7.0 PROJECT ELEMENTS

In conjunction with beginning the access screening process, several key elements that were used in determining the feasibility of the alternatives were developed. General design considerations were determined including the typical section, method of separating the express and general purpose lanes, and access ramp types. Once the general design components were developed, the basis for cost estimating was initiated; this included compiling capital unit cost information and historic O&M costs. Another key element was the formulation of the present value analysis spreadsheet, which included determining a typical range in bonding rates, coverage rates, and present value calculations.

7.1 DESIGN CONSIDERATIONS

The express lane design began by establishing appropriate design criteria for the facility layout. To develop recommended alternatives to minimize impact to these constraints, key design constraints were identified and existing conditions were analyzed to these constraints. Next, a typical section analysis was performed to determine the express lanes configuration. Once the roadway layout was determined, cost estimates were prepared for use in determining the financial feasibility of the final alternative.

7.1.1 Design Criteria

The criteria used for the design of the express lane alternative included the CDOT Transportation Design Guide (1995), A Policy on Geometric Design of Highways and Streets (2001), Roadside Design Guide (2002), Colorado State Highway Access Code (2002), and the CALTRANS High Occupancy Vehicle Guidelines for Planning, Design and Operations (2003). Table 7.1 identifies the applicable design criteria used from these sources.

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Table 7.1
Roadway Design Criteria

Design Criteria	C-470 Mainline Criteria	Mainline Reference	Express Lanes Criteria	Express Lanes Reference	Normal Ramps Criteria	Normal Ramps Reference	Flyover/ Directional Ramps Criteria	Flyover/ Directional Ramps Reference	Loop Ramps Criteria	Loop Ramps Reference	Remarks
Posted Speed (mph)	65		65								
Design Speed (mph)	70	CDOT pg 8-1	70	CDOT pg 8-1	50	PGDH pg 829-830	60/(50)* 50/(40)**	PGDH pg 829-830	30/(25)	PGDH pg 829-830	* XX desirable/ (XX) minimum - System to System ** XX desirable/ (XX) minimum - System to Service
Lane Widths (ft)	12	CDOT pg 8-2	12	CDOT pg 8-2	15 or 12*	CDOT pg 3-31	15 or 12*	CDOT pg 3-31	16	CDOT pg 3-31	* 15' lane width for single lane ramps, 12' for dual lane ramps
Shoulder Widths (ft)											
Inside Shoulder Options (Left Ramp Shoulder)	8* 12** 14***	 PGDH pg 509 NCHRP 414	8* 14***	 NCHRP 414	4 6****	CDOT pg 10-36 PGDH pg 319	4 6****	CDOT pg 10-36 PGDH pg 319	4 6****	CDOT pg 10-36 PGDH pg 319	* Recommended shoulder width, 4' minimum in areas of constraint ** For use where truck DHV > 250 & number of express lanes exceeds 2 in one direction *** Enforcement - Confirm location of enforcement shoulder with CSP **** For use next to barrier Note: All shoulder decisions may be dependant on horizontal sight distance considerations
Outside Shoulder Options (Right Ramp Shoulder)	12 8*	PGDH pg 818 PGDH pg 818	12 14**	PGDH pg 818 NCHRP 414	6 8	CDOT pg 10-36 CDOT pg 10-36	6 8	CDOT pg 10-36 CDOT pg 10-36	6 8	CDOT pg 10-36 CDOT pg 10-36	* For use adjacent to auxiliary lanes ** Enforcement - Confirm location of enforcement shoulder with CSP Note: 6' right ramp shoulders are for single lane ramps, 8' for dual lane ramps or for shoulder adjacent to barrier
HOV Buffer	4										
Minimum Clear Zone (ft)	30	RDG pg 3-4	30	RDG pg 3-4	18	RDG pg 3-4	18	RDG pg 3-6	18	RDG pg 3-4	
Shy Line Offset (ft)	10	RDG pg 5-28	10	RDG pg 5-28	7	RDG pg 5-28	6	RDG pg 5-28	4	RDG pg 5-28	Note: For roadside structures such as signs
Normal Cross Slope (%)	2	CDOT pg 4-2	2	CDOT pg 4-2	2	CDOT pg 10-31	2	CDOT pg 10-31	2	CDOT pg 10-31	
"Z" Slope - 12 ft	6:1	CDOT pg 8-7	6:1	CDOT pg 8-7	6:1	CDOT pg 8-14	6:1	CDOT pg 8-14	6:1	CDOT pg 8-14	
Maximum Super Elevation (%)	0.06	CDOT pg 3-25	0.06	CDOT pg 3-25	0.06*		0.06*		0.06*		*CDOT Preference on ramps.
Minimum Horizontal Radius (ft)	2050	PGDH pg 145	2050	PGDH pg 145	835	PGDH pg 145	510-1340	PGDH pg 145	185-275	PGDH pg 145	Note: Based on maximum super elevation and design speed
Minimum Profile Grade (%)	0.5	CDOT pg 3-39	0.5	CDOT pg 3-39	0.5	CDOT pg 3-39	0.5	CDOT pg 3-39	0.5	CDOT pg 3-39	
Maximum Profile Grade (%)	4	CDOT pg 8-2	4	CDOT pg 8-2	5	CDOT pg 8-2	5	CDOT pg 8-2	5	CDOT pg 8-2	Note: Based on rolling terrain
Maximum Profile Grade at Intersections (%)					250' @ 2%	Douglas County	250' @ 2%	Douglas County	250' @ 2%	Douglas County	
Stopping Sight Distance (ft)	730	PGDH pg 112	730	PGDH pg 112	425	PGDH pg 112	305-570	PGDH pg 112	155-200	PGDH pg 112	Note: Allow horizontal sight distance across barriers. Use 3d graphical solutions for areas with vertical curvature. Glare screen not allowed.
Decision Sight Distance (ft)	1275	PGDH pg 116	1275	PGDH pg 116	1025	CDOT pg 3-15	825-1275	CDOT pg 3-15	625	CDOT pg 3-15	Note: Applies to express lane entrances and critical gores
Rate of Vertical Curve (K)											
Crest	247	PGDH pg 274	247	PGDH pg 274	84	PGDH pg 274	44-151	PGDH pg 274	12-19	PGDH pg 274	
Sag	181	PGDH pg 280	181	PGDH pg 280	96	PGDH pg 280	64-136	PGDH pg 280	26-37	PGDH pg 280	
Minimum Vertical Clearance (ft)	16.5	CDOT pg 3-38	16.5	CDOT pg 3-38	16.5	CDOT pg 3-38	16.5	CDOT pg 3-38	16.5	CDOT pg 3-38	
Light Rail Vertical Clearance (ft)	19-23.5		19-23.5		19-23.5		19-23.5		19-23.5		
Heavy Rail Vertical Clearance (ft)	25		25		25		25		25		
Pedestrian Bridge and Sign Bridge Clearance (ft)	17.5		17.5		17.5		17.5		17.5		
Accel Length (ft)	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	
Decel Length (ft)	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	Varies	PGDH pg 851-855	
Transition Taper Rate	70:1	PGDH pg 822	70:1	PGDH pg 822	25:1	Access pg 55	25:1	Access pg 55			Note: For lane additions and lane drops
Redirect Taper Rate	70:1	Access pg 57	70:1	Access pg 57	50:1	Access pg 57	50:1	Access pg 57			
Terminals											
Entrance	Taper	CDOT pg 10-46									
Exit	Taper	CDOT pg 10-46									
Left Exit	Parallel	CDOT pg 10-46									
Dual Lane	Fig 10-19	CDOT pg 10-51									
Design Vehicle	WB-67		WB-67		WB-67		WB-67		WB-67		

CDOT = Colorado Department of Transportation Design Guide (1995)
PGDH = A Policy on Geometric Design of Highways and Streets (PGDH 2001 Second Printing)
RDG = Roadside Design Guide (PGDH 2002)
Access = Colorado State Highway Access Code (March 2002)

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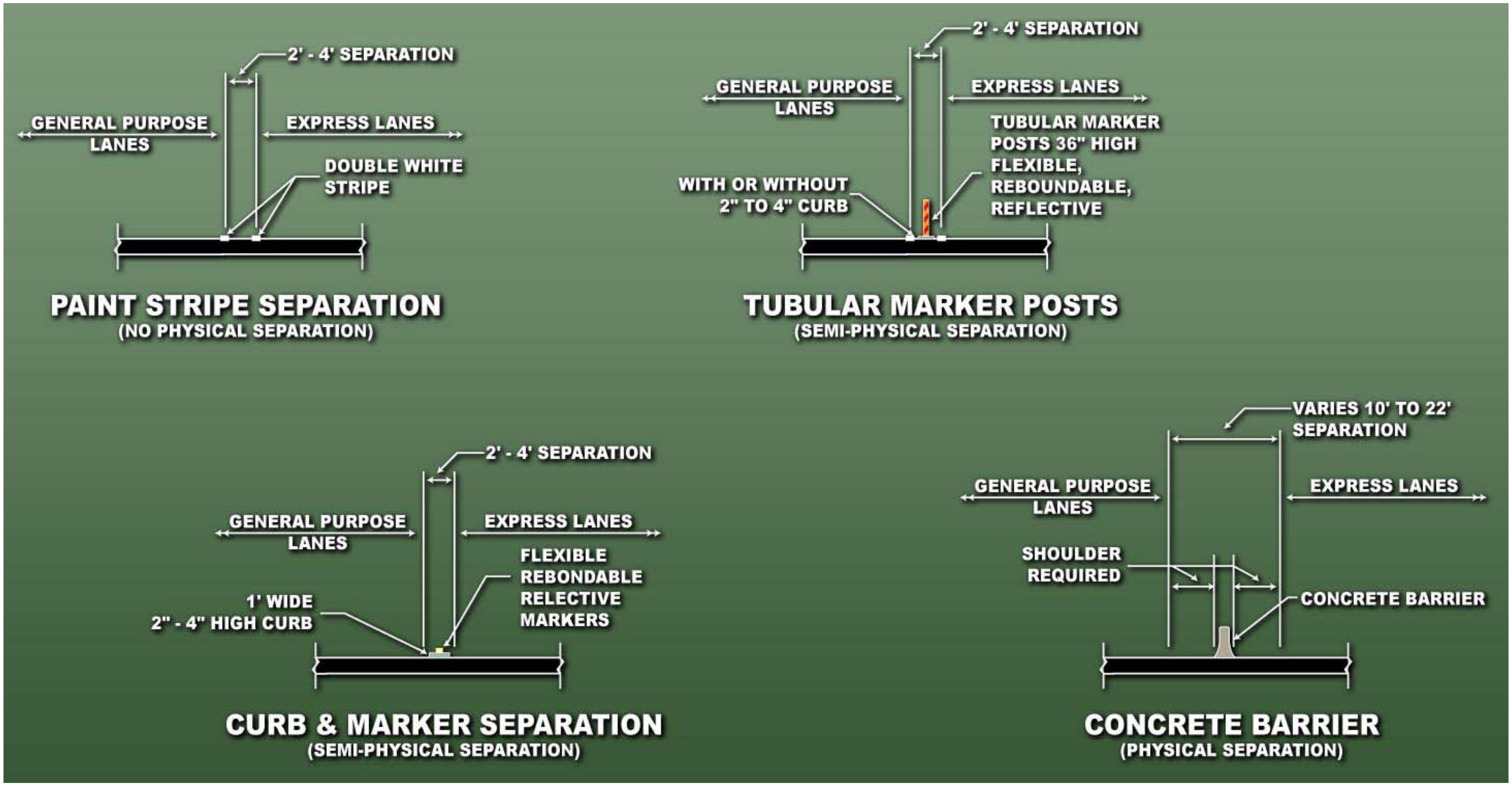
7.1.2 Key Design Issues

As with any roadway project, the final design is based on several factors; this project is no different. Construction costs, environmental impacts, environment justice, Section 4(f)/6(f), express lane ramp design, express lane access types and locations, impacts to the adjacent trail networks, right-of-way (ROW), methods of separation, noise impacts, and roadway typicals all were considered in the ultimate design.

7.1.3 Methods of Separation

Because the express and general purpose lane facilities are two separate facilities with different access locations and different operating characteristics, a separation method was developed that restricted vehicles from traveling between facilities except at designated access points. Four methods of separation were considered, including buffer-separation, tubular marker posts, raised curb and marker, and concrete barrier. Implementation costs, maintenance costs, safety characteristics, and enforcement were all key factors in deciding which method provides the best solution. All options have both positive and negative characteristics, which are shown in Figure 7.1 and discussed in the following actions.

Figure 7.1
Methods of Separation



7.1.4 Buffer Separation

The buffer separation consists of a 4-foot painted buffer between the express and general purpose lanes. While this method is cost effective, it lacks positive enforceability. Without a physical barrier separating the two facilities, vehicles could conceivably enter and exit the express lanes at any point, potentially avoiding the tolling zones and result in lost revenue. Also providing additional enforcement would increase operation costs. Unfortunately, no amount of enforcement would completely eliminate violations. In addition to enforcement difficulties, speed differential with no physical barrier between the two facilities could pose a serious safety hazard. It is anticipated that during the peak hours the general purpose lanes would be moving significantly slower than the express lanes. If a vehicle were to cross over into the other facility, the speed differential between the two facilities could result in a serious accident.

7.1.5 Tubular Marker Posts

Tubular marker posts would use a 2 to 4-foot painted buffer between the two facilities; also, a 3-foot-high tubular marker post/pylon would be installed to separate the two facilities. While providing a visual barrier to drivers in both facilities, the associated maintenance costs to maintain the tubular marker posts would be burdensome for CDOT maintenance staff. In addition to stray vehicles randomly impacting the tubular marker posts, causing CDOT to replace them, the difficulties in maintaining the markers during snow removal would pose a greater issue. The tubular markers would need to be spaced to prevent the possibility of general purpose lane users crossing into express lanes. Similar to the buffer separation method, tubular marker posts would provide little protection against a vehicle leaving one facility and entering another at a large difference in speed.

7.1.6 Curb and Marker

Curb and marker separation would consist of installing a 1-foot wide, 2- to 4-inch-high curb, with flexible re-bondable reflective markers affixed to the top. While reducing the associated maintenance costs found with the tubular marker posts, this method of separation would be problematic during a snow removal, as it would likely be obstructed from view when covered with snow, and it would be subject to impact and damage or removal by a snowplow. This option would pose little visual separation between the two facilities. Also, the raised curb would provide little restriction to a vehicle driving over it, or worse, having the vehicle become airborne upon impact. While providing more of a deterrent than just the buffer separation method, this option would still require manual enforcement to reduce the potential for general purpose lane users to cross into express lanes. Similar to the previous two separation methods, the curb and marker separation method would provide little protection against a vehicle leaving one facility and entering another at a large difference in speed.

7.1.7 Concrete Barrier

The concrete barrier section would involve the construction of a 3-foot-high, 2-foot-wide concrete barrier between the two facilities. The concrete barrier would necessitate the installation of wider shoulders than would the other three separation methods proposed. The concrete barrier would be the most costly of the four methods due to the increased road width and costs associated with constructing the concrete barrier; however, it would provide the greatest safety benefits and eliminate the concern of cross-over traffic between access points. The shoulder between the barrier and travel way should provide adequate room to store most snow during storm events. During storms, snow may need to be loaded onto dump trucks and hauled off site.

Based on the superior safety benefits and low overall maintenance costs associated with the concrete barrier section, this separation method has been chosen for implementation on most of the corridor. In the express lanes segment from Kipling Parkway to Wadsworth Boulevard, where only one express lane will be used in each direction, the buffer separation method has been proposed. The buffer separation method was recommended within this segment due to the potential widening of the express lanes in future years. It is anticipated that eventually four express lanes will be continued from Kipling Parkway to I-70 in a phased approach. This section could be initially constructed at a reduced cost, with the buffer separation fitting inside the existing median. When required, the additional lane in each direction could be added without having to remove the concrete barrier section.

7.1.8 Selection of Final Typical Section

The express lane typical section evolved throughout the study process. The initial typical section used a preferred layout that proposed the complete reconstruction of the general purpose lanes on the outside of the C-470 express lanes. The express and general purpose lanes would both have two 12-foot lanes in each direction. The opposing direction express lanes would be separated with concrete barrier. The initial typical section used preferred shoulder widths of 8-foot inside shoulders and 12-foot outside shoulders in both the express and general purpose lanes.

Based on initial cost estimates to construct the preferred typical section, the typical section required modification to reduce the capital costs. The initial modification reduced the inside shoulder width to 4 feet and the outside shoulder on the general purpose lane to 10 feet. The outside shoulders on both the express and general purpose lanes will still provide adequate width for a vehicle to be stored safely within its limits. The second modification was to reuse the existing pavement for the general purpose lanes and overlay as a means of extending the pavements lifespan. Some pavement sections will need to be replaced due to the substantial cracking and pumping that currently exists in some segments.

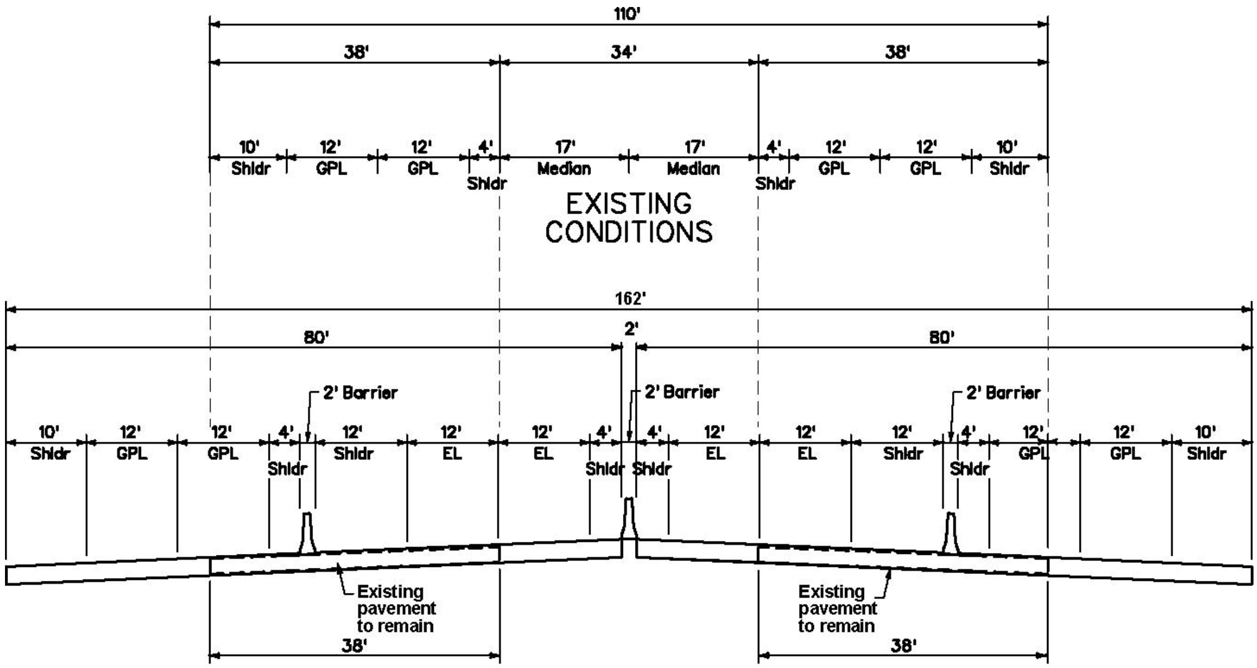
In addition to reducing shoulder widths and reusing existing pavement, other cost savings measures were evaluated. The evaluation determined whether adequate operations could still be provided with a reduced number of express lanes. Two alternatives were developed, including a two-lane reversible facility and a single express lane in each direction facility. A two-lane reversible facility would provide reliability to users in the peak direction at a reduced construction cost. However, the off-peak direction would have no additional capacity added. As the C-470 corridor reaches full build out, there will be less distinction between the peak directions, resulting in similar volumes in both directions during both peak hours. An analysis of corridor operations showed that the two-lane reversible option had significant operational problems in the off-peak direction, resulting in significant breakdowns in the general purpose lanes and surface streets. A cursory cost benefit analysis performed on this alternative showed the projected decrease in construction cost would be offset by the loss in revenue with having only two lanes.

Similar to the two-lane reversible option, the single express lane in each direction would also have a reduced construction cost, but that savings would also be offset by the loss in revenue with having only two lanes. Furthermore, similar operational problems occur along both the express and general purpose lanes due to the lack of capacity to accommodate the demand.

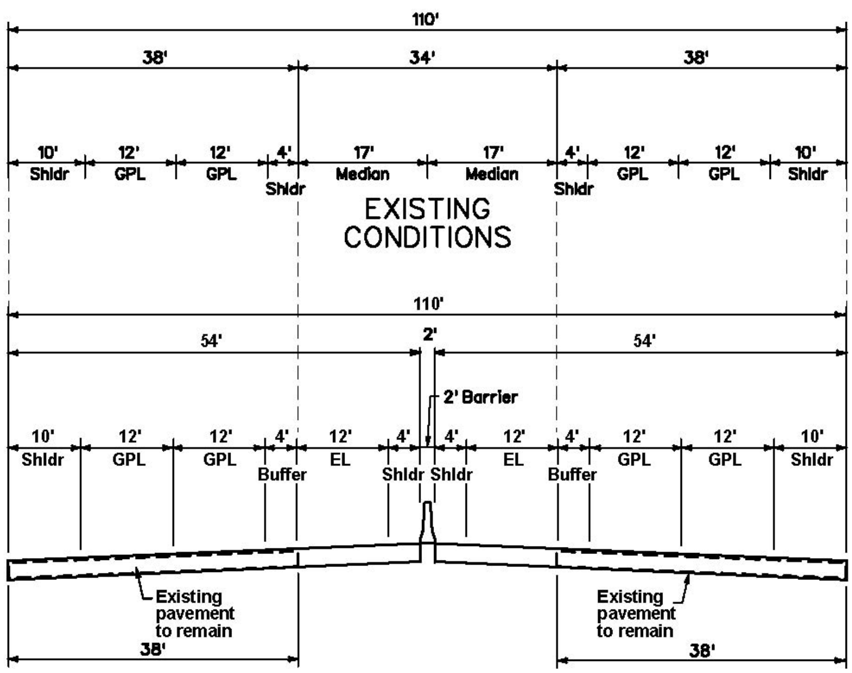
Operationally, these two alternatives did not provide the required capacity and necessary reliability required for an express lane facility.

The previously described four-lane, barrier-separated typical section was therefore selected for recommendation as the preferred concept. The recommended typical section is shown in Figure 7.2.

Figure 7.2
Typical Section



Platte Canyon to I-25



Kipling to Platte Canyon