 1 for its 10-minute layover.

At 5:20 a.m., Red Line train 01 is ready to begin an outbound trip. Since it is already on Track 2, it will proceed straight ahead. The next Red Line train 03, maintaining a 15 minute headway, is due to arrive at Central Station at 5:25 a.m.



Outbound Red Line train 01 proceeds directly on track 1.

Since Track 2 at Central Station is now open for layover, inbound Red Line train 03 will move from Track 1 to Track 2 at the crossover and layover on Track 2 (similar to Red Line train 01).

A pattern has now been established. Red Line trains arrive on Track 1 and crossover to Track 2 before pulling into Central station. Red Lines depart the station directly on Track 2. Green Line trains also inbound on Track 1. However, they inbound directly into the station on Track 1, take a layover, then cross over to Track 2 for outbound departure.

An example Central Station train arrival and departure schedule is shown below. A minimum of 2 minutes of train spacing is maintained and the predictable pattern minimizes passenger confusion. However, the scheduler will likely have to coordinate train arrivals and departures at outlying stations and switches, support timed transfers, and accommodate service level adjustments over the course of the day. These issues may cause the predictable pattern to vanish quickly.

Where different line headways, more frequent service and spacing increases are considered, the scheduler often finds that the use of sophisticated automatic train control (ATC) systems and higher capacity crossover and Wye tracks are needed to develop safe and effective schedules.

Central Station
Red and Green Line Arrivals and Departures

Line	Train	Arr Hdwy	Arr Time	Layover Track	Layover Minutes	Depart Time	Depart Hdwy
Red	01		5:10	2	:10	5:20	
Green	02		5:17	1	:10	5:27	
Red	03	15	5:25	2	:10	5:35	15
Green	04	15	5:32	1	:10	5:42	15
Red	05	15	5:40	2	:10	5:50	15
Green	06	15	5:47	1	:10	5:57	15
Red	07	15	5:55	2	:10	6:05	15
Green	08	15	6:02	1	:10	6:12	15

Route 110 /WESTbound

Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
1W	K		5:04		5:13	5:17	5:22	**5:30**	5:33	5:38	5:49
2W	P		5:21	5:28		5:32	5:37	5:45	5:48	5:53	6:04
3W	K		5:31		5:40	5:45	5:51	6:00	6:03	6:09	6:21
4W	M	5:43	5:57			6:00	6:06	6:15	6:18	6:24	6:36
5W	P		6:02	6:10		6:15	6:21	6:30	6:33	6:39	6:51
6W	K		6:11		6:20	6:25	6:31	6:40	6:43	6:49	7:01
7W	M	6:18	6:32			6:35	6:41	6:50	6:55	7:01	7:13
8W	P		6:32	6:40		6:45	6:51	7:00	7:05	7:11	7:23
9W	K		6:41		6:50	6:55	7:01	7:10	7:15	7:21	7:33
10W	M	6:48	7:02			7:05	7:11	7:20	7:25	7:31	7:43
11W	P		7:02	7:10		7:15	7:21	7:30	7:35	7:41	7:53
12W	K		7:11		7:20	7:25	7:31	7:40	7:45	7:51	8:03
13W	M	7:24	7:38			7:41	7:46	7:55	8:00	8:06	8:18
14W	P		7:39	7:47		7:52	7:58	8:07	8:15	8:21	8:34
15W	K		7:55		8:04	8:09	8:15	8:24	Out of service		
16W	M	8:00	8:14			8:17	8:23	8:32	8:35	8:41	8:54
17W	P		8:09	8:17		8:23	8:29	8:38	Out of service		
18W	P		8:14	8:21		8:27	8:33	8:42	8:55	9:01	9:14
19W	K		8:29		8:38	8:42	8:47	8:56	Out of service		
20W	M	8:40	8:54			8:57	9:02	9:11	9:13	9:19	9:32
21W	P		9:00	9:07		9:11	9:16	9:25	Out of service		
22W	K		9:11		9:20	9:24	9:29	9:38	9:40	9:46	9:59
23W	M	9:29	9:41			9:44	9:49	9:58	10:00	10:06	10:19
24W	P		9:53	10:00		10:04	10:09	10:18	10:20	10:26	10:39
25W	K		10:11		10:20	10:24	10:29	10:38	10:40	10:46	10:59
26W	M	10:29	10:41			10:44	10:49	10:58	11:00	11:06	11:19
27W	P		10:52	10:59		11:03	11:09	11:18	11:20	11:25	11:37
28W	K		11:10		11:19	11:23	11:29	11:38	11:40	11:45	11:57
29W	M	11:29	11:40			11:43	11:49	11:58	12:00	12:05	12:17
30W	P		11:52	11:59		12:03	12:09	12:18	12:20	12:25	12:37
31W	K		12:10		12:19	12:23	12:29	12:38	12:40	12:45	12:57
32W	M	12:29	12:40			12:43	12:49	12:58	1:00	1:05	1:17
33W	P		12:52	12:59		1:03	1:09	1:18	1:20	1:25	1:37
34W	K		1:10		1:19	1:23	1:29	1:38	1:40	1:45	1:57
35W	M	1:29	1:40			1:43	1:49	1:58	2:00	2:05	2:18
36W	P		1:52	1:59		2:03	2:09	2:18	2:20	2:25	2:38
37W	K		2:09		2:18	2:23	2:29	2:39	2:40	2:45	2:58
38W	M	2:32	2:40			2:43	2:49	2:59	3:04	3:09	3:22
39W	K		2:44S		2:51S	(School Days Only)					
40W	P		2:54	3:03		3:07	3:13	3:23	3:25	3:30	3:43
41W	K		3:12		3:21	3:26	3:32	3:42	3:47	3:52	4:05
42W	M	3:36	3:44			3:47	3:53	4:03	4:05	4:10	4:23
43W	P		3:54	4:03		4:07	4:13	4:23	4:25	4:30	4:43
44W	K		4:13		4:22	4:27	4:33	4:43	4:46	4:51	5:04
45W	M	4:36	4:44			4:47	4:53	5:03	5:05	5:10	5:23
46W	P		4:45	4:53		4:57	5:03	5:13	5:15	5:21	5:34
47W	K		4:50		4:59	5:04	5:10	5:20	5:25	5:31	5:44
48W	--							Into service	5:35	5:41	5:54
49W	M	5:15	5:23			5:27	5:33	5:43	5:45	5:51	6:04
50W	P		5:25	5:33		5:37	5:43	5:53	5:55	6:01	6:14
51W	K		5:33		5:42	5:47	5:53	6:03	6:05	6:11	6:24
52W	M	5:45	5:53			5:57	6:03	6:13	6:15	6:21	6:34
53W	P		5:55	6:03		6:07	6:13	6:23	6:25	6:31	6:44
54W	K		6:03		6:12	6:17	6:23	6:33	6:35	6:41	6:54
55W	M	6:15	6:23			6:27	6:33	6:43	6:45	6:51	7:04
56W	P		6:25	6:33		6:37	6:43	6:53	6:55	7:01	7:14
57W	K		6:33		6:42	6:47	6:53	7:03	7:05	7:11	7:24
58W	M	6:45	6:53			6:57	7:03	7:11	7:15	7:20	7:31
59W	P		6:55	7:03		7:07	7:13	7:21	7:25	7:30	7:41
60W	K		7:07		7:15	7:19	7:24	7:32	Out of service		
61W	M	7:23	7:31			7:34	7:39	7:47	7:50	7:55	8:06
62W	P		7:28	7:35		7:39	7:44	7:52	Out of service		
63W	K		7:42		7:50	7:54	7:59	8:07	8:10	8:15	8:26
64W	M	8:00	8:08			8:11	8:16	8:24	Out of service		
65W	P		8:14	8:21		8:25	8:30	8:38	8:40	8:45	8:56
66W	K		8:37		8:45	8:49	8:53	9:01	9:10	9:15	9:26
67W	M	9:00	9:08			9:11	9:16	9:24			
68W	P		9:24	9:31		9:35	9:40	9:48	9:50	9:55	10:06
69W	K		9:53		10:01	10:05	10:10	10:18	Out of service		
70W	P		10:24	10:31		10:35	10:40	10:48	Out of service		
71W	K		10:53		11:01	11:05	11:10	11:18	Out of service		

Route 110 /EASTbound

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC
1E	P			Into service	4:43	4:49	4:53		4:57	5:04	
2E	K			Into service	4:59	5:05	5:09	5:13		5:21	
3E	P			Into service	5:05	5:11	5:15		5:19	5:27	
4E	M			Into service	5:21	5:27	5:31			5:34	5:42
5E	K			Into service	5:36	5:44	5:49	5:53		6:02	
6E	P			Into service	5:45	5:53	5:58		6:03	6:11	
7E	M	5:30	5:40	5:46	5:52	6:00	6:05			6:09	6:17
8E	K	5:44	5:55	6:02	6:06	6:14	6:19	6:23		6:32	
9E	P	5:54	6:05	6:12	6:15	6:23	6:28		6:33	6:41	
10E	M	6:00	6:11	6:18	6:22	6:30	6:35			6:39	6:47
11E	K	6:14	6:25	6:32	6:36	6:44	6:49	6:53		7:02	
12E	P	6:23	6:34	6:41	6:45	6:53	6:58		7:03	7:11	
13E	M	6:38	6:49	6:56	6:58	7:06	7:11			7:15	7:23
14E	K	6:53	7:04	7:11	7:13	7:21	7:26	7:30		7:39	
15E	P	7:08	7:19	7:26	7:29	7:37	7:42		7:47	7:55	
16E	M	7:14	7:25	7:32	7:34	7:42	7:47			7:47	7:55
17E	K	7:24	7:35	7:42	7:43	7:51	7:56	8:00		8:09	
18E	K	7:34	7:45	7:52	7:53	8:00	8:04	8:07		8:14	
19E	P	7:44	7:55	8:02	8:04	8:12	8:17		8:22	8:29	
20E	M	7:55	8:06	8:13	8:15	8:23	8:28			8:32	8:40
21E	K	8:10	8:21	8:28	8:30	8:38	8:43	8:47		8:55	
22E	P	8:25	8:36	8:43	8:45	8:53	8:58		9:02	9:09	
23E	M	8:45	8:56	9:03	9:05	9:13	9:18			9:21	9:29
24E	K	9:05	9:16	9:23	9:25	9:33	9:38	9:42		9:50	
25E	P	9:25	9:36	9:43	9:45	9:53	9:58		10:02	10:09	
26E	M	9:45	9:56	10:03	10:05	10:13	10:18			10:21	10:29
27E	K	10:05	10:16	10:22	10:25	10:38	10:42	10:42		10:50	
28E	P	10:25	10:36	10:42	10:45	10:53	10:58		11:02	11:09	
29E	M	10:45	10:56	11:02	11:05	11:13	11:18			11:21	11:29
30E	K	11:05	11:16	11:22	11:25	11:33	11:38	11:42		11:50	
31E	P	11:25	11:36	11:42	11:45	11:53	11:58		12:02	12:09	
32E	M	11:45	11:56	12:02	12:05	12:13	12:18			12:21	12:29
33E	K	12:05	12:16	12:22	12:25	12:33	12:38	12:42		12:49	
34E	P	12:25	12:36	12:42	12:45	12:53	12:58		1:02	1:09	
35E	M	12:45	12:56	1:02	1:05	1:13	1:18			1:21	1:29
36E	K	1:05	1:16	1:22	1:25	1:33	1:38	1:42		1:49	
37E	P	1:25	1:36	1:42	1:45	1:53	1:58		2:02	2:09	
38E	M	1:45	1:56	2:02	2:05	2:13	2:18			2:21	2:29
39E	K	2:01	2:14	2:21	2:24	2:33	2:39	2:44		2:54	
40E	P	2:20	2:33	2:40	2:43	2:52	2:58		3:03	3:12	
41E	M	2:40	2:53	3:00	3:03	3:12	3:18			3:22	3:36
42E	K	3:00	3:13	3:20	3:24	3:33	3:39	3:44		3:54	
43E	P	3:20	3:33	3:40	3:44	3:53	3:59		4:04	4:13	
44E	M	3:40	3:53	4:00	4:02	4:11	4:17			4:21	4:35
45E	K			Into service	4:12	4:22	4:29	4:34		4:44	
46E	P	3:55	4:08	4:16	4:20	4:30	4:37		4:42	4:50	
47E	M	4:15	4:28	4:36	4:40	4:50	4:57			5:00	5:14
48E	K			Into service	4:50	5:00	5:07	5:12		5:22	
49E	P	4:35	4:48	4:56	5:00	5:10	5:17		5:22	5:30	
50E	M			Into service	5:10	5:20	5:27			5:30	5:44
51E	K	4:55	5:08	5:16	5:20	5:30	5:37	5:42		5:52	
52E	P			Into service	5:30	5:40	5:47		5:52	6:00	
53E	M	5:15	5:28	5:36	5:40	5:50	5:57			6:00	6:14
54E	K	5:25	5:38	5:46	5:50	6:00	6:07	6:12		6:22	
55E	P	5:35	5:48	5:56	6:00	6:10	6:17		6:22	6:30	
56E	M	5:45	5:58	6:00	6:10	6:20	6:27			6:30	6:44
57E	K	5:55	6:08	6:16	6:20	6:30	6:37	6:42		6:52	
58E	P	6:05	6:18	6:26	6:30	6:40	6:47		6:52	7:00	
59E	M	6:20	6:33	6:41	6:45	6:55	7:02			7:05	7:17
60E	P	6:35	6:48	6:56	7:00	7:07	7:12	7:16		7:24	
61E	K	6:50	7:03	7:11	7:15	7:22	7:27		7:31	7:38	
62E	M	7:10	7:21	7:27	7:30	7:37	7:42			7:45	7:57
63E	K	7:30	7:41	7:47	7:50	7:57	8:02	8:06		8:14	
64E	P	7:50	8:01	8:07	8:10	8:17	8:22		8:26	8:33	
65E	M	8:10	8:21	8:27	8:30	8:37	8:42			8:45	8:57
66E	K	8:40	8:51	8:57	9:00	9:07	9:12	9:16		9:24	
67E	P	9:10	9:21	9:27	9:30	9:37	9:42		9:46	9:53	
68E	K	9:40	9:51	9:57	10:00	10:07	10:12	10:16		10:24	
69E	P	10:10	10:21	10:27	10:30	10:37	10:42		10:46	10:53	

CHAPTER 2: EXERCISES

- Prepare a Route 110 master schedule (both directions) for Saturdays. Use the following assumptions:
  - Hours of operation: Begin service at approximately 7:00 a.m. and end service at approximately 10:00 p.m.
  - Headways: Operate a 30-minute trunk headway until approximately 7:00 p.m. and a 60-minute headway thereafter. Operate alternating service on the "K" and "P" branches only. Do not serve the "M" branch.
  - Running Times: Use weekday base period running times in both directions until 3:00 p.m. and after 6:00 p.m. Use peak weekday running times between 3:00 p.m. and 6:00 p.m.
  - Controlling Time Points: Coordinate buses with train arrivals and departures at CON to the maximum extent possible. Assume that eastbound trains arrive at :02, :17, :32 and :47 and that westbound trains depart at :08, :23, :38 and :53 after the hour.

CHAPTER 2: EXERCISE ANSWER SHEET

Master Schedule - Route 110 Saturday Service

The following Master Schedule for Route 110 Saturday service presents one possible answer. It satisfies the frequency, branching and running time specifications. It also starts in each direction at approximately 7:00 a.m. and ends in each direction at approximately 10:00 p.m.

The actual start and end times were controlled by the desire to meet the train schedule as often as possible. The Saturday layovers at CON are considerably longer than weekday layovers when the service better matches the frequency of the trains. A train connection matrix is shown below.

Trip #	Via	Lv DVC	CLD	Arr CON	Lv CON	CLT	CLA	CKP	MYV	Arr WAS	Arr MCC	Trip #	Via	Lv MCC	Lv WAS	MYV	CKP	CLA	CLT	Arr CON	Lv CON	FRY	Arr DVC
-	-	-	-	-	-	-	-	-	-	-		1W	P		6:54	7:01		7:05	7:10	7:19	7:34	7:40	7:53
1E	P		Into Service		6:55	7:03	7:08		7:12	7:19		2W	K		7:24		7:33	7:37	7:42	7:51	8:04	8:10	8:23
2E	K		Into Service		7:25	7:33	7:38	7:42		7:50		3W	P		7:54	8:01		8:05	8:10	8:19	8:34	8:40	8:53
3E	P		Into Service		7:55	8:03	8:08		8:12	8:19		4W	K		8:24		8:33	8:37	8:42	8:51	9:04	9:10	9:23
4E	K	7:58	8:09	8:15	8:25	8:33	8:38	8:42		8:50		5W	P		8:54	9:01		9:05	9:10	9:19	9:34	9:40	9:53
5E	P	8:28	8:39	8:45	8:55	9:03	9:08		9:12	9:19		6W	K		9:24		9:33	9:37	9:42	9:51	10:04	10:10	10:23
6E	K	8:58	9:09	9:15	9:25	9:33	9:38	9:42		9:50		7W	P		9:54	10:01		10:05	10:10	10:19	10:34	10:40	10:53
7E	P	9:28	9:39	9:45	9:55	10:03	10:08		10:12	10:19		8W	K		10:24		10:33	10:37	10:42	10:51	11:04	11:10	11:23
8E	K	9:58	10:09	10:15	10:25	10:33	10:38	10:42		10:50		9W	P		10:54	11:01		11:05	11:10	11:19	11:34	11:40	11:53
9E	P	10:28	10:39	10:45	10:55	11:03	11:08		11:12	11:19		10W	K		11:24		11:33	11:37	11:42	11:51	12:04	12:10	12:23
10E	K	10:58	11:09	11:15	11:25	11:33	11:38	11:42		11:50		11W	P		11:54	12:01		12:05	12:10	12:19	12:34	12:40	12:53
11E	P	11:28	11:39	11:45	11:55	12:03	12:08		12:12	12:19		12W	K		12:24		12:33	12:37	12:42	12:51	13:04	13:10	13:23
12E	K	11:58	12:09	12:15	12:25	12:33	12:38	12:42		12:50		13W	P		12:54	13:01		13:05	13:10	13:19	13:34	13:40	13:53
13E	P	12:28	12:39	12:45	12:55	13:03	13:08		13:12	13:19		14W	K		13:24		13:33	13:37	13:42	13:51	14:04	14:10	14:23
14E	K	12:58	13:09	13:15	13:25	13:33	13:38	13:42		13:50		15W	P		13:54	14:01		14:05	14:10	14:19	14:34	14:40	14:53
15E	P	13:28	13:39	13:45	13:55	14:03	14:08		14:12	14:19		16W	K		14:24		14:33	14:37	14:42	14:51	15:04	15:10	15:23
16E	K	13:58	14:09	14:15	14:25	14:33	14:38	14:42		14:50		17W	P		14:54	15:01		15:05	15:11	15:21	15:34	15:40	15:53
17E	P	14:28	14:39	14:45	14:53	15:03	15:10		15:15	15:23		18W	K		15:23		15:32	15:37	15:43	15:53	16:04	16:10	16:23
18E	K	14:57	15:08	15:16	15:23	15:33	15:40	15:45		15:55		19W	P		15:55	16:02		16:06	16:12	16:22	16:34	16:40	16:53
19E	P	15:25	15:38	15:46	15:53	16:03	16:10		16:15	16:23		20W	K		16:23		16:32	16:37	16:43	16:53	17:04	17:10	17:23
20E	K	15:55	16:08	16:16	16:23	16:33	16:40	16:45		16:55		21W	P		16:55	17:02		17:06	17:12	17:22	17:34	17:40	17:53
21E	P	16:25	16:38	16:46	16:54	17:04	17:11		17:16	17:24		22W	K		17:24		17:33	17:38	17:44	17:52	18:04	18:10	18:23
22E	K	16:55	17:08	17:16	17:24	17:34	17:41	17:46		17:56		23W	P		17:56	18:03		18:07	18:12	18:21	18:34	18:40	18:53
23E	P	17:25	17:38	17:46	17:54	18:04	18:11		18:16	18:24		24W	K		18:24		18:33	18:37	18:42	18:51	19:04	19:10	19:23
24E	K	17:58	18:09	18:15	18:25	18:33	18:38	18:42		18:50		25W	P		18:54	19:01		19:05	19:10	19:19	19:34	19:40	19:53
25E	P	18:28	18:39	18:45	18:55	19:03	19:08		19:12	19:19		-	-	-	-	-	-	-	-	-	-	-	-
26E	K	18:58	19:09	19:15	19:25	19:33	19:38	19:42		19:50		26W	K		19:54		20:03	20:07	20:12	20:21	20:34	20:40	20:53
27E	P	19:58	20:09	20:15	20:25	20:33	20:38		20:42	20:49		27W	P		20:54	21:01		21:05	21:10	21:19	21:34	21:40	21:53
28E	K	20:58	21:09	21:15	21:25	21:33	21:38	21:42		21:50		-	-	-	-	-	-	-	-	-	-	-	-
29E	P	21:58	22:09	22:15	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-

BUS		TRAIN Eastbound	TRAIN Westbound
Eastbound Route 110 arrival at CON	:15 - :16	:17 Lv	:23 Lv
	:45 - :46	:47 Lv	:53 Lv
Eastbound Route 110 departure from CON	:23 - :25	:17 Arr	:23 Arr
	:53 - :55	:47 Arr	:53 Arr
Westbound Route 110 arrival at CON	:19 - :23	:32 Lv	:23 Lv
	:51 - :54	:02 Lv	:53 Lv
Westbound Route 110 departure from CON	:04	:02 Arr	:53 Arr
	:34	:32 Arr	:23 Arr

Notes: