# Two Caltrain Viaducts Grade Separations for Palo Alto:

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The End: Viaduct Examples

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Previous versions submitted to PA City Council:
2018, 2021, 2023, 2024, 2025, 2026

Palo Alto Online, June 14, 2023

Palo Alto architect Joe Bellomo's vision for high-speed rail
http://www.paloaltoonline.com/news/2009/11/27/architect-calls-for-design-contest-for-high-speed-rail

# Viaducts – Summary:
# Comparable or lower cost, less disruption, shorter timeframe, less risk, better future traffic patterns, enables future cost reductions

- **The viaducts approach has construction costs comparable to or much lower than the other alternatives.**

- **Cost avoidance from not lowering roadways at all:**
  - Cost to lower the roadways and reconfigure nearby roadways and intersections
  - Cost for acquisition of private properties for expanded road footprint.
  - Cost of changing utilities under the roadways.
  - Cost of pumps to handle sea level rise and groundwater for lowered roadways.
  - Cost of a permanent maintenance and flooding risk issue

- **Avoids personal costs for families of affected homes.**
  - Loss of part or all of a property, driveway length and access, and street parking.

- **Reduces assembly timeframe and periods of disruption during construction.**
  - Only a few days of disruption at vehicle crossings because no changes to roadways.

- **Risk avoidance due with simpler viaduct approach.**
  - Simplicity reduces risks of surprises and cost and schedule overruns of complex approaches.

- **Enables major cost reductions for future cross-town bike-ped underpasses including:**
  - Grade level crossings, no tunneling, at Seale, El Dorado, El Verano, Lindero.

# Viaducts:
# Conceptual approach

- **All construction within the Caltrain ROW.**
  - Avoids complications of impacting Alma for duration of construction.

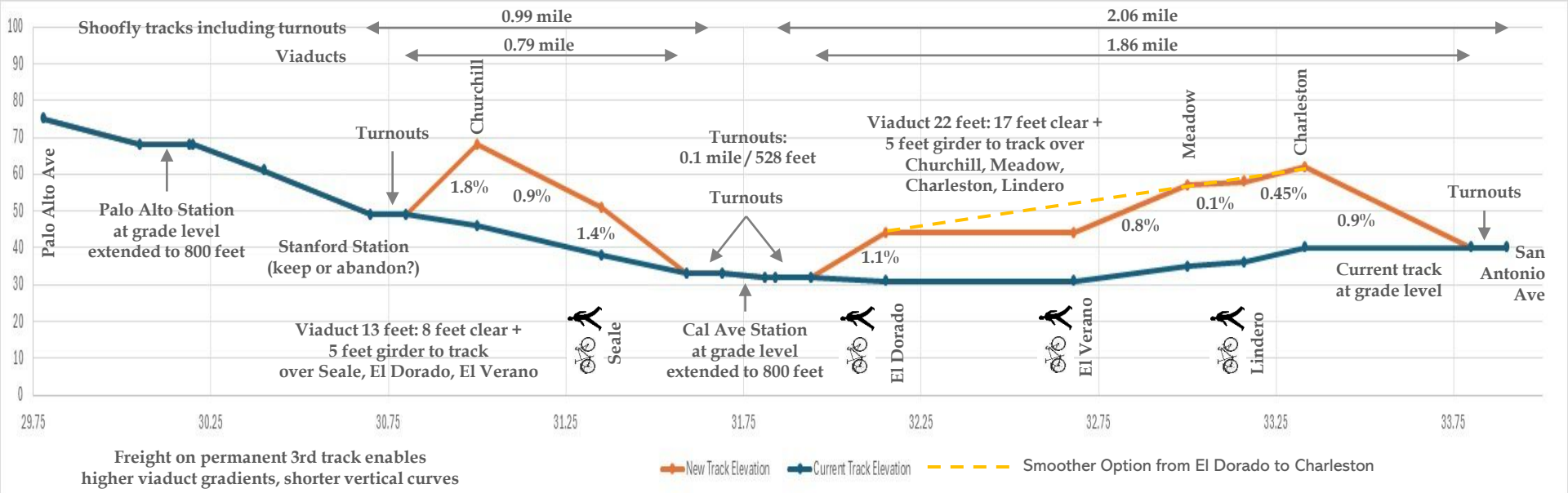
- **Remove freight traffic from viaducts.**
  - Enables shorter vertical curvature and higher gradients.
  - Perhaps reduces viaduct requirements without freight train weight.
  - ➢ Either: Eliminate freight traffic altogether, or ...
  - ➢ Or: keep a third shoofly grade-level track for freight only, with quad gates.
    - ➢ Vehicle, bike, and ped traffic can handle infrequent freight trains.

H St, Union City:
Freight rail line
and BART

- **Shorter vertical curvature and higher gradients enables two viaduct sections:**
  **1) Embarcadero to Cal Ave Station –** up to Churchill, down to Cal Ave.
  **2) Oregon to San Antonio Ave. –** up to Meadow, down from Charleston to SA Ave**.**
  - Viaduct screens and/or trees on one or both sides for residential privacy.
  - Narrow bridge widths at University, Embarcadero, and Oregon prevent shoofly tracks without likely major complex bridge construction.

- **Two grade-level shoofly tracks within the ROW.**
  - From Oregon to Charleston, both tracks on east side of ROW.
  - From Embarcadero to Cal Ave station, one track on east side, one on west side.
  - Temporary: Caltrain borrows part of Peers Park for west side shoofly track, returns it to Palo Alto when complete.
  - Long term: Freight (if it continues) will use the eastmost side track with quad gates.
  - Remove west or both shoofly tracks for a future bike-ped parkway or other uses.

# Viaducts:
# Conceptual approach avoids all major, expensive, risky Issues




<u>Churchill / Meadow / Charleston Avenues roadways unchanged avoids:</u>

- Private property acquisition
- Ped/bike tunnel residential parking impacts
- Complexity, convoluted underpasses, roundabout
- Traffic congestion from new traffic patterns
- Under-street utilities impacts
- Future sea level rise, flood impacts

<u>Viaduct enables new grade-level cross-town connections and other options:</u>

- Bike/ped underpasses beneath viaduct with low-cost paving approaches and pedestrian signals across Alma.
- Citywide greenspace, bike/ped path, or other uses under and adjacent to the viaduct.

# Viaducts:
# Construction approach

- **Caltrain weekday daytime operations continue uninterrupted.**
  - Construction during weekday nights and weekend nights or days.

- **Viaduct construction approach**
  - Prefabricated piers and spans precast offsite, delivered to Caltrain ROW for assembly.

  - Prefabricated piers and spans assembled within Caltrain right-of-way.
    - Churchill: 0.79 miles / 4200 feet; 100-foot spans; 42 spans, 41 piers.
    - Meadow/Charleston: 1.86 miles / 9800 feet; 100-foot spans; 98 spans, 97 piers.
    - Total: 2.65 miles; 140 spans, 138 piers

  - Two crews concurrently to minimize overall construction time.
    - 1 crew on Churchill, 1 crew on Meadow/Charleston

  - Install the Churchill/Meadow/Charleston shoofly tracks and quad gates over a single weekend each, minimizing cross-town traffic disruption.

  - Install the Churchill/Meadow/Charleston Caltrain overpass spans over a single weekend each, minimizing cross-town traffic disruption.

# Viaducts: Costs

| Embarcadero to San Antonio Ave viaduct project | | | | | |
|---|---|---|---|---|---|
| | Item | Per Mile | | Subtotals | Totals |
| | | $M | Miles | $M | $M |
| **Churchill** | | | | | |
| | Construct shoofly tracks, turnouts | 4.00 | 0.99 | 3.96 | |
| | Viaduct | 200.00 | 0.79 | 158.00 | |
| | Remove shoofly track(s), turnounts | 1.00 | 0.99 | 1.00 | |
| | | | | | **162.96** |
| **Meadow/Charleston** | | | | | |
| | Construct shoofly tracks, turnouts | 4.00 | 2.06 | 8.24 | |
| | Viaduct | 200.00 | 1.86 | 372.00 | |
| | Remove shoofly track(s), turnounts | 1.00 | 2.06 | 1.00 | |
| | | | | | **381.24** |
| **Total for viaduct project construction** | | | | | **544.20** |
| | | Per Each | Count | Subtotals | |
| | | | | | |
| **Future 4 connections at $1M each** | | 1.00 | 4.00 | 4.00 | **4.00** |
| **Total with 4 connections** | | | | | **548.20** |

- Construct shoofly tracks: $4M/mile
- Construct viaducts: $200M/mile ($180M/mile referenced; short segments are more expensive)
- Upgrade Palo Alto, Cal Ave stations – extend platforms to 800 feet for CA HSR ($2M each)
- Remove shoofly track(s): $1M/mile
- New crosstown bike-ped connections: Seale, El Dorado, El Verano, Lindero ($1M each)
    - Colorado too close to Cal Ave for viaduct gradient; Loma Verde too close to El Dorado

# Viaducts:
# Costs in range or lower to much lower than alternatives

| | Plan Combinations > | A | B | C | D | | Viaducts |
|---|---|---|---|---|---|---|---|
| **Plans** | | | | | | | |
| | Churchill | Closure with Mitigations | Partial Underpass | Closure with Mitigations | Partial Underpass | | |
| | Meadow/Charleston | Hybrids | Hybrids | Underpasses | Underpasses | | |
| **Costs** | | $M | $M | $M | $M | | $M |
| | Churchill | 115 | 318 | 115 | 318 | | 163 |
| | Meadow/Charleston | 477 | 477 | 844 | 844 | | 381 |
| | Totals | **592** | **795** | **959** | **1,162** | | **544** |
| **Future Costs: new crosstown connections at $62M each** | | | | | | | **$1M each** |
| | 3 or 4 connections | 187 | 187 | 248 | 248 | | 4 |
| **Overall Costs including new crosstown connections** | | | | | | | |
| | | **779** | **982** | **1,207** | **1,410** | | **548** |
| **Notes** | | | | | | | |
| | Costs in 2026 dollars. | | | | | | |
| | Combination costs are based on midpoints from sources in Addendum: Costs. | | | | | | |
| | Meadow/Charleston Hybrids as one "podium" enables Lindero grade-level crossing, so $62M x 3 + $1M x | | | | | | |

# Viaducts: Costs:
# Future cost savings for bike-ped crosstown connections

Base map: Google Earth  Project Annotations: Mike Forster


New crossing underneath Caltrain viaduct

Existing crossing

- **Over $200M cost savings:**
  - **4 crossings at $61M savings per crossing.**
- **Just a paved path under viaduct and a pedestrian beacon for crossing Alma**.
  - No tunneling required
- **$1M cost per grade-level crossing vs. $62M latest Menlo Park Middle tunnel underpass project.**
  - $350K paving plus $750K pedestrian beacon (like those on El Camino)

# Viaducts: Timeframe
## Construction and assembly timeframe parameters, Overlapping tasks as much as practical

- **Begin precasting piers, viaduct spans, other components - early**

- **Construct shoofly tracks – Multiple teams, overlapping tasks**
  - Prepare roadbeds, install track including turnouts: up to 1 month with 2 teams
    - Up to 2 weeks to install the track on the prepared roadbed with 2 teams
  - Install, test, activate catenary poles, wires: up to 2 weeks - overlap roadbed and track installation
  - Interruptions:
    - Crossings: 1 weekend at each crossing (Churchill, Meadow, Charleston)
    - Caltrain: 1 weekend to install 8 turnouts with 4 teams

- **Install piers, viaduct spans, catenaries – Multiple teams, overlapping tasks**
  - Prepare pier footings – 1 day per footing
  - Piers, spans, tracks: up to 3 months
  - Catenaries: up to 1 months
  - Testing: up to 2 weeks
  - Cutover from old tracks to new: 1 weekend
  - Interruptions:
    - Crossings: 1 weekend at each crossing (Churchill, Meadow, Charleston)

- **Remove one or both shoofly tracks, catenaries**
  - Up to 2 weeks; minimal cross-traffic disruptions at Churchill, Meadow, Charleston

- **For construction timeframes, see page: Notes and References: Assembly Parameters and Durations**

# Viaducts: Best Solution Matrix:
# Viaducts the best or the same in all categories

| Combinations> Mead/Charl, Churchill | Combination A: Hybrids, Closure | Combination B: Hybrids, Underpass | Combination C: Underpasses, Closure | Combination D: Underpasses, Underpass | Viaduct |
|---|---|---|---|---|---|
| Simplicity to avoid risk to cost, construction timeframe | Moderately complex, medium risk | Moderately complex, medium risk | Very ccomples, high risk | Very complex, high Risk | Simple, low risk |
| Maintain, Improve All Modes East/West Connectivity | Mixed Results | Mixed Results | Mixed Results | Mixed Results | Maintains |
| Maintain or Improve Traffic Patterns | Mixed Results | Mixed Results | Inconveniet traffic patterns | Inconveniet traffic patterns | Maintains |
| Bike-Ped Circulation: Clear, Safe, Separate from Autos | Improves | Improves | Improves | Improves | Improves |
| Minimizes Caltrain operation disruption | Minimal disruption, shoofly tracks | Minimal disruption, shoofly tracks | No disruption, construction below | No disruption, construction below | Minimal disruptions, Shoofly tracks |
| Reduce Rail Noise and Vibration (Study, July 2020) | Best | Best | Significant (with barrier) | Significant (with barrier) | Significant |
| Construction Noise and Vibration (Study, July 2020) | Severe | Severe | Severe | Severe | Moderate |
| Timeframe of Construction | 4 fyears, 2 years | 4 years, 2.5 years | 4 years, 2 years | 4 years, 2.5 years | TBD; much shorter than others |
| Minimize Visual Changes | Significant | Significant | None | None | Significant; less than berms |
| Minimize Property Acquisition | No property acquisitions | Some property acquisitions | Signifcant property acquisitions | Signifcant property acquisitions | No property acquisitions |
| Minimize impacts on driveway access, parking, street safety | Driveways affected | Loss of street parking | Loss of street parking | Loss of street parking | No impacts |
| Minimize Disruption and Duration of Construction | Major disruptions | Major disruptions | Major disruptions | Major disruptions | Minimal disruptions |
| Avoid Sea Level, Groundwater Issues (Study, January 2024) | Need pump, long-term maintenance, risk of flooding | Need pump, long-term maintenance, risk of flooding | Need pump, long-term maintenance, risk of flooding | Need pump, long-term maintenance, risk of flooding | No risk |
| Avoid Utilities Relocation | Utilities relocation required | Utilities relocation required | Utilities relocation required | Utilities relocation required | No relocation required |
| Minimize Trees Removal or Trimming | TBD; shoofly placement dependent | TBD; shoofly placement dependent | TBD; shoofly placement dependent | TBD; shoofly placement dependent | TBD; shoofly placement dependent |
| Grade Separations Cost | $592M | $795M | $959M | $1,162M | $544M |
| Include 4 New Connections Cost | $779M | $982M | $1,207M | $1,410M | $548m |

See Notes and References for PA studies re Noise and Vibration (2020) and water impacts (2024).

# Viaducts:
# Conclusion: Viaduct grade separations are the best solution for Palo Alto

- **Construction and disruption tim**eframes for the non-viaduct approaches could be much longer than 2 and 4 years
  - And these might be additive: might result in disruptions of 6 years or longer
  - Closing any 2 of the 3 crossings concurrently would cause crosstown traffic to come to a halt

- Even if this report's budget and timeframe are a somewhat optimistic and could increase ... the **viaducts option will still**:
  - Have a comparable or lower cost
  - A shorter assembly timeframe
  - Less risk for cost and schedule than the other complicated approaches
  - Enable future savings on east-to-west crossings
  - Satisfy all of the qualitative criteria:
    - Much less disruption
    - No property acquisitions
    - No impacts on parking or driveways
    - Better traffic patterns
    - Avoids long-term water mitigation maintenance (including pumps)
    - Avoids utilities relocations

# Viaduct: Addendum:
# Costs: Comments on Sources

- **$180M/mile is a good budgetary estimate for PA Caltrain HSR viaduct construction**
  - 15% to 65% higher than all but 1 of the comparable projects referenced in this report
  - All comparison projects had larger scope or characteristics than PA Caltrain

- **CA HSR: $180M/mile, adjusted for inflation (2011 to 2026)**
  - Only source found for CA HSR viaduct/bridge construction

- **US automobile roadway estimates: 4 of 5 between $109M/mile and $156M/mile, adjusted for inflation**
  - HSR likely more costly than roadways due to HSR infrastructure requirements
  - All of these projects had greater characteristics than PA Caltrain:

- **Australia: light rail viaduct: $130M/mile, adjusted for inflation and relative construction costs**
  - But with greater characteristics than PA Caltrain:

- **Lativa, Estonia, Lithuania: HSR viaduct: $128/mile, adjusted for inflation and relative construction costs**
  - But with greater characteristics than PA Caltrain:

- **All projects had medium to long constructions timeframes**
  - 15, 24, 36, 41, 43, 48, and 60 months
  - Some recent other example projects have achieved faster timeframes
  - Even if the assembly timeframes are long, the viaducts approach has minimal disruption and traffic impacts

# Viaduct: Addendum: Costs, Parameter Comparisons

| Projects > Parameter | Tampa (road) | Alligator River (road) | Harkes River (road) | Harbor River (road | San Antonio (road) | Melbourne (light rail viaducts) | Balrica (HSR viaduct) | Caltrain (railway viaducts) |
|---|---|---|---|---|---|---|---|---|
| $M/Mile | $156 | $147 | $115 | $109 | $222 | $130 | $128 | $200 ($180 + factor) |
| Terrain | Palo Alto similar | Complex; over water | Complex; over water | Complex; over water | Palo Alto similar | Palo Alto similar | Level, marshy; tunnels | Sloping flat |
| Clearances (feet) | 30 | 65 | Up to 45 | Up to 65 | 17 to higher | 26 to 35 | 23 to higher | 17 |
| Width (feet) | 60 | 40 | 35 | 47 | Over 60 | 78 (2 @ 39) | (not reported) | 55 |
| Span section lengths (feet) | 130 | 80 to 170 | Up to 164 | 78 | 100+ | 90 to 120 | Up to 160 | 100 |
| Special mitigations | Salt water, winds | Corrosion | Corrosion | Winds, seismic, vessels | (not mentioned) | (not mentioned) | (not mentioned) | Seismic |
| Project scope | Viaduct, cantenaries only | Viaduct, cantenaries only | Viaduct, cantenaries only | Viaduct, cantenaries only | Frontage road, other extras | 5 stations, park, full project | Elec infra; stations; 4-tracks | Viaducts, shoofly, cantenaries |

Parameter supports the $180M estimate because the cost is lower or the characteristics are larger than Palo Alto.

# Viaduct: Addendum:
# Costs: Palo Alto, Menlo Park Current Proposals

- Palo Alto Churchill Closure with Mitigations: $115M midpoint, $104M to $126M, tracks at grade level, Churchill vehicle traffic closed / bike-ped underpass and upgrades at Embarcadero and Page Mill, night and weekend traffic limitations, 2 years
  - https://www.paloalto.gov/files/assets/public/v/1/transportation/rail/connecting-palo-alto/fact-sheet/churchill-closure_factsheet_pa_june_7_2024.pdf

- Palo Alto Churchill Partial Underpass: $318M midpoint, $285M to $351M, tracks at grade level, Churchill/Alma vehicle/bike/ped traffic access limited, loss of street parking, property acquisitions, 2.5 to 3 years
  - https://www.paloalto.gov/files/assets/public/v/1/transportation/rail/connecting-palo-alto/fact-sheet/churchill-partial-underpass_factsheet_pa_june-3_2024.pdf

- Palo Alto Meadow-Charleston Hybrids: $477M midpoint, $428M to $526M, tracks raised 15 feet, Meadow-Charleston traffic access limited, no property acquisitions but driveways affected, 4 years
  - https://www.paloalto.gov/files/assets/public/v/1/transportation/rail/connecting-palo-alto/fact-sheet/meadow-charleston-hybrid_factsheet_pa_june-6_2024.pdf

- Palo Alto Meadow-Charleson Underpasses: $844M midpoint, $756M to $932M, tracks at grade level, Meadow-Charleston traffic closed/Alma traffic limited during construction, property acquisitions, 4 years
  - https://www.paloalto.gov/files/assets/public/v/1/transportation/rail/connecting-palo-alto/fact-sheet/meadow-charleston-underpass_factsheet_pa_june-3_2024.pdf
- All share these characteristics: pump station/long term maintenance and risk of flooding, utilities relocation, construction 2 to 4 years; 2026 dollars.

- Underpass costs, Menlo Park / Middle Avenue: $62M
  - https://nationaltoday.com/us/ca/menlo-park/news/2026/02/04/menlo-park-struggles-to-fund-costly-rail-crossing-project/

- Underpass costs, Palo Alto / Homer Avenue: $13.6M ($5.2M 2005, 2.6 inflation 2026 February); likely no longer allowed by Caltrain
  - https://www.paloaltoonline.com/news/2005/05/05/homer-tunnel-officially-opens

# Viaducts: Addendum:
# Costs: California, US, Florida, North Carolina, South Carolina

- **Viaduct: cost per mile for CA HSR: $180M, 2026 dollars; $9.8B / 113 miles, $90M midpoint estimate, 2011 dollars**
  - **https://hsr.ca.gov/wp-content/uploads/2025/06/BPlan_2012CostChanges09_12.pdf page 10**

- **Viaduct: cost per station for heavy rail transit (HRT): $45.9M (adjusted 2026 dollars; 6 HRT projects)**
  - **https://projectdelivery.enotrans.org/fta-capital-costs-database/**

- **Grade-level east track moved/new cost per mile: $3.0M, 2026 dollars; $2.6M for new HSR single track; increased for catenaries..**
  - **https://www.scribd.com/document/428116190/2017-RailRoadEngineering**

- **Viaduct: cost per mile for a 2-lane automobile roadway: $156M, 2026 dollars; $235M / 1.9 miles, 2021 dollars.**
  - **Location: Tampa, Selmon West Extension.**
  - **Construction timeframe: 41 months.**
  - **https://aspirebridge.com/magazine/2022Spring/AspireBook_Spring22_2022DesignAwardspdf.pdf pages 12-16**
  - **https://www.tampa-xway.com/initiatives/completed-projects/selmon-west-extension/**

- **Viaduct: cost per mile for a 2-lane automobile roadway: bridge: $147M, 2026 dollars; $450M / 3.2 miles, 2025 dollars.**
  - **Location: North Carolina, Alligator River.**
  - **Construction timeframe: 36 months.**
  - **https://aspirebridge.com/magazine/2026Winter/Aspire-Winter2026.pdf**

- **Viaduct: cost per mile for a 2-lane automobile roadway bridge: $115M, 2026 dollars; $60M / .6 miles, 2023 dollars.**
  - **Location: North Carolina, Harkers River Bridge**
  - **Construction timeframe: 15 months (spread over 33 month due to no April to September construction restriction).**
  - **https://aspirebridge.com/magazine/2023Fall/Aspire-Fall2023.pdf pages 24-29**

- **Viaduct: cost per mile for a 2-lane automobile roadway bridge: $109M, 2026 dollars; $55M / .6 miles, 2021 dollars.**
  - **Location: South Carolina, Harbor River Bridge.**
  - **Construction timeframe: 43 months.**
  - **https://aspirebridge.com/magazine/2023Summer/Aspire-Summer2023.pdf pages 26-29.**

# Viaducts: Addendum:
# Costs: Texas, Australia, Baltic States

- **Viaduct: cost per mile for a 6-lane automobile roadway expansion: $222M, 2026 dollars; $1.5B / 7.6 miles, 2024 dollars.**
  - **Location: San Antonio, Northeast Expansion Central.**
  - **Construction timeframe: 60 months (including a large non-viaduct scope)**
  - **https://aspirebridge.com/magazine/2024Summer/Aspire-Summer2024.pdf pages 5 to 9.**
  - **https://www.txdot.gov/35nex/nex-central.html**

- **Viaduct: cost per mile for 2 single track rail viaducts: $130M, 2026 dollars; Aus$190/km, converted, adjusted for relative construction factor, 2018 dollars (Australia).**
  - **Location: Melbourne Caulfield to Dandenong Level Crossing Removal Project**
  - **Construction timeframe: 24 months.**
  - **https://www.premier.vic.gov.au/no-more-level-crossings-between-dandenong-and-city**
  - **https://www.constructionbriefing.com/news/how-do-infrastructure-project-cost-and-timelines-compare-across-nations/8035523.article (US vs Australia, US vs France)**

- **Viaduct: cost per mile for a 2 track rail viaduct: $128M, 2026 dollars; $72M Euro /km, converted, adjusted for relative construction factor, 2026 dollars (Lativa, Estonia, Lithuania).**
  - **Location: Lativa, Estonia, Lithuania: Rail Baltica project.**
  - **https://www.railbaltica.org/news/kalev-kallemets-rail-baltica-is-a-necessary-and-relatively-inexpensive-megaproject/**
  - **https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Comparative_price_levels_for_investment (France vs. Baltic)**


**Melbourne**

# Viaducts: Addendum
# Timeframe parameters

- Catenary renewal: 0.4 miles per day; up to 150 miles (250km) per year / 365.
  - https://uic.org/com/enews/article/at-uic-the-world-s-rail-platform-french-innovation-in-catenary-renewal-for-the
- Piers, drilled: 2 piers per day for piers greater than 60 inches in diameter
  - https://connect.ncdot.gov/resources/Structures/StructureResources/NCDOT%20Working%20Days%20Guidelines%20for%20Structure%20Construction,%2001-05-2016.pdf
- Track, new per day: 0.5 miles per day (8-hour shift)
  - "replace 10,000 ties or several thousand feet of rail in a concentrated work window (often 48 hours)" (Google AI response)
  - 3250 ties per mile, for 10,000 ties (above), 3 miles over 48 hours, 1.5 miles per 24 hours
  - https://www.trainorders.com/discussion/read.php?1,774445
- Viaduct span lengths: 100 feet applied here (98 to 145 feet in practice); 19,200 feet means 192 spans, 191 piers
  - https://www.pci.org/PCI_Docs/Publications/PCI%20Journal/2014/Spring/Full-span%20precasting%20for%20light-rail%20transit%20and%20high-speed%20railway%20bridges.pdf
- Viaduct spans installed per shift or day
  - 1 span per day: https://www.idc-online.com/technical_references/pdfs/civil_engineering/Longer_and_Longer_Concrete_Viaducts_for_Transportation_Growing_Needs.pdf
  - 2 spans per day https://www.pci.org/PCI_Docs/Publications/PCI%20Journal/2014/Spring/Full-span%20precasting%20for%20light-rail%20transit%20and%20high-speed%20railway%20bridges.pdf

# Viaducts: Addendum: Timeframe Parameters and Durations

| Item | Action | Parameters | Per shift etc. | Days |
|---|---|---|---|---|
| **Shoofly tracks** | With turnouts, catenaries | | | |
| | Tracks | 6.10 miles (3.05 miles x 2, but concurrently) | 0.5 miles | 7 |
| | Catenaries | 6.10 miles (3.05 miles x 2, but two teams) | 0.4 miles | 8 |
| **On-Site Assembly** | Viaducts | 14,000 feet; 100-foot spans; 140 spans, 138 piers | | |
| | Pier footings and caps | 138; 2 teams, 2 per day; overlap with spans | 2 per shift per team | 35 |
| | Spans | 140; 2 teams, 2 per day; overlap with piers | 2 per shift per team | 35 |
| | New tracks on spans | 2.65 miles; overlap with spans | 0.5 mile | 6 |
| | Catenaries | 2.65 miles; overlap with tracks | 0.4 miles | 8 |
| | Testing | Inspections (overlap with catenaries), trial runs | | 14 |
| | Activation | 2 days | | 2 |
| **Disruptions** | | | | |
| | Caltrain | Turnouts installation (4 teams) | 1 weekend | 2 |
| | Churchill/Meadow/Charleston | Shoofly tracks, quad gates (4 teams) | 1 weekend each | 3 |
| | Churchill/Meadow/Charleston | Viaduct overpasses (1 team each) | 1 weekend each | 3 |
| | Caltrain | Turnout(s) removal (4 teams) | 1 weekend | 2 |

# Viaducts: Addendum: General Information

**General Configuration Parameters**

- **CA HSR platform length: 800 feet**
  - **https://www.railjournal.com/passenger/high-speed/shorter-platforms-for-california-high-speed-rail/**
- **Clearance above roadways: 17 feet (16.6 feet) for California**
  - **https://dot.ca.gov/-/media/dot-media/programs/traffic-operations/documents/hov/hov-guidelines-2020-a11y.pdf**
- **Inflation calculator, non-residential construction: 4.7% average per year**
  - **https://edzarenski.com/category/inflation-indexing/**
- **Pedestrian crossing candidate locations in Palo Alto**
  - Note: This report moves Colorado and Loma Verde to El Dorado and El Verona, for sufficient distance from Oregon.
  - **https://www.cityofpaloalto.org/files/assets/public/v/1/transportation/projects/southern-palo-alto-bikeped-railroad-crossings/spa-ped-bike-connectivity_existing-conditions-report_final.pdf**
- **Pedestrian hybrid beacon costs (Caltrans): $300K to $1.5M; used $750K plus $350 for paving and other costs**
  - **https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/policy/202505-tsb-25-01-phb-guidelines-a11y.pdf**
- **Rail height above clearance: 5 feet (4 to 5.5 feet)**
  - **https://meadhunt.com/designing-steel-plate-girder-bridges/**

**Best Solution Matrix References**

- **Criteria based on Appendix E, City Council Staff Report, Meeting Date 9/5/17.**
  - **Expanded criteria and evaluations by Mike Forster.**
- **Vibration/Noise Study, July 2020:**
  - **https://connectingpaloalto.com/wp-content/uploads/2020/08/Noise-Vibration-Comparative-Analysis-Report.pdf Page 24**
- **Sea Level Rise Study, January 2024:**
  - **https://connectingpaloalto.com/wp-content/uploads/2024/03/Attachment-C-Sea-Level-Rise-Assessment-1.pdf**

# Viaducts: Addendum:
# Embarcadero to Cal Ave: Construction Sequence

**Constraints**
**Constraints**
- **ROW width requires one shoofly track on either side of existing tracks**

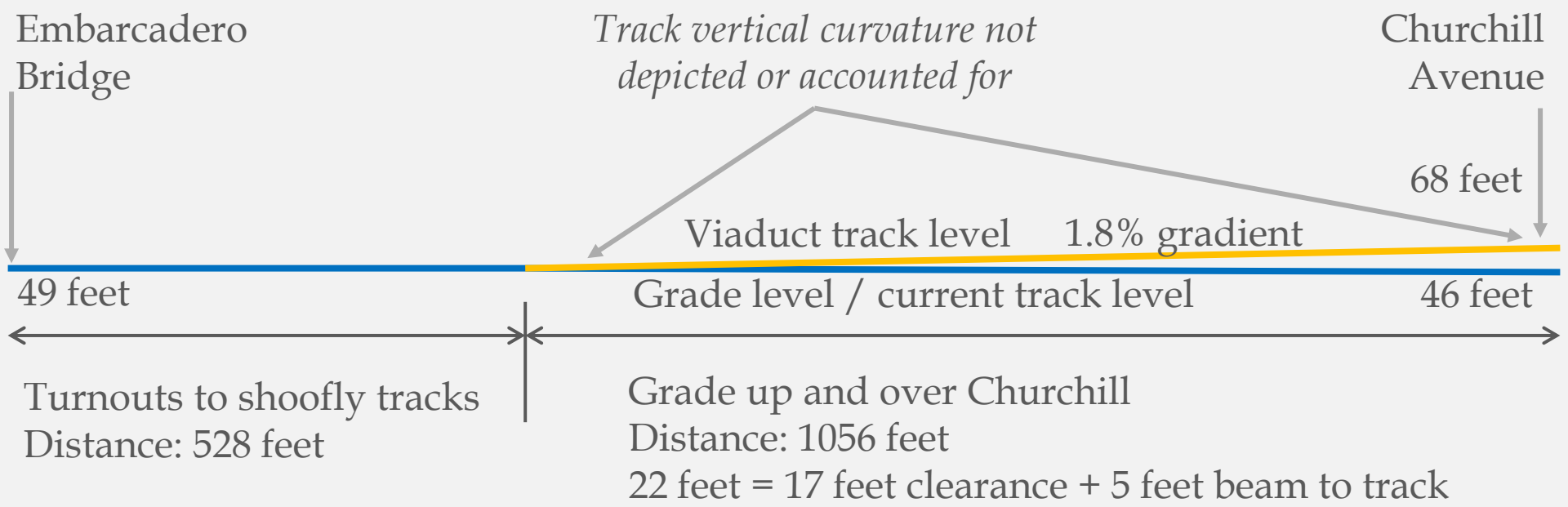
**Sequence**
- **Install new eastside poles and catenaries at the Alma edge to cover the existing eastside track and shoofly**
- **Remove the existing eastside poles and catenaries**
- **Install new eastside shoofly track**
- **Use existing eastside track and shoofly for Caltrain operations**

- **Borrow part of Peers Park from Palo Alto**
- **Install new westside poles and catenaries for the shoofly track**
- **Remove existing westside poles and catenaries**
- **Install new westside shoofly track**
- **Use both shoofly tracks for Caltrain operations**

- **Remove existing Caltrain tracks**
- **Install Embarcadero to Cal Ave viaduct**
- **Use viaduct for Caltrain operations**

- **Remove westside poles, catenaries, shoofly track**
- **Retain and use eastside shoofly track for freight traffic**
- **Return borrowed part of Peers Park to Palo Alto**

# Viaducts: Addendum:
# Elevation Profile: Embarcadero to Churchill



# Viaducts: Addendum: Peninsula Examples

- **Burlingame: Chose a viaduct plus berm approach: fully elevates tracks, does not lower roads**
  - https://burlingame.org/DocumentCenter/View/2932/Presentation-Slides---Virtual-Community-Meeting-July-13-2022-PDF
  - https://www.caltrain.com/media/33194/download

Broadway (proposed)

Cadillac Way underpass (proposed)
Similar to future
Palo Alto Bike-Ped crossings

- **San Bruno: Viaduct-like - as built:**
  - **Minimal road lowering at San Bruno Ave**
  - **Minimal or no road lowering at San Mateo Ave**
  - **Little or no impact on nearby properties**

San Bruno Avenue

San Mateo Ave

- **Redwood City: Favoring a viaduct approach, plan 1A, north of Highway 84**
  - Caltrain grade separation plans take shape in Redwood City | Local News | smdailyjournal.com

# Viaducts: The End:
# Visually Attractive Examples of Viaduct Grade Separations

- Elevated tracks do not have to be berms that might divide cities.

(Images from Google Earth / Streetview)

Montessoro, Italy

Paris, France - Bercy

Sunnyside, NY

Paris, France – Blvd. St. Jacques

Berlin, Germany – SPUR 2017

Union City, CA – Kennedy Park - BART