PAVEMENT ACOUSTIC MAPPING TECHNOLOGY DEMONSTRATION PROJECT

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ABSTRACT

Traffic noise is a constant environmental concern of the public. Pavement is the primary product for State Departments of Transportation and tire/pavement noise is the primary noise source for most vehicles operating at cruising freeway speed. Extensive California experience and research has found that, a change in pavement acoustics generates a similar change in roadside noise levels. Pavement acoustics impact roadside noise levels in a predictable, quantifiable, and measurable way − most the time. ‘Quieter’ pavements can be an effective solution and tool for mitigating highway noise impacts and addressing noise complaints. Building on National Academy of Science /NCHRP OBSI research, Caltrans paired short-interval tire/pavement acoustic measurements, using the AASHTO T-360 OBSI Tire/Pavement Measurement Standard, with global position system (GPS) coordinates and then mapped this data on a geographic information system (GIS) webserver. The GIS webserver was setup to allow all the stake holding transportation agencies access to view and use the acoustic information. The GIS data shows sound level and location relative to roadside neighborhoods. This measurement procedure allows a much more systematic approach to addressing corridor-wide noise complaints and provides an objective process to rank order pavement rehabilitation projects that would reduce noise levels in roadside neighborhoods. From this new measurement approach, it is possible to accurately estimate roadside community noise levels due to the highway, with much more precision. This approach provides a much-needed tool for SDOTs to address noise complaints and concerns much more effectively.

BACKGROUND

In the heart of the Silicon Valley, in Santa Clara (SCl) County, a 24 mile-long six lane freeway, SCl-85, serves as a primary transportation corridor. SCl-85 bends around the west side of the city of San Jose and connects, in both the north and south, with US-101, which runs along the east side of San Jose. The southern 18 miles of SCL-85 are the 'newest' portion of this corridor. Earlier highway planners prudently set aside ROW for a future extension of the SCl-85 corridor. A lot of the land had originally been agricultural, and the freeway ROW sat empty, and quiet, for decades while residential development in the adjacent neighborhoods exploded. Many computer companies such as Apple, Hewlett-Packard, and IBM are located short distances from the northern end of this corridor, and they contributed to the exponential growth of Silicon Valley.

Most the property adjacent to the entire length of SCl-85 is residential. Neighborhood noise levels in the southern extension jumped with the sudden transition from 'no-freeway' to a six-lane freeway. The sound wall system along this corridor is extensive and tall masonry sound walls line the roadway all the way to the ends of on/off ramps (Figure 1 Top SCL-85 corridor with red lines indicating sound walls). The terrain is generally level and there are not any significant elevation differences between the roadway and adjacent residences other than elevated road crossings or elevated interchange ramp connectors. This portion of SCL-85 also restricts heavy trucks usage, one of the few freeways in northern California to use this noise mitigation option as listed in 23 CFR 772. Despite both the extensive sound wall system and the heavy truck restrictions, noise has remained a concern and quality of life issue for the surrounding neighborhoods.

(Figure 1 – next page)

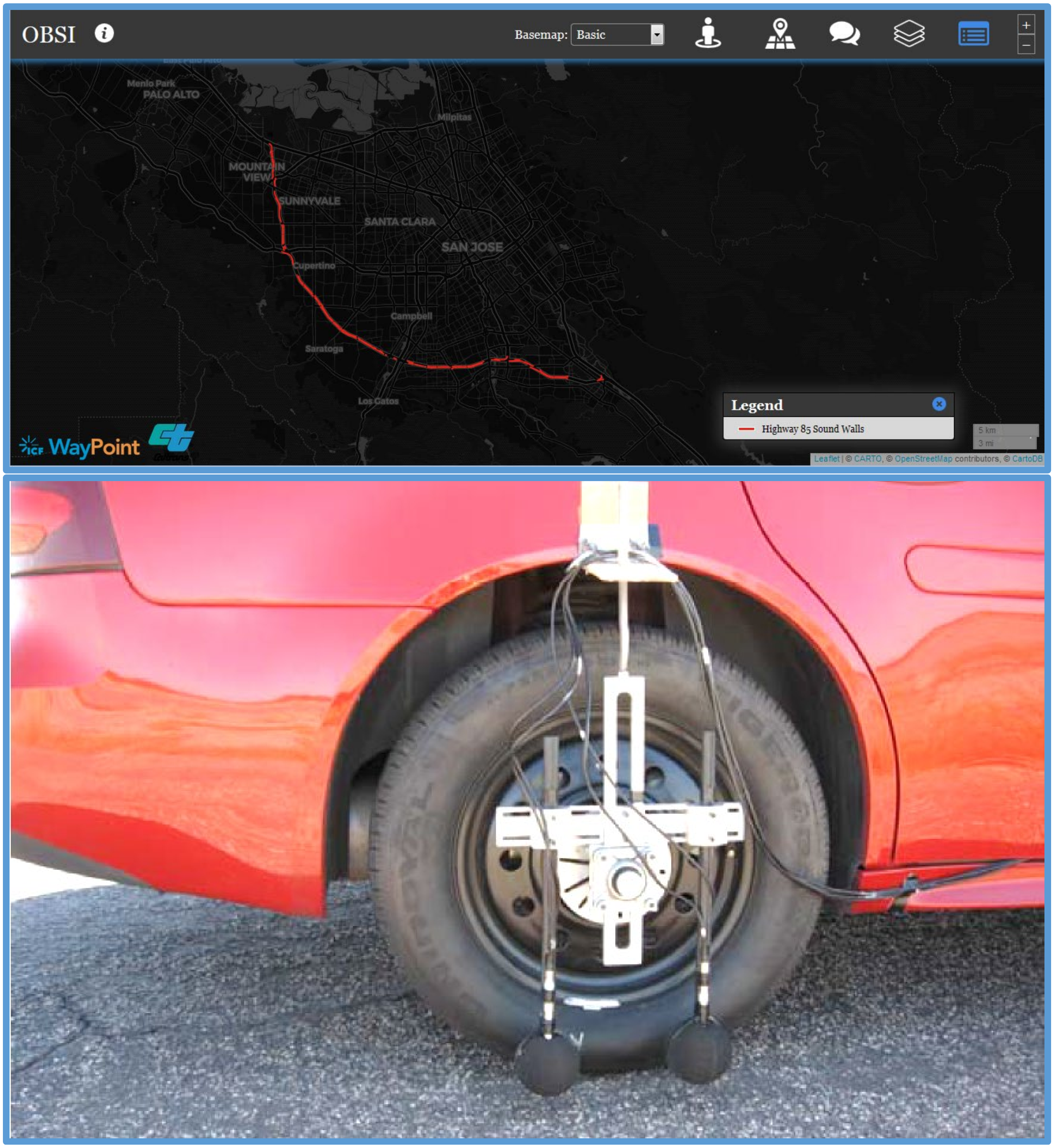


Figure 1. Top: GIS Webserver showing 24-mile-long Santa Clara County Route 85 (SCl-85) corridor in Silicon Valley with extensive sound wall system shown in red. Bottom: AASHTO Standard T-360 On-Board Sound Intensity (OBSI) measurement probes used to map pavement acoustics.

California law shifted some responsibility to local or regional transportation agencies and allowed them more autonomy in managing their own transportation funds and local transit projects. The regional transportation agency, Santa Clara Valley Transit Authority (VTA) is responsible for public transit services, congestion management, and specific highway improvement projects in the county. Caltrans often oversees and partners with VTA in highway related work that Caltrans was once solely responsible for before the southern extension of SCL-85.

The noise complaints around the new southern portion of the corridor were about general overall ambient noise that was dominated by a large amount of traffic noise. Noise measurements, that were initiated in response to noise complaints, didn't pinpoint any specific noise source or section of the corridor. Because the general terrain is level, none of the neighborhoods are elevated above the freeway. The residences don't have a line-of-sight to an opposite sound wall that might generate a reflective condition. Except for elevated interchange connector ramps, little traffic can be seen from the resident's perspective.

Over the years, there have been several attempts by both Caltrans and VTA to address the noise complaints generated by the SCl-85 corridor extension. The most obvious noise mitigation options of sound walls and truck restrictions had been used. One option that keeps being proposed is adding absorptive treatment to the existing sound walls. Caltrans' historic experience with this approach is that it is expensive, and any reductions are difficult, if not impossible, to quantify. This topic was just recently studied in greater detail in NCHRP 886(1). The conclusions from this research generally matched those discussed in Caltrans' Technical Noise Supplement (2). Caltrans' Traffic Noise Protocol states, that absorptive treatment should be considered if, "noise receptors on one side of the highway have a direct line of sight to a new barrier or new retaining wall on the opposite side of the freeway." (3) These roadway cross sectional conditions are not present along this corridor.

As NCHRP 886 research determined, reductions due to absorptive treatments are very hard to definitively quantify at large distances from the sound wall and *at best, may* be on the order of 2 to 2.5 dB. The benefit to cost ratio appears to be low for retroactively installed absorptive treatments. Another design complication is the addition of more weight and material to an existing sound wall designed for high-probability seismic loading. Other approaches of mitigating traffic noise levels needed to be considered.

The complaints were about general freeway noise − no neighborhood or section of the corridor stood out from another. The SPL noise measurements didn't seem to be any worse in one neighborhood than another and direct reflection didn't seem to be a noise source. The neighborhoods just wanted the overall freeway noise levels to be reduced. The complaints seemed to indicate that overall freeway noise was the root concern and the most productive way to address this is to measure and try to reduce the source noise levels. Heavy trucks had been restricted from using the southern 18 miles of SCl-85. Lowering speed and enforcing it probably wouldn't be popular, productive, or successful with the public. The only noise source generator on a vehicle which transportation agencies have control over is the pavement. It was decided to take a closer look at the pavement acoustics.

NEW MEASUREMENT PROCESS AND TOOL

Since the opening of the SCL-85 corridor southern extension, a great deal has now been learned about pavement acoustics. The tire/pavement measurement process initially developed by General Motors and modified by Caltrans is now being used by multiple SDOTs which collaborated in the Transportation Pooled Fund-5(135), Tire/Pavement Noise Research Consortium (4). OBSI is now used by several academic institutions and industry pavement researchers. OBSI has been studied by the National Academy of Sciences, in NCHRP Report 630(5). The AASHTO Standard development was funded and supported by the FHWA. In 2016, the measurement process become AASHTO Standard T 360-16 Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method (6).

OBSI measurements are a very precise way to quantify and compare the acoustic properties of different pavements. A Standard Reference Test Tire (SRTT) is driven a constant 60 mph and two microphone probes measure sound intensity (power) five inches from the both front and rear areas in the tire/pavement contact patch. The phased-matched microphone probes work in conjunction with clever signal processing to 'focus' only on the tire/pavement noise and 'reject' wind noise and noise from other sources (see Figure 1 Bottom). OBSI has proven to be an accurate, quick, inexpensive, and portable measurement methodology. OBSI measurements have allowed acousticians and pavement engineers to better understand and categorize the acoustic properties of pavements with far more precision and detail than any roadside-based sound pressure level (SPL) measurements.

Prior to the development of OBSI, very little was known about the acoustic properties of pavement. Pavement was the largest element of transportation infrastructure and only anecdotal information about a pavement's noise level or acoustic properties was known before OBSI was developed for use by SDOTs. In the last 15 years, there has been huge gains made in the topic of pavement acoustics. An extensive amount of pavement acoustic data has been collected and inventoried. Pavement specifications and construction processes have changed rapidly to avoid constructing loud pavements near sensitive noise receptors. Many SDOT rigid pavement tining specifications changed from transverse tining or random transverse tining to longitudinal tining very quickly due to OBSI research. New pavements, like the Next Generation Concrete Surface (NGCS)(7) and Caltrans' Groove-and-Grind have now been developed for rigid pavements to specifically reduce tire/pavement noise levels and reduce roadside noise levels.

Typical OBSI values of 98^{-} to 113^{+}dB may seem excessive or loud, but this is the sound power measured just five inches from the contact patch of a test tire going 88 feet-per-second. This OBSI tire/pavement noise level drops off in a predictable manner as distance from the tire/pavement contact patch increases. NCHRP 630 determined that most all the noise from a vehicle operating at highway cruising speed is tire/pavement related. NCHRP 842(8) used OBSI and controlled pass-bys, as well as another advanced measurement process, beamforming, to confirm this is true for 18-wheeled heavy trucks as well. At 25 feet or 50 feet from the roadway, the overall noise level from any vehicle, on any pavement, can be accurately estimated if the OBSI level is known (as shown in Table 1). Roadside noise levels can be accurately predicted with only OBSI tire/pavement measurements. This is an extremely important concept for SDOT noise practitioners! It has direct application for mapping pavement acoustics. Changing the pavement acoustics, changes the roadside acoustics and roadside noise levels. Extensive California experience shows that most the time, this change is an almost 1:1 correlation.

Vehicle / Distance	Offsets (to be subtracted from OBSI level) dB
Light Vehicles (Passenger Cars) at 25 ft	21.8
Light Vehicles (Passenger Cars) at 50 ft	28.3
Heavy Trucks at 25 ft	12.9
Heavy Trucks at 50 ft	19.2

Table 1: Offsets for Statistical Pass-by SPL from Measured OBSI (dB) as determined by NCHRP 630.

OBSI tire/pavement noise measurements have been correlated to 25- and 50-foot roadside SPL measurements. The offsets in Table 1 can be used to determine the noise level generated by a light vehicle (Passenger Car) or heavy truck passing-by on any specific pavement, at a distance either 25 or 50 feet away. For example, to estimate the roadside noise level for any specific pavement, the OBSI level of that pavement must first be known or measured. To estimate the roadside noise levels of a passenger car that is passing-by (cruising) 50 feet away on a specific pavement, subtract 28.3 dB from the OBSI level. With a pavement OBSI measurement of 107 dB, a passenger car will have a SPL of (107 – 28.3) 78.7 or about 79 dBA on that specific pavement at 50 feet away. A heavy truck passing by, on the same pavement, at 50 feet away, would have an SPL measurement of (107 – 19.2) 87.8, or about 88 dBA on a sound level meter that is 5 foot above the pavement elevation.

If pavements have been measured and inventoried, the noise levels between pavements can be determined by the difference between the two different pavement OBSI levels. Accurate acoustic comparisons can be made by age and across different kinds of pavements. A pavement acoustic inventory is a powerful design tool to help engineers more confidently determine if a project pavement design choice will increase or decrease noise levels. A pavement acoustic inventory is also a useful tool for responding to noise complaints and/or determining if a quieter pavement strategy would be successful in lowering noise levels.

PAVEMENT ACOUSTIC VARIATION

The important conclusions drawn from an extensive amount of OBSI measurements that were paired with controlled pass-by measurements, is that tire/pavement noise is the primary noise source of most vehicles at freeway speeds. As SDOTs do not have the authority to affect tire selection, the focus must be on pavement. Pavement is only half of the tire/pavement noise generator on any vehicle, yet there is enough variability in pavement to influence, sometimes significantly, roadside noise levels. Pavements acoustic vary, sometimes significantly, due to material properties, or surface texture, or age and wear. Accurately quantifying pavement acoustics is a very important tool and process to assist SDOTs in addressing highway related noise issues.

The public's concerns about traffic noise from any project are always a challenge for SDOTs.

AASHTO T-360 OBSI acoustic measurement standard accurately quantifies how loud or quiet pavements can be. The biggest pavement parameters that seem to influence pavement noise levels are: aggregate size, surface texturing, and having a 'negative' subsurface texture − open cavities below the tire contact patch for air to go. Between extremes, pavements can vary by about 15 dB. As a single pavement ages, a variation of 5 to 7 dB is typical. Very elevated noise levels can be generated by pavement that has been severely rutted by snow tires and chains. Chip seal pavement rehabilitation projects that use large aggregates elevate noise. Bridge decks that have aggressive-roughened surface texture in order to elevate friction coefficients will also elevate tire/pavement noise levels. For reference, rehabilitating an old-worn-out and loud pavement with a new quiet replacement can provide a 5 to 10 (9) dB reduction − a similar reduction as what might be provided by a sound wall. OBSI research has consistently shown there is much more pavement variation than the 4.6 dB that is an input variable in TNM. TNM analysis defaults to 'average' pavement which is a mix of flexible and rigid pavements measured with roadside SPL microphones over 25 years ago.

2012 SCL-85 NOISE STUDY WITH OBSI MEASUREMENTS

In 2012, Illingworth & Rodkin completed a noise study report (10), which used TNM, to analyze proposed transportation improvements along the SCL-85 corridor. It was a large project and normal ambient SPL neighborhood noise measurements were made to validate the 'existing conditions' noise simulation. AASHTO T-360 OBSI tire/pavement measurements were also taken for the entire length of the corridor in both the northbound and sound directions as shown in Figure 2. This was the first project of this size that measured and reported corridor-long pavement acoustics and examined using OBSI measurements to assist in validating the 'existing-conditions' TNM simulation.

The pavements in this corridor are representative of typical pavements found on California freeways: old and new, flexible and rigid, and off and on structures. In this data set, OBSI samples varied by about 10 dBA (97.5 to 108.2) along the entire length of the corridor. The tire/pavement OBSI noise levels jump whenever a transversely tined bridge deck texture was encountered. The older and very worn longitudinally tined rigid pavement in the north end is louder than the newer flexible pavement in the south end of the corridor.

AASHTO T-360 OBSI measurements are based upon a 5 second average taken at 60 mph (88 feet per sec). The measurement is the average OBSI level of a 440-foot length of pavement which should be representative of the type of pavement that needs to be acoustically characterized and quantified. Different kinds of pavement mixes and placement will generate a certain spectral shape. Similar 'families' of pavement will have similar shaped spectra

Figure 3 shows the spectra for the non-bridge-deck pavements which define three acoustically distinct sections of the SCl-85 corridor. The top graph of Figure 3 is OBSI measurements in the northbound direction and the bottom graph is OBSI measurements in the southbound direction. The northern section of the corridor is very old and worn and loud, longitudinally tined rigid pavement. The middle section is relatively new rigid pavement. Acoustical differences between old and younger rigid pavement can be seen. The southern portion is flexible pavement. Pavement selection is usually driven by axle loading (traffic volume), budget, and pavement maintenance cycles. Acoustic impacts on neighboring communities are also beginning to get consideration. Therefore, it is important to accurately measure, inventory, and understand pavement acoustic properties and performance. The perspective of SDOT's should be that this is product design and the acoustics of the product matter to the consumer − nobody wants a loud refrigerator compressor running in their kitchen.

On the bridge decks, the 10-dB pavement noise level alone, is greater than the 5 (to 7 dB) reduction California sound walls must provide for acoustic 'feasibility' as required by the NEPA analysis process in 23 CFR 772. This real-world pavement variation is much greater than the TNM pavement variation in the software analysis. TNM is not accurately simulating what is really happening. The real-world pavement differences and the assumed differences in TNM makes it difficult to validate 'existing conditions' simulation results with field measurements. It makes more engineering sense to design the bridge deck noise source to be quieter, than it does to interrupt the path and mount a tall heavy and expensive sound wall on the bridge to shield the roadside.

(Figures 2 & 3 – next pages)

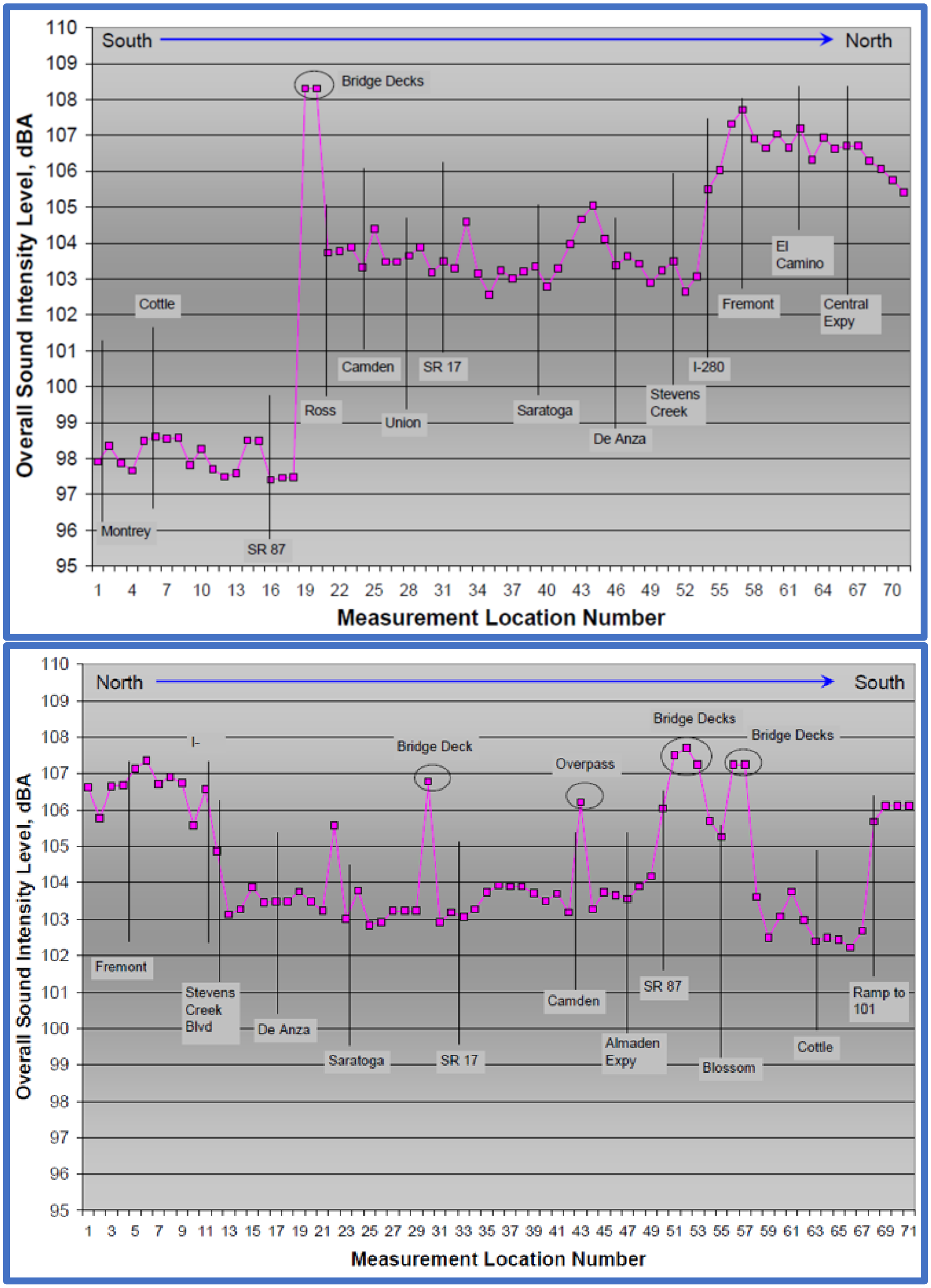
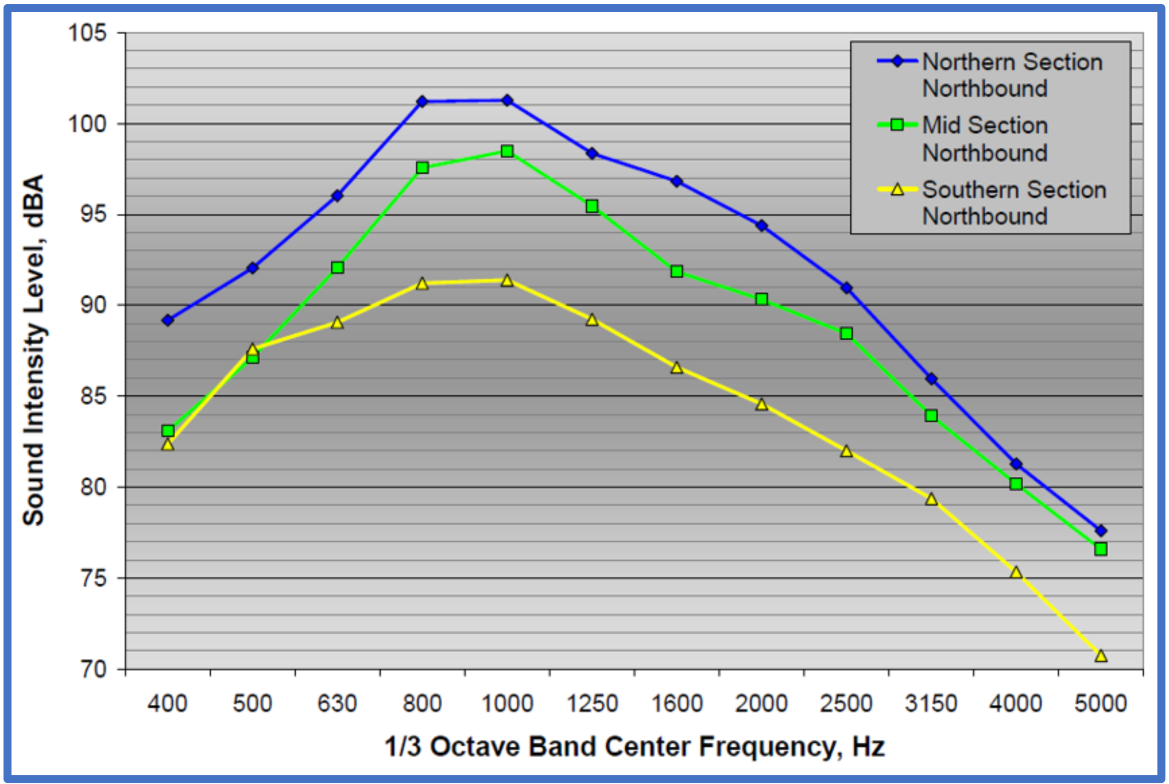


FIGURE 2: 2012 AASHTO T-360 OBSI 5-second Measurements, Outside Lane only. Top: Northbound Direction, Bottom: Southbound Direction.



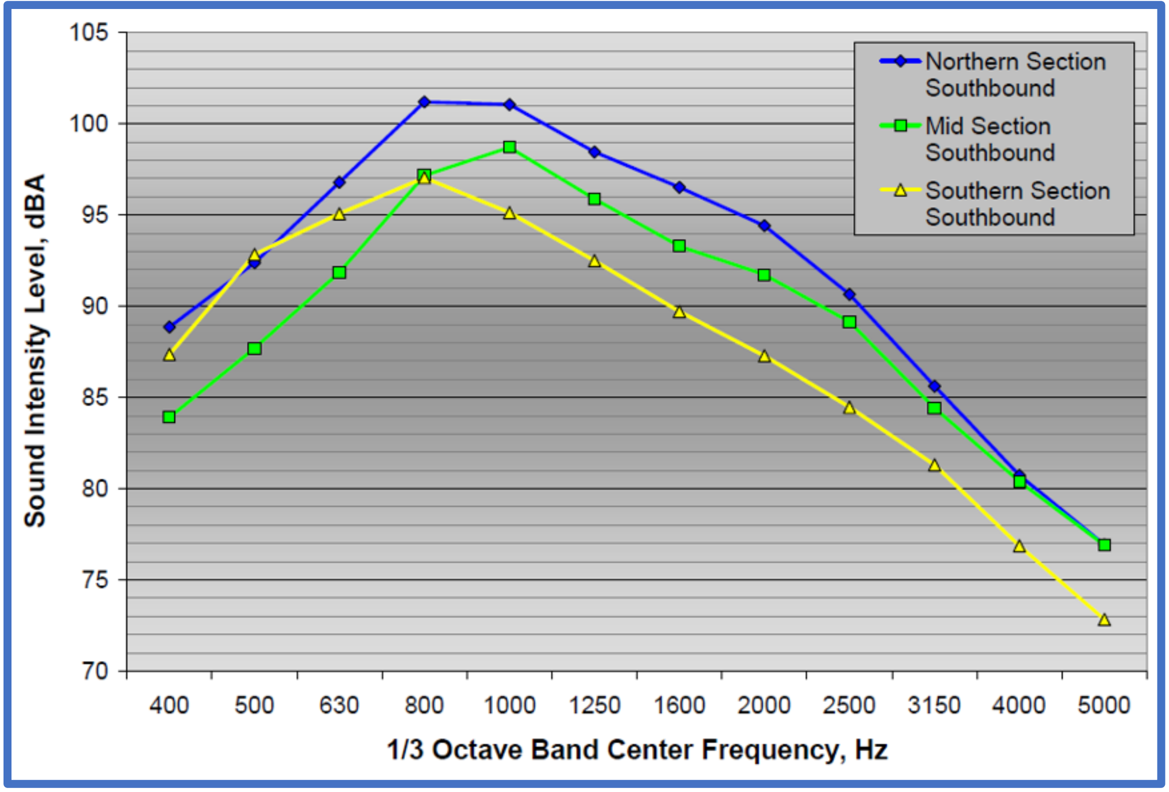


FIGURE 3: Pavement Spectra for 2012 AASHTO T-360 OBSI 5-second Measurements. Top: Northbound Direction, Bottom: Southbound Direction.

MORE PRECISE PAVEMENT ACOUSTIC MEASUREMENTS

The SCL-85 corridor is surrounded by residential housing and living costs are very expensive. This creates a lot of continuous pressure for Caltrans and VTA to address highway noise complaints and control highway noise levels. Many years after completion of the corridor's southern extension through established residential neighborhoods, the noise complaints persisted. VTA was still evaluating how best to address them and concurrently communicating with Caltrans.

The only large-scale alternative left seemed to be placing expensive absorptive treatment on the existing sound walls and basing this retrofit strategy on expensive and uninformative neighborhood SPL measurements. Historically, the acoustic benefit to cost ratio of adding absorptive treatments to existing sound walls had never been very good. Based on prior experience, it would be very difficult, if not impossible, to quantify a reduction, due to absorptive treatment, in neighborhoods that were ¼ to ½ mile away from the freeway. The only apparent solution to the acoustic problem, by using established measurement process and procedures, was not a wise use of resources.

Caltrans decided to take an innovative approach to mapping SCl-85 acoustics and build on the digital innovations of Silicon Valley. With the new knowledge gained by previous tire/pavement acoustic research efforts, a modified OBSI measurement study that would better characterize and map the pavement acoustic loud 'spots' that might be impacting roadside neighborhoods. A new technology demonstration would combine OBSI pavement measurements with GPS coordinates and present the acoustic data in a GIS map. The idea for the concept had first been proposed by the pavement specialists at Transtec Group during collaborative TPF 5-135 quiet pavement research.

The acoustics properties for all the different pavements on this corridor had been studied in the 2012 noise study. From many previous bridge acoustic studies done in California, it was known that bridge decks were constructed using a transversely tined surface texture which elevates tire/pavement noise by 8 to 10 dB over quieter textures. Open graded flexible pavements tended to be quieter and aged pavements are louder than new pavements. What had not been done before, was mapping out the pavement variation lane-by-lane on a six-lane 24-mile-long corridor and presenting the pavement acoustic variations in a comprehensive system map.

With the systematic mapping the fundamentals of the source-path-receiver concept could be applied to better address noise complaints. OBSI measurements would quantify source levels and source position. Mapping provides path distance and details between the source and the receiver. The receiver position is easily determined from the mapping. Objective 'acoustic accounting' can quantify noise level impacts on receptors and quantify noise impacts on neighborhoods. Paving projects that reduce roadside noise levels (quieter pavement strategies) can be prioritized objectively by the amount of decibel reduction per receiver per dollar spent.

MODIFYING THE OBSI SAMPLE SIZE

The AASHTO T-360 OBSI Standard uses a 5 second interval as the fundamental sample rate. This 5 second sample was selected to characterize the average spectral content and sound power of consistent 440-foot patches of pavement. There is nothing magical about the 5 second OBSI sample rate used to characterize the pavement acoustics. The OBSI measurements could be done continuously if needed for measuring construction consistency or measuring and comparing impulse noise due to pavement discontinuities.

For this technology demonstration project, it was decided to try 0.05 sec measurements and combine them into one 0.10 sec for recording. This data would then be paired with GPS data that was also recorded at 0.10 second interval. This data is recorded on a test vehicle going 60 mph, so each data point represents two 4.4-foot samples combined into a larger sample that represents 8.8 feet of pavement. The 142 five-second OBSI measurements taken for the 2012 noise study represent only a very small sampling of the corridor pavement and revealed a variation of 10 dB. The 2019 OBSI data set is far more comprehensive with over $60{,}000^+$ individual OBSI measurements.

In Figure 4, the variation between the quietest and loudest samples covered about a 20 dB range. The additional 10 dB variation seems to be impulsive noise from pavement transitions or bridge/structure joints and abutments. Even the smaller OBSI time samples of 0.05 seconds don’t do a very good job of quantifying impulse noise. Impulse noise doesn’t increase the noise levels of longer duration noise measurements. But the impulses are a part of the soundscape and the public does hear them. The impulse noise locations are identifiable on the GIS mapping as red dots and these noise generators should be targeted for remediation. Under certain meteorological conditions, impulse noise from elevated structures can be heard at large distances.

Figures 4 mapping shows the overall corridor pavement variation. Note the color-coded ‘Noise Scale’ that goes from quiet-green to loud-red. The yellow-orange colored pavement data on the north end of the corridor is the very old longitudinally-tined rigid pavement that has undergone various pavement rehabilitation over its’ many-decades, long lifespan. The green pavement at the south end is a relatively new and quieter flexible pavement. The gaps in the Figure 4 Bottom lane-by-lane data are due to the read and write processing of the data.

In Figure 5, the loudest orange-red sections of pavement are on structures and are the legacy of transversely-tined rigid pavement bridge/structures decks. Caltrans has since changed deck texturing specifications to a much quieter Groove-and-Grind specification. In Figure 5 Bottom, the interchange connector ramps are loud noise sources and they are positioned three to four stories above the surrounding area. A 48-inch-tall solid concrete safety barrier would provide the dual function of being a safety feature as well as a very effective and inexpensive way to block tire/pavement noise from the roadside community below. The bottom of Figure 5 shows the GIS layers which control the data layers.

(Figures 4 & 5 – next pages)

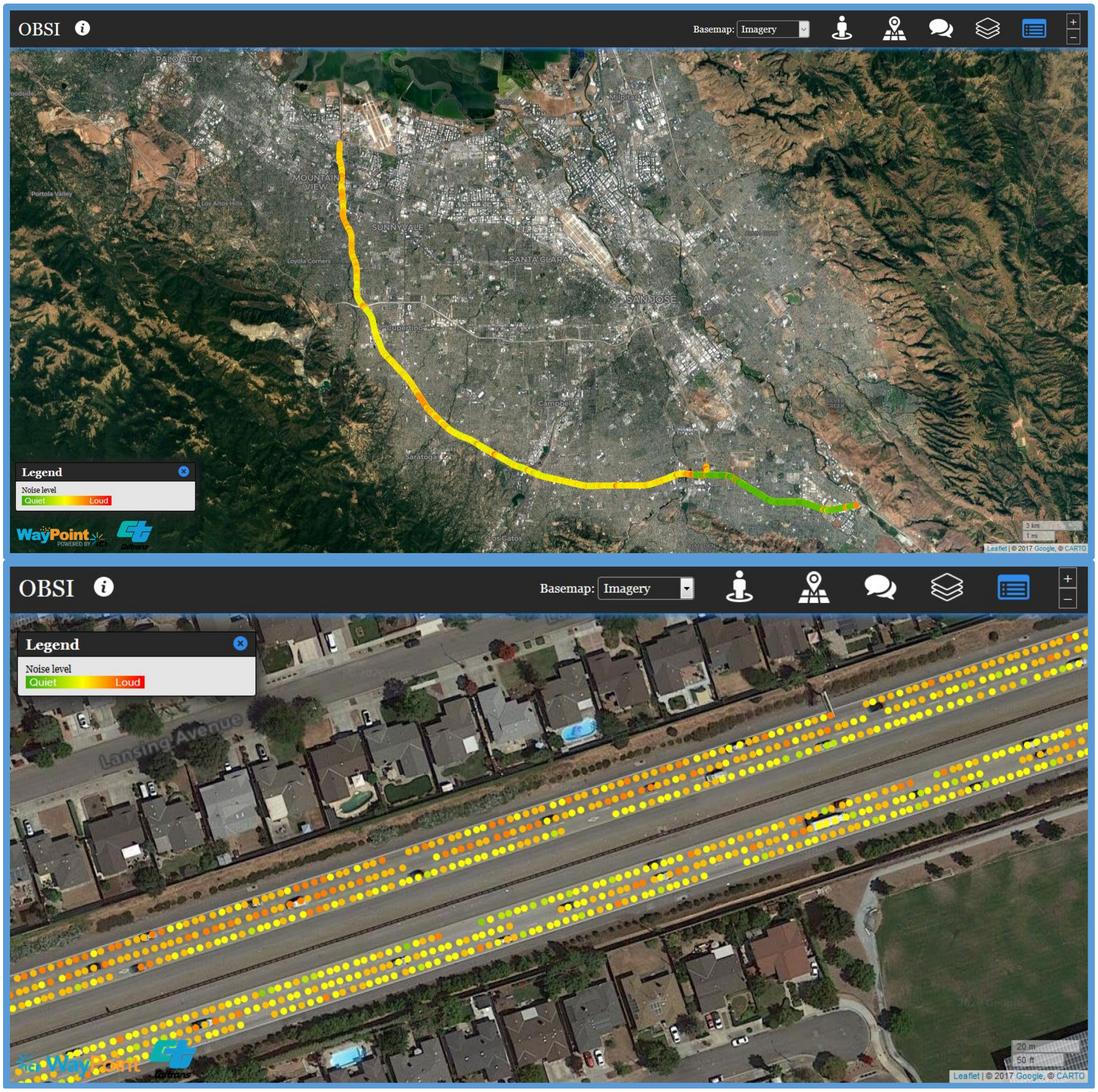
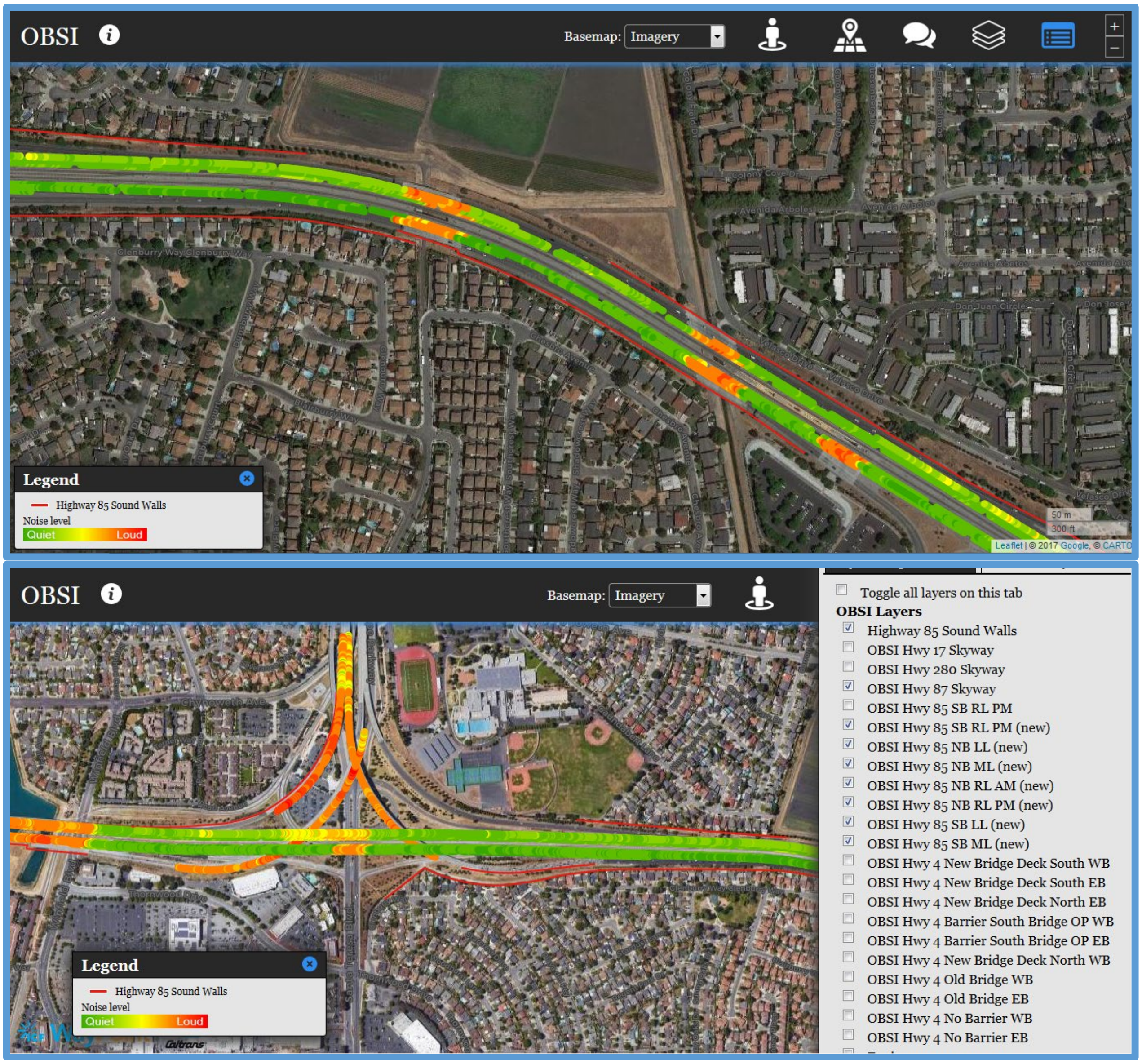


FIGURE 4: Corridor OBSI Pavement Noise Levels, with color Noise Scale. Green is quiet and red is loud. Top: Entire 24 mile Six-lane corridor, Bottom: OBSI levels lane-by-lane



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OBSI Layers

- ☑ Highway 85 Sound Walls
- ☐ OBSI Hwy 17 Skyway
- ☐ OBSI Hwy 280 Skyway
- ☑ OBSI Hwy 87 Skyway
- ☐ OBSI Hwy 85 SB RL PM
- ☑ OBSI Hwy 85 SB RL PM (new)
- ☑ OBSI Hwy 85 NB LL (new)
- ☑ OBSI Hwy 85 NB ML (new)
- ☑ OBSI Hwy 85 NB RL AM (new)
- ☑ OBSI Hwy 85 NB RL PM (new)
- ☑ OBSI Hwy 85 SB LL (new)
- ☑ OBSI Hwy 85 SB ML (new)
- ☐ OBSI Hwy 4 New Bridge Deck South WB
- ☐ OBSI Hwy 4 New Bridge Deck South EB
- ☐ OBSI Hwy 4 New Bridge Deck North EB
- ☐ OBSI Hwy 4 Barrier South Bridge OP WB
- ☐ OBSI Hwy 4 Barrier South Bridge OP EB
- ☐ OBSI Hwy 4 New Bridge Deck North WB
- ☐ OBSI Hwy 4 Old Bridge WB
- ☐ OBSI Hwy 4 Old Bridge EB
- ☐ OBSI Hwy 4 No Barrier WB
- ☐ OBSI Hwy 4 No Barrier EB

FIGURE 5 Top: Systemwide noise with quiet (green) and loud (orange & red) pavements and with sound walls (red line) shown. Bottom: Interchange noise showing elevated ramp-connector pavement noise levels and GIS layers on the right.

Extensive OBSI bridge-deck experience has shown, that changing a transversely texture deck surface to a longitudinal texture can dramatically reduce noise levels by 8 to 10 dB. Caltrans has changed its' bridge deck specifications from transversely tined texture to a Groove-and-Grind surface texture (see Figure 6) which greatly reduces roadside noise levels. This much quieter rigid surface texture was a product of the collaborative efforts of TPF 5-135. Google Earth and Google Street View can be used to help determine the kind of pavement present and its general condition; however, the Street View can be dated and may not represent current conditions.

FIGURE 6 Top: Red lines show easily identifiable and loud, transversely tined surface texture pattern on Google Street View map, Bottom: Close-up of quiet longitudinal Groove-and-Grind rigid pavement texture used both on and off Caltrans structures.

With the knowledge that pavement acoustics directly influence roadside noise levels, a program can be developed to rehabilitate the pavement and lower noise levels. With an OBSI inventory of different pavements for reference, reductions from quieter pavement alternatives (quieter pavement strategies) can be estimated with relatively high accuracy. Benefit/costs of noise reducing pavement rehabilitation projects can be calculated with much more objectivity. Quieter-pavement rehabilitation projects along the corridor could be prioritized based on the amount of the reduction and the number of benefitted receptors and cost associated with the work. Quieter pavement will provide more quantifiable and predictable noise relief for the neighborhoods than questionable absorptive treatments. Using a pavement acoustic mapping, it is much easier to measure and quantify and map before and after conditions and improvements. Quieter pavement will work on both sides of the road – absorptive treatment would only work for one side of the road. Money is being put into pavement and not walls. Caltrans' experience with many quieter pavement projects is that 'readily noticeable' reductions are possible and even small reductions of 1.5 to 3 dB are heard and appreciated by the roadside neighborhoods.

CONCLUSION

Highway noise is an on-going environmental issue for many roadside communities. Using the new acoustic measurement technology of OBSI, noise concerns can be addressed more effectively. The noise levels for a major element of highway transportation infrastructure − pavement, can now be mapped with more precision.

Extending a freeway through established residential communities demands that extra effort and consideration be used to address noise impacts. Every noise reducing strategy should be applied when building a freeway through an established neighborhood; tall walls with absorptive treatments, quieter pavements, quieter bridge decks, quieter interchange connector ramps, 48-inch (or taller) concrete safety barriers on interchange ramps. Constructing an extensive system of tall expensive sound walls without consideration of pavement or other elements may not be enough − even though it fulfills NEPA and FHWA requirements. Heavy truck restrictions can provide some additional reduction – but, again, may not be enough.

Additional roadside reductions are possible by lowering noise levels generated by specific highway design elements. The largest reduction can come from lowering tire/pavement source levels with quieter pavements, quieter bridge textures, quieter interchange-ramp connector texture. Short, 4 to 5-foot-tall concrete safety barriers on elevated interchange-ramps and bridges could also function as short sound walls and block tire/pavement noise from nearby noise-impacted receptors.

Mapping pavement acoustics and using quieter pavements to reduce roadside noise levels has important benefits for assisting SDOTS in addressing noise related challenges:

1) Having an inventory of OBSI pavements acoustics is a very important tool for addressing highway traffic noise.
2) In some cases, quieter pavement can provide reductions that are equal to, or exceed, the reductions provided by sound walls.
3) Quieter-pavement strategies work on both sides of the road – not just one, like a sound wall or absorptive treatment.
4) Quieter-pavement strategies don't create potential reflection issues like sound walls and some super-quiet pavements can absorb 3-4 dBs of additional traffic noise.
5) Quieter pavements can be used to address noise complaints, either proactively in the

design phase or retroactively to noise complaints.

6) Quieter pavements can be used in combination, with or without sound walls, to further (or additively) reduce freeway noise levels.
7) Addressing noise issues after construction is expensive and complex and OBSI mapping may be a solution.
8) Turning down the noise at the source is far more productive and less expensive than building tall expensive sound walls or adding absorptive treatment to existing sound walls.
9) TNM does not address pavement variation.
10) The public and transportation agencies want money to go into roadways − not sound walls or expensive absorptive sound wall treatments.

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