CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

California High-Speed Rail Project: A Study of the Palo Alto Section

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EXECUTIVE SUMMARY

Scope

The primary aim of this research project was to investigate the possibility of tunneling the upcoming California High-Speed Train tracks, thereby avoiding an above-ground train. Our investigations focus primarily on the social, economic, and political implications of tunneling. The three means by which we will investigate these issues are:

- A survey of stakeholders to understand the goals and preferences with regard to the project as a whole.
- An economic model with variable inputs that determines the financial feasibility of a tunneled option
- An urban design study of four alternative development schemes

Survey Conclusions

A survey of local residents, employees, and Stanford students showed that survey respondents:

- Care more about minimizing the visual impact, noise and environmental impact of the rail line significantly more than the cost of the project.
- Are in favor of a HSR station in Palo Alto, even if it brings high-density development to the area.
- Believe that the two greatest concerns about HSR are the physical division of Palo Alto and the noise, vibration and other disturbances due to HSR operation, which indicates a strong opposition to an above ground alignment.

Urban Design Options

For this project, we envisioned four urban design options.

Baseline
The as-drawn plan from Appendix 2-D of the Bay Area to Central Valley Final Program Environmental Impact Report/Environmental Impact Statement (Program EIR/EIS). This plan involves minimal surrounding development.
Tunneled HSR with mid-density development
Development focuses on community-oriented design first and considers economic feasibility a secondary, yet still important, goal.
Tunneled HSR with high-density development
Development pushes the limits of what could be considered "acceptable" in the community in an attempt to significantly curb the cost of tunneling.
Tunneled HSR with extreme high-density development
Development is strictly a function of economic feasibility, with community-oriented goals as an afterthought.

MACDADI Results

By using the MACDADI decision making tool, we found that a tunneled HSR with mid-density development is best design option when considering stakeholder average preferences for connectivity and economics. No single design option was found to be better regarding stakeholder average preferences for environmentalism and the economy.

Economic Results

Our economic calculations showed that if the High-Speed Rail Authority contributed $500 million to the project, Palo Alto would need to raise approximately $1.3 billion for the tunneled option.

- For the Tunneled HSR with mid-density development and a 1% sales tax, there is a $773 million funding deficit.
  - o   Total development = 1,021,258 square feet
- For the Tunneled HSR with high-density development and a 1% sales tax, there is a $291 million funding deficit.
  - o   Total development = 3,350,154 square feet
- For the Tunneled HSR with extreme high-density development and a 0.5% sales tax, the funding requirement is met.
  - o   Total development = 9,280,392 square feet

INTRODUCTION

1.1 - Statement of Problem

In recent months, there has been significant opposition to the proposed alignment of the high speed train, especially along the Peninsula. Menlo Park and Atherton filed a lawsuit contesting the validity of the EIR, and there has been extensive discussion among residents and City Councils along the Peninsula regarding how to influence the design decisions of California High Speed Rail Authority (CHSRA).

The most recent proposal by the CHSRA shows the HSR tracks running at-grade along a significant portion of the right-of-way, with grade-separated crossings and select elevated portions of the track when deemed necessary.[1] This has naturally brought on severe criticism from the surrounding communities because of the far-reaching implications of an at-grade and elevated structure. Some of the more pressing concerns relate to physical divisions of cities along the Peninsula, noise and other disturbances created by massive construction efforts and the operation of a new rail line, as well as the increased congestion, traffic, and growth that the train is likely to bring.

Designers, engineers, industry professionals, and community organizations have begun to look at alternate solutions to help mitigate these concerns. Specifically, there has been discussion of a proposal to tunnel the high-speed rail through this San Jose-San Francisco corridor. While a complete tunnel along the Peninsula would be a massive undertaking, the potential for a partially tunneled rail at key locations along the corridor could be a viable solution.

In the case of Palo Alto, there appears to be a real opportunity to tunnel the high-speed rail. Much of the concern over a potential tunnel revolves around cost; it is significantly more expensive to tunnel the HSR line, and CHSRA is not required to tunnel the tracks so long as the EIR for the above-ground solution is approved. However, there is a significant opportunity for new development in the area surrounding the potential HSR station in Palo Alto (the current Caltrain station), which could begin to at least bridge the costs between the above-ground and below-ground alignments, if not cover the difference outright.

1.2 - Scope and Objectives

Because of the potential value in development along the Palo Alto right of way, especially in the downtown area, this research project aims to study the feasibility of a tunneled high-speed rail line through Palo Alto by integrating economic, political, and social perspectives into the design process. This project is limited in scope to Palo Alto.

Using MACDADI (Multi-Attribute, Collaborative Design, Analysis, and Decision Integration) as a foundation, the objective of the project is to develop and analyze four design alternatives with regard to vertical rail alignment and the surrounding transit-oriented development. The project consists of three parts:

1) A survey of stakeholders to understand the goals and preferences with regard to the project as a whole.
2) An economic model with variable inputs that determines the financial feasibility of a tunneled option.
3) An urban design study of four alternative development schemes.

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[1] See Appendix G for CHSRA documentation.

2.0 - PROJECT PROCESS

We began this project by researching similar massive infrastructure debates from around the Bay Area. One project studied was the Embarcadero Freeway in downtown San Francisco. In 1985, San Francisco's Board of Supervisors voted to replace the Embarcadero, but voters defeated the measure in 1987. Once the Loma Prieta earthquake damaged the bridge in 1989, the structure was no longer usable. When presented the option between repairing the structure and replacing it with an at-grade boulevard, the ground level option passed the Board of Supervisors by one vote.

The main point gleaned from this study was the massive number of impassioned people on both sides of the argument before a decision was made. Citizens from Chinatown closed their shops to march in support of repairing the freeway, and other citizens threatened to destroy the freeway themselves if repairs were attempted. Once the structure was replaced, however, few complained about its absence.

Before we began this project, various individuals and groups had already looked at the possibility of tunneling the High Speed Rail. John Barton and Tony Carrasco had initially spearheaded a vision for bringing Caltrain and High Speed Rail underground and selling air rights above to help pay for the extra cost. In addition, classes at Stanford University have examined the issue, exploring possible advantages and disadvantages to above ground and tunneled options, coupled with various development schemes and financial models.

We next met with Stanford Civil Engineering Professors John Barton, John Haymaker, John Kunz, and Ray Levitt. They provided us with various tools with which we could analyze various organizational and design scenarios, including SimVision[2], MACDADI, and Narrator. They also provided us with names of specialists and industry professionals who we could consult with questions.

Gary Griggs, a consulting professor in Stanford's Civil Engineering Department and former president of the U.S. infrastructure department of Parsons Brinckerhoff, proved to be very helpful in providing us information regarding tunneling and obtaining accurate cost data.

When we called the California High-Speed Rail Authority, we were given the phone number of John Litzinger, the project manager from HNTB Corporation. He infored us that all design options were still under review, and that many design decisions had yet to be made. This gave credence to our assumption that very little about the design of the rail line's profile had been decided, and that changing it for different design scenarios was appropriate for the scope of this study.

To further understand the environmental impacts of such a large construction project, we consulted with Stanford Civil Engineering Professor Mike Lepech. He introduced us to the Economic Input-Output Life Cycle Assessment tool published by Carnegie Mellon University. This online database allowed us to input the estimated cost of our tunneling project, and using 1997 data on cost/carbon relationships, gave us an estimate for how much carbon the project would be releasing into the air per million dollars spent.

To understand how the air rights for development could raise money for the tunnel, we spoke with several local developers, including Mollie Ricker, Chop Keenan, Roxy Rapp, and John McNellis. John McNellis was extraordinarily helpful in teaching us the economics of how development like this would work, and what assumptions would have to be validated in order to raise the considerable amount of capital needed.

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[2] For a complete SIMVISION model of the entire project schedule, see Appendix I.

3.0 - MACDADI

3.1 - Description of MACDADI

MACDADI (Multi-Attribute, Collaborative Design, Analysis, and Decision Integration) is a tool developed by Stanford Civil Engineering Professor John Haymaker to organize complex projects and aid in the decision-making process. It assesses stakeholder preferences across a number of different goals, assigns quantifiable metrics to these goals in terms of the given design alternatives, and weighs the stakeholder preferences against these metrics to determine the "best solution." Developing a MACDADI model follows the progression of steps outlined below:

1) Identify stakeholder groups
2) Define goals of the project
3) Collect stakeholder preferences of the goals
4) Determine design alternatives
5) Develop quantifiable metrics for each goal
6) Assign values based on these metrics to each design alternative
7) Analyze the design alternatives in terms of weighted value based on the stakeholder preferences

3.2 - Identify Stakeholder Groups

We identified seven stakeholder groups to include in our study:

1) People who live and work in Palo Alto
2) People who live, but do not work, in Palo Alto
3) People who work, but do not live, in Palo Alto
4) People who spend time in Palo Alto, but neither work nor live in the city
5) Business owners in Palo Alto
6) Palo Alto government officials
7) Stanford students

In the distributed survey, respondents (n=225) were asked to identify their affiliation to Palo Alto and the surrounding area.[3] These survey options did not translate directly into the stakeholder groups listed above. Rather, we used the sum total of the information gathered on the first page of the survey to filter the respondents into the correct stakeholder group.[4]

3.3 - Define Project Goals

We developed a set of goals based on three broad categories: **economic** goals, **environmental** goals, and goals regarding **connectivity**. The goals are centered around the

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[3] For further discussion of the survey and results, see Section 4 of this paper. The actual survey can be found in Appendix C-2.
[4] For more information on determining stakeholder groups, see Appendix A.

influence the high speed rail and surrounding development might have on the Palo Alto community as a whole.[5]

The **economic goals** are defined as:
1) Minimize cost to Palo Alto
2) Increase housing capacity in Palo Alto
3) Increase number of jobs in Palo Alto

The **environmental goals** are defined as:
1) Minimize environmental impact of the train and surrounding development
2) Minimize noise from construction and operation of train
3) Minimize vibrations as a result of construction and operation of train
4) Safety during train operation

The **connectivity goals** are defined as:
1) Ability to bike/walk to living, working, and retail environments
2) Blend station and rail line into surrounding architectural aesthetic
3) Easy access to trains (CalTrain & High Speed Rail)
4) Minimize traffic congestion in Palo Alto due to construction
5) More open space and public parks in the downtown area

3.4 - Collect Stakeholder Preferences

The second page of the online survey was geared towards identifying which goals respondents felt were most important. Through a forced ranking system, each respondent was required to rate the level of importance of each goal within a given category.[6] Pictured below is the page of the survey asking respondents to rank their preferences of the three categories of goals.

Figure 1 - Connectivity Stakeholder Preferences

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[5] For further discussion on the selection of goals, see Appendix B.
[6] For an explanation of the survey set-up, see Appendix C-1.

2. Please indicate the importance of the following environmental and safety goals.

	1 (Least Important)	2	3	4 (Most Important)
Minimize environmental impact of the train and surrounding development	◡	◡	◡	◡
Minimize noise from construction and operation of train	◡	◡	◡	◡
Minimize vibrations as a result of construction and operation of train	◡	◡	◡	◡
Safety during train operation	◡	◡	◡	◡

If there is another issue you feel strongly about, please write it here:

[   ]

Figure 2 – Environmental/Safety Stakeholder Preferences

3. Please indicate the importance of the following economic goals.

	1 (Least Important)	2	3 (Most important)
Increase housing capacity in Palo Alto	◡	◡	◡
Increase jobs in Palo Alto	◡	◡	◡
Minimize cost to Palo Alto	◡	◡	◡

If there is another issue you feel strongly about, please write it here:

[   ]

Figure 3 – Economic Stakeholder Preferences

Using a simple mathematical formula, we were able to translate the survey results of the goal rankings into stakeholder preference data compatible with the MACDADI process. In the MACDADI analysis, each stakeholder group is assigned 100 total points to be awarded to individual goals within each goal category. The following graphs depict the cumulative distribution among all stakeholder groups of point values across these goal categories.
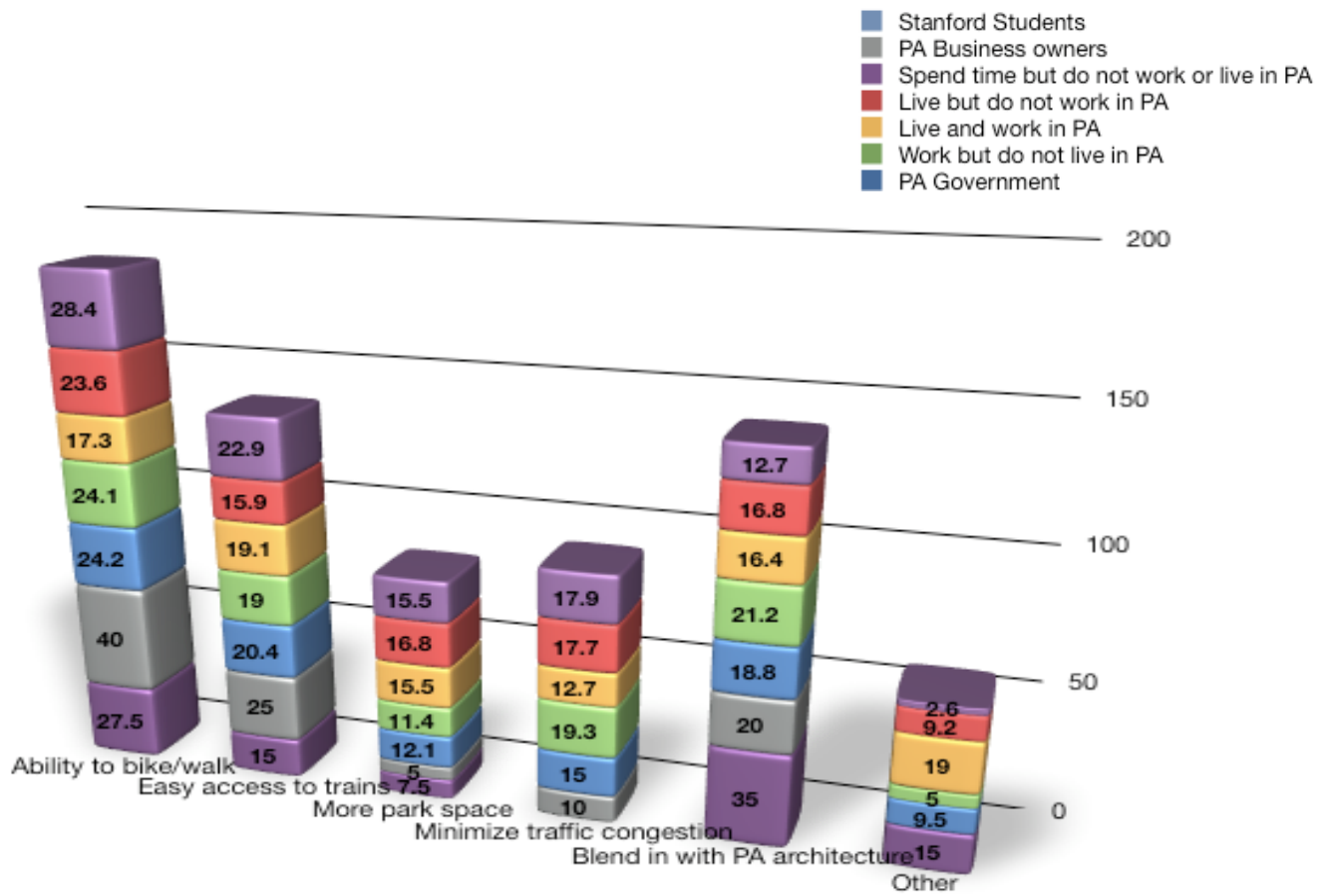
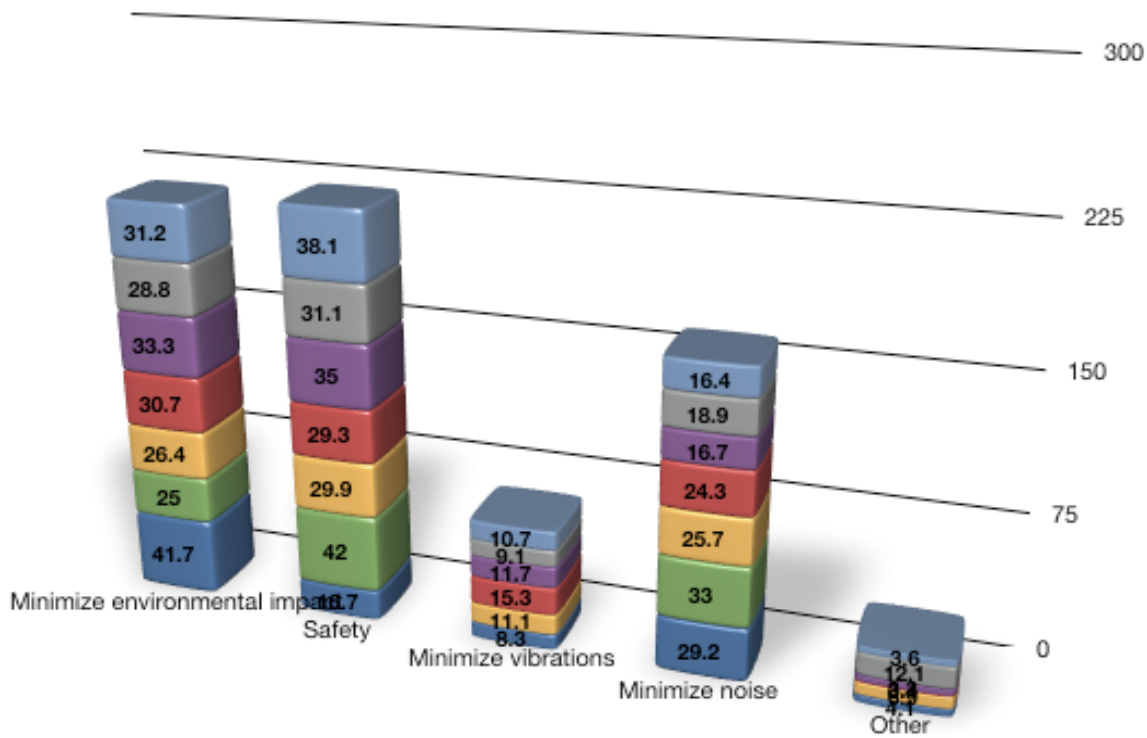*Figure 4 - Connectivity goals across stakeholder groups*

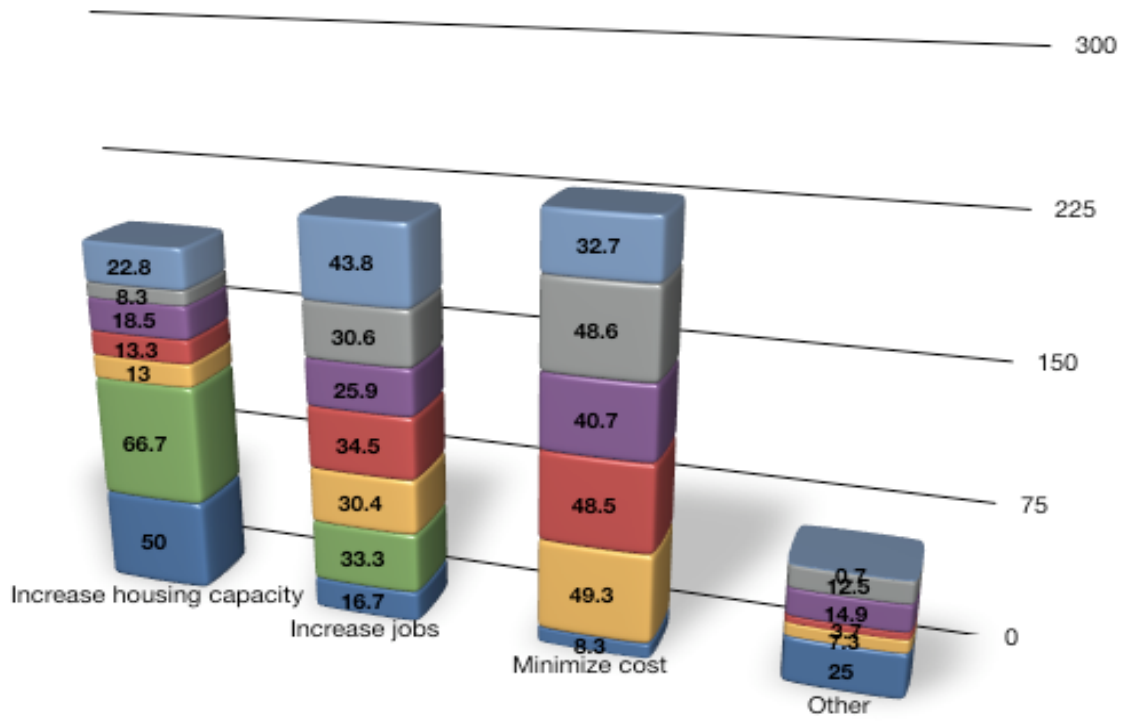*Figure 5 – Environmental/Safety goals across stakeholder groups*

Figure 6 - Economic goals across stakeholder groups

3.5 - Determine Design Alternatives

We established four schematic design alternatives to be evaluated using the MACDADI system. These schemes were conceived using our best judgment as to the "correct" solutions to many of the urban design decisions we were confronted with; however, we also used the survey in a fairly non-scientific context to give us a feel for the important community issues and larger concerns that this project faces.[7]

Baseline
> The as-drawn plan from Appendix 2-D of the Bay Area to Central Valley Final Program Environmental Impact Report/Environmental Impact Statement (Program EIR/EIS). This plan involves minimal surrounding development.

Tunneled HSR with mid-density development
> Development focuses on community-oriented design first and considers economic feasibility a secondary, yet still important, goal.

Tunneled HSR with high-density development
> Development pushes the limits of what could be considered "acceptable" in the community in an attempt to significantly curb the cost of tunneling.

Tunneled HSR with extreme high-density development
> Development is strictly a function of economic feasibility, with community-oriented goals as an afterthought.

3.6 - Develop Quantifiable Metrics

For each of the project goals listed in Section 3.3, we developed a metric to evaluate how successfully a design alternative achieved this goal. For example, we chose to evaluate the connectivity goal of "Ability to bike/walk to living, working, and retail environments" by measuring the number of miles of new dedicated bike/walking paths created.[8]

MACDADI evaluates each metric on a rating scale of -3 to 3, assigning a value based on a design alternative's ability to meet the project goal. For example, a schematic design with an added 4.4 miles of bike paths would score a 2 for that metric, while an option that only adds .4 miles of path would score a -2. The sum total of these values once each metric for each goal is taken into account gives an "overall value" of a design option.

3.7 - Analyze Design Alternatives

Because each goal is not of equal importance to the stakeholders, the final step in the MACDADI process is to incorporate stakeholder preferences into the valuation of design options.[9] Each goal is weighted according to the preferences of the stakeholders so that certain metrics do not sway the "overall value" as much as others. This weighted valuation system gives a more accurate picture of the true desirability of one design alternative over another.

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[7] The details of the design alternatives and the thought process behind their development is addressed in Section 4 of this paper.
[8] A spreadsheet of each goal and its corresponding metric is pictured in Appendix D-1.
[9] For more information on stakeholder preferences, refer to Section 3.4.

The weighted overall assessed design quality of the design alternatives are as follows:

In terms of connectivity goals
1) Baseline: -98.4
2) Tunneled HSR with mid-density development: 111.5
3) Tunneled HSR with high-density development: 27.2
4) Tunneled HSR with extreme high-density development: -84.7

In terms of environmental goals
1) Baseline: 249.1
2) Tunneled HSR with mid-density development: 246.5
3) Tunneled HSR with high-density development: 246.5
4) Tunneled HSR with extreme high-density development: 246.5

In terms of economic goals
1) Baseline: 70.2
2) Tunneled HSR with mid-density development: 90.8
3) Tunneled HSR with high-density development: 48.1
4) Tunneled HSR with extreme high-density development: 15.5

Sum total of weighted overall assessed design quality[10]
1) Baseline: 220.9
2) Tunneled HSR with mid-density development: 448.8
3) Tunneled HSR with high-density development: 321.8
4) Tunneled HSR with extreme high-density development: 177.3

According to the data we collected, option #2 (Tunneled HSR with mid-density development) is preferable, because it has the highest sum total of weighted overall assessed design quality. While this may not be completely accurate because of flaws in our data collection and analysis techniques, it is fair to say that it begins to tell a story about the collective desires of stakeholders in the area regarding the high speed rail and potential development in downtown Palo Alto.

4.0 - SURVEY

4.1 - Purpose

For the purposes of this project, the survey was meant to:

- Inform the MACDADI model through stakeholder preference data.
- Cause citizens to think about solutions to mitigate HSR's impact on the community in a more realistic fashion.

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[10] This valuation is slightly misleading because it assumes that each goal category is weighted equally (i.e. this model assumes people care just as much about economic goals as they do about connectivity issues). For discussion about the potential inaccuracies in our results, see Appendix E-2.

- Analyze concerns, doubts, expectations, etc. about the HSR in an organized way that can ultimately inform the design process.

The first objective has already been addressed in Section 3 of this paper, which discussed MACDADI modeling. The second objective will be addressed in Section 6 of this paper, when we discuss in more detail the urban design considerations in this project. The third objective, the analysis of the survey results, follows.

4.2 - Survey Conclusions

In general, survey respondents (n=225):

- Care more about minimizing the visual impact, noise and environmental impact of the rail line significantly more than the cost of the project.
- Are in favor of a HSR station in Palo Alto, even if it brings high-density development to the area.
- That live in Palo Alto are the group most in favor of a tunneled HSR with high-density development in the downtown area.
- In the younger age demographics tend to care more about having a stop in Palo Alto, yet less about whether or not the track is tunneled.
- Seem very willing to compromise on the issue of development so long as the HSR is tunneled because:
    - They think parks and community spaces are more desirable than shopping options.
    - They do not want development without the HSR.
- That live in Palo Alto are strongly opposed to development in general, but would rather see retail and commercial space than housing.
- That live outside of Palo Alto are somewhat opposed to development, but would prefer housing.
- That plan on being in the Palo Alto area for a longer period of time tend to oppose development.
- Tend to support the HSR project as a whole. However:
    - Older generations tend to be less supportive than younger generations.
- Believe the greatest benefit of the HSR project is ease of transportation to the Central Valley and Los Angeles.
    - The second-ranked benefit is a cohesive plan to improve transit options along the Peninsula.
- Believe that the two greatest concerns about HSR are the physical division of Palo Alto and the noise, vibration and other disturbances due to HSR operation, which indicates a strong opposition to an above-ground solution.

4.3 - Survey Analysis

To analyze the survey results, we looked at three different categories of questions broken down among different demographics.[11]

Trade-offs
> Respondents were asked to choose one design feature over another in terms of proposed development as well as rail construction.

Level of support
> Respondents were asked how supportive they were of the HSR project.

Benefits and Concerns over HSR
> Respondents were asked to identify what they believed to be the greatest benefits of the HSR project, as well as their greatest concerns, among a limited set of responses.

The demographics we identified as useful to analyze the survey results were:

1) Age
2) Time respondent expects he or she will spend in Palo Alto in the future
3) Broad stakeholder groups (not the same breakdown as in the MACDADI analysis)
4) Familiarity with the project
5) Distance of residence from the current Caltrain tracks

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[11] There are many possible questions to analyze from this survey; however, we felt that these three were the most important to consider for the purposes of the project.

4.3.1 - Trade-offs

The trade-offs are broken down into two categories; those that cover the actual rail line itself and those that cover proposed development options.
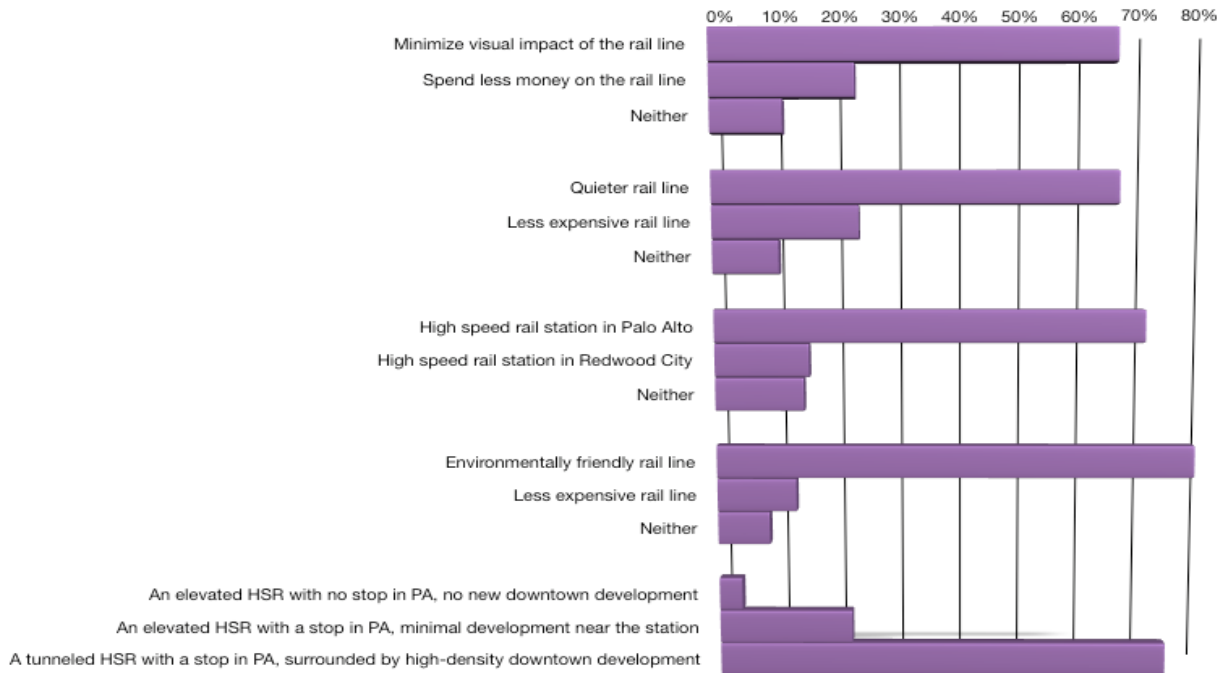
Figure 7 - Rail trade-offs

In Figure 7, we see that respondents to the survey care more about minimizing the visual impact, noise and environmental impact of the rail line significantly more than the cost of the project. This graph also shows that survey respondents are in favor of a HSR station in Palo Alto, even if it brings high-density development to the area.

Surprisingly, those that live in Palo Alto are the group most in favor of a tunneled HSR with high-density development in the downtown area (81%).[12] However, when asked solely about the station location, only 66% of those that live in Palo Alto responded that they would like a HSR station in their city. 17% from this group responded "Neither", likely because these citizens would like to see either a tunneled HSR with no stop in Palo Alto and no new development, or they would like to see HSR eliminated from the Peninsula altogether.[13] For the purposes of our research, however, we chose to eliminate these two options as feasible solutions.

There is a strong trend in the favorability of a tunneled HSR with high-density development based on the length of time a respondent expects to stay in the Palo Alto area. Those that will be here for longer tend to favor the tunneled option, while those that will be leaving the area sooner are more inclined to favor an elevated track with a stop in Palo Alto and minimal development in the area. However, it is also important to note that only a little over 60%

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[12] Graphs comparing trade-off evaluations across different demographics can be found in Appendix C-3

[13] Based on written responses in the "Other" categories throughout the survey, we determined that the two options listed here are the preferred solutions for the majority of those respondents who answered "Neither".

of the respondents who plan on being in the Palo Alto area for longer than 10 years favor a HSR station in Palo Alto, while nearly 90% of respondents who will be in the area for less than 10 years favor a Palo Alto station.

According to the survey results, younger age demographics tend to care more about having a stop in Palo Alto, yet less about whether or not the track is tunneled. While each age demographic strongly supports reducing environmental impacts over reducing cost of the rail line, it is interesting to note that older demographics seem to care a little bit more about the environmental impacts than younger ones, who give the financial concerns more consideration.
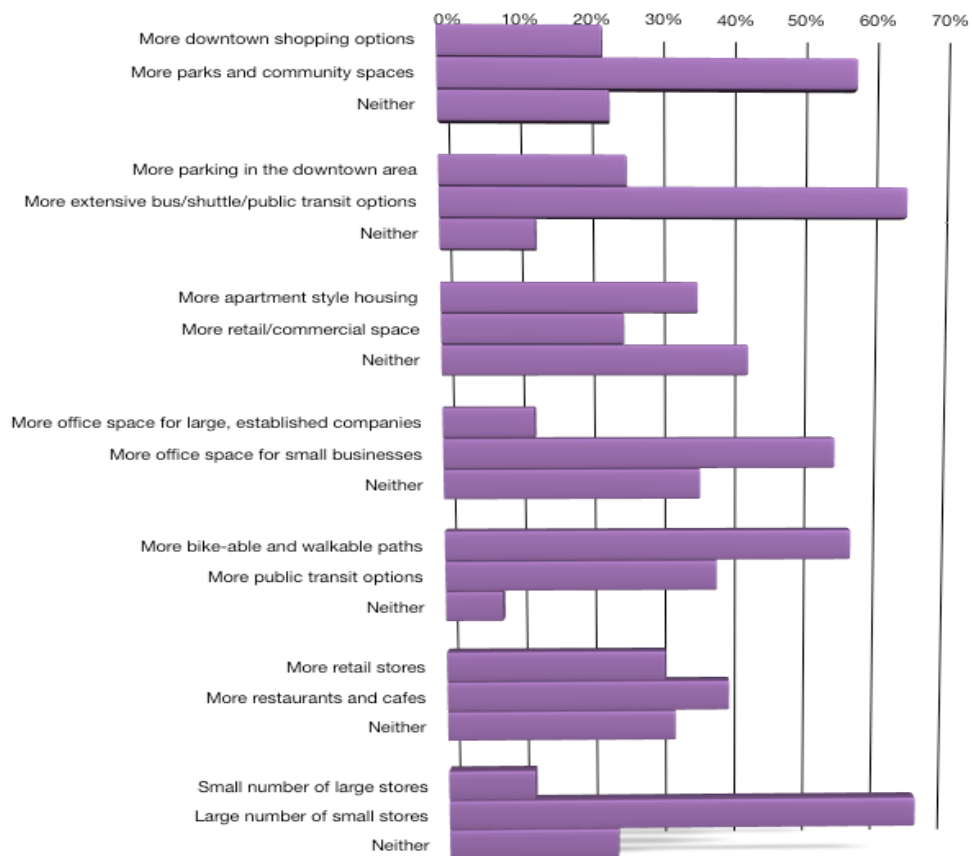
Figure 8 - Development trade-offs

In Figure 8, while a majority of respondents made it clear that high-density development in the downtown area was a viable option, many of the responses in this section make it clear that parks and community spaces are more desirable than shopping options. This, coupled with the 41% of respondents who answered "Neither" when asked about the desirability of apartments or retail/commercial space, leads us to believe that development on its own is not wanted. While this is not a revelation in its own right, it is interesting to note that, based on figure 1 (rail line tradeoffs), respondents seem very willing to compromise on the issue of development so long as the HSR is tunneled. This willingness to sacrifice density and added development in exchange for a more suitable track alignment is integral for finding a feasible solution in this project.

The data regarding the trade-off of apartment-style housing and retail/commercial space seems fairly even across each response, but there are stark differences in opinion among stakeholder groups.[14] Those that live in Palo Alto are strongly opposed to development in general, but would rather see retail and commercial space than housing. Those that live outside of Palo Alto are very strongly in favor of housing, but are still somewhat opposed to development of either type of space.

Those that plan on being in the Palo Alto area for a longer period of time tend to oppose development, answering "Neither" to a higher percentage of the trade-off questions. However, this same demographic is the group most strongly in favor of a tunneled track and high-density development. This could be an indication of the value of a tunneled track and a strong willingness to compromise on the issue of added development.

4.3.2 - Level of Support

Across the entire respondent pool, there tended to be strong support for the HSR project as a whole, as depicted in Figure 9.
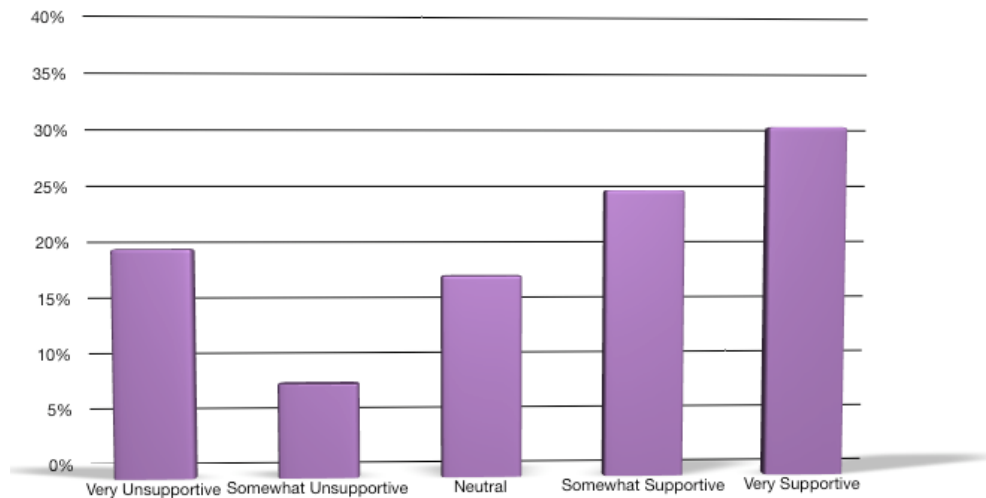
Figure 9 - Level of support for HSR project

The U-shape of Figure 9 suggests strong polarization, and Figure 11 informs us that this trend grows stronger as respondents feel that they are more informed about the project.

The trends seen in Figure 9 tend to hold true regardless of how long a respondent expects to stay in the Palo Alto area (Figure 10). While those planning to stay in Palo Alto a longer time showed the strongest opposition to the project, they were by no means unsupportive of the project.

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[14] See Appendix C-3 for more graphs of survey results.

Level of support for the HSR project vs. length of time planned on spending in PA
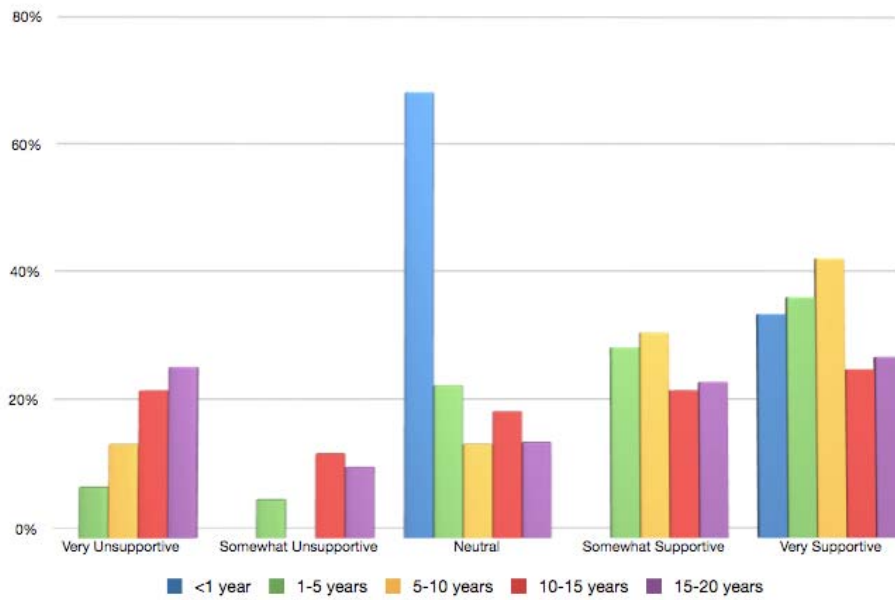
Figure 10 - Level of support vs. time to be spent in PA

Evaluating against a respondent's level of familiarity with the HSR project, as in Figure 12, suggests that the level of support becomes more evenly distributed as citizens become more informed.

Level of support in terms of familiarity with the HSR project
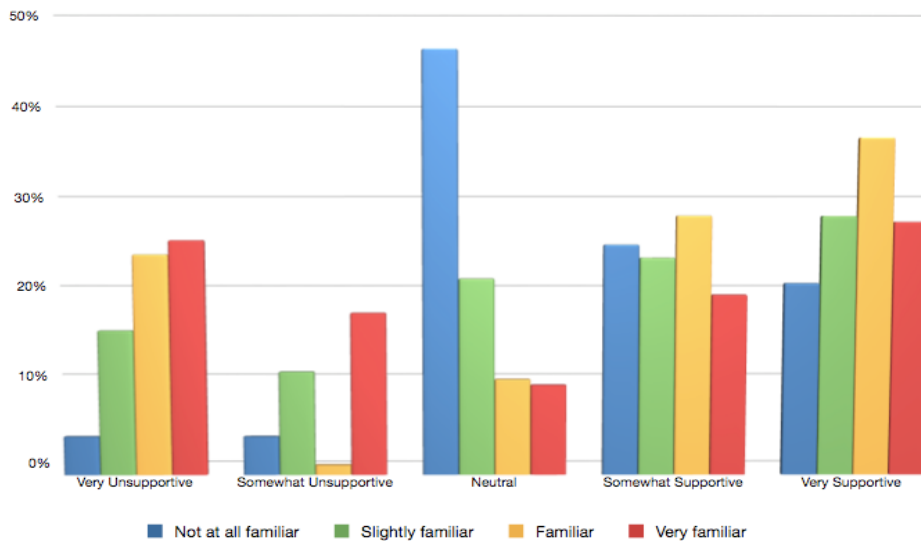
Figure 11 - Level of support vs. familiarity with HSR

While the trend among respondents who were "very unsupportive" slopes upwards, we cannot conclude that length of time expected to stay in Palo Alto has a drastic effect on the level of support. This conclusion can be made when looking at age demographics as well (Figure 13), although there seems to be slightly more variation in the U-shape of the graph in this situation.

Level of support for HSR across age demographics
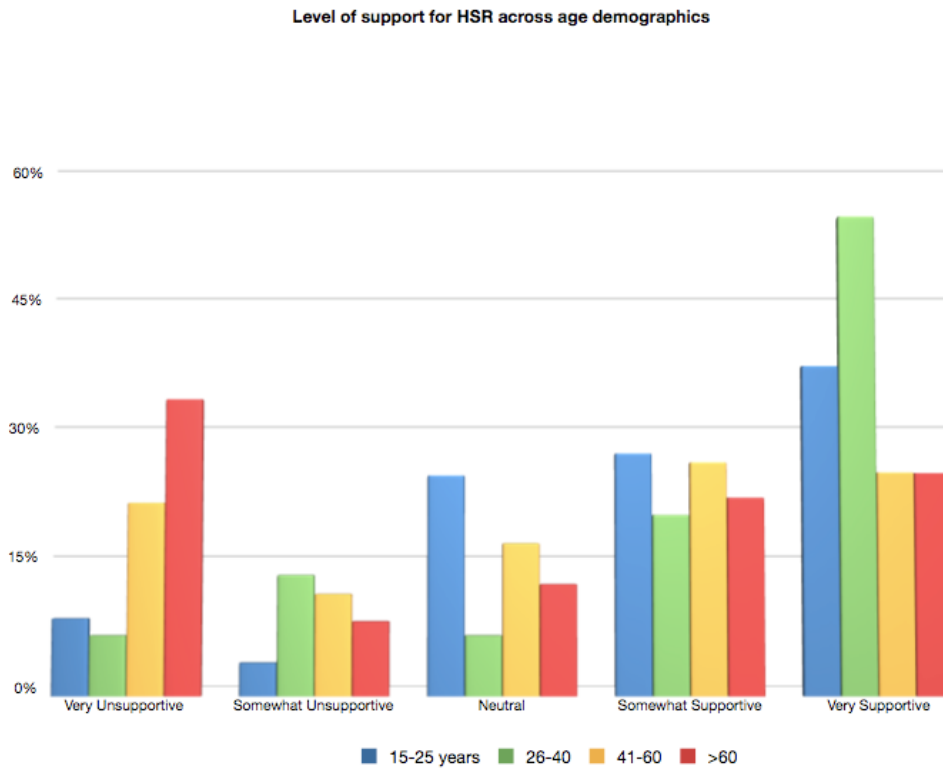
Figure 12 - Level of support vs. age

Older generations tend to be less supportive than younger ones, and it is interesting to note the strong level of support among 26-40 year olds. Because of the length of the HSR project, this demographic is quite important.

4.3.3 - Benefits and Concerns

The greatest benefit of the HSR project, according to survey respondents, is ease of transportation to the Central Valley and Los Angeles. The second-ranked benefit is a cohesive plan to improve transit options along the Peninsula.
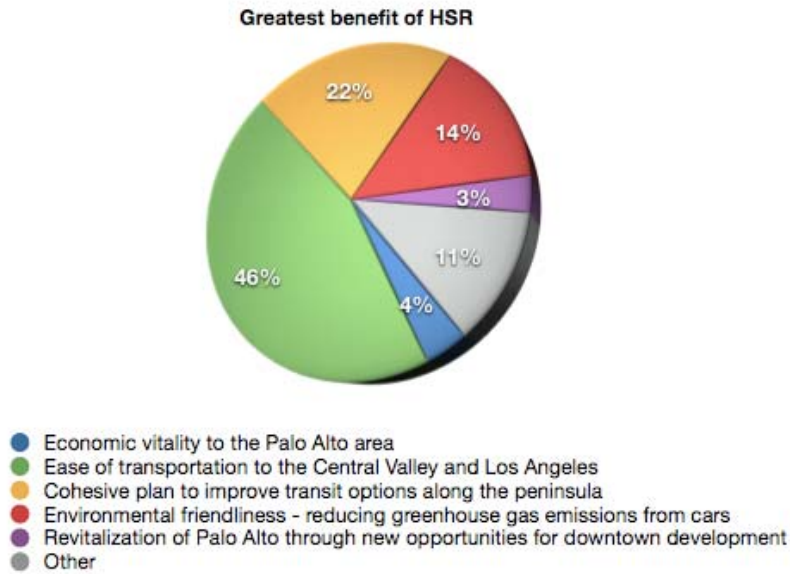
Figure 13- Greatest benefit of HSR

Figure 13 indicates that the major perceived value of HSR lies in its ability to move people through California and connect them to alternate modes of transportation. The added economic benefits that would accompany HSR are not a major perceive benefit for survey respondents. In fact, the environmental benefits of the rail ranked above any economic stimulus.

It is important to note that a significant number of the responses in the "Other" category spoke with a similar voice: "There is no benefit to HSR". We can gather from these responses that citizens who are strongly opposed to HSR see little to no value in the project.

Greatest concern about HSR

- Cost of rail line and station construction to PA
- Drawn-out construction time
- Traffic congestion in PA due to construction
- Noise, vibration, and other disturbances related to HSR operation
- Unwanted development brought to PA
- Physical division of PA by HSR line
- Low ridership
- Other
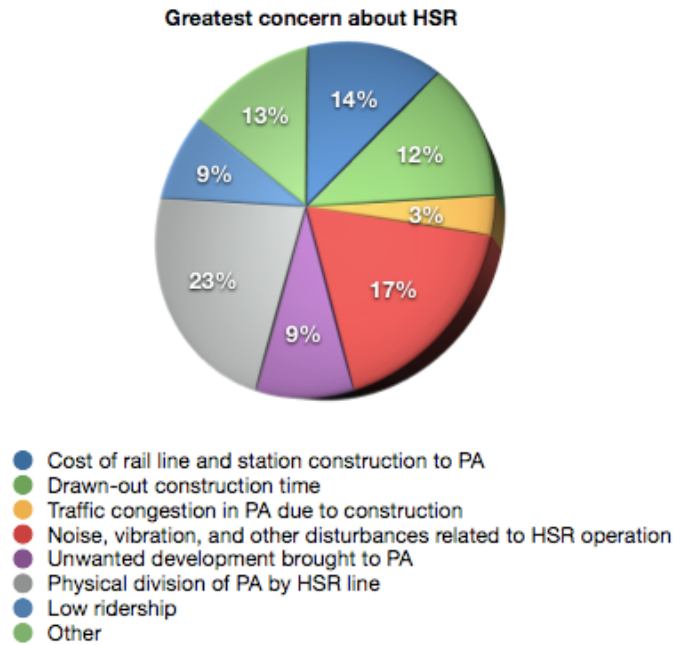
Figure 14- Greatest concern about HSR

   When asked about the greatest concern regarding the HSR project, responses were not nearly as skewed. There are a number of concerns that carry equal weight, reinforcing the delicate nature of this project as a whole.

   The top two responses, physical division of Palo Alto and the noise, vibration and other disturbances due to HSR operation, indicate a strong opposition to an above ground solution. These two concerns can be eliminated by the construction of a tunnel. However, the cost of rail line and station construction is also a concern, and a tunneled solution will inevitably results in higher costs for the city.

5.0 - ECONOMICS

Based on our economic model, the total new development required to fund a tunneled HSR configuration is:

Residential: 5,320,000 square feet
Retail: 302,249 square feet
Commercial: 2,900,000 square feet

5.1 - Assumptions

We formulated our data with the following assumptions in mind:

- High-Speed Rail authority will contribute $500 million, which is similar to the cost of a 100% elevated structure
- Stanford will accept payment of $1 for use of the land[15]
- Palo Alto is willing to accept an additional sales tax of between 0.5-1% for 20 years
- Palo Alto could declare the area under consideration in this study to be a Redevelopment Zone (approximately 95% of the property taxes assessed for the new development will be paid to Palo Alto over the course of 20 years, the lifetime of a Redevelopment Zone)
- A developer will accept a fee of 5% of the hard costs of construction
- Infinite absorption of developed property
- City of Palo Alto will allow all new development needed by rezoning the spaces and relaxing certain building regulations
- Prices are not those from the current economic situation, but rather 2007 prices. This corresponds to profits/SF of:
  - Residential: $125
  - Retail: $100
  - Commercial: $150

5.2 - Cost Data

The four cost estimates prepared correspond to the following four design options:

1) **As Drawn** in Appendix 2-D of the Program EIR/EIS: **$150,097,137**
2) All 6.92 kilometers on an **elevated structure**:   **$510,000,000**
3) With **6.92 kilometers** of Cut & Cover Double Track **Tunnel**:   **$1,019,387,321**
4) With **13.84 kilometers** of Cut & Cover Double Track **Tunnel**: **$1,981,446,530**[16]

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[15] This assumption is based on the following logic: Stanford currently obtaining little benefits from the land, as the only development on the property in question is the Sheraton Hotel, MacArthur Park, the bus terminal, and the Red Cross. In return for this land use, the city may be more accommodating to Stanford's hospital expansion plans. In the long run, it would benefit Stanford if a HSR line was built close to the campus, and there is a possibility that lawsuits will preclude this from happening if the train is not below-grade. Stanford will inherit the revenue stream from this development once the costs of tunneling are covered.

5.3 - Estimating the Palo Alto Section

The original unit cost data for our economic model comes from pages 4-A-7 through 4-A-8 in Appendix 4-A of the Bay Area to Central Valley Final Program Environmental Impact Report/Environmental Impact Statement (Program EIR/EIS) found on the California High Speed Rail Authority's website. Palo Alto is part of the CALTRAIN 7 section as defined by the Program EIR/EIS. The total length of CALTRAIN 7 is given as 22.55 kilometers, of which it is assumed Palo Alto makes up 6.92 kilometers.

Unit costs provided in the Program EIR/EIS were assumed to be in May 2006 U.S. Dollars. They were updated to May 2009 U.S. Dollars using a total inflation of 5.61%, obtained from inflationdata.com.

To estimate the cost of Palo Alto's section of the plan drawn in Appendix 2-D of the Program EIR/EIS, unit quantities for length were taken as 6.92. To estimate the costs of various line items such as the cost for Earthwork (Cut, Fill) and Structures (Retaining Walls), the total cost originally estimated for the CALTRAIN 7 section for each line item was multiplied by length of Palo Alto's section divided by the total length of the CALTRAIN 7 section (that is, 6.92 km / 22.55 km). The number of street under-crossings needed in Palo Alto was identified as four (Alma Street, Churchill Avenue, Meadow Drive, and Charleston Road), and that cost was factored in as well.

While the CALTRAIN 7 section includes 1 kilometer of 'Cut & Cover Double Track Tunnel' and 1.4 kilometers of 'Trench Short', the plan drawn in Appendix 2-D does not appear to include these segments within Palo Alto, so they were omitted from Palo Alto's cost estimate. This omission also leads to a conservative estimate of the difference between the tunneled option and the option drawn in Appendix 2-D of the Program EIR/EIS.

To calculate a ballpark figure for the maximum amount of money that would need to be raised by Palo Alto to fund the undergrounding, the cost for option 1 (Baseline Cost) was subtracted from the cost for option 4.

5.4 - Alterations to Initial Cost Estimates

Mr. Gary Griggs provided us with a more current set of unit prices. Computing new cost estimates based on the updated numbers resulted in and a slight decrease in price for the As-Drawn option, and significant increases in price for the tunneled options. Based on information from Mr. Griggs and a tunneling engineer from Parsons Brinckerhoff, we roughly estimated that an elevated structure would cost approximately $300 per square foot of deck. This yielded a much more expensive estimate for the elevated structure, one that Mr. Griggs and the tunneling engineer agreed sounded much more reasonable.[17]

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[16] The 13.84 km tunnel refers to two 6.92 km double track tunnels, one for HSR and one for Caltrain and Union Pacific Railroad. Option #3, the 6.92 km double track tunnel would only serve an HSR line, while Caltrain and Union Pacific would continue to operate above-grade.

[17] For the complete cost sheet, see Appendix I.

5.5 - Alternate Funding Sources

Sales Tax

By altering the tax increase rate and the duration of the tax, we can estimate the additional revenue that Palo Alto will generate to contribute to the tunnel. Because of the added development, we also assume an increase in taxable retail revenue for Palo Alto of $2,400/year per square foot of added retail. This is derived from the assumption that every square foot of added retail will bring in $200/month.

For design options 2 and 3, a 1% sales tax is added, while option 4 is only a 0.5% increase.[18] A higher sales tax was added in options 2 and 3 to balance out the loss of revenue from less development. In option 4, the community would be accepting significantly higher densities, so we assumed a smaller increase in sales tax in that case.

Redevelopment Zone

Yet another possible source of income is if the area can be classified as a redevelopment zone. This would allow Palo Alto to obtain much more revenue through Property Taxes than it would otherwise get. The percentage of property taxes going to Palo Alto and the duration of the tax are variables that are easily altered.

HSR Contribution

Finally, the last source of funding for the tunnel comes from how much the High-Speed Rail authority is willing to contribute to the project. The lowest amount is assumed to be the estimated cost of the As-Drawn plan from Appendix 2-D of the Program EIR/EIS. A more accurate estimate should be higher, since the High-Speed Rail authority should be willing to pay a premium for Palo Alto in order to avoid the lawsuits that would delay construction.

5.6 - Estimating Economic Feasibility of the Project

To make a rough estimate of the economic feasibility of tunneling, we:

- Begin with the cost of the 13.84 kilometer double track tunnel (option #4)
- Add the developer fee
- Add Palo Alto's ground lease from Stanford
- Subtract the total profit from the project (profit/SF multiplied by the total SF)
- Subtract the city revenue from added sales tax
    From the increase in sales tax assumed to be passed by vote, as well as from increased economic activity in the added retail development.
- Subtract the income from increased property tax
- Subtract the contribution of High-Speed Rail Authority

If the result was less than zero, the tunnel was assumed to be economically feasible. If the result was greater than zero, square footage numbers were increased until that threshold was crossed.

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[18] Design options are introduced in Section 3.5 and discussed in more detail in Section 6 of this paper.

6.0 - URBAN DESIGN

6.1 - Overview of Design Solutions

The goal of this project was to develop schemes that balanced urban design solutions with stakeholder preferences and financial feasibility in different ways. Therefore, the four urban design solutions we developed are based on three key factors:

1) Survey results and analysis
2) Economic considerations
3) Our own interpretations of beneficial urban design

We focused on a few key elements throughout the design process:

- Circulation within the development zone
- Transportation access[19]
- Placement and orientation of spaces based on use
- Zoning guidelines and regulations[20]

The following discussion will center on each of the four design alternatives studied in terms of the MACDADI model.[21] We will present a greater vision for each of the schemes, the pros and cons of each design, and the rationale behind some of the fundamental design choices.

6.2 Baseline Design

6.2.1 - Vision

In this scheme, Palo Alto has accepted the as-drawn vertical track alignment. CHSRA has agreed to grant Palo Alto a station. Stanford chooses to develop a minimal amount of small retail and commercial space. However, the current zoning of that area does not allow for substantial development. There are minimal improvements to the public transit infrastructure, namely a relocation of the bus terminal to a more convenient position directly connected to El Camino Real.

6.2.2 Pros and Cons

Pros
- Palo Alto is not required to contribute any money towards the construction of HSR.

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[19] Parking is not discussed in these scenarios because it is assumed that the combination of an underground parking structure for the HSR station, as well as smaller underground parking structures throughout the development, can accommodate the increase in necessary parking. However, parking will be limited in this area to promote use of public transit and biking/walking. Costs of underground parking structures were included in calculations of construction costs used in the economic analysis, even though parking is not discussed here.

[20] It is clear we did not follow all zoning guidelines in these designs; however, we did consider them, and intentionally chose to break them in a number of instances. We are assuming that Palo Alto is willing to consider a massive rezoning effort in this area to accommodate the new development.

[21] Graphics of the urban design solutions can be found in Appendix F.

- The alignment through Palo Alto is grade-separated at all crossings, and Caltrain uses the opportunity presented by HSR construction to grade separate its crossings as well.
- The low-density environment consistent with much of current Palo Alto is maintained.
- There is no influx of people into the city because of new housing or job opportunities presented by development associated with HSR.

Cons
- HSR tracks maintain, and even intensify, the physical barrier of train lines running through the city.
- Above ground tracks intensify noise and vibration due to train operation.
- Little is accomplished to improve the infrastructure of the downtown area.

6.2.3 - Design Choices

Changes in infrastructure are the only significant design decisions presented to Palo Alto. Moving the bus terminal to a more convenient location along El Camino will shorten transit times by eliminating the complicated navigation of the current bus loop. The route from bus to HSR station will be easily walkable, and there will be no significant difference in convenience for passengers attempting to travel between the bus terminal and the downtown area. This design choice is purely based on reducing bus traffic along University Ave. and simplifying bus routes for the majority of buses traveling to this terminal.

6.3 - Tunneled HSR with mid-density development

6.3.1 - Vision

Development in this scheme focuses on community-oriented design while considering the economic feasibility of the scheme as a secondary, yet important, goal. Citizens can easily bike or walk from Alma St. to El Camino, as well as within the newly proposed development. The development creates a stronger connection between downtown Palo Alto and the Stanford campus. This is in part because of the increased bike and pedestrian access, but also because the new development helps bridge the interstitial space between the two areas that was previously bare land with a railroad track acting as a sort of barrier. While this development is an increase in density from what Palo Alto is typically accustomed to, the building heights only rarely exceed typical building heights in the downtown area. There is some mixed use development, but many of the buildings are single use.

The scheme calls for a linear park running the length of Palo Alto along what is currently the Caltrain right of way. This 4.2 mile park varies in width from fifty to eighty feet along the corridor and provides easy access for bikers and pedestrians traveling from South Palo Alto to the downtown area. The park terminates in what is currently El Camino Park, which will remain a large open space because of the current plans to bury an underground emergency water reservoir.

There is a central transit hub located at the current University Ave. underpass, achieved by creating a bus loop that drops below University Ave. and loops back out to El Camino. This central transit hub sits directly below the linear park, giving easy access to public transit options for bikers and pedestrians.

6.3.2 - Pros and Cons

Pros
- Palo Alto can pay for a portion of the tunneled alignment.
- There is no concern over at-grade crossings.
- There is no physical barrier dividing Palo Alto.
- The development connects downtown with the Shopping Center and the Stanford campus.
- A linear park provides new open space in the city and creates a connection across Palo Alto.
- Public transit infrastructure is upgraded to be more accommodating.
- There will be a new community center for Palo Alto.
- There are new job opportunities in the downtown area.
- The development provides the foundation for growth and evolution of Palo Alto in the future.

Cons
- The development falls well short of paying for the tunnel, so additional funding will be needed.
- There will be added congestion in the downtown area.
- Palo Alto must accept at least some new development in the downtown area.
- Does little to accommodate vehicular traffic flow through the newly developed area.
- Does little to seamlessly carry the downtown "feel" through the new development

6.3.3 - Design Choices

Transit and Circulation

Much of the value of the proposed development, both socially and economically, derives from the introduction of HSR. Therefore, it is of utmost importance to center urban design decisions around transportation. This includes improvements in the accessibility of public transit, the movement of vehicular traffic through the space, and the circulation of people to and from, or within and through, the new development.

According to the survey results, improvements in public transit and connectivity between transit options was an important goal. A key feature in this design, which will ultimately carry through each successive scheme, is a transformation of the University Ave. underpass into a central transit hub. Buses become a door to door service for passengers traveling on Caltrain or HSR, and a covered terminal where passengers are not required to move vertically from bus to train station enhances the feeling that this is a central transit hub.

Of course, vehicular traffic will not disappear regardless of how seamlessly integrated a public transit system may be. To accommodate for, and also regulate, the increased vehicular traffic that this area will inevitably experience, we diverted car traffic for the train station to the Northern side of University Ave., where there is a dedicated turn-out for cars dropping off passengers or picking them up.

However, we made a conscious decision to focus our efforts on improving public transit and the bike-ability and walkability of the new development, so vehicular traffic routes

sometimes took a backseat. For instance, we chose to create dedicated bike connections through the North side of the new development instead of simply pulling roads all the way across the space. While this would have diverted more traffic from El Camino, the survey indicated that citizens cared more about improving the bike-ability and walkability instead of minimizing traffic congestion (reference graphs).

Parks and Community

In line with the transit decisions that improve connectivity, the inclusion of a linear park through the entirety of Palo Alto brings together the North and South sides of the city. It also bridges the divide that is currently created by the at-grade Caltrain tracks. The linear park snakes towards the center of the new development once it crosses University as a way to maximize potential retail development in that section without eliminating the park. This section of the park then becomes a hybrid between a linear park and a pedestrian mall as a way to transition into what is a more urban environment.

We also chose to place a community center at the heart of this new development to mitigate any concerns that this area might become too urban. Located directly across from the historic train station, this community center would help weave the new development into the fabric of Palo Alto instead of creating a separate urban entity that remains a distinctly different piece of the city.

Development

The development in this scheme does not fully embrace the concept of mixed-use. We chose to design the development according to the opinion (derived from the survey) that new housing was not desirable. Without housing, a key component of the "new urbanist" approach is missing, and mixed-use no longer makes the most sense in this context. Of course, it is impossible to redevelop an area like this without housing at all; we simply chose to place it sparingly above some of the retail spaces North of University. South of University, we developed commercial properties. We removed the Sheraton hotel from this area because that land provided opportunity for higher densities without creating an obtrusion.[22] We chose not to drastically exceed the typical 50 foot height limits for this portion of the development, but instead created three to five story office buildings meant for smaller start-ups and other professional services instead of larger, more established companies.

6.4 - Tunneled HSR with high-density development

6.4.1 – Vision

Development pushes the limits of what is considered "acceptable" in the community in an attempt to significantly curb the cost of tunneling. However, this design does not stray from principles of new urbanism that call for easy access to transportation options and bike-able and

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[22] While the Sheraton's ground lease does not expire until 2042, it is our assumption that the hotel can be compensated for its removal, and that this would not significantly affect the financial scenarios we have discussed in Section 5 of this paper.

walkable circulation pathways. There are bike lanes along E-W streets, and there is a central transit hub that has a dedicated bus loop for drop-off at the train station.

The buildings push some of the height limits typically seen in downtown Palo Alto, yet the taller buildings are strategically placed to maintain view corridors and enhance the feel of the new urban environment rather than detract from it. Much of the development is mixed use, with retail along the first floors, and either residential apartments or commercial space on the floors above. While the Sheraton has been removed, a new 10-story hotel in the same area has replaced it.

The 3.8 mile linear park terminates at the intersection of Alma St. and University Ave., and a piece of what is currently El Camino Park is maintained as open space, which accommodates the emergency water reservoir to be buried in that area.

6.4.2 - Pros and Cons

Pros
- Palo Alto can pay for a significant portion of the tunneled alignment.
- There is no concern over at-grade crossings.
- There is no physical barrier dividing Palo Alto.
- The development connects downtown with the Shopping Center and the Stanford campus.
- A linear park provides new open space in the city and creates a connection across Palo Alto.
- Public transit infrastructure is upgraded to be more accommodating.
- There are new road connections from Alma to El Camino.
- The new development begins to carry the downtown "feel" through the new development.
- There are new housing and job opportunities in the downtown area.
- The development provides the foundation for growth and evolution of Palo Alto in the future.

Cons
- The development revenue still falls short of paying for the tunnel, so additional funding will be needed.
- There will be added congestion in the downtown area.
- Palo Alto must accept significant new development in the downtown area.
- The development will alter the urban fabric of Palo Alto.

6.4.3 - Design Choices

Transit and Circulation

The logic behind the central transit hub discussed in the previous development scheme still holds true in this higher density scenario. Because of higher density development, though, we felt that it was important to provide more access for passenger vehicles in the area. We created two new East-West oriented road connections, one from Quarry Rd. to Everett Ave. and one from the El Camino Real off-ramp to Emerson St.

The connection from Quarry to Everett becomes the pick-up and drop-off point for train passengers, as we have a much wider section of the street with dedicated turn-outs for cars. This diverts traffic related to HSR and Caltrain away from University so as not to clog that main artery connecting Alma and El Camino.

Parks and Community

While we increased the vehicular traffic across this space, we maintained the North-South biking and walking access. The linear park still runs through most of Palo Alto, terminating at the intersection of Alma and University. This provides the Palo Alto community with easier biking and walking access to downtown and connects the neighborhoods flanking the right of way along that section of the corridor while maximizing quality retail space on the North side of University Ave. A pedestrian walking connection remains from the transit hub through the newly developed retail space.

Development

The retail environments of downtown Palo Alto and the Stanford Shopping Center are thriving, yet there is currently no viable connection between the two. In this development scheme, we focused on connecting these two spaces with dense retail development in that interstitial space. Because this design was in part driven by economic concerns, we added several floors of residential apartments above these retail spaces. In general, mixed-use development is on the rise in this scheme because of the introduction of significant housing increases in the area. The commercial spaces to the South of University Ave are also topped with residential units, and rise above the 50 foot height limit.

Although we removed the Sheraton, we included a newly constructed hotel that rises above the rest of the development. Because of the addition of HSR, it is likely that a larger hotel would fare well in the new environment. It would provide its guests with access to retail centers, restaurants, and modes of public transportation to travel in the area. The hotel is placed along El Camino and next to what is currently the Westin Hotel to avoid as much as possible any disruption a taller building might cause.

6.5 - Tunneled HSR with extreme high-density development

6.5.1 - Vision

Development is almost purely a function of economic feasibility, with community-oriented goals as an afterthought. This scheme transforms the space between Alma St. and El Camino into a dense urban environment. A number of very tall commercial office buildings sit in this space, along with a few residential towers; retail is interspersed along the ground floors of these towers. This new development transforms Palo Alto by adding thousands of new residences, and it brings the business world of Silicon Valley into the heart of Palo Alto.

A linear park runs through South Palo Alto, but terminates some time before it reaches the downtown area. Through innovative construction techniques, developers are able to build smaller buildings over the buried emergency water reservoir. While there is very little open space, this scheme is very walkable and accommodates those using public transit. Instead of a

central transit hub, though, El Camino becomes a main bus artery to drop passengers off at a convenient location to walk through the new development to the train station or to the current downtown area.

6.5.2 - Pros and Cons

Pros
• Palo Alto can pay for the entirety of the tunneled alignment.
• There is no concern over at-grade crossings.
• There is no physical barrier dividing Palo Alto.
• The development connects downtown with the Shopping Center and the Stanford campus.
• A linear park provides new open space in the city and creates a connection across Palo Alto.
• Public transit infrastructure is upgraded to be more accommodating.
• There are new road connections from Alma to El Camino.
• The new development begins to carry the downtown environment through the new development.
• There are new housing and job opportunities in the downtown area.

Cons
• There will be added congestion in the downtown area.
• Palo Alto must accept substantial new development in the downtown area.
• The development will drastically alter the urban fabric of Palo Alto.
• The development breaks all height limitations previously seen in Palo Alto.
• The linear park does not extend through the downtown area.

6.5.3 - Design Choices

Transportation and Circulation

We created a more complete grid of city streets in this development scheme to accommodate the high density development. While there are no dedicated biking or walking paths, the city streets make this development pedestrian-friendly and create strong connections from Alma to El Camino at multiple points throughout. The central transit hub has been removed because the street scheme allows El Camino to become a main artery for bus transit.

Parks and Community

This design creates a high-density extension of the downtown area, boosting its economic vitality while straying from the community-oriented mindset of Palo Alto. The linear park still provides newly created open space in the city, but it does not extend through the downtown development because we aimed to maximize economy.

Development

        Development is highly integrated in a mixed-use environment because there is a significant increase in housing capacity. This development is meant to be a place where people live and work, so a complete integration of different uses is necessary. We did not adhere to the typical height limits of Palo Alto as a way to maximize the economic value of the project. It was difficult to maintain any sort of view corridors in this scheme, but heights tend to rise from East to West to create at least somewhat of a gradation from the current downtown area through this new development. We also chose to remove the historic train station because it no longer fit into the surrounding aesthetic and would have been out of place in this new development.

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Appendix A - Choosing stakeholder groups

       While this list of stakeholders is not comprehensive, it covers a significant portion of the population that will be affected by, or have a strong opinion about, the proposed HSR line. We are aware of the possible overlap among stakeholder groups, as one person can technically be a business owner who lives and works in Palo Alto. However, we chose to assign stakeholders in overlapping groups to the least-represented group to which they belong (i.e. a business owner who lives and works in Palo Alto would be classified as a business owner because we received fewer responses from people in this category).

       After attending several Palo Alto City Council and Chamber of Commerce meetings, we determined a list of stakeholder groups, some of whom were represented that these meetings, that would be impacted directly, both positively and negatively, by the HSR project through Palo Alto. This includes taxpayers, residents, commuters, Palo Alto employees, and Stanford students. These groups will be impacted in different ways, either financially, or as neighbors to the development and users of the operational train. Most importantly, our list of stakeholders included one common factor: a direct relationship to Palo Alto, either by living or working there. Thus, we did not include outside groups interested in the project, such as land developers or the California-wide HSR Authority.

Appendix B - Choosing appropriate goals

In selecting our project goals, we chose to divide the goals up into three separate categories, defined in Section 3.3. We attempted to select objectives that were both related to the urban design of the project (New Urbanism, etc.) and to the economic development opportunities that the HSR project presents to Palo Alto. We were careful to select goals that were not obviously tilted strongly toward one specific design option, and which were quantifiable and reasonably predictable through our urban design plans. A notable exception to the quantifiable goals was that of blending the HSR development with the existing architectural aesthetic, which we judged would be an important goal to Palo Alto community members.

<u>Appendix C-1 - Creating the survey</u>

       Our motivation for dividing the goals was process-driven. In traditional MACDADI, a stakeholder will be allotted 100 points to distribute as they see fit across the goals of the project (i.e. they would rank economic sub-goals against connectivity sub-goals). We administered the survey using Stanford's Center of Integrated Facility Engineering's Surveymonkey.com account, which does not allow users to utilize the 100-point allotment system. Thus, we required users to rank goals from 1 to 5 (least important to most important, on a five-goal category) to highlight tradeoffs and preferences in goals. We did not wish for users to have to rank 12 goals from 1 to 12, as we were concerned that the results would display some ordering bias. Thus, we chose to separate the project goals into three separate categories which the users ranked separately.

       We offered the stakeholders the opportunity to indicate their preferences on tradeoffs presented, and used that data to inform our urban design plan. We included demographic information so that we could filter the responses and obtain valid, differentiated stakeholder data.

       The survey was distributed electronically to Palo Alto citizen groups, Stanford University dormitory list servers, and municipal organizations. We received 225 completed online surveys (an 83.6% survey completion rate).

Appendix C-2 - The complete survey

1. Do you live in Palo Alto?

Yes   No

2. How close do you live to the existing CalTrain tracks?

<200 feet

200 feet-1/4 mile

1/4 - 1/2 mile

>1/2 mile

3. How often do you ride CalTrain?

Every day   1-5 times/week   1-5 times/month   1-5 times/year   Never

4. How often do you think you will ride the high speed rail once it is completed?

0-4 times/year

5-8 times/year

>8 times/year

5. How old are you?

15-25 years

6. Are you familiar with the high-speed rail project?

○ Not at all familiar   ○ Slightly familiar   ○ Familiar   ○ Very familiar

7. In the next 20 years, about how much time do you see yourself spending in the Palo Alto area?

○ <1 year

○ 1-5 years

○ 5-10 years

○ 10-15 years

○ 15-20 years

8. How long have you been in the Palo Alto area?

○ <1 year

○ 1-5 years

○ 5-10 years

○ 10-20 years

○ >20 years

9. Please select all of the following which apply to you:

☐ I own a business in Palo Alto

☐ I work in Palo Alto

☐ I spend time in Palo Alto, but am not employed in the city

☐ I am a Palo Alto Government Official

☐ I am employed by Stanford

☐ I am a Stanford Student

☐ Other (Please Specify)

[_____]

10. To what extent are you supportive of the HSR through Palo Alto?

○ Very unsupportive

○ Somewhat unsupportive

○ Neutral

○ Somewhat supportive

○ Very supportive

1. Please indicate the importance of the following goals relating to connecting Palo Alto regionally and locally.

	1 (Least Important)	2	3	4	5 (Most Important)
Ability to bike/walk to living, working, and retail environments	○	○	○	○	○
Blend station and rail line into surrounding architectural aesthetic	○	○	○	○	○
Easy access to trains (CalTrain & High Speed Rail)	○	○	○	○	○
Minimize traffic congestion in Palo Alto due to construction	○	○	○	○	○
More open space and public parks in the downtown area	○	○	○	○	○

If there is another issue you feel strongly about, please write it here:

[   ]

2. Please indicate the importance of the following environmental and safety goals.

	1 (Least Important)	2	3	4 (Most Important)
Minimize environmental impact of the train and surrounding development	○	○	○	○
Minimize noise from construction and operation of train	○	○	○	○
Minimize vibrations as a result of construction and operation of train	○	○	○	○
Safety during train operation	○	○	○	○

If there is another issue you feel strongly about, please write it here:

[   ]

3. Please indicate the importance of the following economic goals.

	1 (Least Important)	2	3 (Most important)
Increase housing capacity in Palo Alto	○	○	○
Increase jobs in Palo Alto	○	○	○
Minimize cost to Palo Alto	○	○	○

If there is another issue you feel strongly about, please write it here:

[   ]

40

1. Which would you prefer?

- More downtown shopping options
- More parks and community spaces
- Neither

2. Which would you prefer?

- Minimize visual impact of the rail line
- Spend less money on the rail line (assuming Palo Alto will be responsible, at least in part, for the added costs)
- Neither

3. Which would you prefer?

- Quieter rail line
- Less expensive rail line
- Neither

4. Which would you prefer?

- More apartment-style housing
- More retail/commercial space
- Neither

5. Which would you prefer?

- More office space for large, established companies (i.e. larger tech corporations, biomedical research companies, etc.)
- More office space for small businesses (start-ups, personal services, etc.)
- Neither

6. Which would you prefer?

- More bike-able and walkable paths
- More public transit options
- Neither

7. Which would you prefer?

- More retail stores
- More restaurants and cafes
- Neither

8. Which would you prefer?

- Small number of large stores
- Large number of small stores
- Neither

9. Which would you prefer?

⏾ More parking in the downtown area (near the train station)

⏾ More extensive bus/shuttle/public transit options

⏾ Neither

10. Which would you prefer?

⏾ A high speed rail station in Palo Alto

⏾ A high speed rail station in Redwood City

⏾ Neither

11. Which would you prefer?

⏾ An environmentally friendly rail line

⏾ An inexpensive rail line

⏾ Neither

12. Which would you prefer?
(Keep in mind that the Caltrain tracks will follow the HSR tracks, i.e. a tunneled HSR line will bring Caltrain underground as well, and elevated HSR tracks will mean elevated Caltrain tracks, too.)

⏾ A high speed train on an elevated track with no stop in Palo Alto, and no new development in the downtown area

⏾ A high speed train on an elevated track with a stop in Palo Alto, accompanied by minimal development near the station

⏾ A tunneled high speed train with a stop in Palo Alto, surrounded by high-density development in the downtown area near the station

1. What do you see as the greatest benefit of the HSR project?

⏾ Economic vitality to the Palo Alto area

⏾ Ease of transportation to the Central Valley and Los Angeles

⏾ Cohesive plan to improve transit options along the peninsula

⏾ Environmental friendliness - reducing greenhouse gas emissions from cars

⏾ Revitalization of Palo Alto through new opportunities for downtown development

⏾ Other (please specify)

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2. What is your greatest concern about the HSR project?

⏾ Cost of rail line and station construction to Palo Alto

⏾ Drawn-out construction time

⏾ Traffic congestion in Palo Alto due to construction

⏾ Noise, vibration, and other disturbances relating to the operation of the HSR

⏾ Unwanted development brought to Palo Alto

⏾ Physical division of Palo Alto by the HSR line

⏾ Low ridership

⏾ Other (please specify)

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Appendix C-3 - Graphs from survey analysis
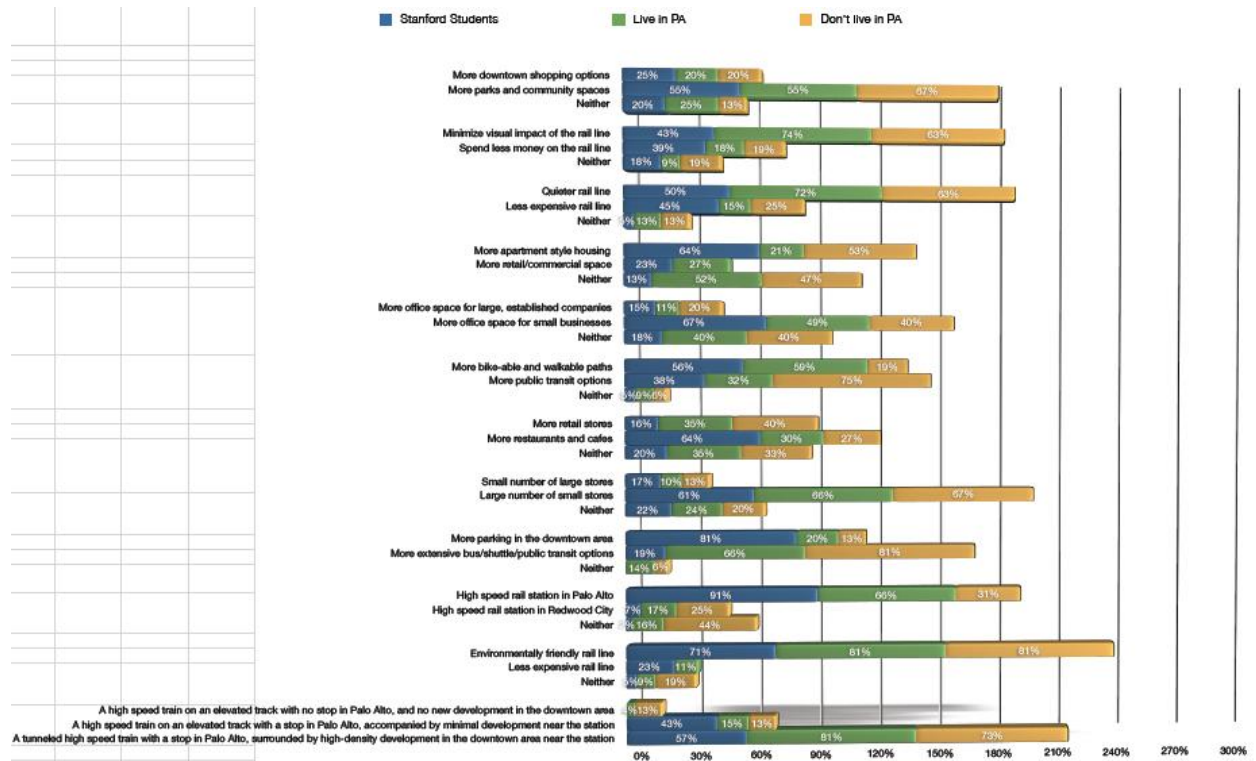
Figure 15 – Trade-offs vs. stakeholder group: Percent responses
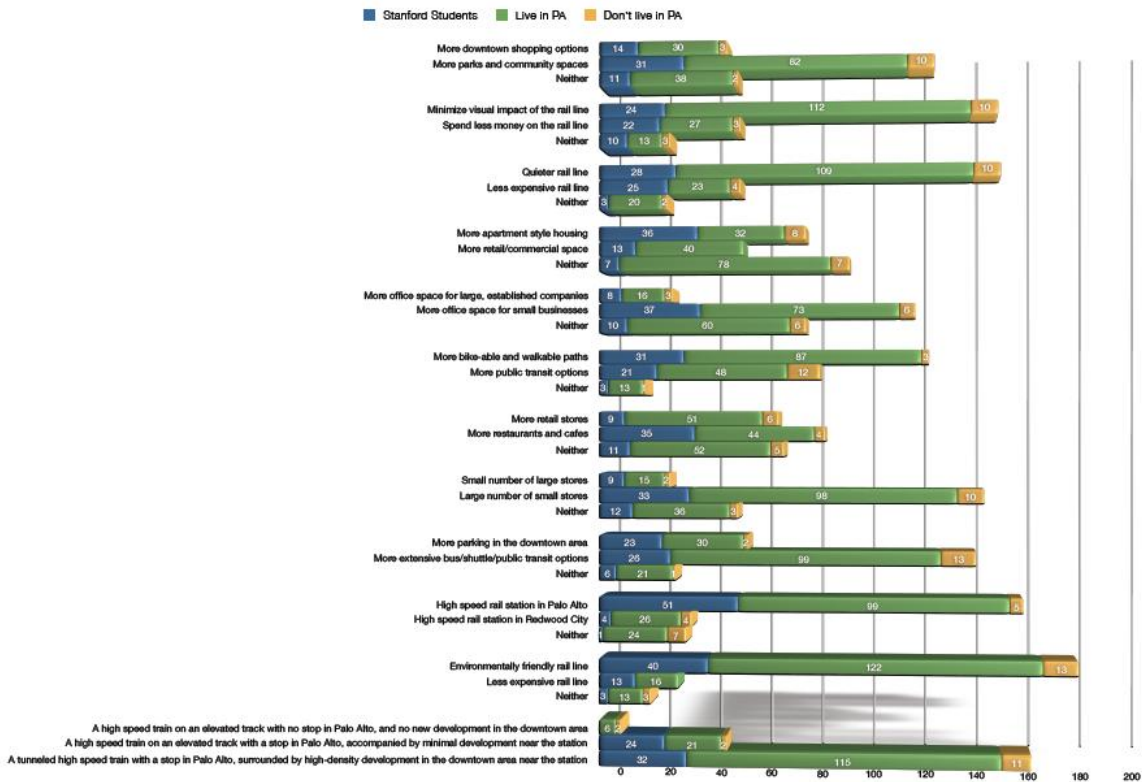
Figure 16 – Trade-offs vs. Stakeholder group: Number of responses
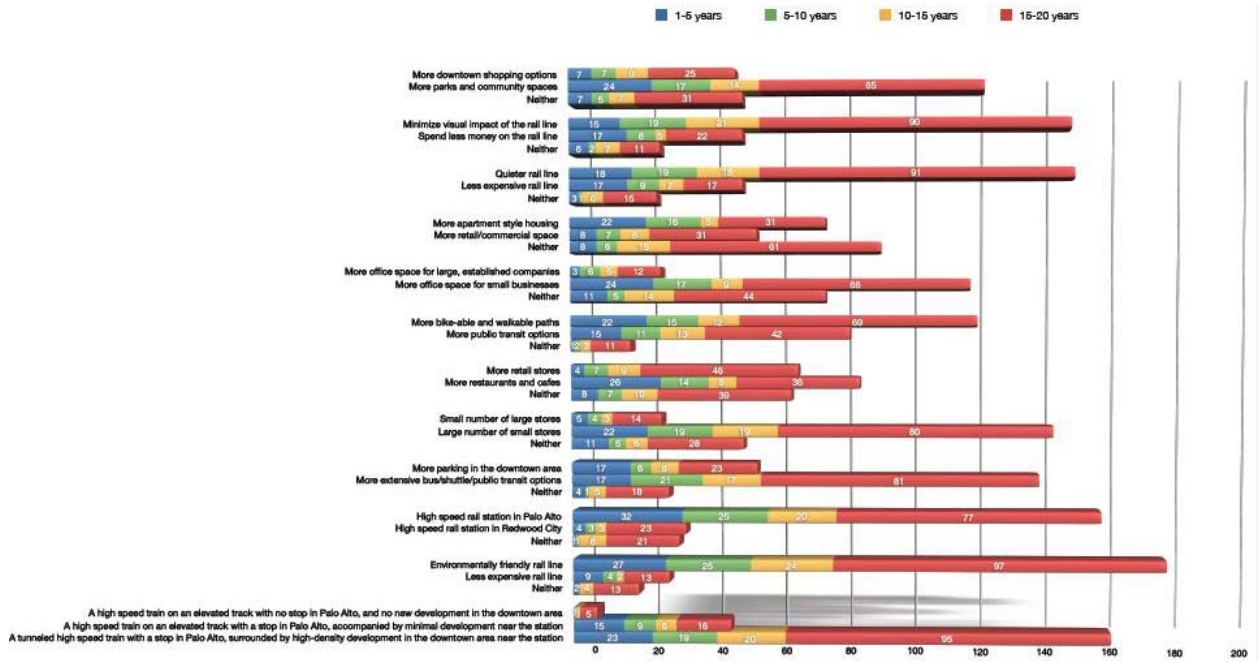
Figure 17 – Trade-offs vs. time to be spent in Palo Alto: Number of Responses
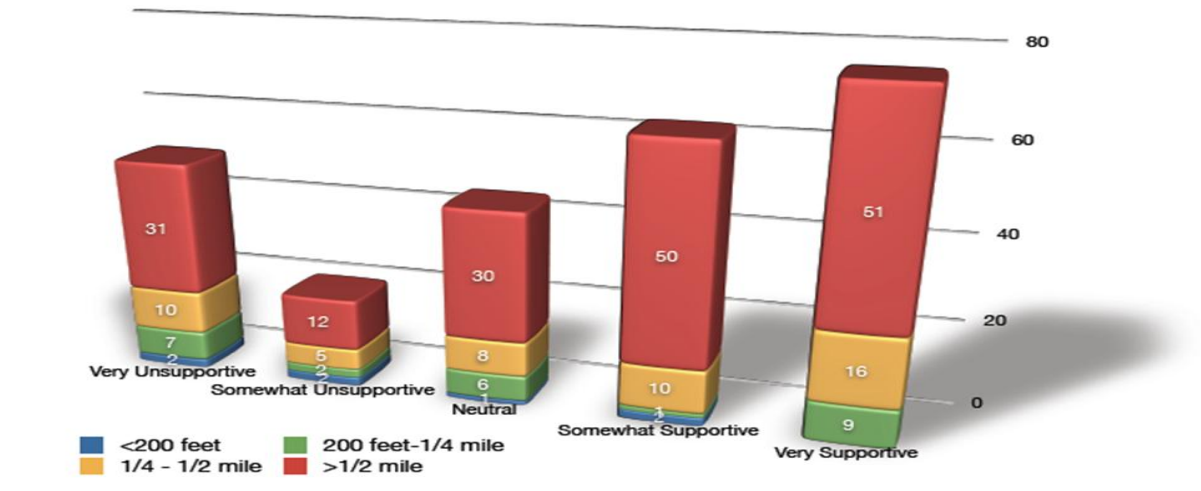
Figure 18 - Level of support vs. proximity of residence to tracks
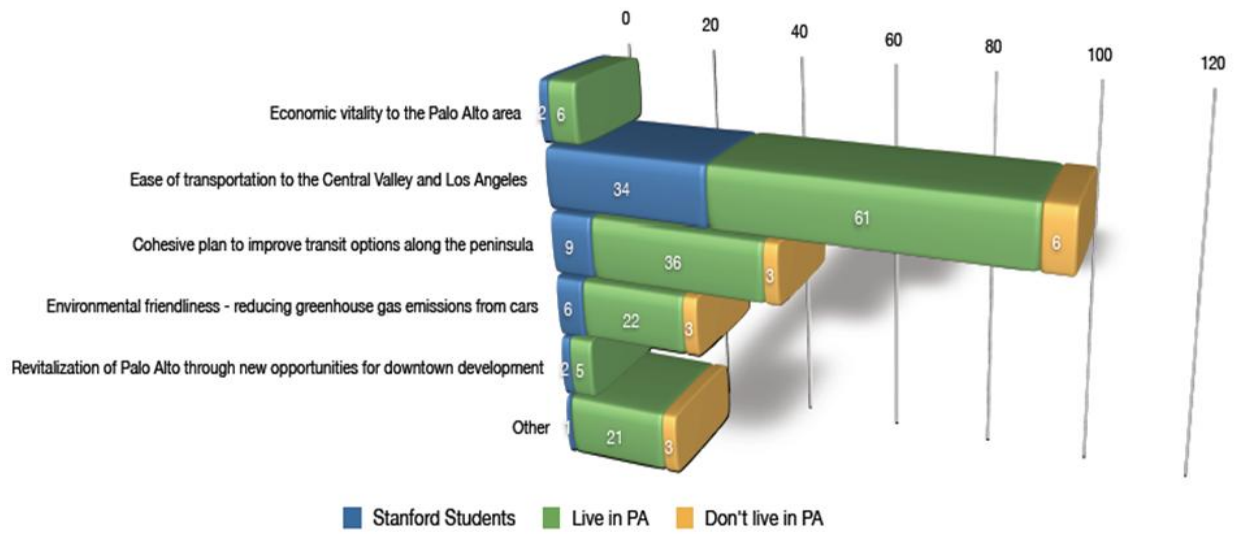
Figure 19 – Greatest perceived benefit by Stakeholder group
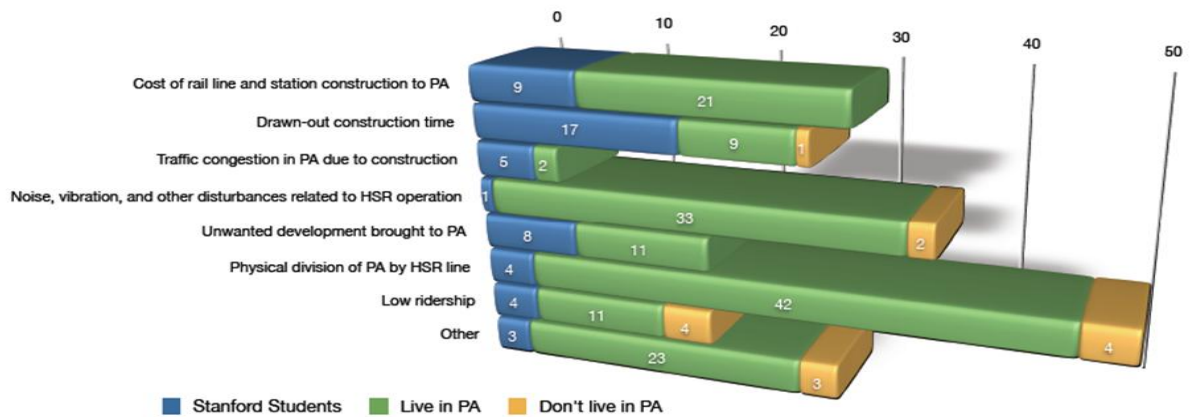
Figure 20 – Greatest concern by Stakeholder group

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Figure 21 Chart

Axis: 0, 20, 40, 60, 80, 100

- Economic vitality to the Palo Alto area: 21 4 1
- Ease of transportation to the Central Valley and Los Angeles: 37 | 5 | 28 | 31
- Cohesive plan to improve transit options along the peninsula: 8 | 4 | 20 | 16
- Environmental friendliness - reducing greenhouse gas emissions from cars: 6 | 4 | 14 | 8
- Revitalization of Palo Alto through new opportunities for downtown development: 2 1 3
- Other: 9 | 15

Legend: 15-25 years | 26-40 | 41-60 | >60

Figure 21 – Greatest perceived benefit vs. Age demographic

Figure 22 Chart

Axis: 0, 12.5, 25, 37.5, 50

- Cost of rail line and station construction to PA: 10 | 2 | 9 | 9
- Drawn-out construction time: 17 | 2 | 5 | 3
- Traffic congestion in PA due to construction: 5 | 2
- Noise, vibration, and other disturbances related to HSR operation: 2 | 4 | 20 | 10
- Unwanted development brought to PA: 8 | 5 | 6
- Physical division of PA by HSR line: 4 | 7
- Low ridership: 4 | 6 | 21 | 18
- Other: 3 | 10 | 9 | 16

Legend: 15-25 years | 26-40 | 41-60 | >60

Figure 22 – Greatest concern vs. Age demographic

Metrics for the evaluation of the design options:

These metrics are used to evaluate different design options' performance on the goals associated with the project. The design option will receive a score of -3 to 3 for each goal, depending on its performance.

Goal	Metric	-3	-2	-1	0	1	2	3
Ability to bike/walk to living, working, and retail environments	Distance of bike/walking paths in downtown PA	0 miles	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	>5 miles
More open space and public parks in the	Acres of park land	Loss of >8 acres	Loss of 4-8 acres	Loss of 0-4 acres	0 acres	0-6 acres	6-12 acres	>12 acres
Easy access to trains (CalTrain and HSR)	Ease of movement between transit systems	People abandon one or more modes of transportation because they are unable to easily understand the systems	People regularly miss their trains due to difficulty navigating between transits	People are able to move between some modes of transportation, but are unable to easily access other modes	People are able to move between modes of transportation after consulting a map or directory	People can move between transit systems by following signs	People with a slight familiarity with the Palo Alto Transit Station hub are able to easily find their way to trains without signs	Everyone is able to move intuitively between modes of transportation
Minimize traffic congestion in Palo Alto due to construction	Number of path or road connections across tracks/between Alma and El Camino	<=3 crossings	4 crossings	5	6	7	8	>8 crossings
Blend station and rail line into surrounding architectural aesthetic	Underground, at grade, elevated (our own assumptions)	Breaks all zoning codes, height limits, and introduces completely new visual perception of downtown PA through extremely dense development	Breaks a significant number of zoning regulations, buildings are significantly taller that surrounding architecture, development is very dense, and only a select few buildings even attempt to blend in to standards	There is a mix of traditional architecture with new, more urban styles that push zoning guidelines and introduce a select few large scale buildings that impact the visual aesthetic of the area	Breaks with architectural traditions of downtown, introduces a higher density environment, but somewhat remains to the standard of the typical downtown development	Breaks with traditional architecture of downtown, but does not completely alter the architectural standard of the downtown area	Makes every attempt to mimic the architectural aesthetic, but does not achieve this in every single new building	Blends seamlessly with the current University Ave. aesthetic

Figure 23 – Connectivity Goals Metrics

Goal:	Metric:	-3	-2	-1	0	1	2	3
Increase housing capacity in Palo Alto	Square feet of residential housing added	<-125000 SF	-125000 - 0 SF	0 - 150000 SF	150000 - 300000 SF	300000-600000 SF	600000 - 1000000 SF	>1,000,000 SF
Increase jobs in Palo Alto	Number of jobs created (through development, HSR operations)	lose 4000 jobs	lose 2000 to 4000 jobs	lose 0 to 2000 jobs	0 jobs	0 to 7500 jobs	7500 to 15000 jobs	>15,000 jobs
Minimize cost to Palo Alto	Cost of construction of residential,. Commercial, and retail	$1,400,000,000 - 1800000000	$1,000,000,000 - $1,400,000,000	$600,000,000 - $1,000,000,000	$400,000,000 - 600000000	$200,000,000 - $400000000	$0 - $200,000,000	$0

Figure 24 – Economic Goals Metrics

Goal:	Metric:	-3	-2	-1	0	1	2	3
Minimize environmental impact of the train and surrounding development	Carbon emissions from construction (MTCO2E)	3.75 billion	3.75-3 billion	3-2.25 billion	2.25-1.5 billion	1.5-.75 billion	.75-0 billion	0
Minimize noise from construction and operation of train	Number of trains per day on type of track	236 trains/day on elevated track			236 trains/day at grade			236 trains/day tunneled
Minimize vibrations as a result of construction and operation of train	Amount of vibration	An unlivable amount of vibration	A significant amount of vibration	Slightly more vibration	As built currently	Some vibration	Minimal vibration	No vibration
Safety during operation	Number of at-grade crossings	>5 at-grade crossings	5	4	3	2	1	0

Figure 25 – Environmental/Safety Goals Metrics

Appendix D-2 - Metrics for each design option

Evaluation of options: This is the quantitative value we associated with each design option, to be evaluated against the metric set for each goal.

	Minimize environmental impact of the train and surrounding development	Safety during train operation	Minimize vibrations as a result of construction and operation of train	Minimize noise from construction and operation of train
Urban design #1	0	0	Subjective judgement	Subjective judgement
Urban design #2	414000 MTCO2E	0	Subjective judgement	Subjective judgement
Urban design #3	1350000 MTCO2E	0	Subjective judgement	Subjective judgement
Urban design #4	3130000 MTCO2E	0	Subjective judgement	Subjective judgement

Figure 26 – Evaluation of Environmental/Safety Goals

The MTCO2E number was calculated from Carnegie Mellon's Economic Input-Output Life Cycle Assessment (http://www.eiolca.net/index.html). This tool requires the input of cost values for each design option.

	Minimize environmental impact of the train and surrounding development	Safety during train operation	Minimize vibrations as a result of construction and operation of train
Urban design #1	3	3	-1
Urban design #2	2	3	2
Urban design #3	2	3	2
Urban design #4	2	3	2

Figure 27 – Scoring Environmental/Safety Goals

	Ability to bike/walk to living, working, and retail environments	Easy access to trains (CalTrain & High Speed Rail)	More open space and public parks in the downtown area	Minimize traffic congestion in Palo Alto due to construction	Blend station and rail line into surrounding architectural aesthetic
Urban design #1	0	Subjective judgement	0	6	Subjective judgement
Urban design #2	2.13	Subjective judgement	1.56	10	Subjective judgement
Urban design #3	2.14	Subjective judgement	-0.06	12	Subjective judgement
Urban design #4	0	Subjective judgement	-7.16	15	Subjective judgement

Figure 28 – Evaluation of Connectivity Goals

	Ability to bike/walk to living, working, and retail environments	Easy access to trains (CalTrain & High Speed Rail)	More open space and public parks in the downtown area	Minimize traffic congestion in Palo Alto due to construction	Blend station and rail line into surrounding architectural aesthetic
Urban design #1	-3	-2	0	0	1
Urban design #2	0	1	1	3	2
Urban design #3	0	1	-1	3	-1
Urban design #4	-3	2	-2	3	-3

Figure 29 – Scoring Connectivity Goals

	Increase housing capacity in Palo Alto	Increase jobs in Palo Alto	Minimize cost to Palo Alto
Urban design #1	0	0	0
Urban design #2	326538	511	$337 million
Urban design #3	1456503	1675	$1.1 billion
Urban design #4	5486989	4640	$4.3 billion

Figure 30 – Evaluation of Economic Goals

	Increase housing capacity in Palo Alto	Increase jobs in Palo Alto	Minimize cost to Palo Alto
Urban design #1	-1	0	3
Urban design #2	1	1	1
Urban design #3	3	1	-2
Urban design #4	3	1	-3

Figure 31 – Scoring Economic Goals

Housing capacity was defined as the total amount of new residential development (in square feet).

Each one of the evaluations of the design options with respect to the goals required cost, square footage, and physical model information data. The physical model data we used in this evaluation, presented above, was obtained directly from the computer model of each of the design options:

	Option 1	Option 2	Option 3	Option 4
SF of New Residential	0	326538	1456503	5486989
SF of New Commercial	0	559812	1462698	3170649
SF of New Retail	0	134908	430953	622754
Total New SF	0	1021258	3350154	9280392
Total Cost of Development ($)	0	337204100	1107910950	4275681300
Total New Jobs Created	0	510.629	1675.077	4640.196

Figure 32 – Economic data calculations for design options

The development cost and job creation numbers presented above were calculated using the development square footage data. The following assumptions were made:

Total new SF of residential development **x** $350
+
Total new SF of commercial development x $350
+
Total new SF of retail development x $200
=
Total cost for development

We made the assumption that one job would be created per 2000 square feet of new development (of any time: residential, commercial, and retail).

Appendix E-1 - Limitations and Flaws of MACDADI

MACDADI is a useful tool developed by Stanford University Civil Engineering Department's Center for Integrated Facility Engineering that is used to evaluate design options against stakeholder preferences in a quantitative manner. It was useful in our research project because it allowed us to use our collected stakeholder preferences and use that data to evaluate the "best" design option.

MACDADI presents us with several limitations, however. These will be discussed here and should be considered when evaluating the results of this tool.

MACDADI does not "weight" stakeholders. Thus, when we averaged stakeholder preferences across all groups, all stakeholders were averaged equally. For example, the "Live and Work in Palo Alto" stakeholder group was weighted as equals with the "Spends time but does not live in Palo Alto" group. Thus, a group that may not necessarily be impacted as much as another stakeholder group, is given equal weighting.

Another limitation is the way we chose to evaluate the metrics. We subjectively chose the metrics with which to assign values of -3 to 3 to the design options. We are not experts in many of the fields and we used our best estimates based on our research. However, there is still room for error in these values.

Finally, there were several metrics that were not measureable before the train is actually built. For these, we used our best subjective judgment to evaluate these design options.

<u>Appendix E-2 - Flaws in our survey techniques</u>

Stakeholders are simply asked for their preference weighting on a goal without knowledge of what kind of metric will be used to quantitatively evaluate the goal for the different design options. Thus, the same goal may be evaluated using a different metric which may be very preferable to a specific stakeholder (such as miles of bike paths) while this same metric may not be as preferable to another stakeholder. Thus, in the survey, we should have included at least a description of the metric we would use to evaluate each goal.

        We completed the survey using Stanford CIFE's Surveymonkey.com account, which does not allow for users to utilize the 100-point allotment system. Thus, we required users to rank goals from 1 to 5 (least important to most important, on a five-goal category) to highlight tradeoffs and preferences in goals. A forced ranking was not preferable to us, as we wanted to have stakeholders have the ability to allot a certain number of points to each goal, and also to be able to allot zero points, if desired, for a more accurate reflection of their preferences. However, this option was not available in the Surveymonkey.com account we used to create and electronically administer the survey. We selected the forced-ranking option rather than allowing users to rank all goals as "very important" because we wanted to emphasize the tradeoffs inherent to the project.

        We separated the goals of the survey into three parts: Connectivity, Economic, and Environmental/Safety goals. This strays from the traditional setup of MACDADI, which requires stakeholders to weight preferences across all goals. However, for the execution of our survey, we did not wish for users to have to rank 12 goals from 1 to 12, as we were concerned that the results would display some ordering bias (that is, goals higher on the list would be preferred over goals listed toward the end of the page). Thus, we chose to separate the project goals into three different categories which the users ranked separately.

        In order to fully document the preferences on tradeoffs between different areas of the project, a survey method should be developed which allows stakeholders to rank preferences across all goals (inclusive of the three different goal areas currently listed). However, this should not be force-ranked; it should allow stakeholders to weight their preferences numerically, perhaps using the 100-point system of MACDADI. Future researchers will need to find a way to accomplish this without using Surveymonkey.com.

        Future investigators should also consider offering more information about the project and design options being considered to survey respondents. According to our survey, 42.9% of survey-takers were either "Not at all familiar" or "Slightly familiar" with the HSR Project. In order to obtain more accurate preference data from these groups, more information should be offered so that stakeholders can make more informed preference choices.

        Another limiting factor in our survey is our list of stakeholder groups and the potential for overlap among groups. For example, several "Other" respondents wrote that they both "Owned a business in Palo Alto" and "Lived and worked in Palo Alto". We chose not to weight these preference responses twice by placing them in both stakeholder categories; for these cases we placed the response in the stakeholder group that had received the lesser number of responses between the two. Future researchers should find a way to reconcile this obvious overlap of stakeholder groups.

Appendix F - Urban design graphics

Figure 33 – Tunneled HSR with mid-density development (Option 2)
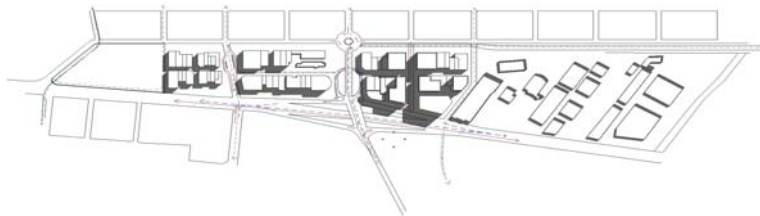
Figure 34 – Tunneled HSR with high-density development (Option 3)
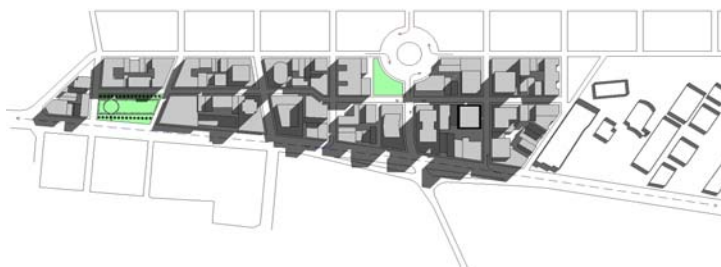
Figure 35 – Tunneled HSR with extreme high-density development (Option 4)
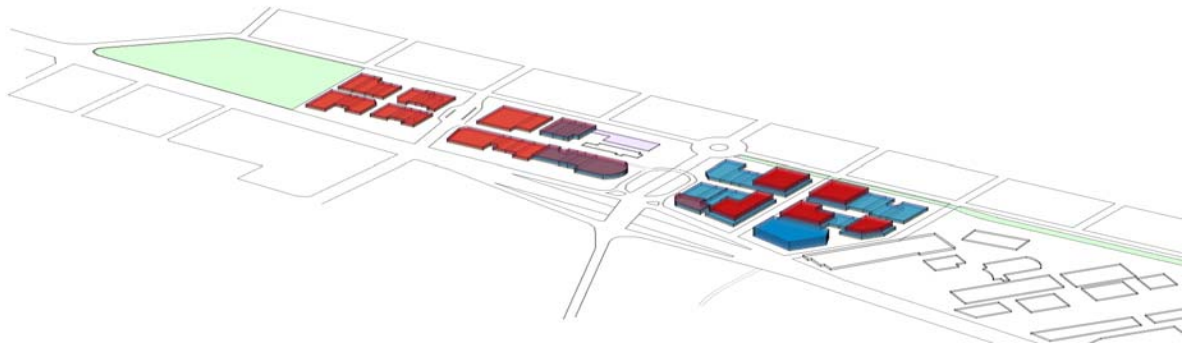
Figure 36 – Tunneled HSR with high-density development (Option 3)
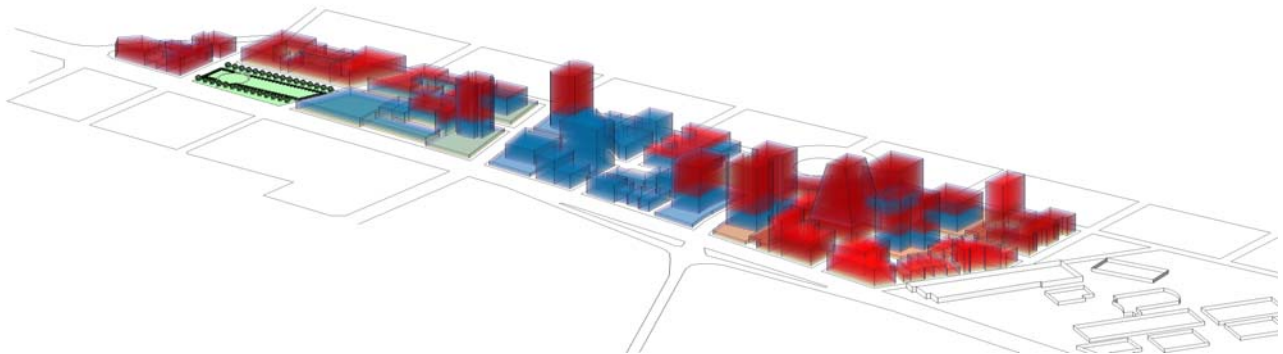
Figure 37 – Tunneled HSR with extreme high-density development (Option 4)

Park and Community Space

Retail (Ground Floor)

Residential (Apartments and Condos)

Commercial (Office or Small Business)

Appendix G – CHSRA As-Drawn Proposal
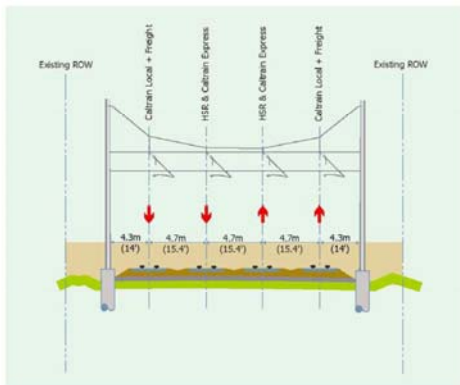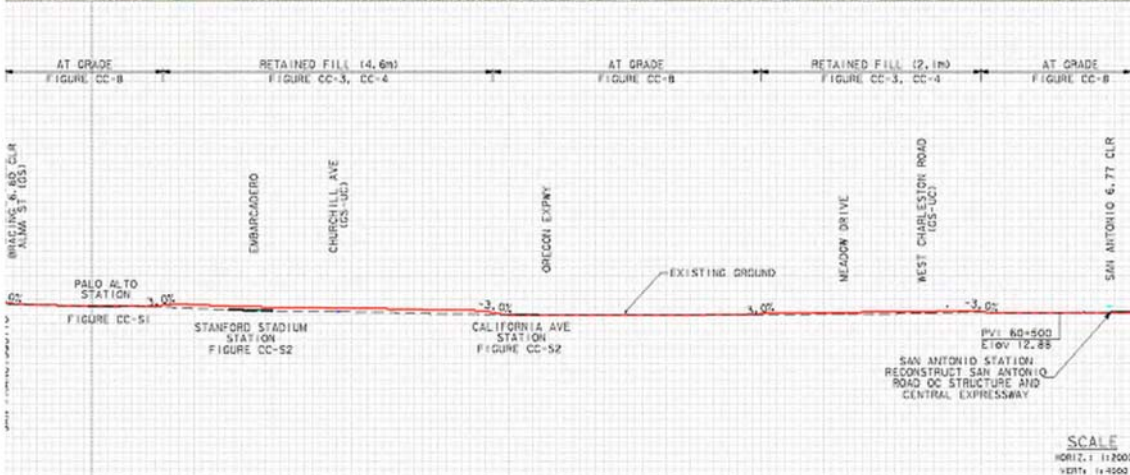
Cross Section of At Grade Tracks
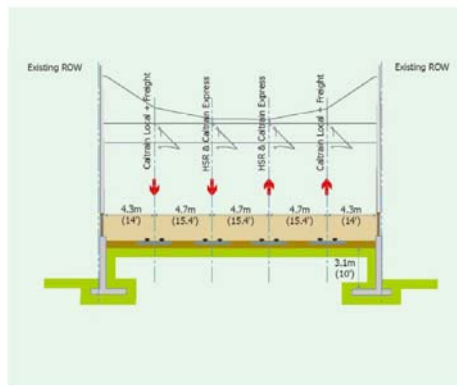
Cross Section of Elevated Tracks

Source: CHSRA Program EIR/EIS Appendix 2-D

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Appendix H - Complete cost sheets

Bay Area to Central Valley HST Final Program EIR/EIS

				CALTRAIN 7 AND 8			
COST ELEMENTS				**QUANTITIES**			
Alignment Cost		**UNIT**	**UNIT PRICE ($)**	**Palo Alto to Santa Clara**		**Santa Clara to Diridon Station**	
				CALTRAIN 7		**CALTRAIN 8**	
Track				**Quantities**	**Item Cost ($)**	**Quantities**	**Item Cost ($)**
	Double Track Section-Total	km		22.55		5.00	
1	Double Track Section - At Grade	km	993,167	20.15	20,012,312	0.15	148,975
2	Double Track Section - On Structure	km	1,878,243	0.00	0	1.00	1,878,243
3	Double Track Section - In Tunnel or Subway	km	1,878,243	1.00	1,878,243	3.70	6,949,497
4	Double Track Section - In Trench	km	1,878,243	1.40	2,629,540	0.15	281,736
	Single Track Section - Total	km		0.00		0.00	
5	Single Track Section - At Grade	km	496,583	0.00	0	0.00	0
6	Single Track Section - On Structure	km	939,121	0.00	0	0.00	0
7	Single Track Section - In Tunnel or Subway	km	939,121	0.00	0	0.00	0
8	Single Track Section - In Trench	km	939,121	0.00	0	0.00	0
9	Freight Double Track - At Grade	km	993,167	0.00	0	0.00	0
10	Freight Single Track - At Grade	km	496,583	0.00	0	0.00	0
Earthwork and Related Items							
1	Site Preparation - Undeveloped	hectare	12,081	0.00	0	0.00	0
2	Cut	m3	9	667,535	5,942,145	373,996	3,329,172
3	Fill	m3	9	626,633	5,578,051	1,143,150	10,175,891
4	Borrow	m3	13.35	0.00	0	0.00	0
5	Spoil	m3	0.00	0.00	0	0.00	0
6	Cut/Fill Slopes (Landscaping/Erosion Control)	hectare	8,075	0.00	0	0.00	0
7	Fencing (Both Sides of R/W)	km	101,733	21.55	2,192,343	1.35	137,339
8	Special Drainage Facilities	5% of Earthwork			685,627		682,120
Structures/Tunnels/Walls							
1	Standard Structure	km	13,733,933	0.000	0	0.000	0
2	High Structure	km	16,480,720	0.000	0	1.000	16,480,720
3	Long Span Structure	km	37,577,568	0.000	0	0.000	0
4	Waterway Crossing - Primary	km	28,876,734	0.000	0	0.000	0
5	Waterway Crossing - Secondary (Irrigation/Canal Crossing)	km	23,119,226	0.000	0	0.000	0
6	Twin Single Track Drill & Blast (<6 Miles)	km	75,040,254	0.000	0	0.000	0
7	Twin Single Track TBM (<6 Miles)	km	55,464,535	0.000	0	0.000	0
8	Twin Single Track TBM w/3rd Tube (>6 Miles)	km	78,846,643	0.000	0	0.000	0
9	Double Track Drill & Blast	km	83,740,573	0.000	0	0.000	0
10	Double Track Mined (Soft Soil)	km	96,247,282	0.000	0	0.000	0
11	Seismic Chamber (Drill & Blast/Mined)	ea	94,803,899	0.000	0	0.000	0
12	Crossovers	ea	94,803,899	0.000	0	0.000	0
13	Cut & Cover Double Track Tunnel	km	48,123,641	1.000	48,123,641	3.700	178,057,471
14	Trench Short	km	49,668,587	1.40	69,536,022	0.15	7,450,288
15	Trench Long	km	39,272,836	0.000	0	0.000	0
16	Mechanical & Electrical for Tunnels	km	1,931,362	1.000	1,931,362	3.700	7,146,040
17	Retaining Walls	km	4,399,945	7.500	32,999,590	0.000	0
18	Containment Walls	km	1,500,559	0.000	0	0.000	0
19	Single Track Cut and Cover Subway	km	30,077,276	0.000	0	0.000	0
Grade Separations							
1	Street Overcrossing HSR - Urban	EA	17,167,417	0.00	0	3.00	51,502,250
2	Street Overcrossing HSR - Suburban	EA	6,485,469	0.00	0	0.00	0
3	Street Overcrossing HSR - Undeveloped	EA	1,093,628	0.00	0	0.00	0
4	Street Undercrossing HSR - Urban	EA	17,930,413	7.00	125,512,892	0.00	0
5	Street Undercrossing HSR - Suburban	EA	6,866,967	0.00	0	0.00	0
6	Street Undercrossing HSR - Undeveloped	EA	1,157,211	0.00	0	0.00	0
7	Street Bridging HSR Trench	EA	0	0.00	0	0.00	0
8	Minor crossing closure	EA	178,032	0.00	0	0.00	0
Rail and Utility Relocation							
1	Single Track Relocation (temporary)	km	1,271,661	0.00	0	0.00	0
2	Single Track Relocation (permanent)	km	1,271,661	0.00	0	0.00	0
3	Single Track Removal	km	63,372	0.00	0	0.00	0
5	Major Utility Relocation - Urban	km	680,338	0.00	0	0.00	0
7	Major Utility Relocation - Suburban	km	273,407	0.00	0	0.00	0
8	Major Utility Relocation - Undeveloped	km	13,988	0.00	0	0.00	0

CALTRAIN 7 AND 8							
COST ELEMENTS				**QUANTITIES**			
Alignment Cost		UNIT	UNIT PRICE ($)	**Palo Alto to Santa Clara**		**Santa Clara to Diridon Station**	
				CALTRAIN 7		**CALTRAIN 8**	
Track				Quantities	Item Cost ($)	Quantities	Item Cost ($)
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2	Double Track Section - On Structure	km	1,878,243	0.00	0	1.00	1,878,243
3	Double Track Section - In Tunnel or Subway	km	1,878,243	1.00	1,878,243	3.70	6,949,497
4	Double Track Section - In Trench	km	1,878,243	1.40	2,629,540	0.15	281,736
	Single Track Section - Total	km		0.00		0.00	
5	Single Track Section - At Grade	km	496,583	0.00	0	0.00	0
6	Single Track Section - On Structure	km	939,121	0.00	0	0.00	0
7	Single Track Section - In Tunnel or Subway	km	939,121	0.00	0	0.00	0
8	Single Track Section - In Trench	km	939,121	0.00	0	0.00	0
9	Freight Double Track - At Grade	km	993,167	0.00	0	0.00	0
10	Freight Single Track - At Grade	km	496,583	0.00	0	0.00	0
Earthwork and Related Items							
1	Site Preparation - Undeveloped	hectare	12,081	0.00	0	0.00	0
2	Cut	m3	9	667,535	5,942,145	373,996	3,329,172
3	Fill	m3	9	626,633	5,578,051	1,143,150	10,175,891
4	Borrow	m3	13.35	0.00	0	0.00	0
5	Spoil	m3	0.00	0.00	0	0.00	0
6	Cut/Fill Slopes (Landscaping/Erosion Control)	hectare	8,075	0.00	0	0.00	0
7	Fencing (Both Sides of R/W)	km	101,733	21.55	2,192,343	1.35	137,339
8	Special Drainage Facilities	5% of Earthwork			685,627		682,120
Structures/Tunnels/Walls							
1	Standard Structure	km	13,733,933	0.000	0	0.000	0
2	High Structure	km	16,480,720	0.000	0	1.000	16,480,720
3	Long Span Structure	km	37,577,568	0.000	0	0.000	0
4	Waterway Crossing - Primary	km	28,876,734	0.000	0	0.000	0
5	Waterway Crossing - Secondary (Irrigation/Canal Crossing)	km	23,119,226	0.000	0	0.000	0
6	Twin Single Track Drill & Blast (<6 Miles)	km	75,040,254	0.000	0	0.000	0
7	Twin Single Track TBM (<6 Miles)	km	55,464,535	0.000	0	0.000	0
8	Twin Single Track TBM w/3rd Tube (>6 Miles)	km	78,846,643	0.000	0	0.000	0
9	Double Track Drill & Blast	km	83,740,573	0.000	0	0.000	0
10	Double Track Mined (Soft Soil)	km	96,247,282	0.000	0	0.000	0
11	Seismic Chamber (Drill & Blast/Mined)	ea	94,803,899	0.000	0	0.000	0
12	Crossovers	ea	94,803,899	0.000	0	0.000	0
13	Cut & Cover Double Track Tunnel	km	48,123,641	1.000	48,123,641	3.700	178,057,471
14	Trench Short	km	49,668,587	1.40	69,536,022	0.15	7,450,288
15	Trench Long	km	39,272,836	0.000	0	0.000	0
16	Mechanical & Electrical for Tunnels	km	1,931,362	1.000	1,931,362	3.700	7,146,040
17	Retaining Walls	km	4,399,945	7.500	32,999,590	0.000	0
18	Containment Walls	km	1,500,559	0.000	0	0.000	0
19	Single Track Cut and Cover Subway	km	30,077,276	0.000	0	0.000	0
Grade Separations							
1	Street Overcrossing HSR - Urban	EA	17,167,417	0.00	0	3.00	51,502,250
2	Street Overcrossing HSR - Suburban	EA	6,485,469	0.00	0	0.00	0
3	Street Overcrossing HSR - Undeveloped	EA	1,093,628	0.00	0	0.00	0
4	Street Undercrossing HSR - Urban	EA	17,930,413	7.00	125,512,892	0.00	0
5	Street Undercrossing HSR - Suburban	EA	6,866,967	0.00	0	0.00	0
6	Street Undercrossing HSR - Undeveloped	EA	1,157,211	0.00	0	0.00	0
7	Street Bridging HSR Trench	EA	0	0.00	0	0.00	0
8	Minor crossing closure	EA	178,032	0.00	0	0.00	0
Rail and Utility Relocation							
1	Single Track Relocation (temporary)	km	1,271,661	0.00	0	0.00	0
2	Single Track Relocation (permanent)	km	1,271,661	0.00	0	0.00	0
3	Single Track Removal	km	63,372	0.00	0	0.00	0
5	Major Utility Relocation - Urban	km	680,338	0.00	0	0.00	0
7	Major Utility Relocation - Suburban	km	273,407	0.00	0	0.00	0
8	Major Utility Relocation - Undeveloped	km	13,988	0.00	0	0.00	0

Appendix I - SimVision Model

SimVision is a commercial organizational tool used in industry and government to simulate the effectiveness of human work in a project. Unlike similar tools, SimVision does not only measure the work needed to complete the project, but the management of both work and people. The tool created over 25 years at Stanford University, answers the questions "Where are communication, quality and safety most likely to fail, and what can we do to prevent it?" and "Can we reliably achieve our schedule, cost and quality objectives?[23]" Used as both an educational and commercial tool, SimVision models allow users to clearly map out their work and see possible snags in their organization.

For High Speed Rail to reach the construction phase, a cooperative groundwork between the different organizations involved in the project is necessary. The agencies involved with HSR do not have the benefit of having worked on a project such as this and that previous experience that many reach for when working on a new project only exists in the form of consultants. Modeling the time period necessary to reach the construction phase of HSR can bring together all involved in the project to give input on the process, allowing for many pitfalls to be addressed beforehand.

Another benefit of modeling for a project such as HSR is the educational benefits it provides the public. A simple model of who is involved in the HSR and how they are involved can greatly inform the public on where they can act to make sure their concerns are considered. The survey done by our group shows that there are areas of disagreement between stakeholders, which if addressed early enough will not delay the project in later stages.

The focus of our research has been to analyze the effects of different options for bring HSR to and through Palo Alto. Running HSR, Caltrain and freight trains through a tunnel in Palo Alto is an option that has caused debate among Palo Alto and other Peninsula citizens. This option with development above ground was chosen for the basis of our SimVision model. The model looks at the time period that the VPUE Research group would present its findings to when HSR would be approved to run through a tunnel with a train station in Palo Alto. A modified version of the model is also included, along with a sample model of how to involve the community in the decision making process (Figure 41). Though not exact, these models still serve as educational tools and possible templates for the agencies involved.

Figure 39 depicts some of the political actions necessary for HSR to reach the construction phase. The light blue shapes are milestones which have defined completion dates and tasks which much be completed to reach the milestone. Tasks, yellow boxes, are actions completed by positions (the green figures) which are assigned to tasks, shown by solid blue lines. Dashed light grey lines denote a position assigned to a meeting (the purple boxes), which can be made to reoccur daily, weekly, etc. Solid black lines between the tasks shows dependency of tasks and the path the model follows to complete the project.

Each meeting, task, position, and milestone have properties which can be altered, affecting the simulation. The above model's simulation is the baseline case of the model. It was modeled as the ideal version of HSR, with the project being ready for construction beginning next September. This model is absent of the factors which delay projects (communication problems, worker distractions, mistakes, rework). If these factors are included in the project, as

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[23] ePM, August 27, 2009, http://www.epm.cc/default.php

in Figure 40, the length of the project is increased. The red and green dashed lines represent rework and communication links respectively. Other ways to affect a projects time line are altering the number of full time employees each position represents (i.e. for the VPUE group, the position has 5 persons allocated to it) or the experience of each position (low, medium, high).
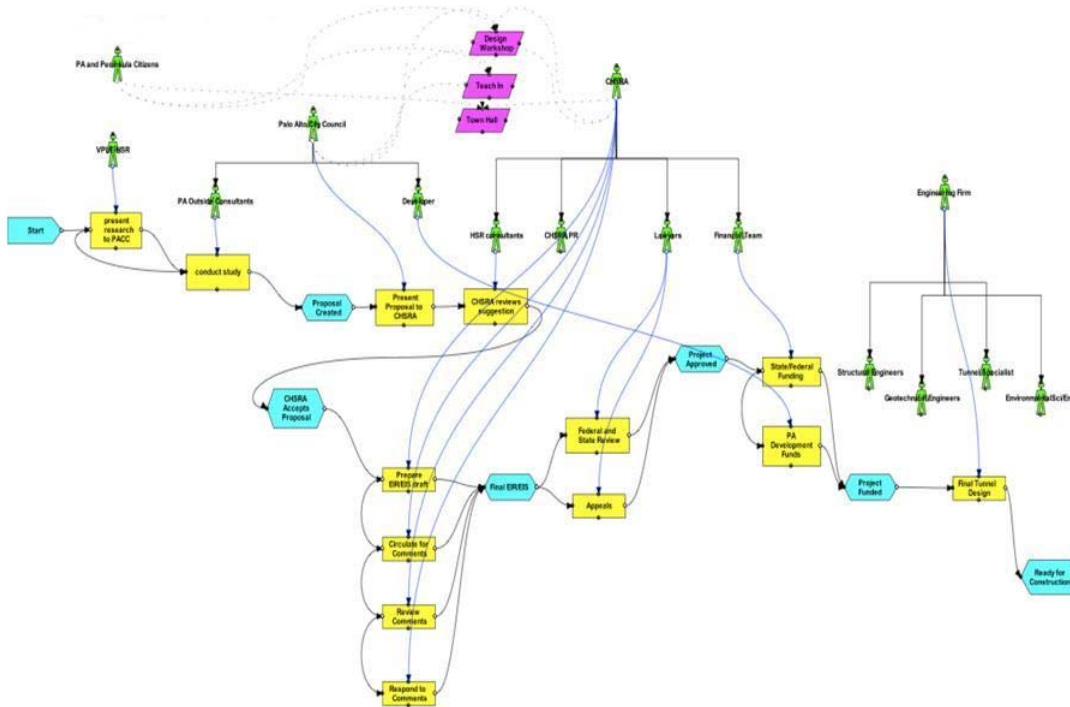
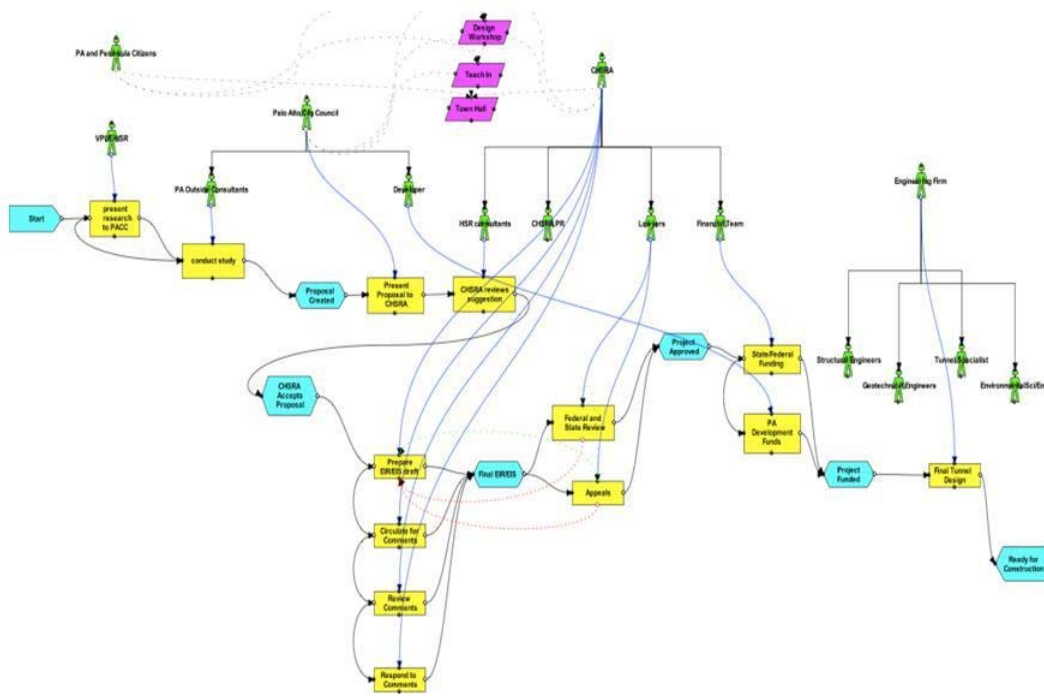

Figure 38 – Political Process Model, idealized case
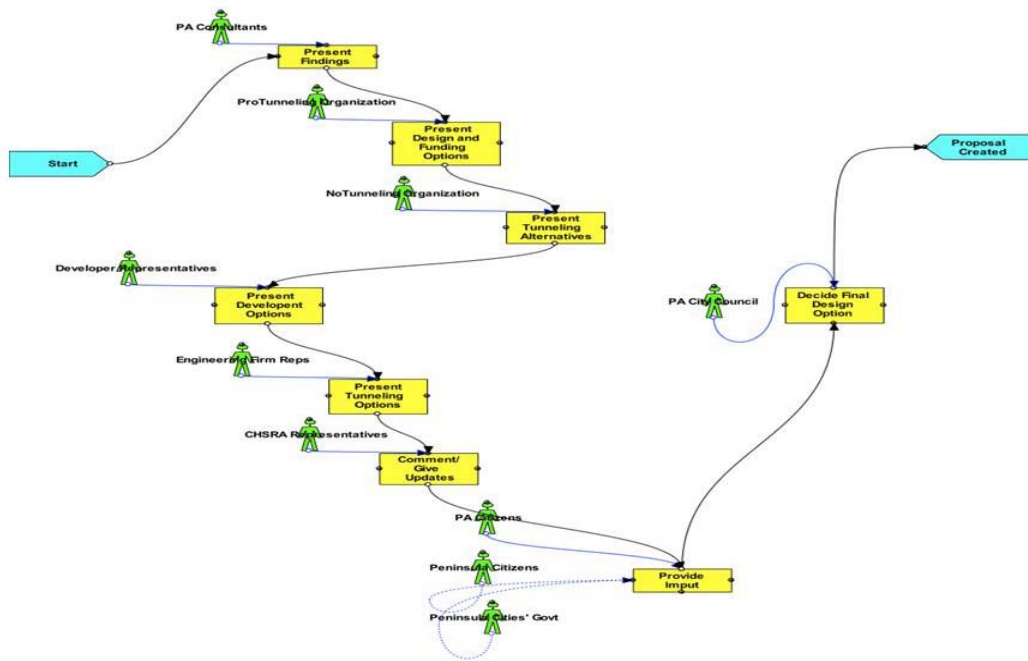
Figure 39 – Political Process Model, realistic case

Figure 40 – Community Involvement Model