

TYPICAL GRADE SEPARATION METHODS for the Peninsula Rail Program
 San Francisco to San Jose on the Caltrain Corridor
 Characteristics of Typical Methods for Grade Separating Railroad Tracks from Roadways

This table summarizes general information for each vertical option for ten areas of interest.

TYPE OF STRUCTURE FOR RAILROAD	ELEVATION (TOP OF RAIL, RELATIVE TO AT-GRADE TOP OF RAIL)	COST (RELATIVE TO AT-GRADE CONSTRUCTION)		DESCRIPTION
AERIAL VIADUCT	~30 feet above	3 times		An aerial structure called a "viaduct" supported by columns or, sometimes when spanning long distances, on beams (i.e. bents) supported by columns.
BERM	0 to 15 feet above	2 times		There are three options for berms, or raised earth options. (1) Berm: compacted raised earth with tracks located at the top. (2) Mechanically Stabilized Earth: compacted raised earth stabilized by metal "straps" and contained by walls on either side. (3) Retained Fill: compacted raised earth stabilized by retaining walls
AT-GRADE	0	1		Tracks at the same level as surrounding ground level. Roads go over or under the tracks. Most of the trains on the Caltrain right of way are at grade and intersect with roads at grade crossings (i.e. they are not separated from one another).
OPEN TRENCH	0 to 30 feet below	3.5 times		Below ground option where tracks are constructed below ground level with the space above tracks open to air.
CLOSED TRENCH (CUT AND COVER TUNNEL)	30 to 45 feet below	5 times		Shallow tunnel constructed by first excavating a trench and then roofed over.
DEEP TUNNEL (BORED/ MINED)	~100 feet below	7 times		Deep tunnel constructed using a tunnel boring machine (TBM) that starts at one end and bores through to the tunnel exit. Cut and cover is required at both the tunnel approach and exit for TBM to start at a deep enough depth.

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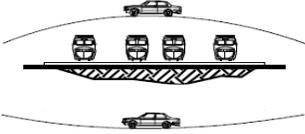
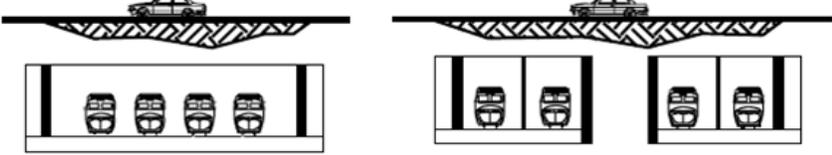
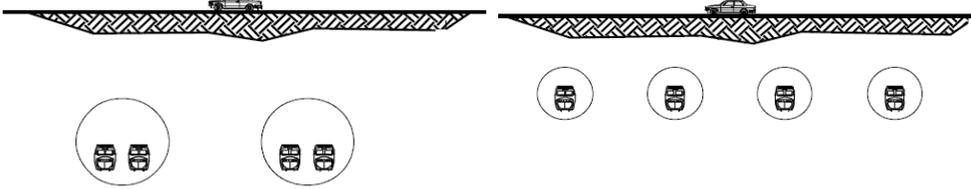


TYPE OF STRUCTURE FOR RAILROAD	EXAMPLE IMAGES	
AERIAL VIADUCT		
BERM		
AT-GRADE		
OPEN TRENCH		
CLOSED TRENCH (CUT AND COVER TUNNEL)		
DEEP TUNNEL (BORED/ MINED)		

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TYPE OF STRUCTURE FOR RAILROAD	TYPICAL SECTIONS
AERIAL VIADUCT	
BERM	
AT-GRADE	
OPEN TRENCH	
CLOSED TRENCH (CUT AND COVER TUNNEL)	
DEEP TUNNEL (BORED/MINED)	

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TYPE OF STRUCTURE FOR RAILROAD	SERVICE & STATIONS (ALIGNMENT AND STATION PERFORMANCE)		
	Community	Rider	Requires Relocation of Caltrain Stations
AERIAL VIADUCT	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	
BERM	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	
AT-GRADE	+ Minimal to no reduction in the number of Caltrain stations. + Retains opportunity to improve service to all stations.	+ Minimal to no reduction in the number of Caltrain stations. + Retains opportunity to improve service to all stations.	
OPEN TRENCH	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, etc) may reduce number of stations along Peninsula	
CLOSED TRENCH (CUT AND COVER TUNNEL)	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, fire/life safety requirements, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, fire/life safety requirements, etc) may reduce number of stations along Peninsula.	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, fire/life safety requirements, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, fire/life safety requirements, etc) may reduce number of stations along Peninsula.	
DEEP TUNNEL (BORED/ MINED)	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, fire/life safety requirements, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, fire/life safety requirements, etc) may reduce number of stations along Peninsula.	- Possible reduction in number of Caltrain stations due to high cost of re-constructing stations (vertical circulation, fire/life safety requirements, etc) which may reduce Caltrain service to some cities. - High cost of constructing HST stations (vertical circulation, fire/life safety requirements, etc) may reduce number of stations along Peninsula.	

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TYPE OF STRUCTURE FOR RAILROAD	CONSTRUCTION REQUIREMENTS (CONSTRUCTABILITY)				
	CONSTRUCTION ROW REQUIREMENTS (Generic info; Actual requirements for SF-SJ not yet established)	Length of Construction Period	Construction Impact to Caltrain Service	Width of Right of Way Needed (Construction)	Width of Right of Way Needed (Final)
AERIAL VIADUCT	<ul style="list-style-type: none"> * Requires approximately 20 feet on either side of column for foundation and column construction * Requires at least entire width beneath viaduct structure for construction * May require re-alignment of tracks and/or roads to maintain traffic/train operations during construction 				
BERM	<ul style="list-style-type: none"> * Requires approximately 15 to 30 feet from base of berm/wall for construction * May require re-alignment of tracks and/or roads to maintain traffic/train operations during construction 				
AT-GRADE	<ul style="list-style-type: none"> * Requires approximately 10 feet from track centerline for construction * Will require modification of existing grade crossings: roads will need to go over or under tracks, or closure of crossing. * May require re-alignment of tracks and/or roads to maintain traffic/train operations during construction 				
OPEN TRENCH	<ul style="list-style-type: none"> * Requires approximately 15 to 20 feet from trench wall to allow for construction * Requires periodic staging areas, approximately 1 to 2 acres, every mile or so * May require re-alignment of tracks and/or roads to maintain traffic/train operations during construction 				
CLOSED TRENCH (CUT AND COVER TUNNEL)	<ul style="list-style-type: none"> * Requires approximately 15 to 20 feet from trench wall to allow for construction * May require re-alignment of tracks and/or roads to maintain traffic/train operations during construction * Shallow tunnels may have buoyancy issues, dependent on water table * No risk of subsidence to adjacent structures if located approximately 20 feet from excavation * Will require cross passages between tunnels, ventilation shafts, and emergency evacuation (can be located with ventilation shafts) 				
DEEP TUNNEL (BORED/ MINED)	<ul style="list-style-type: none"> * Requires 2 tunnel diameters from ground to top of tunnel * Approximately 4 to 5 acres required at beginning of tunnels and 2 acres at end of tunnel for construction purposes * Risk of settlement for all infrastructure above tunnels * No buoyancy issues due to depth * Will require cross passages between tunnels, ventilation shafts, and emergency evacuation (can be located with ventilation shafts) 				

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TYPE OF STRUCTURE FOR RAILROAD	FREIGHT (CONSTRUCTABILITY)	
	IMPACTS ON/FROM FREIGHT OPERATIONS	Incompatibility of HST with Freight
AERIAL VIADUCT	<ul style="list-style-type: none"> - Necessitates stronger structural requirements and therefore possibly larger structures. - Elevated tracks makes access to spurs connecting to freight customers challenging. - Longer distances required for elevation changes than for Caltrain or HST due to lower maximum grades: Freight - 1% vs. Caltrain - 2%, HST - 2.5%-3.5% 	
BERM	<ul style="list-style-type: none"> - Elevated tracks makes access to spurs connecting to freight customers challenging. - Longer distances required for elevation changes than for Caltrain or HST due to lower maximum grades: Freight - 1% vs. Caltrain - 2%, HST - 2.5%-3.5% 	
AT-GRADE	<ul style="list-style-type: none"> - Least effect 	no issues
OPEN TRENCH	<ul style="list-style-type: none"> - Below-grade tracks makes access to spurs connecting to freight customers challenging. - Longer distances required for elevation changes than for Caltrain or HST due to lower maximum grades: Freight - 1% vs. Caltrain - 2%, HST - 2.5%-3.5% 	
CLOSED TRENCH (CUT AND COVER TUNNEL)	<ul style="list-style-type: none"> - Below-grade tracks makes access to spurs connecting to freight customers challenging. - Longer distances required for elevation changes than for Caltrain or HST due to lower grades: Freight - 1% vs. HST-2% - Diesel locomotives necessary as electric locomotives lack adequate power. Therefore, vent shafts will be required for cover extending beyond 300 to 500 linear feet due to diesel locomotives. 	
DEEP TUNNEL (BORED/ MINED)	<ul style="list-style-type: none"> - Below-grade tracks makes access to spurs connecting to freight customers challenging. - Longer distances required for elevation changes than for Caltrain or HST due to lower maximum grades: Freight - 1% vs. Caltrain - 2%, HST - 2.5%-3.5% - Diesel locomotives necessary as electric locomotives lack adequate power. Therefore, vent shafts will be required for cover extending beyond 300 to 500 linear feet due to diesel locomotives. 	

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TYPE OF STRUCTURE FOR RAILROAD	SAFETY (COMMUNITY)		
	Community	Rider	Time Required for Emergency Response
AERIAL VIADUCT	+ Aerial viaduct option allows for removal of grade crossings which improves community safety. - Added safety benefit from removal of grade crossings lost if Caltrain and/or Freight are at-grade.	+ Access to tracks for emergency vehicles available. - Increased difficulty responding to emergency events and evacuating passengers.	
BERM	+ Berm/raised earth option allows for removal of grade crossings which improves community safety. - Added safety benefit from removal of grade crossings lost if Caltrain and/or Freight are at-grade.	+ Access to tracks for emergency vehicles available - Increased difficulty responding to emergency events and evacuating passengers.	
AT-GRADE	+ Removal of grade crossings for HST improves community safety. - Benefit of grade crossings available only if HST is at-grade. Otherwise, Benefit is lost as grade crossings may not be removed.	+ No change to current level of safety. Easy access for emergency vehicles.	
OPEN TRENCH	+ Below ground option allows for removal of grade crossings which improves community safety. - Added safety benefit from removal of grade crossings lost if Caltrain and/or Freight remain at-grade. - Requires barrier to prevent unauthorized access to open trench	+ Access to tracks for emergency vehicles available - Increased difficulty responding to emergency events and evacuating passengers.	
CLOSED TRENCH (CUT AND COVER TUNNEL)	+ Below ground option allows for removal of grade crossings which improves community safety. - Added safety benefit from removal of grade crossings lost if Caltrain and/or Freight remain at-grade.	- Access to tracks limited to emergency egress locations and beginning/end of tunnel. - High increase in difficulty in accessing passengers. - Increased risk for passengers and emergency response teams.	
DEEP TUNNEL (BORED/MINED)	+ Below ground option allows for removal of grade crossings which improves community safety. - Added safety benefit from removal of grade crossings lost if Caltrain and/or Freight remain at-grade.	- Access to tracks for emergency response extremely limited - High increase in difficulty in accessing passengers. - Increased risk for passengers and emergency response teams.	

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TYPE OF STRUCTURE FOR RAILROAD	CROSS CONNECTIVITY: VEHICLE, PEDESTRIAN, BICYCLE (COMMUNITY)		
	Community	Rider	Delays to Automobile Traffic
AERIAL VIADUCT	+ Significant improvement. + Allows for open and full cross connectivity below aerial structures. - Benefit available only if Caltrain, HST, and Freight are all elevated. Otherwise, if Caltrain and freight remain at grade, benefit is lost.	-	
BERM	+ Significant improvement. + Allows cross connectivity via tunnels under berm structures. - Benefit available only if Caltrain, HST, and freight are all elevated. Otherwise, if Caltrain and freight remain at grade, benefit is lost.	-	
AT-GRADE	+ Improvement through grade separating existing roadway crossings. - Benefit only available if HST is at-grade. Otherwise crossings may not be grade separated.	-	
OPEN TRENCH	+ Improved connectivity via roadway crossings over trenches. - Benefit available only if Caltrain, HST, and freight are all in trench. Otherwise, benefit is lost.	-	
CLOSED TRENCH (CUT AND COVER TUNNEL)	+ Significant improvement. + Allows for open and full cross connectivity. - Benefit available only if Caltrain, HST, and freight are all in tunnel. Otherwise, benefit is lost.	-	
DEEP TUNNEL (BORED/ MINED)	+ Significant improvement. + Allows for open and full cross connectivity. - Benefit available only if Caltrain, HST, and freight are all in tunnel. Otherwise, benefit is lost.	-	

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TYPE OF STRUCTURE FOR RAILROAD	OPEN SPACES (COMMUNITY)		ADJACENT PROPERTIES (COMMUNITY)	
	Community	Rider	Community	Rider
AERIAL VIADUCT	+Available space below aerial structure provides opportunity to move some services below structure, thereby opening up open spaces in other locations.	-	+ Does not limit roadway access to properties adjacent to roadway crossings. - Additional right of way may be necessary for construction and temporary tracks.	-
BERM	- Limited to no new open spaces.	-	+ Minimal to no limitation on roadway access to properties adjacent to roadway crossings. - Additional right of way may be necessary for construction and temporary tracks.	-
AT-GRADE	- No new open spaces.	-	- Limits roadway access to properties adjacent to grade separations due to road over/under at-grade track. - Additional right of way may be necessary for construction and temporary tracks.	-
OPEN TRENCH	+ Possible new open spaces available via the option to partially enclose the trench, in addition to roadway or rail crossings.	-	+ Minimal to no limitation on roadway access to properties adjacent to roadway crossings. - Additional right of way may be necessary for construction and temporary tracks.	-
CLOSED TRENCH (CUT AND COVER TUNNEL)	+Available space above tunnel for new open space and/or provides opportunity to move some services above tunnel, thereby opening up open spaces in other locations. - Vent structures and emergency egress reduce some open space.	-	+ Does not limit roadway access to properties adjacent to roadway crossings. - Additional right of way may be necessary for construction and temporary tracks.	-
DEEP TUNNEL (BORED/ MINED)	+Available space above tunnel for new open space and/or provides opportunity to move some services above tunnel, thereby opening up open spaces in other locations. - Vent structures and emergency egress reduce some open space.	-	+ Does not limit roadway access to properties adjacent to roadway crossings. - Additional right of way required at beginning and end of bored tunnel for construction purposes. - Additional right of way may be necessary for temporary tracks for construction of vent structures and emergency egress.	-

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TYPE OF STRUCTURE FOR RAILROAD	NOISE & VIBRATIONS (NATURAL ENVIRONMENT)		
	Community	Rider	Noise from Operations (w/o mitigation)
AERIAL VIADUCT	- Unless structure is partially enclosed, noise is free to radiate. + Some mitigation available to reduce noise. + Lighter weight vehicle creates less noise - Elevated structure does not have natural noise absorption	+ Least noise except from flange on track.	
BERM	- Noise equal to or greater than today. - Unless structure is partially enclosed, noise is free to radiate. + Lighter weight vehicle creates less noise + Raised earth structure has some natural noise absorption	+ Least noise	
AT-GRADE	+ Similar to today but slightly less due to equipment weight.	+ Least noise except reflected sound	
OPEN TRENCH	- Moderate noise especially if treated.	+ Very moderate noise especially if walls are treated	
CLOSED TRENCH (CUT AND COVER TUNNEL)	+ Noise level dependent on wall treatment and linear feet of cover. + Minimal noise for covered and open areas. - High noise impact at vent shafts. For diesel locomotives, vent shafts required for cover extending beyond 300 to 500 linear feet.	- Noise level dependent on amount of cover and wall treatment. Noise increases as the percentage of cover increases.	
DEEP TUNNEL (BORED/ MINED)	+ Noise mitigated except at vent shafts. - High noise impact at vent shafts. For diesel locomotives, vent shafts required every 300 to 500 linear feet.	- Noise is reflected from structure into passenger cars.	

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TYPE OF STRUCTURE FOR RAILROAD	VISUAL (NATURAL ENVIRONMENT)		
	Community	Rider	Visual Impact / Obstruction
AERIAL VIADUCT	- Structure may be perceived to divide community, however there is significant available space below aerial structure. + Design of structure can vary the appearance greatly	-	
BERM	- Structure may be perceived to divide community as structure is solid earth or retaining walls. + Design of structure/retaining walls can vary the appearance greatly	-	
AT-GRADE	+ Similar to today with no increase in perceived division physically or visually.	-	
OPEN TRENCH	+ Reduces perception of a divided community, however tracks still physically divide community - Requires barrier to prevent unauthorized access to open trench	-	
CLOSED TRENCH (CUT AND COVER TUNNEL)	+ Reduces perception of a divided community. - Visual impact at above ground vent shafts and at tunnel entrance/exit.	-	
DEEP TUNNEL (BORED/MINED)	+ Reduces perception of a divided community. - Visual impact at above ground vent shafts and at tunnel entrance/exit.	-	

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TYPE OF STRUCTURE FOR RAILROAD	RIDE QUALITY	
	Community	Rider
AERIAL VIADUCT	-	+ Scenic views of bay, hills, environment.
BERM	-	+ Scenic views of bay, hills, environment.
AT-GRADE	-	+ Some scenic views of bay, hills, environment.
OPEN TRENCH	-	- No view but not enclosed.
CLOSED TRENCH (CUT AND COVER TUNNEL)	-	- Enclosed areas noisy. For varying levels of cover, shifting between enclosed and open could be disorienting. - No view.
DEEP TUNNEL (BORED/ MINED)	-	- Enclosed, noisy, disorienting. - No view.

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