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Investing in Quiet: A Self-Funding Approach to Mitigating Noise Emissions from Train Horn Use at Grade Crossings

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INVESTING IN QUIET: A SELF-FUNDING APPROACH TO MITIGATING NOISE EMISSIONS FROM TRAIN HORN USE AT GRADE CROSSINGS

By

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"Transportation—
I blush to utter a truism
now so frequently ignored—
is a means
and not an end"

-Lewis Mumford
in "The Roaring Traffic's Boom," *The New Yorker*, 1955

To Dr. David H. Black,
from whose ecology classes
grew the roots of this thesis.

Acknowledgements:

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Two participants in this undertaking—unlike relatives, advisors, or others stuck with me—could have opted out of the lengthy obligation it entailed. Dr. Stanislav Markus and Dr. Elisa Alvarez-Garrido nonetheless shared their time, insights, and candor. The recommendations they provided fundamentally transformed this paper from a sprawling monograph into a clearer, more concise, more convincing case. Its strengths are theirs.

Any errors or omissions are mine alone. *Caveat lector.*

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Summary:

This paper makes the case for implementing “Quiet Zones”—public, at-grade, road-rail crossings where the usual federal requirement that locomotives sound their horns is suspended—in Richland County, South Carolina. Quiet Zones cost money: in some instances, a few thousand dollars; in cases where federal rules require substantial upgrades to infrastructure, millions. It may nonetheless cost more to *not* implement them.

Existing research has found that properties exposed to chronic noise pollution are worth less; with train horn noise, that impact is specific to residential property. [1] Property taxes fund most of the United States’ local governments. At the same time, federal regulations place responsibility for establishing Quiet Zones on the proverbial shoulders of those governments—a clear alignment of costs and benefits[2] While higher property values are not the only benefit of Quiet Zones, they are the most powerful argument in a nation with over 120,000 public grade crossings and $36 *trillion* in residential property.[3]

This study makes that argument from start to finish. It models sound levels, regresses property values on that sound, proposes 14 Quiet Zones for Richland County, estimates their total implementation cost, computes the projected increase in property values that would result, and proposes a new organizational approach to the task.

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[1] Bellinger, “The Economic Valuation of Train Horn Noise”; Kim, Park, and Kweon, “Highway Traffic Noise Effects on Land Price in an Urban Area”; Andersson, Jonsson, and Ögren, “Property Prices and Exposure to Multiple Noise Sources”; Walker, “Silence Is Golden.”

[2] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings § 222.9, § 222.37.

[3] Hasson, “Deadly Railroad Crossings Challenge States”; Federal Railroad Administration, “Highway-Rail Grade Crossings Overview”; Richardson, “Housing Market Gains More Value In 2020 Than In Any Year Since 2005.”

Introduction

This is a rebuttal in four parts. Its overarching goal is to lay to rest any doubts that Richland County, South Carolina would benefit from the implementation of "Quiet Zones" (QZs)—groups of at-grade road-rail crossings at which the usual federal rule requiring train drivers to sound their vehicle's horn is suspended outside of emergencies. Each of its major sections addresses, then strives to disprove, an argument that might be raised against such an implementation.

Part I comprises three principal sections. The first briefly discusses some of the reasons that noise pollution ought to be treated by governments and planners as an urgent problem. The second makes the case that train horn noise ought to receive particular focus—not because it is severe within the study area, but because the characteristics of train horn use and regulations in the United States make it a remarkably onerous form of noise. The third contrasts Quiet Zones with two alternative approaches to mitigating horn noise: crossing closure and grade separation.

Part II builds on existing scholarly research into the relationship between exposure to train horn noise and residential property values. It constitutes an expansion in the scale and scope of such efforts, one spanning over 100,000 impacted properties, hundreds of railroad crossings, and an entire county rather than a single neighborhood or crossing. In lieu of their costly fiend measurements or simplified sound models, Part II applies ISO 9613-2—a scientifically-sound yet easily-scalable model of acoustical attenuation—to the creation of a far more sophisticated model of sound exposure. That is followed by a regression analysis that explores the relationship between modelled noise exposure and assessed property values in order to quantify the community cost of chronic train horn noise use. In essence, Part II attempts to rebut the argument that the quantitative impact of horn noise is insufficient to justify a policy response, let alone finance that response.

Part III describes and carries out the process of identifying, designing, and costing out Quiet Zones in the real world. It recommends the implementation of fourteen specific Quiet Zones spanning the width and breadth of Richland County. Each proposed Quiet Zone has been evaluated for eligibility using the FRA's own "Quiet Zone Calculator" as the agency itself recommends all Quiet Zone planners do.[4] Then, using the sound level data computed in Part II, each property's pre- and post-implementation exposure level is estimated. The difference between the two is calculated for each impacted property. That figure is summed, then combined with the results of Part II to estimate the economic upside of implementing Quiet Zones solely in terms of their impact on residential property values.

Part IV, lastly, begins with an attempt to explain why—despite repeated appeals by citizenry and elected officials alike—not one Quiet Zone has been implemented in the study area [or anywhere near it]. Next, this part reviews the lack of progress on Quiet Zones in the study area by city, county, or state. It then discusses the relevant political dynamics and suggests what has kept each of those entities from acting. Lastly, Part IV proposes a specific new approach to remedy the situation and analyzes the factors that will enable this new approach to succeed where past attempts have failed.

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[4] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings Appendix E§(I)(A)(5).

South Carolina's state motto means "while I breathe, I hope."[5] It has been over twenty years since the FRA first described the Quiet Zone rules and more than fifteen since they took effect,[6] and not a single one of the 140+ open, public, at-grade crossings that daily and nightly produce noise in Richland County has been granted Quiet Zone status.[7] Breath and hope have not been enough. This paper suggests what might be.

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[5] "Facts and Symbols | Quick Facts about South Carolina."

[6] Federal Railroad Administration Office of Railroad Development, *Draft Environmental Impact Statement: Proposed Rule for the Use of Locomotive Horns at Highway-Rail Grade Crossings*; "Final Rule -- Use of Locomotive Horns at Highway-Rail Grade Crossings, 2006 | FRA."

[7] Fisher, "Quiet Zone Locations by City and State | FRA."

Prologue: Eastern Florida, August 1990

That this paper exists at all is, as an FRA history of the Quiet Zone program explains, a result of events in Florida. Like many states, Florida allowed municipalities to ban the use of train whistles under certain conditions, creating an exception to the statewide requirement that otherwise existed. Specifically, Florida's silencing provision allowed municipalities to ban whistle use during nighttime (10 pm to 6 am) hours at crossings provided those crossings were equipped with both gates and flashing lights; presumably, it was felt that these two safety features would adequately offset any danger otherwise presented by the 'silent' approach of a train. Despite such safety measures, however, accident rates at crossings with whistle bans nearly tripled. The FRA "consider[ed] many possible factors" before concluding that the elevated rate of accidents at such crossings was, indeed, the lack of train horn use. It responded with Emergency Order 15, which overruled Florida's local whistle bans.[8]

The FRA then expanded its study of the silent train question beyond Florida. The agency determined that no-whistle level crossings increased the incidence of collisions nationwide even at those crossings equipped—like Florida's problem crossings—with flashing lights and traffic-blocking gates. Notably, the calculated increase in collisions nationwide was just under 67%, whereas the Florida-specific figure was 195%.[9] Congress responded to the FRA's discovery by passing legislation ordering the agency to develop and issue a nationwide version of its Florida order, effectively creating a national

[8] "Train Horn Rule - History and Timeline."

[9] "Train Horn Rule - History and Timeline."

equivalent of state-level laws requiring whistle use at grade crossings.[10] As with state-level statutes, moreover, Congress's version provided for exceptions to the requirement while substantially delegating the specifics of such exceptions to the FRA[11].

The resulting FRA regulation, "The Final Rule on the Use of Locomotive Horns at Highway-Rail Grade Crossings," took effect in June 2005.[12] It spelled out in detail a process for establishing Quiet Zones, establishing different requirements for areas where a whistle ban had never existed, areas where such bans had existed before federal preemption, and—in a transparent concession to political considerations—for grade crossings in the Chicago metropolitan area.[13] The announcement of the final QZ rule in the Federal Register discloses that the FRA held some four public hearings on the proposed rule(s) in the Chicago area, an accommodation not repeated elsewhere. Still more telling is the FRA's admission in the same document that "[the] six-county Chicago Region …accounts for <u>the biggest concentration</u> of 'whistle bans' <u>and associated casualties</u> in the nation" (emphases added).

For those communities unlucky enough to lack Chicago's political clout, the FRA promulgated a set of rules designed (in theory) to strike a fair balance between safety and noise. There is a strong case to be made for their having gotten that balance very wrong. However, that and other arguments about and criticisms of 49 CFR 222 would turn this paper into a book (and nearly did). 49 CFR § 222 is here to stay, as are the railroad tracks

[10] Schenk, H.R.4867 - 103rd Congress (1993-1994): An Act to authorize appropriations for high-speed ground transportation, and for other purposes.

[11] Schenk, H.R.4867 - 103rd Congress (1993-1994): An Act to authorize appropriations for high-speed ground transportation, and for other purposes, Title III.

[12] Use of Locomotive Horns at Highway-Rail Grade Crossings.

[13] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings.

that run through Richland County. The noise pollution that results from these factors, however, *can* change. The following paper attempts to make a substantive case for seeking that change at once.

PART I: THE CASE FOR QUIET

> "The Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare."
>
> -*Noise Control Act of 1972*[14]

Recent years have seen a wave of municipal ordinances and laws that reflect a growing awareness of noise pollution as a serious issue in the United States.[15] In doing so, these communities in question are finally responding to what may be one of the most pervasive negative externalities in American society besides greenhouse gas emissions. Noise pollution is a devastating force, especially because of the apathy with which some members of society treat it.[16] It is possible that pleas to address noise so often fall on deaf ears because its victims have stopped noticing it, even if it has not stopped harming them. The fury with which American society responds to the return of a previously-eliminated source of noise, or to those rare sources of noise that are totally novel[17] (remember vuvuzelas?) suggests that no one ever really adapts to the unnaturally-high levels of sound present in so many cities. They merely learn to ignore their own suffering.

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[14] Rogers, An Act to control the emission of noise detrimental to the human environment, and for other purposes.

[15] "'Like Acoustic Trash': Quiet Clean NOVA Group Forms to Ban Gas Powered Leaf Blowers | WJLA"; Grablick, "Washingtonians Are In A Huff About Leaf Blowers Again, Pandemic Edition"; West, "New York City Council Members Want to Dial Down Sirens."

[16] Ford, "Loud Trains?"

[17] Nwanevu, "Sonic Boom Tests Terrified Oklahoma City Residents 50 Years Ago"; Flanders, "Sound Effects"; "Why Is The F-35 Based In Vermont?"; Mazurek, "No Longer a 'Quiet Zone'"; Pitts, "'It's Driving Me Insane,' Train Horn Back In Waltham Quiet Zone After Crossings Fail Federal Inspection – CBS Boston"; DeSmet, "City Council Approves $14M in FAA Home Buyout Grants."

That noise, however, has changed nothing about its relationship with them. Chronic exposure to noise pollution is not merely annoying or stressful—although those are two of its known effects.[18] It causes severe health effects in persons who would otherwise be healthy. An adult exposed to this pervasive poison will have higher blood pressure, is more likely to have a lethal car accident as a result of fatigue and may be at a greater risk of heart attack or stroke.[19] Chronic exposure to noise pollution even raises the blood pressure of *children*.[20]

Noise pollution causes economic damage as well. People exposed to noise pollution are less productive,[21] homes exposed to certain kinds of noise are worth less,[22] and children educated in impacted areas suffer from delayed cognitive development.[23] Unfortunately, however, many common sources of noise are a byproduct of a value-adding activity that others do not wish to eliminate. An airport may irritate those living close nearby yet generate value for the broader community in which it lies.

Fortunately, many sources of noise pollution have gradually faded and will continue to do so as a result of technological innovations. Aircraft—already dramatically quieter than in past decades[24]—will further improve since a noisy jet engine is a less-efficient jet engine. If and when electric aircraft become viable, they will be almost

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[18] Passchier-Vermeer and Passchier, "Noise Exposure and Public Health."

[19] Passchier-Vermeer and Passchier; Lee, Fleming, and others, "General Health Effects of Transportation Noise."

[20] United States Environmental Protection Agency, "Noise and Its Effects on Children."

[21] Basner et al., "Auditory and Non-Auditory Effects of Noise on Health."

[22] Bellinger, "The Economic Valuation of Train Horn Noise"; Walker, "Silence Is Golden."

[23] United States Environmental Protection Agency, "Noise and Its Effects on Children."

[24] Astley, "Jet Engines Are Getting Quieter."

silent.[25] Even if—despite catastrophic climate change—combustion-powered jet engines remain the norm, efforts at shielding the public from that particular form of aircraft noise nevertheless promise further reductions in its impact.[26]

A similar pattern exists with automobiles. As vehicles with electric rather than internal combustion drivetrains gradually come to dominate the US auto and truck markets, road traffic will become quieter, particularly (since the difference between conventional and electric vehicles' noise emissions is greatest at slower speeds) in built-up areas, where speeds are lower.[27] Additionally, the electrification of trucks—which will allow for the use of regenerative braking—will bring the elimination of hated compression braking noise.[28]

All of these reasons for hope stand in stark contrast with the situation with respect to train horns. The one development in train horn technology in the past thirty years—wayside horns, which allow for the use of a fixed horn at crossings, thereby shrinking the impacted area—is expensive and actually <u>increases</u> the total (i.e., duration-weighted) amount of noise in its immediate vicinity. There is no prospect of further technological developments improving the situation at all. Train horns—unlike virtually every other major source of environmental noise pollution—are **loud for loudness' sake.** Nothing other than Congressional action will change circumstances for the better. And while there are signs that members of Congress are warming to the idea of federal funding to address

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[25] "Kitty Hawk's New Electric Aircraft Is Quieter than a Dishwasher."

[26] Stewart, "NASA Tests a Plane That Is Very, Very Quiet."

[27] Noel, "Will Electric Cars Result in Quieter Communities?"

[28] MacKenzie, "2020 Volvo FE Electric Truck First Drive Review"; McIntosh and Hannaby, "Australian/New Zealand Governments' Response to Truck Compression Brake Noise."

the issue,[29] it would be wholly irresponsible to rely on action by that most unhurried of institutions when the impacts of horn noise are so widespread and so severe. Time may change federal laws and regulations surrounding train horn use. As time waits for no one, this paper will focus on the costs and benefits of addressing the problem through existing channels. Of those channels, Quiet Zones offer the only reliably viable path to progress.

Quiet Zones are the only viable approach

There are three basic approaches to addressing train horn noise within the constraints of current federal regulations. The first and simplest solution is to close grade crossings responsible for undue noise emissions. Geometry, however, foredooms any attempt to fully eliminate horn noise by this method alone. After all, the fact that the crossing *is* a nuisance suggests that it lies close to a settled area; that a crossing exists at all indicates that limiting human activity to one side of the right-of-way is not a practical option. Accordingly, a community attempting to address its noise problem through crossing closure alone must either cut itself in half or accept a substantially-incomplete solution.

The second approach is to untangle road and rail by raising or lowering one or both—i.e., grade separation. This tactic has the additional benefit of facilitating the outright closure of other crossings without turning the railroad into an impregnable barrier. It is, however, catastrophically costly. Moreover, the perceived convenience of newly grade-separated crossings is likely to induce new demand for the road that feeds it via induced demand.

[29] Meng, Quiet Communities Act of 2021.

Data on similar scenarios support this theory. The construction of an overseas bridge, for instance, that eliminates reliance on vehicle ferries—which, like level crossings, impose an unavoidable wait time on motorists—appears to induce substantial demand, and while there are some differences between the two scenarios, there are nevertheless plenty of similarities.[30]

Grade separation proposals—including the long-unbuilt "Assembly Street Grade Separation" project[31]—typically call for a road bridge over railroads, since in the United States, tunneling is still more costly, while raising or lowering the train tracks would require miles of reconstruction. Using a road bridge, of course, forces cars and trucks to ascend, then descend, a slope. This carries a risk of air pollution and noise pollution that Quiet Zones do not present. The air pollution comes from two sources. One is the exhaust of the vehicles in question, as vehicles made to ascend slopes emit more than those travelling over flat ground.[32] The other source of air pollution is the inevitable need to brake during descent. Application of virtually any road vehicle's brakes creates particulate emissions.[33] it is worth noting that this can be true of EVs as well as conventional vehicles. Moreover, vehicles—in particular, heavy trucks that must incessantly shift gears on uphill and downhill segments and which rely on noisy

[30] Nielsen, Hovgesen, and Lahrmann, "Road Infrastructure and Demand Induction."

[31] South Carolina Department Transportation et al., "Public Meeting Handout - Online Meeting."

[32] Al-Rifai, "Effect of Road Grade, Vehicle Speed, and Vehicle Type on NO2 Emissions on Urban Roads in Jordan."

[33] Gonet and Maher, "Airborne, Vehicle-Derived Fe-Bearing Nanoparticles in the Urban Environment: A Review."

compression braking in the process[34]—using the new overpass may emit greater levels of noise than they did prior to the completion of the improvement.

The third and final technique, of course, is the introduction of Quiet Zones. Like grade separation projects, Quiet Zones cost taxpayers more in immediate expenditure than inaction. They also lack the brute simplicity of crossing closures and the flashiness of grade separations, particularly when the latter are advertised—entirely falsely—as panaceas to traffic congestion despite decades of evidence and near-total consensus among planners that “solving” traffic by building roads is utterly foolish. Despite these shortfalls in marketability, Quiet Zones come closer to Pareto efficiency than any alternative, simultaneously increasing safety, decreasing noise, and—potentially—generating more value than they cost. That value merely needs to be computed.

[34] McIntosh and Hannaby, “Australian/New Zealand Governments’ Response to Truck Compression Brake Noise.”

PART II: DECIBELS TO DOLLARS

"It's the economy, stupid."

-James Carville[35]

This part of the paper seeks to emulate past efforts—in particular, those by Bellinger (2006) and Walker (2015)—to quantify the relationship between noise exposure and residential property values. The ultimate objective of Part II is the production of an estimated cost—in dollars—of at least one metric of noise. In this regard, it is quite similar to Bellinger and Walker's works in particular and innumerable hedonic analyses in general. There are nonetheless two major contrasts between Part II and Bellinger and Walker's works. The first concerns the method used to estimate sound exposure. Unlike the latter—which utilizes noise measurements collected in the field for that specific purpose,[36] this study relies exclusively on an electronic model of noise conditions in its area of focus. In contrast with the former—which projected the noise contours of an existing study onto a wholly different study area—the model utilized in this paper is a complex GIS model that simulated the connection between distinct properties and distinct crossings <u>over seventy million times</u>.

Second, whereas Bellinger analyzed a single crossing and Walker worked with a particular part of one city, this part's scope is rather larger. It spans the entirety of Richland County, South Carolina, which covers 772 square miles (2000 km^2), contains at least half a dozen municipal governments, and is home to over 400,000 persons. The

[35] Bates, "Footnotes: Words from a Ragin' Cajun."

[36] Walker, "Silence Is Golden," 8.

regression analysis at the core of this part, meanwhile, uses data from over 109,000 residential properties.

Obtaining, refining, and mapping property data

Before either noise modelling or regression analysis could begin, however, the requisite datasets had to be obtained. Rail crossing data can be obtained from the FRA's Office of Safety Analysis without expense; inventory reports (in the form of PDFs) and inventory files (in .CSV form) are available. Upon importing the .CSV file for South Carolina into ArcGIS Pro, the Richland County crossings with "estimated" listed as their "location source" value (the alternative would be "exact") were individually checked for accuracy. Some had to be adjusted, though only one by more than 10 meters. The crossings outside Richland were not individually checked in this manner but rather refuted via a visual scan of the map—since rail lines were already marked on it for reference purposes—in search of obvious misplacements (at the zoom level utilized, these would have been any more than about 10 meters). In any event, no such instances were identified.

Property data proved far more difficult to either obtain or map. Richland County's GIS Department will not—even for academic research—share any of their parcel files with the public without payment, and they charge $0.50 per parcel. There are over [N] parcels in the county. Such expenditure was therefore out of the question.

Instead, a series of web-scraping operations was used to obtain information on the properties—but not the parcels themselves—from the free, publicly-accessible "RichlandMaps" site operated by the county government. The data of relevance (to the regression later in this part) were parcel acreage, total square footage, year the main building of the property was constructed, and address. For each property, the latter datum point was then inputted into ESRI's automated geocoding service, which automatically placed as many of the points as possible. Geocoding successfully placed most of the points, but a few thousand either geocoded incorrectly—a few somehow geocoded to Canada or Brazil—or were simply placed at the centroid of the county.

In many instances, <u>mis</u>placed properties could be corrected for their incorrectly-inputted names ("street" instead of "road," for instance, or spelling errors). However, hundreds, if not thousands had to be manually identified and placed, a lengthy process given the area and number of points involved, not to mention the investigation often required.

<u>Un</u>placed points, by contrast, presented no great enigma, as most appeared to have failed to geocode as a simple result of Richland's breakneck rate of real estate development. These corresponded to tract homes for which ESRI's geocoding service did not yet have any street names or locations. Such cases were resolved by consulting Richland's map and Google Maps, then manually placing the point at the apparent centroid of each parcel just as both Richland (on their read-only, non-copiable GIS layer of parcels) and ESRI's geocoding service (most of the time) had done.

Lastly, the data were filtered. Existing research—in particular, one of the two studies foundational to this one—suggested that only residential properties are significantly affected by noise pollution, so the main goal of filtering the dataset was the removal of non-residential properties. Additionally, higher-rise (not true high-rise residences, of which there are none) residential structures were to be filtered out, since the noise impacts of train horns on such structures is likely to be substantially different due to the introduction of a third dimension and their generally higher quality of construction than low-rise homes. The full list of filtrations applied at this stage is provided in Table 1.[37]

Table 1: List of attributes used to filter the dataset. Properties possessing any one of these were removed.

"Zoning description:"	Zoning Codes:	Land Types:
Heavy Commercial	C-1, -2, -3, -3a, -4, and -5 (these are all commercial)	"CROP LAND"
General Commercial	M-1, M-2 (these are industrial)	"TIMBER LAND"
Office Commercial	TROS (Traditional Recreation Open Space District)	"COMMERCIAL LAND"
Neighborhood Commercial	RC (Rural Commercial)	"MARKET VALUE OF AGRIC LAND" (there was only one; unclear what happened in that case)
Rural Commercial		RESIDENTIAL MULTI FAMILY LAND
Office & Institutional		
Light Industrial		
Heavy Industrial		
Basic Industrial		

Implementing ISO 9613-2 in ArcGIS Pro

It should be noted that ISO 9613-2 is, like each of that entity's standards, copyrighted. Its implementation in the course of this study will therefore be generally

[37] Two more rounds of filtration would be used to remove obviously-incorrect entries later, as is documented later in this part beginning on page 39.

described so that access to 9613-2 is not absolutely necessary in order to understand the steps involved. If the description offered by this section is inadequate, NoiseTools.net (one of the modeling platforms evaluated before the final selection of 9613-2) was thoroughly helpful, as it offers visual depictions of much of the underlying steps required by the standard. Lastly, because the ISO standard's explanatory notes are few in number, the non-engineer may—like this study's author—wish at times to reference the indispensable *Handbook of Engineering Acoustics*.[38] Its thorough descriptions and explanations offer an ideal counterpoint to the 18 terse pages of ISO 9613-2.

Setting up propagation paths

Although—since a train is not stationary while sounding its horn—a source of horn noise can be thought of as a line rather than a point, ISO 9613-2 does not comprehensively accommodate line sources, merely advising the use of a series of points to represent lines. This creates an immediate dilemma in all but the simplest projects, as it increases the number of iterations of each of the required ISO formulae. That would have been a particularly serious problem in the case of this study, as the analysis of links between 120,000+ properties and 290+ crossings already threatened to make the computational requirements insurmountable.

Fortunately, ISO 9613-2 *also* allows for the treatment of a line source as a single point—one placed in the middle of that line source. Under ISO's rules, there are three preconditions for doing so. First, the many points representing the line in question must not vary substantially in height. This is implicitly true of train tracks vehicles given rail

[38] Müller and Möser, *Handbook of Engineering Acoustics*.

vehicles' inability to handle more than the slightest inclines, and analysis of satellite elevation data in ArcGIS Pro confirmed that the changes in elevation across individual crossing zones were minor. Second, the "propagation conditions" must remain constant from source to receiver. In ISO jargon, this simply means that atmospheric conditions between the two cannot materially vary; again, the very nature of this study—it concerns just part of one region of one state—makes this condition a mere formality. Atmospheric conditions are unlikely to vary starkly in an area only slightly larger than a county except during extreme outlier events, and this study would never end if it attempted to factor in *every* eventuality.

The third requirement—that the distance from source to receiver be at least double "the largest dimension H_{MAX} of the sources"—is not quite as easily met. Admittedly, there are many links in this study's model that break that rule because the "largest dimension" of a train sounding its horn is up to 1,760 ft. That figure is the result of applying the longest horn duration the FRA allows—20 seconds—to 60mph, which is the highest speed at which the FRA uses time-based horn patterns rather than fixed distances (trains travelling at higher speeds are supposed to sound their horns starting a quarter-mile from the crossing, regardless of the resulting duration).[39] The dataset of this study is therefore not *entirely* in compliance with the third condition.

Despite that, this study uses a single point to represent each line of horn use because doing so is simultaneously practical and conservative. The approach is practical

[39] Technically, the FRA regulations say that a train travelling at *exactly* 60mph ought to use the fixed distance rule rather than the fixed duration rule, but the difference between 60 and $60 - \frac{1}{\infty}$ is, as they say, infinitesimal.

because it limits the number of links for which calculations must be made, no small consideration given the number of sources and receivers involved. It is also the more conservative approach because this study aims to calculate the *maximum* horn exposure each property experiences. Representing each horn use segment as a point does not make any source-receiver link seem any shorter than it would be under the more complex approach. As regards distance, it only makes some properties seem further from the crossing. In implementing the entire ISO standard, distance is overwhelmingly the most important input variable, so the net effect of this rule-bending is a more conservative estimate of the total noise impact from train horns. That is good. This study exists to argue that train horns are a serious problem; underestimating their severity can only make that assertion easier to defend.

One minor—it had only one precondition, and this study meets it—adjustment involves A-weighting, the (relatively minor) adjustment of decibel levels at different frequencies "try to take into account the frequency dependence of human hearing."[40] A-weighted sound power is denoted as dB*(*A). The ISO standard explains that all sound calculations within it can be assumed to fall into the fourth octave (mid-band frequency 500Hz) "if only A-weighted sound power levels of the sources are known."[41]That is the case here. Not did it prove impossible to obtain band-specific sound power level on a

[40] Müller and Möser, *Handbook of Engineering Acoustics*, 33.

[41] ISO, "Attenuation of Sound During Propagation Outdoors–Part 2: A General Method of Calculation (ISO 9613-2)," n. 1.

single train horn—the apparently-common[42] Nathan K-5LA—but there are multiple train horn models in use. There is no telling which crossings are subject to which mixture of horn models, nor how these patterns have changed. However, federally-compliant train horns have nearly-identical dB(A) because the FRA uses that very metric to define minimum and maximum volumes.[43] The alternative procedure was therefore employed. Incidentally, this reduced the number of iterations of some calculations that needed to be preformed by nearly 90% (from eight per link to one).

Forming links

Having thus tailored the modeling methodology to the limitations and requirements of this study, each of the approximately 120,000 residential properties mapped in its purpose-built dataset was then linked to each publicly-accessible, open, at-grade road-rail crossing. The linking lines were geodesic in order to account for the slight impact of the curvature of the Earth on some of the longer lines. They were also limited—no link longer than 10km was drawn. This cutoff was chosen by inputting wildly-favorable conditions (favorable, that is, to noise travelling further: hard surfaces below, no wind, hot weather, and so on) into the ISO formulae to determine at what distance peak noise levels would fall below 50dB. 50dB was chosen because it is

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[42] No authoritative resource listing the market share of various models or even makes of train horn in the United States could be located. Instead, the author used informal sources, including reading posts on a forum run by train enthusiasts, to determine which models of horn are dominant. The Nathan K-5LA and its sibling, the Nathan K-5L, appear to be reasonably popular. No raw data on the octave-specific sound power of either could be determined, just the pdf of a report from the early 1990s. Its graphs could not be reverse-engineered for their data despite attempts to do so. Nonetheless, official sources support the choices of horn model made, including those from USDOT's own Volpe Center. See Keller and Rickley, "Study of the Acoustic Characteristics of Railroad Horn Systems," 34.

[43] Appendix E, 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings.

indisputably less than or equal to the lowest assumed "background loudness" figures used in present research (across several measurements of *L*). This process quickly revealed that 10km was more than sufficient a maximum link distance.

Drawing a link between each residential property and each crossing within 10km (including crossings *outside* the county, the conservative approach) produced around 70 million geodesic links. The catastrophic effect their creation had on a previously-brisk GIS workstation made it clear that the adjustments made to limit their number without materially reducing accuracy had been justified. The substantial computational burden implicit in that delay also informed the decision not to compute barrier effects, a choice felt to be acceptable given that the Bureau of Transportation Statistics also ignored barrier effects in producing their "National Transportation Noise Map,"[44] the closest thing the United States has to a government-produced noise map of the variety required of European Union member states.[45]

Extracting needed data from propagation paths

The distance of each link represented what ISO calls d_p, which is the distance from point to receiver as "projected onto the ground plane."[46] The ISO formulae also require an input called *d*, which is simply the distance from point to receiver as-the-crow flies. Since this study used geodesic lines to represent d_p (after all, the "ground plane"

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[44] Bureau of Transportation Statistics, "National Transportation Noise Map"; Volpe National Transportation Systems Center. Environmental Measurement and Modeling Division, "National Transportation Noise Map Documentation," 8.

[45] European Parliament and Council of the European Union, Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

[46] ISO, "Attenuation of Sound During Propagation Outdoors–Part 2: A General Method of Calculation (ISO 9613-2)," 6.

has, on average, a slight curvature!) then the only difference between the two metrics is a function of applying the Pythagorean Theorem, since *d* is the hypotenuse. In other words:

$$d = \sqrt{{d_p}^2 + (h_s - h_{r)}{}^2}$$, where:

d_p is simply the geodesic length of each link as described above, **in meters**

h_s is the "height of point source above the ground"[47] (emphasis added), and

h_r is the same measurement with respect to the receiver.

Source height—or h_s—was assumed to be 5 meters for the sake of computational simplicity; casual searches of the internet quickly made it clear that a modern locomotive is just under that height; when the placement of that locomotive on top of train tracks that in turn lie on a raised bed of gravel is factored in, it is functionally equivalent to 5 meters above the wider ground elevation. h_r was assumed to be 2 meters. This assumption, too, is an integer for computational efficiency, while the choice of 2m in specifically reflects a desire to approximate the mean height above ground level of 1) an adult standing on the ground surface, 2) an adult standing on the ground floor of a building, and 3) an adult standing on the surface of higher floors, keeping in mind that the overwhelming majority of homes in the dataset are one or two stories tall. Because each of the computations of *d* involved a link that could be up to 10,000 meters long, it is unsurprising that the application of the above equation resulted in values of *d* essentially identical to those of d_p. Figure 1 illustrates the slight difference between the two values.

[47] ISO, 6.

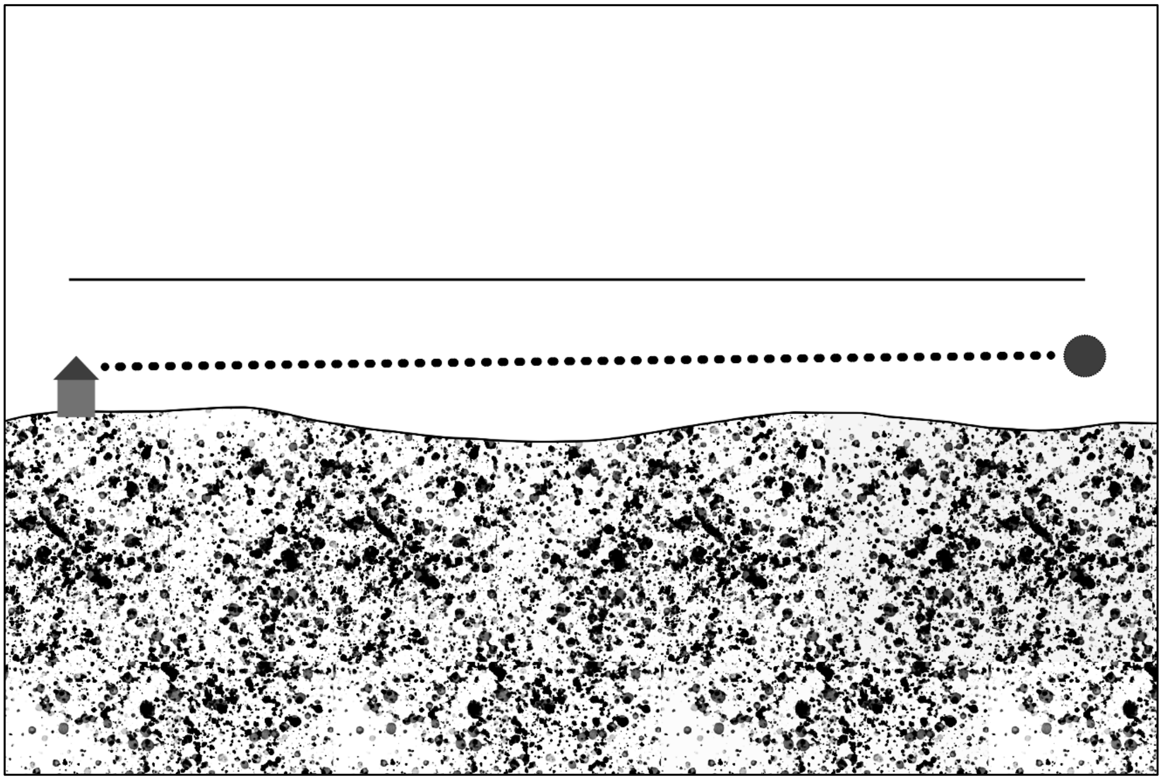

Figure 1: A visual depiction of the difference between d_p (the solid, level line) and d (the dotted, very slightly angled line). Note that neither is impacted by the relative elevation of the ground surface (from some imaginary baseline elevation)

Computing attenuation values

The next step was to calculate the three attenuation terms utilized in this application of the standard. The first, “attenuation due to geometrical divergence,” or A_{div}, needs no explanation; its only variable input is d (The exact equation is not listed here since it needs no explanation and out of a desire to stay well within the limits of free use doctrine.

Most difficult of all was the computation of A_{gr}, which accounts for the reflective or absorptive role of various types of ground surface along the length of each line. Its computation involves a byzantine process too lengthy and too proprietary to justify or allow a full description; instead, a general depiction is provided. Each line is divided into three zones—source, middle, and receiver. The length of the source and receiver segments is a function of the two height variables previously discussed on page 28. Since those are constant in this analysis, so were the lengths of the source and receiver zones: 150m and 60m (≈ 492 and 197ft), respectively. The middle zone consists of whatever is left over and is therefore omitted if the line is ≤ 210m in length (the source and receiver zones are always kept as they *are* allowed to overlap).

To calculate A_{gr}, the average ground factor, or *G*, of each segment is needed. $G = 0$ where the ground has a hard surface and 1 where it has a soft surface. For surface information, European Space Agency (ESA) landcover data from its Sentinel II satellite was obtained via ESRI (the publisher of ArcGIS Pro), which had also processed that data using machine learning.[48] Each of the 9 surfaces that the ESA data includes was assigned a 0 or 1 to reflect its hardness or softness, although "flooded vegetation" areas, of which there were very few, were assigned a value of 0.5 in accordance with ISO's instructions to assign intermediate values to intermediate surfaces.[49] Table 2 lists each of the nine surface coverage types along with the value of *G* assigned to it. Each of the approximately 210 million segment sections was then marked with the average value of *G* along its length. After that, the resulting value of *G* for each of the three segments was

[48] ESRI's exact description of the process applied is "This map was produced by a deep learning model trained using over 5 billion hand-labeled Sentinel-2 pixels, sampled from over 20,000 sites distributed across all major biomes of the world. The underlying deep learning model uses 6 bands of Sentinel-2 surface reflectance data: visible blue, green, red, near infrared, and two shortwave infrared bands. To create the final map, the model is run on multiple dates of imagery throughout the year, and the outputs are composited into a final representative map of 2020." For the LivingAtlas catalogue entry from which this description was derived, see ESRI, "Esri 2020 Land Cover."

[49] The simple mean of hard and soft surfaces was used because the "fraction of the region that is porous," is unknown, so a more precise figure could not be assigned.

run through two more layers of formulae, then summed, yielding the appropriate A_{gr} value of each segment.

Table 2: List of the ground surface types in the ESA/ESRI surface cover dataset utilized for computing ground attenuation, along with the value of *G* assigned to each. (For the two types that were/should have been absent, an explanatory note is provided instead).

Surface Type	***G* assigned (or a note explaining its absence)**
Water	0
Trees	1
Grass	1
Flooded vegetation	0.5
Crops	1
Scrub/shrub	1
Built Area	0
Bare ground	0
"Snow/ice"	*Assumed (correctly) to be erroneous. Only an infinitesimal area was thus coded; it was manually corrected by referencing satellite imagery to determine the correct surface material.*
"Clouds"	*Not present within the boundaries of the study area (Richland County plus a 10km buffer).*

The third and final attenuation term used in this study, "attenuation due to atmospheric divergence," or A_{atm}, required the selection of an average temperature and relative humidity figure from a limited number of choices in Table 2 of the ISO standard; the selection of temperature and humidity figures would output an "atmospheric attenuation coefficient," α. The temperature and relative humidity values selected, 20° C and 70%, respectively, related to Richland County and Columbia, respectively. Efforts to find county-level historical relative humidity data were unsuccessful.[50]

Computing additional components

The three selected attenuation terms having been calculated, only two inputs remained. One was D_c, which ISO terms the "directivity correction." Oddly, the ISO instructions provide its two component terms, but do not explain how to compute one of them, rendering that exercise pointless. The instructions simply list its value when a sound radiates "into free space," which is simply 0.[51] Arguably, train horns—mounted slightly above the surface of a locomotive's roof—radiate into slightly more than 2π steradians (a sphere = 4π steradians). However, since ISO 9613-2's instructions are insufficient—it is difficult to avoid suspecting that missing information lies in another standards document that must also be purchased—this study assumes that horn noise, too, radiates "into free space." Fortunately, that dispensation results in lower—not higher—estimated sound levels and is therefore consistent with this study's tendency towards conservative estimation.

Pulling it all together

The last value to obtain was L_w, the sound power level of the input. In the case of this study, the L_w figure utilized was already A-weighted, so there was no need to complete a separate set of calculations for the various octaves as would otherwise be the

[50] "Richland County, SC Weather - USA.Com."

[51] ISO, "Attenuation of Sound During Propagation Outdoors–Part 2: A General Method of Calculation (ISO 9613-2)," 8.

case. L_w was set to 143 dB(A), a value equivalent to the lowest value of attenuated L_w of any of the most popular models offered by either of the two selected manufacturers, Nathan Airchime and Leslie.[52] The attenuation values (in this case, A_{gr}, A_{div}, and A_{atm}) were then summed to produce A, or the "attenuation term." Next, A was subtracted from $L_{w.}$ This yielded the estimated A-weighted volume experienced by the receiver point at one end of the link when a train sounds its horn at the other end. Of course, almost every one of the receiver points had many such links converging on it as a result of there being many crossings within 10km.

To make this dataset both manageable and compatible with regression analysis, a further step of data processing was necessary. This consisted of summarizing all of the links arriving at each separate receiver point, i.e., conducting a dissolve operation. The links—and their data—were amalgamated by generating four statistics for each property's group of links: the sum of their dB(A) figures, their mean, their minimum, and, most importantly, their maximum. The latter was the intended primary output of this process; the other three were included only for the sake of thoroughness and to enable additional analysis if they proved significant—which they did not end up doing consistently.

To provide plenty of options in the later regression analysis, the L_{MAX} value of each point was further processed into a number of alternative metrics. One set consisted of variables representing the excess peak exposure above an assumed background level of

[52] Studies published by USDOT's Volpe Center—essentially its in-house think tank—also utilized Nathan and Leslie products for their analyses, plus the then-prototypical Automated Horn System (see Keller and Rickley, "Study of the Acoustic Characteristics of Railroad Horn Systems," iii.).

noise; copies of this variable were produced for assumed background levels of 50, 55, 60, and 65 dB(A). Another variable called "IsOver65dB" identifies which properties are exposed to at least that much noise—i.e., it is a simple binary value. [53]

The end product of this process was a layer of approximately 120,000 points representing Richland County residential properties; a few more rounds of data clean-up proved necessary before it appeared that most of the incompatible and/or incorrectly-scraped fields had been removed. Every effort was made to catch individual outliers—for instance, a 72-bedroom, 9-building apartment complex which the RichlandMaps site two bedrooms—i.e., the per-unit number in place of the property's total number of bedrooms and bathrooms. The other type of corrupted data that could only be detected and corrected manually were "fat finger" entries. Some of the preliminary (later to be replaced due to their excessive complexity) regression models tested incidentally uncovered such outliers. They were manually corrected.

To systematically detect other suspect entries, the ratio of bedrooms to bathrooms was computed and added as a field; properties for which that ratio was under 0.5 or over 5 were discarded. This tactic was taken because manually correcting the hundreds of such properties would not have been practically possible, especially since the attributes of some such properties could only have been decisively determined via an in-person visit and/or a title search.

[53] It should be noted that every single one of these sound variables is technically a little incorrect, as all such figures were based on the A-weighted sound power of the horn sources. It was, however, omitted from their names to dispense with the annoyance of typing "(A)" at the end of every new regression model tested, especially since there were no *non*-A-weighted figures tested, making the designation of little use.

This process left 109,615 residential properties, none of which had obvious errors from the web-scraping part of the project. The points were enriched with additional variables informed or inspired by existing works of research. One variable, for instance, *inFRB* (for "in fast road buffer [zone];" its name was created in ArcGIS Pro, ergo the geometrically-descriptive name). *inFRB* is a binary categorical variable which indicates whether a property is within 1,125 ft (~343m) of the nearest controlled-access road. Its inclusion was justified—and that specific threshold was obtained from—existing research into the typical distance from such highways at which property values are damaged .[54]

Another data enrichment step attempted to account for the appeal of living near (some) lakes. To produce a polygon layer representing lakes in the study area—but only those lakes that might have enough name recognition to impact nearby property values—OpenStreetMap (OSM) data for the state was downloaded from a German mapping firm, GeoFabrik, which daily repackages most of the world's OSM data.[55] Efforts to obtain the data directly from OSM proved impractical, in part due to their file sizes, so GeoFabrik's dataset was more than sufficient. One of the map layers included in the GeoFabrik data represented areas of water; this was then filtered in order to limit it to area water features (in GIS terms, polygon features) whose "Name" field included "Lake." This proved an effective, readily-replicable method of removing ponds masquerading as 'lakes,' perhaps because their owners had given them such names. Based on existing Dutch research into the relationship between various measures of proximity to water and property values, it was decided that this study would use a relatively-strict test for lake proximity. Indeed,

[54] Langley, "Highways and Property Values: The Washington Beltway Revisited," 17.

[55] "Geofabrik Download Server."

the existing Dutch paper found steep drop-offs in benefits beyond a distance of 40m (131.2ft) from water.[56]

On the assumption that the high density of water features in the Netherlands might have conditioned Dutch homebuyers to be pickier, and in recognition of the somewhat-different aquatic recreation cultures of the two nations, the threshold distance was increased to 100 meters for this study. One contrast between the two study locales is that no American would ever pedal an *Omafiets*[57] to their moored boat; they would more likely have a larger boat and bring it with them using a truck or SUV. American homebuyers, the thinking went, would perceive a lake 100 meters from home as being practically in their yard.

An additional variable used to enrich the dataset (and which had to be custom-prepared) consisted of a decimal figure representing the average percentage tree cover in the property's census block group. This was partly inspired by similar research that analyzed the *exact* canopy cover of a parcel[58] and within 100 and 250m (≈328 and 820ft, respectively) of the parcel.[59] The latter two proved unreliable in later regression efforts, perhaps because of the use of points to represent parcels—after all, some of the parcels in this study are quite large. On the other hand—because the blocks, and, in turn, block *groups* of the US Census are almost invariably delineated by public roads, rare is the

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[56] Rouwendal, Levkovich, and van Marwijk, "Estimating the Value of Proximity to Water, When Ceteris Really Is Paribus."

[57] Lit. translation: "granny bike." This refers to the fixed-gear bikes with an upright riding position that constitute the majority of the Netherlands' vast supply of bicycles. *Omafietsen* are not designed for particularly long distances, hence their particular relevance to the question of amenity distance thresholds.

[58] This specific approach was not a viable option in this case—the property dataset is made of points, so parcel-specific spatial analysis would have been impracticable.

[59] Sander, Polasky, and Haight, "The Value of Urban Tree Cover."

parcel that does not fall entirely within the boundaries of a block group (or block!). Therefore, using block groups to attempt to measure the same amenity was deemed an appropriate adaptation; as will become clear shortly, regression analysis supported that hypothesis.

In addition to these candidate explanatory variables, a number of others that ultimately proved insignificant or significant only in *some* models were also tested. One was the proximity to high-voltage transmission lines (Colwell, 1990). Another, the personal-crime-discounted distance to the nearest park utilized in a Baltimore study (Troy and Grove, 2008) was not consistently significant. In both cases—high-voltage lines, and, to a greater extent, the 'personal danger-discounted park proximity' metric—it is likely that the input data employed is partly to blame. Colwell's study used parcels in parcel shape—not, as this does, points standing in for parcels. Moreover, this paper's study area is so large that the sheer variety of designs, heights, and maintenance conditions of its many transmission lines is potentially too great to induce any common effect. Whatever the plausibility of successfully reproducing the Baltimore study with perfect data, the park data obtained (via GeoFabrik) from OSM was too irregular and fragmented to yield uniform effects. Some playing fields, for example, were listed as "pitches," others, as "parks." Some were divided into individual playing fields, while others were lumped together with their neighbors.

The last explanatory variable was <u>not</u> the product of existing research but rather an independent development: *tGSSR*. It attempts to account for the high premium that homebuyers with children frequently place on homes in specific school attendance zones—or, to a lesser extent, entire school districts—considered desirable.[60] To produce such a figure for each property, the attendance zones for elementary, middle, and high schools in each of the three school districts in the study area were drawn (and traced, extensively, from the National Center for Education Statistics' indispensable map on ESRI's "Living Atlas" sharing platform).

Each attendance zone's corresponding level (at each of the three levels of schooling) was searched for on GreatSchools.org, a school-rating website whose school ratings are embedded by Zillow in the pages of homes listed therein. It was assumed that this would make it fairly impactful. At the same time, the use of quantitative scores rather than—as was originally tested—categorical attendance zones would keep the regression model efficient, free of singularities, and minimally-impacted by multicollinearity. The three GreatSchools scores, represented by intermediate variables *eGSSR*, *mGSSR*, and *hGSSR*, were totaled to produce *tGSSR*.

Regression Analysis

In producing regression models for this study, there were two basic steps. The first, the identification of a simple yet significant model, proved straightforward; Bellinger's regression variables required only limited modifications for application to. The second step was to test the six types of noise variable for their respective levels of significance. The first of these was simply L_{MAX}, the foundation of all of the others. Each of the four 'marginal noise over an assumed threshold' variables, as they might be

[60] For a particularly-dramatic example of parents' efforts to ensure that their children receive a high-quality education, see Self, "A Mom Got Her Kid into a Top Columbia School by Paying a Stranger's Water Bill."

described—*ExposureOver50dB* being the first of the four—was also tested. Lastly, in recognition of Walker's use of a similar (albeit L_{DNL}-based) metric, a categorical variable called *IsOver65dB* was also tested.

Richland County's assessor website does not list—and this study's dataset therefore does not include—a single "appraised value" field, though one could have been reconstituted by adding the building, agricultural, and non-agricultural values of each property.[61] Moreover, because a larger agricultural value deflates the taxable worth of the property and therefore lowers government revenues from property taxes—a key ingredient in this endeavor—the most sensible and conservative approach would be to regress against each property's taxable value.

First, however, all properties with a taxable value of $0 were removed.[62] it is entirely possible that utilizing some other metric in place of taxable value would have resulted in a higher adjusted R^2 value. Indeed, *substantial* regression testing over sale price data proved highly successful earlier in this study. However, as taxable value is the most appropriate metric to use, it was decided to use only it. After all, that value represents the property tax base on which city, county, and schools must substantially subsist. As will be outlined in Part IV, those funds are, under the plans of this paper, to additionally be administered by MTIPIA, the public authority proposed and described in that section.

[61] The assessor site's inclusion of each parcel's agricultural and non-agricultural value reflects the fact that South Carolina offers substantial property tax deductions on agricultural land.

[62] there were many such properties, as might be expected of an area centered on the state capital and therefore containing many non-taxpaying residentially-zoned properties: long-term care/treatment facilities operated by the South Carolina Department of Mental Health, for instance.

Regression testing in R:

The first model in which the completed dataset of 109,615 residential properties was regressed was an adaptation of Bellinger's. Besides its greater scope, there are three important contrasts between it and Bellinger's work. First, because a large number of the parcels in this study's dataset were listed by the county as having an acreage of zero,[63] the total square footage variable—which is understandably correlated with actual acreage—had to bear much of the explanatory burden that ought to have been borne by the acreage variable. Second, there is no real analogue to Bellinger's *"RiverView"* in this dataset as the third contrast renders it unnecessary.

Third, the manual subdivision of data that Bellinger used as a proxy for the effects of terrain on noise was not replicated. Bellinger's study has little choice but to include such a step due to the limited applicability of its 'model' to the area it studied. Unfortunately, whereas that area includes substantial topographical variation, the existing study on which Bellinger relied was produced in Iowa, and involved a crossing surrounded by characteristically-flat terrain.[64] The enormous disconnect between the topography of Bellinger's study area and the study from which it estimated noise exposure in that area therefore explains Bellinger's need to intervene by splitting that dataset. This study—with its purpose-modelled noise data—needs no such adjustment.

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[63] The working theory explaining this is that it occurs when developers gain approval from Richland to subdivide existing parcels (as they have been doing at breakneck speed for a few years now), and sell / build the home before the county has managed to catch up with the necessary updates to its own parcel fabric. Each parcel's metes-and-bounds description, after all, must generally be interpreted by a human GIS editor, and the frequent batches of dozens of subdivision homes likely being dropped into the Richland GIS department's to-do pile by present development pace. This could be entirely incorrect.

[64] Gent, Logan, and Evans, "Automated-Horn Warning System for Highway-Railroad Grade Crossings."

By contrast, this paper—despite also taking a two-dimensional approach to sound modelling, albeit a more sophisticated one—has so expansive a modelling effort backing it that such manual adjustments are not necessary. Each regression model applied the variables listed in Table 3. Only one of the sound variables listed in that table was used in each model. Each of the other variables was used in all six models.

Table 3: Variables utilized in regression analysis

Category	**Name**	**Format**	**Meaning**
Noise exposure	*MAX_SPL_basic*	A rational number between 0 and 144 (actual highest value ≈ 123) dB(A)	Highest level of horn exposure the property regularly (≥1 occurrence / day), dB(A)
	ExposureOverXdB	A rational number between 0 and (143 – *X*) dB(A)	Highest excess regular exposure to train horn noise over an assumed background level *X*
	IsOver65dB	A Boolean value (TRUE/FALSE)	Whether the point's L_{MAX} is over 65 dB(A)
Home	*TotalSF*	A rational number ≥ 0	The total area of the home in square feet (can include some types of outdoor spaces like decks)
Lot Area	*ParcelAcreage*	A rational number ≥ 0	The area of the parcel in acres. Note that many of these = 0 (see footnotes of page 40 for discussion)
Home	*ActYrBlt*	An integer between 1740 and 2020, inclusive	Year home was built per the "Actual Year Built" field on its Richland assessor page
School	*tGSSR*	Integer between 0 and 30, inclusive	Σ of the GreatSchools.org scores of the elem., mid., and high schools for which each property is zoned
Natural	*mean_gridcode*	A rational number between 0 and 100, inclusive	The percentage of the census block in which the property lies that is covered by tree canopy (x 100)
Water	*Lake 100*	A Boolean (as text, = "Y" or "N")	Whether the property is within 100m of a named lake (see passage beginning on page 35 for further explanation)

The resulting model was iterated to produce one version with each of the variables in the category "Noise exposure." See Figure 2 through Figure 7 (located on pages 43 through 45) for the graphical outputs of each of those models' summaries in R.

```
Call:
lm(formula = Taxable_Val ~ MAX_SPL_basic + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5739830   -36360   -12714    19299  7521867

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)    395746.456  26709.030  14.817  < 2e-16 ***
MAX_SPL_basic    -195.329     27.499  -7.103 1.23e-12 ***
TotalSF            54.272      0.116 467.920  < 2e-16 ***
Parcel_Acreage    139.532     14.645   9.527  < 2e-16 ***
ActYrBlt         -232.037     13.281 -17.471  < 2e-16 ***
tGSSR            5916.429     58.682 100.821  < 2e-16 ***
mean_gridcode     297.207     16.909  17.576  < 2e-16 ***
Lake100        132809.183   2043.594  64.988  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 97220 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7131,    Adjusted R-squared:  0.713
F-statistic: 3.891e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 2: R output of the first (base) regression model—in which L_{MAX} ("MAX_SPL_basic") is the noise variable

```
Call:
lm(formula = Taxable_Val ~ ExposureOver50dB + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5736567   -36450   -12704    19387  7526580

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       4.332e+05  2.622e+04  16.521   <2e-16 ***
ExposureOver50dB -3.989e+02  3.036e+01 -13.140   <2e-16 ***
TotalSF           5.425e+01  1.159e-01 467.959   <2e-16 ***
Parcel_Acreage    1.391e+02  1.463e+01   9.507   <2e-16 ***
ActYrBlt         -2.540e+02  1.326e+01 -19.165   <2e-16 ***
tGSSR             5.928e+03  5.849e+01 101.348   <2e-16 ***
mean_gridcode     2.806e+02  1.668e+01  16.824   <2e-16 ***
Lake100           1.331e+05  2.043e+03  65.152   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 97170 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7134,    Adjusted R-squared:  0.7134
F-statistic: 3.897e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 3: R output of the second model (noise variable = excess peak exposure over 50 dB(A))

```
Call:
lm(formula = Taxable_Val ~ ExposureOver55dB + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5735702   -36531   -12657    19418  7529695

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       4.499e+05  2.611e+04   17.23   <2e-16 ***
ExposureOver55dB -5.263e+02  3.307e+01  -15.91   <2e-16 ***
TotalSF           5.424e+01  1.159e-01  468.07   <2e-16 ***
Parcel_Acreage    1.394e+02  1.463e+01    9.53   <2e-16 ***
ActYrBlt         -2.625e+02  1.322e+01  -19.86   <2e-16 ***
tGSSR             5.926e+03  5.842e+01  101.45   <2e-16 ***
mean_gridcode     2.745e+02  1.661e+01   16.53   <2e-16 ***
Lake100           1.332e+05  2.042e+03   65.23   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 97130 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7136,    Adjusted R-squared:  0.7136
F-statistic: 3.901e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 4: R output of the third model (noise variable = excess peak exposure over 55 dB(A))

```
Call:
lm(formula = Taxable_Val ~ ExposureOver60dB + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5736088   -36568   -12640    19302  7531971

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       4.494e+05  2.596e+04  17.313   <2e-16 ***
ExposureOver60dB -6.583e+02  3.853e+01 -17.084   <2e-16 ***
TotalSF           5.424e+01  1.159e-01 468.110   <2e-16 ***
Parcel_Acreage    1.403e+02  1.462e+01   9.593   <2e-16 ***
ActYrBlt         -2.626e+02  1.315e+01 -19.965   <2e-16 ***
tGSSR             5.913e+03  5.836e+01 101.324   <2e-16 ***
mean_gridcode     2.725e+02  1.658e+01  16.432   <2e-16 ***
Lake100           1.330e+05  2.041e+03  65.179   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 97110 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7137,    Adjusted R-squared:  0.7137
F-statistic: 3.903e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 5: R output of the fourth model (noise variable = excess peak exposure over 60 dB(A))

```
Call:
lm(formula = Taxable_Val ~ ExposureOver65dB + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5737907   -36441   -12653    19252  7532461

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       4.341e+05  2.571e+04  16.883   <2e-16 ***
ExposureOver65dB -8.425e+02  4.883e+01 -17.252   <2e-16 ***
TotalSF           5.424e+01  1.159e-01 468.141   <2e-16 ***
Parcel_Acreage    1.413e+02  1.462e+01   9.663   <2e-16 ***
ActYrBlt         -2.553e+02  1.304e+01 -19.573   <2e-16 ***
tGSSR             5.894e+03  5.833e+01 101.061   <2e-16 ***
mean_gridcode     2.745e+02  1.655e+01  16.584   <2e-16 ***
Lake100           1.327e+05  2.041e+03  65.003   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 97110 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7137,    Adjusted R-squared:  0.7137
F-statistic: 3.903e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 6: R output of the fifth model (noise variable = excess peak exposure over 65 dB(A))

```
Call:
lm(formula = Taxable_Val ~ IsOver65dB + TotalSF + Parcel_Acreage +
    ActYrBlt + tGSSR + mean_gridcode + Lake100, data = FinalData)

Residuals:
     Min       1Q   Median       3Q      Max
-5739572   -36577   -12681    19401  7529670

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     4.222e+05  2.596e+04  16.259   <2e-16 ***
IsOver65dBTRUE -8.131e+03  6.140e+02 -13.244   <2e-16 ***
TotalSF         5.425e+01  1.159e-01 467.902   <2e-16 ***
Parcel_Acreage  1.397e+02  1.463e+01   9.547   <2e-16 ***
ActYrBlt       -2.498e+02  1.316e+01 -18.982   <2e-16 ***
tGSSR           5.929e+03  5.850e+01 101.365   <2e-16 ***
mean_gridcode   2.968e+02  1.644e+01  18.060   <2e-16 ***
Lake100         1.334e+05  2.043e+03  65.281   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 97170 on 109606 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.7134,    Adjusted R-squared:  0.7134
F-statistic: 3.897e+04 on 7 and 109606 DF,  p-value: < 2.2e-16
```

Figure 7: R output of the sixth model (noise variable = whether the peak excess exposure is greater than 65 dB(A))

The results of these models are summarized in Table 4.

Table 4: A summary table comparing the performance of the six versions of the model used (with six different noise metrics). Note that all six had the same p-value: < 2.2 x 10^{-16}. Despite their equal number of explanatory variables, Adj. R^2 is listed to permit easy comparison with models of more or less complexity.

Sound variable	**Estimated coeff. ($)**	**t-value**	**Pr(>|t|)**	**F-stat. of model**	**Adjusted. R^2**
L_{MAX}	-195.329	-7.103	1.23 x 10^{-12}	3.891 x 10^4	0.713
Excess exposure over 50 dB(A)	-3.989 x 10^2	-13.140	< 2 x 10^{-16}	3.897 x 10^4	0.7134
Excess exposure over 55 dB(A)	-5.263 x 10^2	-15.91	< 2 x 10^{-16}	3.901 x 10^4	0.7136
Excess exposure over 60 dB(A)	-6.583 x 10^2	-17.084	< 2 x 10^{-16}	3.903 x 10^4	0.7137
Excess exposure over 65 dB(A)	-8.425 x 10^2	-17.252	< 2 x 10^{-16}	3.903 x 10^4	0.7137
Is exposed to >65 dB(A) peak horn noise	-8.131 x 10^3	-13.244	< 2 x 10^{-16}	3.897 x 10^4	0.7134

Note that excess exposure over 65 dB(A) performed as well as or better than any of the other five across every single evaluation metric. Despite that, the overall performance of each of the models is close enough to justify inclusion of all six approaches in the next step of this analysis: quantifying the total current cost of horn noise exposure, or L_{COST}. This figure—in all six of its manifestations—should not be mistaken for the similar figure ($L_{COST_{\Delta QZ}}$) in Part III; the latter describes the total reduction in noise cost that might be expected from the implementation of that part's proposed plan of improvements.

The procedure for determining the total current loss of appraised value from train horn exposure is straightforward: the sum of each of the 5 quantitative metrics (the sum, that is, of each of their impact metrics) was multiplied by the estimated coefficient of that metric. In the case of the single categorical variable, the estimated coefficient was simply multiplied by the number of properties at which it = TRUE. Computing this total estimate for all six of the noise metrics tested provides an idea of the minimum statistically-supported total loss Table 5 lists the inputs and resulting outputs—the estimated total impact figures—of this step.

Table 5: The total reduction in property values (assessed) implied by the regression model of each of the six sound metrics tested. N.b. that the first column describes each variable—it does not necessarily list the variable's actual name (as used in R, etc.). This substitution was made to ensure ease of reading.

Sound variable (described)	**Impact metric, Σ**	**Estimated coefficient**	**Estimated impact**
L_{MAX}	7045013.06	-195.329	$1,376,095,356.00
Excess exposure over 50 dB(A)	1631540	-3.989×10^2	$650,821,306.00
Excess exposure over 55 dB(A)	1160571.38	-5.263×10^2	$610,808,717.29
Excess exposure over 60 dB(A)	765920.0852	-6.583×10^2	$504,205,195.25
Excess exposure over 65 dB(A)	466981.5596	-8.425×10^2	$393,431,964.30
Exposed to > 65 dB(A)	51456	-8.131×10^3	$418,388,736.00

In summary, the six regression models tested—each which is significant in its own right—suggest that, as a result of the train horn noise[65] to which they are exposed, Richland County's taxpaying, single-family residential properties *alone* lose at least $393 million in combined value. That comes in addition to the damaged physical health, worsened educational outcomes, and psychological harm that also result.[66]

That alone is cause for action.

[65] As measured in terms of peak exposure when that exposure > 65 dB(A).

[66] Passchier-Vermeer and Passchier, "Noise Exposure and Public Health."; Haines et al., "Chronic Aircraft Noise Exposure, Stress Responses, Mental Health and Cognitive Performance in School Children."

PART III: THE PRICE OF PEACE

> "Shall we make our cities livable for ourselves and our posterity? Or shall we by timidity and neglect damn them to fester and decay?"
>
> *-Lyndon Baines Johnson, 1966*[67]

Introduction

From here, this study departs from the two existing works to which it owes so much. Neither Walker nor Bellinger's study sought to apply its conclusions to a specific project or proposal, though Bellinger does note that the estimated reduction in the value of affected homes could be put to use in a cost-benefit analysis.[68] This part does as much.

One of the more common objections raised to Quiet Zone proposals is that their expense is excessive. In Bismarck, North Dakota, voter objections to the price tag of a proposed plan of Quiet Zones ended its prospects.[69] A local paper in Ark Valley, Kansas mused that "It [the tradeoffs of Quiet Zones] may be an issue we discuss until the end of time," an argument it raised under the fairly typical headline "Quiet [Z]ones worth the cost?"[70] In Ann Arbor, Michigan, voter opposition was still more direct, with 73% of online survey responses preferring inaction to progress.[71] Within the study area of this paper, the issue of cost has derailed plans for Quiet Zone implementation at least once.[72]

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[67] Johnson, "Special Message to the Congress Recommending a Program for Cities and Metropolitan Areas."

[68] Bellinger, "The Economic Valuation of Train Horn Noise," sec. Abstract.

[69] "New Proposal for 'quiet' Zone in Bismarck."

[70] "Quiet Zones Worth the Cost?"

[71] Stanton, "Ann Arbor Drops $7M Plan for Train Horn 'Quiet Zone' - Mlive.Com."

[72] "Blow Horns, No More: Establishing Railroad Quiet Zones | Community and Economic Development - Blog by UNC School of Government."

Many of these cases reflect a failure to adequately convey the benefits—particularly to property values—of Quiet Zones to the electorate. Other proposals' failure to progress can be ascribed to the fact that most QZ budgets include some payment to the railroad that owns the right-of-way—an action that hardly promises to be popular, however justified it may be on legal grounds.[73] The petering out of other QZ proposals on financial grounds is not a function of the cost of the infrastructure, nor the cost of compensating railroad(s), but rather a byproduct of perceived liability, particularly in the form of increased insurance costs, as in Manteca, California.[74]

Manteca's insurance 'problem,' for its part, existed only because 1) Manteca's QZ proposal included so-called Alternative Safety Measures (ASMs), which—as will be discussed shortly—the FRA disincentivizes due to their lower expected efficacy, a fact that surely inflated the projected insurance costs and 2) Manteca is part of an insurance pool of 20 California cities, and the other 19 would have had to unanimously agree to Manteca's increased coverage under its plan. Had Manteca simply developed a QZ proposal that did not require ASMs, its plan would not have faced so insurmountable a hurdle as the veto power of 19 disinterested other governments.

Similarly, had Ann Arbor refrained from asking the general public to exercise an uncodified veto power over a project already greenlit by its duly-elected representative government (surely a step taken only out of a politician's undying terror of doing anything unpopular), it, too, might have successfully implemented a Quiet Zone and

[73] The track is, after all, the property of the railroads, and they can expect some degree of inconvenience during QZ construction, particularly if it occurs at the glacial pace all too typical of American roadworks

[74] "Silencing Horns May Be Costly."

reaped its benefits. Part of the blame in these cases may be assigned to the FRA for writing regulations that require a dizzying list of entities to arrive at some nebulous consensus before one shovel can strike the earth, but both Ann Arbor and Manteca added further veto power to additional entities—and they did not have to.

The cost of implementing Quiet Zones need not be steep. Many of the costlier—and, frequently, unrealized—past proposals for Quiet Zones across America are unnecessarily expensive. What accounts for the gap between the very costly plans that elected officials so often propose and the cheaper, more minimalistic plans they *could* propose? Some of this phenomenon may be attributable to the agency problem inherent to public-works spending directed by elected officials who do not personally pay for those works—especially if the private sector recipients of public works contracts thus funded express their gratitude during the next campaign cycle. More importantly, the tendency to suggest more expensive plans that face little prospect of success reflects politicians' terror of being associated with an accident, or, God forbid, *death* at a silenced crossing. To hedge against such a tragedy—which would undoubtably kill the career of the sponsoring official if not the road user who disregards the many warning signals of QZ crossings—elected decision-makers too often simply agree to the most elaborate version of QZ suggested by their technical staffs. As that usually happens to be the most expensive such option, such a choice often dooms QZ proposals to stonewalling by opponents of 'wasteful' spending.

Part IV of this paper will discuss an alternative political and fiscal approach to the problem of building consensus around QZ proposals; incidentally, the envisioned alternative approach also does much to insulate technical decision-making about Quiet

Zones from the whims and furies of the public and the anxieties of politicians. The hope is that doing so might prevent the ‘death from a thousand cuts’ that befalls the overwhelming majority of such proposals. For its part, this section, Part III, will strive to minimize the cost of every one of its proposed Quiet Zones.

Identifying Quiet Zones

To maximize the viability of the proposed program of Quiet Zones for Richland County, this study does not advocate for the inclusion of every one of that area’s approximately two hundred open, at-grade road-rail crossings. Of those crossings, only about half have two-quadrant gates and flashing lights—the two safety devices required at every crossing in a Quiet Zone per FRA rules.[75] As a rule, crossings with such features are public; given the great expense of their initial installation, few if any private crossings in the entire county possess them. That patten is fortunate, as the second principle guiding this paper’s identification of Quiet Zones is that the number of private crossings be minimized. While federal regulations permit the inclusion of such crossings in Quiet Zones, their inclusion greatly complicates matters. Unlike the rules governing the establishment of QZs at public crossings, which include a clear, established (if somewhat complex) formula to determine QZ eligibility, the FRA regulations dealing with private crossings call for an assessment of each private crossing by a cumbersomely-large group of individuals.

Specifically, the CFR requires a “diagnostic team” to evaluate any private crossings within the QZ candidate area and directs that team to answer at least twenty

[75] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings.

questions about such crossings, fourteen of which require a site visit by the entire team. That team generally includes representatives of the railroad(s) that own and/or operate along the trackage in question, representatives of state, local, and (where it exists) county government and—virtually without exception—members of the private planning/engineering/consulting firms hired to manage such efforts.

Unsurprisingly, adhering to this portion of the rules adds substantial time, money, and complexity to the QZ planning process. In part, this cost and difficulty results from the apparent inability of any level of government anywhere in the country to implement new Quiet Zones without expansive and expensive private-sector assistance. While private crossings were not automatically excluded from consideration in developing the proposed program of Quiet Zones, they *were* heavily disfavored. As a rule, private crossings in less built-up areas—i.e., where there are fewer persons impacted by noise and less potential loss of property value—were excluded from consideration.

This policy is further supported by the generally-higher operating speeds of trains in those areas. For several reasons, a faster-moving train presents a greater potential hazard than a slower one, *ceteris paribus*. In short, a faster train has a greater stopping distance, lower effective visibility from the cab, and, since the volume of the horn does not change with speed, less horn time at any given volume.[76] The diagnostic team—whose mere existence already presents a far greater risk of mission creep, delays, and cost overruns than the strictly formulaic approach utilized at public crossings—could complicate the implementation of QZs to a greater degree at higher-speed private

[76] When a train is travelling relatively faster, the 15-20 seconds of horn use are stretched out over a lengthier span of track and therefore extend further along the right-of-way.

crossings than at lower-speed ones. Fortunately, the segments of track passing through the more heavily-populated areas of the county typically have a lower speed limit than those in outlying exurban areas (see Figure 8 for a county-level view of maximum reported track speeds and Figure 9 for a zoomed-in view of the same in the center of Columbia).

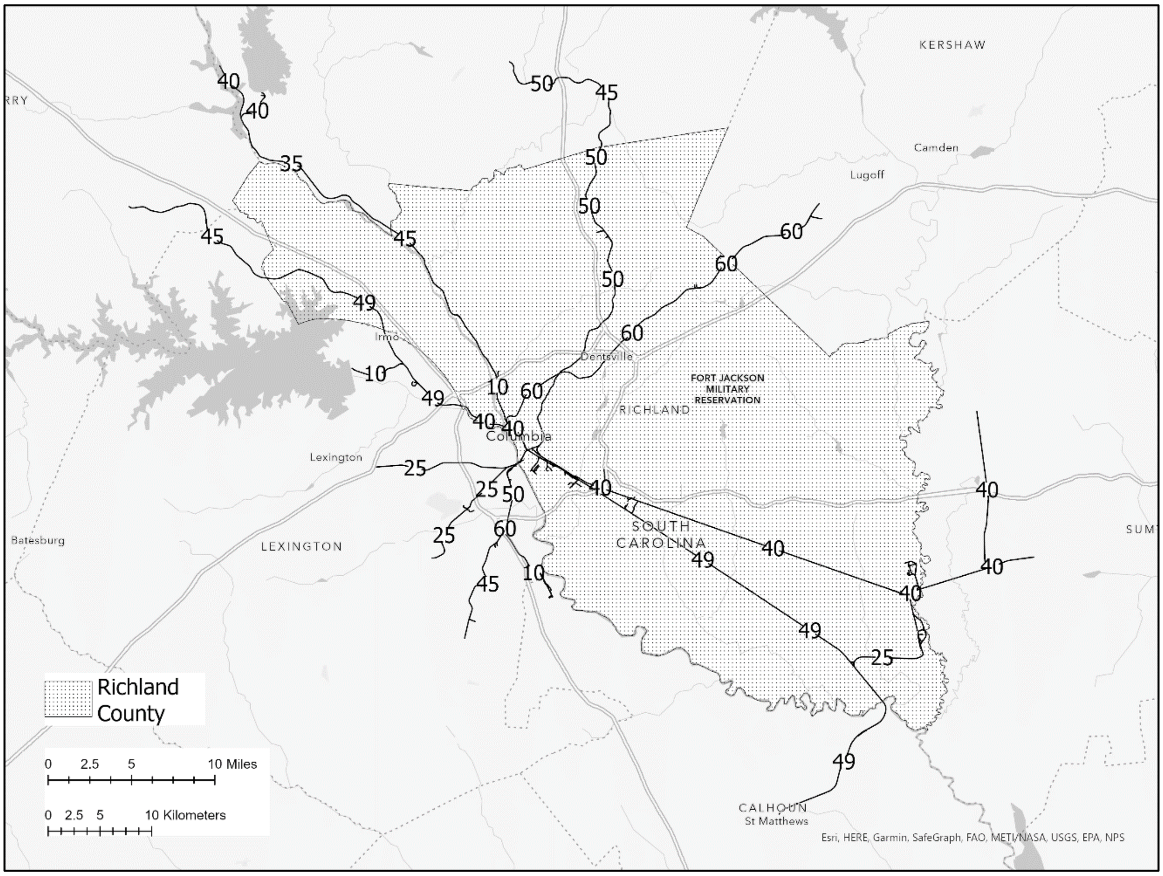

Figure 8: Maximum reported train speed along trackage per FRA inventory file of nearest at-grade crossing (in miles per hour)

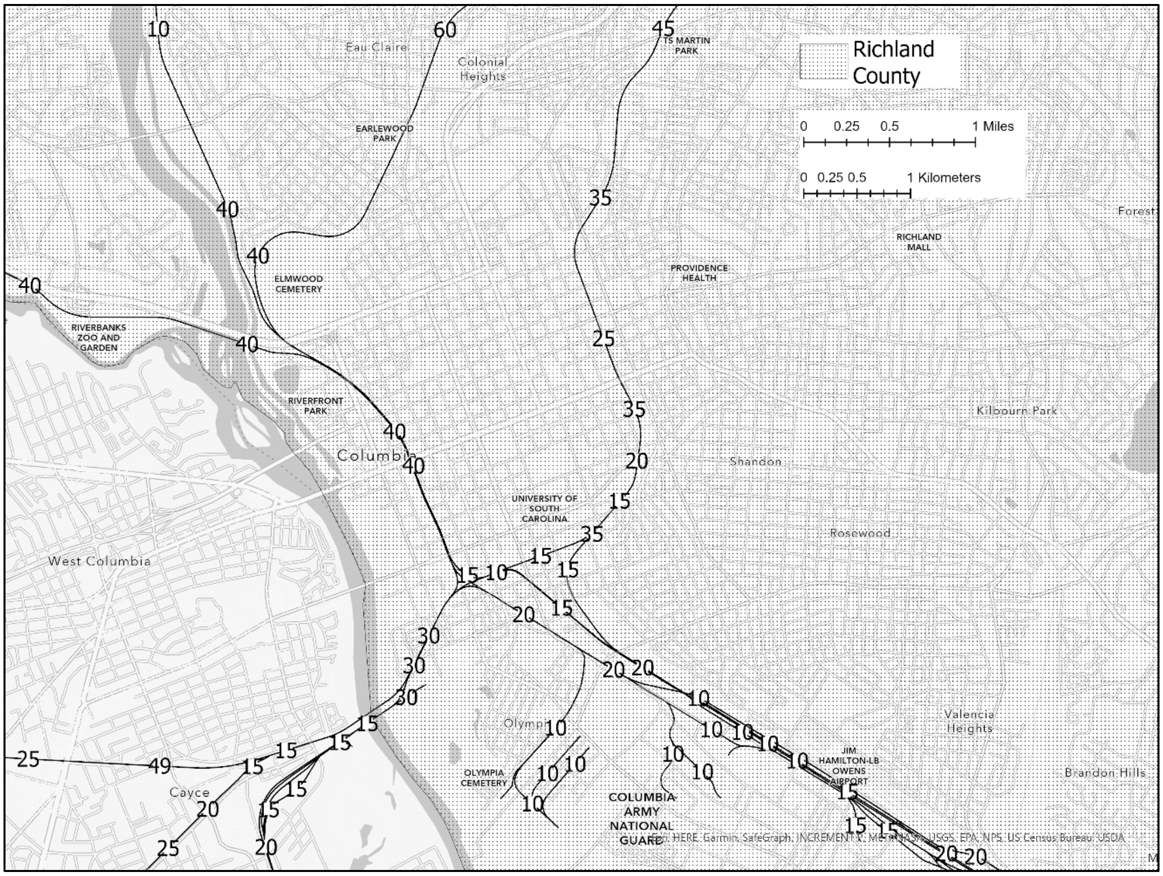

Figure 9: Zoomed-in view of the maximum reported train speed along trackage per FRA inventory file of nearest at-grade crossing (in miles per hour)—in this instance, in the downtown Columbia area

The third and final consideration that restricted the identification of potential QZs in the study area is a product of a rule within the Quiet Zone regulations stating that "If more than one New Quiet Zone or New Partial Quiet Zone will be created within a single political jurisdiction, ensure that each New Quiet Zone or New Partial Quiet Zone will be separated by at least one public highway-rail grade crossing."[77] While the "within a single political jurisdiction" clause may offer a workaround—particularly in this specific case, as the boundaries of the various municipalities in the study area are complex—the

[77] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings, sec. (§ 222.35(a)(1)(iii).

safe, conservative approach to this requirement is to adhere to it rather than attempting to out-lawyer the federal government.

In practice, all three rules work in concert to greatly simplify the selection of combinations of crossings. In general, each of the Quiet Zones this study proposes consists of an unbroken series of public crossings (satisfying the third rule), each of which has, at minimum, flashing lights and two-quadrant gates (per the first rule) and which is separated from the next Quiet Zone along its right-of-way by at least one public crossing. Since private crossings are usually excluded and crossings without two-quadrant gates and flashing lights are always excluded, they tend to lie between Quiet Zones. Since the unquieted crossings between Quiet Zones need only to be public, those crossings that are public yet which lack the minimum required equipment are ideal candidates for that role, and typically fill it.

Federal Alphabet Soup: QZRI, RIWH, NSRT, ASMs, and SSMs

Basic requirements

Two-quadrant gates and flashing lights at every crossing are not the only hurdles to Quiet Zone eligibility. For a specific new[78] Quiet Zone outside of the privileged 'Chicago Region' to gain approval from the FRA, it must have a Quiet Zone Risk Index (QZRI) that is less than or equal to the National Significant Risk Threshold (NSRT). The QZRI must also be less than or equal to the Risk Index With Horns (RIWH). The FRA updates the NSRT biannually; as of the completion of this study, the most recent update

[78] "New" in the context of QZs (outside of the Chicago region) means that the QZ in question does not belong to the category of "pre-rule" zones described in 49 CFR § 222.9.

was on January 8, 2021.[79] That update raised the NSRT, making Quiet Zone status comparatively easier to obtain than before the update.

While the task of calculating the QZRI and RIWH of a particular set of crossings is not mathematically difficult, it is time-consuming. Fortunately, the FRA has produced a web-based calculator that does most of the work, the "Quiet Zone calculator." Furthermore, the FRA calculator pulls up the relevant data for each crossing from the agency's crossing inventories. It is therefore unsurprising that virtually every member of the cottage industry around Quiet Zone implementation uses the calculator in their reports, no matter how expensive, technical, or formal the rest of that report may be.

If the QZRI is too high for the inputted set of crossings to collectively achieve Quiet Zone status, there are two types of improvements that can be utilized to remedy the situation. One set of improvements are collectively called "Supplementary Safety Measures," (SSMs); the other set are "Alternative Safety Measures" (ASMs). ASMs have numerous disadvantages. A Quiet Zone that relies on ASMs must be specifically approved by the FRA, which requires a detailed report on the crossing(s) in question. By contrast, a Quiet Zone that utilizes only SSMs merely needs to fulfill a list of requirements—there is comparatively little need to wait on federal regulators to respond. If the ASMs are not approved, of course, the delay they produce is even greater.

Furthermore, ASMs are far harder to budget and plan for than SSMs because the latter are far, far more common (as the FRA intended). A public authority—or student—wishing to estimate the cost of a particular Quiet Zone without the aid of an engineering

[79] United States Government Publishing Office et al., Adjustment of Nationwide Significant Risk Threshold. Notices.

staff can nonetheless do so by utilizing the many existing professional estimates of SSM costs. There are far fewer such existing estimates for ASM costs. The heightened risks of delay and/or modifications that ASMs present (because they require case-by-case review by the FRA) make it even more difficult to accurately forecast their costs.

Lastly, some forms of ASM—in particular, what the FRA calls "non-engineering ASMs"—require periodic reevaluation in the years following approval. That requirement reflects the less-predictable outcome of non-engineering ASMs, which can consist of, for instance, the use of "[a] sustainable public education and awareness program." It is easy to imagine how such a program could have vastly diverging outcomes when utilized by two locations within the economically and culturally heterogenous United States. Woe betide the elected official who greenlights spending on Quiet Zones, only for the FRA to revoke QZ status as a result of ASM-associated reevaluation. Their relative rarity is understandable given that consideration.

This study recommends no ASMs. The elevated risks—of cost overruns, delays, and even FRA revocation of Quiet Zone status—that they carry are disqualifying. Instead, in instances where it has proven necessary to lower the QZRI of suggested Quiet Zones, this study identifies and recommends the lowest-cost combination of SSMs that will have such an effect. The recommended plan of Quiet Zones includes four types of SSM: permanent crossing closure (used sparingly), installation of four-quadrant gates, construction of "mountable medians with reflective traffic channelization devices," and of “non-traversable curb medians with or without channelization devices,” in the terminology of the FRA’s Quiet Zone Calculator site.[80]

There are other SSMs available. Many are mere refinements of the four-quadrant gate SSM. One option, for instance, is the installation of four-quadrant gates *and* vehicle detection sensors to warn train drivers if a particularly-determined lawbreaker manages to get stuck *between* the entry and exit gates.[81] This study does not utilize those SSMs; although they were evaluated during the QZRI calculation phase of planning, their marginal costs far outstrip their marginal benefits.

The only other SSMs on offer are temporary crossing closure, conversion of streets from two-way to one way, and grade separation. Temporary closures are only of use if a public authority wants to stagger its installation of improvements, and the potential backlash they present is too great a risk—after all, if the crossing were utilized by the public so little that they would not complain in numbers, the crossing could simply be *permanently* closed.

Conversion of a street from two- to one-way is unlikely to produce significant cost savings as contrasted with four-quadrant gate installation since the crossing-arm mechanisms would still likely require relocation and rewiring. Moreover, the use of a one-way street in place of an otherwise-identical two-way street is inconsistent with present norms of planning (good planning that strives to make cities livable, that is, as one-way conversion might be consistent with the kind of cars-over-people planning that

[80] “FRA - Quiet Zone Calculator v. 2.2.2,” sec. “SSM Codes”; 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings Appendix B.

[81] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings Appendix A § 2.

gutted so many cities in the mid-20th century).[82] Such an alteration would, moreover, alter the relative connectivity of different areas, a vital consideration for public transit, school buses, commercial traffic, and emergency services, to name a few impacted services. Implementing it in good faith would therefore call for substantial study and public comment. The former carries the risk of cost overruns; the latter would inevitably delay or even halt progress if the public become sufficiently incensed.

Finally, grade separation of crossings is—as documented in Part I—inconsistent with this study's stated goal of making Quiet Zones as affordable as possible, Moreover, grade separation can introduce harms to quality of life that do not result from Quiet Zone implementation. These, too, are discussed in Part I. One additional factor worth considering is implementation time. The complexity of grade separation renders it vulnerable to delays even if all goes according to plan, in which event such a project is still a slow one. Considering the nearly two decades that have passed since the concept of placing Quiet Zones in Columbia / Richland was first suggested in an official capacity, this alone renders grade separation an unacceptable option.

Choosing SSMs for the proposed Quiet Zones

Initial analyses of Richland County level crossings—governed by the guiding principles previously discussed and with a view to maximizing the reduction in noise exposure for as many people and homes as possible—yielded over a dozen prospective Quiet Zones within the county. Each of them was then modelled in the FRA's Quiet Zone Calculator to determine the relative cost it might incur. The dollar amounts at this stage,

[82] Speck, *Walkable City*, 177–80.

it should be noted, had no absolute significance, as a pop-up disclaimer announces to anyone who logs on to the site. The figures were utilized only to enable identification of any crossings or entire Quiet Zones whose marginal benefits (in noise reduction) could not justify its marginal costs.[83]

The actual process of identifying which, if any, SSMs ought to be utilized was straightforward. If the calculator indicated that the proposed Quiet Zone would have a QZRI under the NSRT, it was simply added to the list of QZs to advance to the next step of analysis. If the calculator indicated that SSM installation would be needed to reach that threshold, the next step was to compute the impact of installing the cheapest SSM (a mountable median, i.e., “mountable median curb with reflective traffic channelization devices”) on the crossing with the worst existing QZRI. If the QZRI was still too high, the task was repeated, with the *two* crossings with the worst existing QZRIs receiving the cheapest possible intervention. This process continued as long as necessary, always working from cheapest intervention to most expensive and from worst to best crossing (per their QZRIs). In cases where the threshold could be passed with by multiple permutations of the same number of interventions, the policy was to design the QZ to place the interventions in question at the crossings with the greatest amount of road

[83] The marginal cost-benefit ratios’ application in this manner informed the decision to exclude the two crossings between the “Benedict – Greenview” and “Wales Garden – Olympia” QZs , as the expected worst-case cost of modifying the pedestrian crossing in that pair was determined to exceed the marginal benefit of their inclusion. Of course, it is possible that approval could be gained for their inclusion without modification since pedestrian crossings are essentially exempt from 49 CFR § 222. However, because this *particular* pedestrian crossing is close to numerous bars, it was felt that the risk of death or injury presented in this case (due to the diminished capacity of pedestrians in the area at particular times) would call for the implementation of costly pedestrian crossing improvements, even grade separation. They were therefore excluded (the other crossing was excluded in order to comply with § 222.35).

traffic. The assumption underlying this guideline was that doing so would potentially maximize the prevention of injury and death.

It should be noted that both regulatory and engineering constraints limited the number of permutations of SSMs that could be tested with each prospective QZ. The FRA-mandated minimum length of either type of median curb is 100ft (≈ 30.4m), or as little as 60ft (≈20m) if there is a residential driveway between 60 and 100 feet from the crossing. If there is a commercial driveway, a public road, or more than four residential driveways within 100 feet of the crossing, it cannot be upgraded with either type of median curb. This constraint had an enormous impact because so many railroad tracks in South Carolina (as in California and New England) are paralleled by one or more roads just a short distance away. Crossings near such roads could not receive either of the SSMs that utilizes a median curb.

Engineering considerations further limited the number of SSM options. A median curb, even the narrowest such curb, has a nonzero width, so there must be room for it in the existing roadway—without narrowing existing lanes to less than about 12 feet, which at least one SCDOT publication indicates is a "standard lane width."[84] Neither lane count reductions (a "road diet") nor removal of existing streetside parking was considered as an option, though doing so would have eliminated engineering obstacles to median installation. The political problem posed by threatening either perceived road capacity or free parking supply disqualifies such road modifications. After all, this study's

[84] South Carolina Department Transportation, *The South Carolina Manual on Uniform Traffic Control Devices for Streets and Highways*, secs. 3-2.02.

recommendations are carefully designed to avoid the pitfalls that have thwarted other QZ proposals elsewhere.

With the possible exception of one or two crossings that might require a few inches' additional pavement width within the existing legal right-of-way—only an actual engineering study by a licensed engineer and surveyor can conclusively determine whether this is the case—widening roads to enable median curb construction was not considered. Widening any of the roads in question more than a few inches would require the relocation of those crossings' existing two-quadrant gate arms; the cost of such an alteration approaches the cost of installing four-quadrant gates, so it is simply not an option within the guiding principles of this study.

The restrictions on four-quadrant gate installations, by contrast, are virtually nonexistent. If any of the roads for which improvements are suggested were wider than about 64 feet (19.5m), the installation of four-quadrant gates might not be viable, as the Federal Highway Administration (FHWA) indicates that the maximum length of a single gate arm is around 32 feet when the gate is not installed by the railroad itself.[85] Analysis of other Quiet Zone proposals in which railroads were tasked with such construction work found a consistent tendency for the compensation offered to / requested by them to clearly exceed market rates for the same work. There are further reasons to minimize railroads' direct involvement in SSM construction as much as possible; these are discussed in Part IV alongside other political and tactical considerations.

[85] Ogden and Cooper, "Highway-Rail Crossing Handbook, 3rd Edition."

Only four crossings within the proposed Quiet Zones are slated for closure under this study's proposal. One is private and serves as an alternate, unpaved driveway for an industrial facility; the primary, paved driveway of that facility would remain open.

The other private crossing slated for closure serves a presently-undeveloped wooded lot, in the center of which lies a single home. The location of the larger parcel in the booming Lake Murray area suggests that it will be developed at some future point. That prospect provides the owners of the 'nail house' in its center with a powerful incentive to sell it to the owner(s) of the larger parcel, enabling development. In fact, the home recently burned to the ground, so it is not inconceivable that its owners might be more willing to sell their property to the owner(s) of the surrounding parcel.[86]

If that development-enabling consolidation does not occur, then, at worst, the private driveway presently serving the property will remain unchanged. If the county (or a functional public authority tasked with implementing Quiet Zones, as described later in this study) wishes to pursue implementation of the Quiet Zone containing it (QZ reference name: "Lake"), the use of a diagnostic team might be justifiable in consideration of the surrounding area's high property values.

Alternatively, if the county/authority decides not to pursue either crossing closure or the use of a diagnostic team, it can simply wait out the likely redevelopment of the parcel. When the developer—with their comparatively-deep pockets—seeks the necessary approvals for such work, the county/authority will have abundant leverage. They can use that leverage to ensure that the developer agrees to cooperate on the closure

[86] Staff, "Officials Investigate Cause of Large Fire at 100-Year-Old Home in Ballentine"; "Dutch Fork Fire Rescue | Facebook."

or substantial improvement of that crossing. An added advantage of this approach is that the developer could—and almost certainly *would*—finance their share of any crossing improvements by making them the responsibility of the HOA that customarily owns the roadways and common infrastructure of new subdivisions in that area. No doubt the future residents of such a development would accept their share of that cost well into the future if the only alternative were the resumption of train horn use so close to their homes. Likewise, if the development of the property occurs *after* the implementation of Quiet Zones in the area, the developer will have even greater incentive to also seek resolution of the crossing issue in order to protect their investment. After all, if their development is among the last in its area than *still* subjected to regular horn noise—due to the proximity of the crossing, <u>devastating</u> levels of noise—buyers willing to pay the developer's asking price might prove elusive.

In addition to these two private crossings, the study recommends the closure of two public crossings. Each lacks gates and lights, and neither carries materially-significant amount of traffic. Nor is either of them far from at least one alternative crossing that will remain open.

Indeed, all four crossings marked for closure under this proposal are within a few hundred feet of other crossings, so that any reduction in connectivity resulting from their closure ought to be miniscule. All four crossings have minimal levels of traffic. All four are one lane in each direction (the dirt roads, of course, do not have lanes, *per se*). All four are no more than a hundred feet long, so a simple "ROAD CLOSED" barrier on each side ought to be sufficient to close them to the standards of the FRA (the closure of a longer road, by contrast, could conceivably call for the construction of more complex and costly barriers).

The two public crossings to be closed would not (barring some exceptional courtroom wrangling on behalf of purportedly-injured would-be crossers) require the payment of any compensation to anyone. The two private crossings ought not result in too onerous a cost to any public authority responsible for Quiet Zones. In the case of the private crossing that consists of the back driveway of an industrial property, there is—as with the lake-area property—ample room for the county/authority to reach an understanding with the property's owners. First, the gravel driveway of that crossing is so clearly worse than the primary, paved driveway serving the same property that any compensation claims if the county/authority opts to close it would not, in theory, be prohibitively costly. Secondly, the property is not a residence but a business, and an industrial one at that; the inconvenience and opportunity cost associated with relocating is far, far higher for such a property owner than it would be for a homeowner. The county/authority might utilize that practical reality by tactfully pointing out to the property's owner(s) that, barring their cooperation, the alternative is the eminent domaining of the entire parcel—an outcome the business's owner(s) would surely seek to avoid even at the cost of giving up the secondary driveway.

Resulting Quiet Zone Designs

Despite the many restrictions imposed by engineering considerations, federal regulations, and a desire to minimize costs, this lengthy Quiet Zone calculation and evaluation process ultimately yielded fourteen viable QZs. Five of them achieve eligibility without a single piece of new infrastructure—excepting the pair of required

“NO TRAIN HORN” signs at each crossing.[87] Combined, the fourteen QZs proposed would eliminate horn noise from seventy-nine level crossings, seventy-five of which would remain open. Four-quadrant gates installations (up from two, not zero) would be required at ten of them, mountable median curbs with channelization devices would be needed at two, and one more would receive a non-mountable median curb.

As previously described in detail, four crossings—two public, two private—would need to be closed to comprehensively implement this proposal. Because road traffic levels are one of the input variables in the formulae for computing QZRI, the listed traffic counts for these four crossings were added to the nearest one or two crossings as directed by the FRA. The traffic counts for many of the crossings, it should be noted, were many years old—at least one dated back to 2005. Initially, this was a source of concern, but further examination dispensed with such worries—more recent traffic count data from SCDOT indicates that many (in all likelihood, <u>most</u>) of the roadways in question have lower traffic counts than they did at the time of their respective FRA-listed traffic studies. Despite the region’s growth, this is not an unforeseeable outcome. The traffic counts on major arterial roads generally defied this trend, suggesting that, to some degree, existing traffic has consolidated onto those roads. Happily, this consolidation of traffic patterns suggests that the proposed Quiet Zones are still entirely viable, since one of the guiding principles in their creation was that, whenever possible, crossing improvements be planned for busier roads rather than quieter ones.

[87] This sign can hardly be called “infrastructure” given its near-pointlessness—what road user would be willing to flagrantly disregard the flashing lights, chiming bells, rumble of an approaching train and lowered gate arm—and possibly further improvements— present at every new QZ crossing, yet would balk at disobeying a piece of reflective metal on a stick?

Cost Estimation

While the FRA Quiet Zone Calculator does produce an output called "estimated total cost" for any QZ, it should be noted that upon logging into the Calculator, a message box immediately appears, warning that "Dollar estimates that are provided for SSMs are only for order of magnitude comparison between scenarios generated by the calculator and are not reflective of what the actual costs may be." Despite the warning, at least one Quiet Zone proposal encountered during the research for this study took the calculator's "cost" field as interchangeable with an actual engineer's estimate.[88]

In truth, producing a *universally*-applicable formula or model capable of estimating the cost of a Quiet Zone is likely an impossible task. Construction cost estimates are not known for their accuracy; estimates of the cost of public works projects are legendarily inaccurate. Nonetheless, there is some utility in attempting to estimate the overall cost of the fourteen proposed Quiet Zones. Production of such an estimate permits the comparison of the project's estimated costs with its anticipated benefits. Given that the primary goal of this study is to dispense with excuses for inaction on Quiet Zones in the study area, that ratio is of central importance.

To a substantial degree, the difficulty of accurately estimating the cost or timeline of an infrastructure project reflects the many opportunities to find new hurdles inherent to such projects. That part of the variability—uncertainty—cannot be budgeted for, although attempts to approximate what could go wrong persist, particularly through the aggressive use of contingency costs. That said, the materials required for each SSM are known—

[88] "City of Decatur Community Transportation Plan, Appendix B: Rail Road Quiet Zone."

precisely known, thanks to the granularity of the FRA's regulations. That granularity allows the known inputs to be broken down—from "mountable median curb with traffic channelization devices," for instance, into linear feet of concrete and number of reflective channelizing posts. If an existing high-quality estimate containing those specific inputs can be identified—and, even better, indexed to geographic and temporal cost indices—that portion of the QZs' costs can be approximated.

After substantial research, it became clear that one study stands out as both reasonably recent and of superb quality: an August 2019 study analyzing the prospect of QZ implementation in Encinitas, California. To the extent that Quiet Zone feasibility analyses / studies / reports can be called a genre, the Encinitas analysis is its unrivaled masterpiece. It contains engineering plans, construction cost estimates produced by a licensed civil engineer, overall project cost estimates prepared by the engineering services giant WSP (which evidently compiled the report),[89] a detailed relative timeline that accounts for the need to wait on outside entities, and even a comprehensive list of optional additional upgrades discussed by the city and its consulting engineers, along with the reason for each individual item's recommendation or removal.[90]

The only downside of the Encinitas report is no fault of its own—to the extent infrastructure costs correlate with overall costs of living and goods, Encinitas and Richland County are worlds away, despite the latter's rapid growth in recent years. The cost of construction in California cannot be regarded as universally-applicable within the

[89] "Our Story | WSP."

[90] WSP, "Quiet Zone Feasibility Analysis."

United States. It is therefore advisable to utilize some form of cost index to adjust the resulting figures.

In the spirit of making this study as useful as possible to others, it utilizes a combination of two data products offered by the federal government rather than the arguably more-authoritative Engineering News Record indices.[91] The two indices chosen were the FHWA's National Highway Construction Cost Index (NHCCI) and the "Regional Price Parities" index from the Bureau of Economic Analysis (BEA) for 2019, the year the Encinitas study was published. However, because the former indicates a slight fall in highway construction costs between the third quarter of 2019 and the fourth quarter of 2020 (the latter being the most recent available such figure) and given the dramatic escalation in inflation in intervening months, the former index will not be utilized.[92] As for the state-level adjustments offered by the BEA, the respective values for California and South Carolina are 116.4 and 91.5.

It should be noted that the cost of the four crossing closures called for by this proposal was not included in cost estimates. There are three reasons for this. First, it may not prove necessary to close all four. Quiet Zone regulations *do* allow for the inclusion of private crossings <u>even if those crossings lack the baseline features</u> required of public crossings (two-quadrant gates and flashing lights).[93] However, as previously noted, inclusion of private crossings requires the use of a "Diagnostic Team." It is difficult to

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[91] Lee and Grant, "Inflation and Highway Economy Studies"; Wilmot and Cheng, "Estimating Future Highway Construction Costs."

[92] "National Highway Construction Cost Index (NHCCI) | Open Data | Socrata."

[93] 49 CFR Part 222—Use of Locomotive Horns at Public Highway-Rail Grade Crossings § 222.7(c).

anticipate the cost and practicability of doing so without knowledge of the entity that seeks implementation—this entity could be the city/county, as demands for action on Quiet Zones in the study area have typically suggested. Alternatively, it might be the semi-independent public authority whose creation is suggested in Part IV. As will be explained in Part IV, there are reasons to believe that the latter entity would be more cost-effective at Quiet Zone implementation than the city or county. The question of what entity implements the QZs could therefore introduce still greater uncertainty.

Second, the cost of crossing closure could also vary substantially if either of the private crossings requires the use of eminent domain, and the amount that would be involved in such a step—along with the legal and other professional costs that might be incurred in the process—cannot be practically predicted.

Lastly, there is reason to believe that the cost involved would be comparatively minor. The Quiet Zone calculator website, for instance, indicates that the "cost" of crossing closure is $5,000; this contrasts sharply with the $100,000 "cost" for four-quadrant gate installation listed by the same website (these figures, of course, are for comparative purposes only).[94] It is in the context of these three factors that the decision to disregard the four crossing closures in cost estimation was made.

To obtain an estimate of the cost of implementing the proposed Quiet Zones—crossing closures excepted—the number of units of inputs (e.g. linear feet of concrete, number of channelization devices, hours of labor, hours of machinery rental, etc.) were first listed. Some of these are known constants: a crossing with a median will have no

[94] "FRA - Quiet Zone Calculator v. 2.2.2."

more than 200 ft of median curb if built to do no more than comply with FRA regulations. Others are based on the Encinitas study: the number of channelization devices per crossing, for instance, was estimated by comparing the engineering plans of that study (which include a translucent “before” view) with satellite imagery of the pre-QZ crossing in order to determine how far apart Encinitas’ consulting engineer placed the barriers.

The number of units of each input was multiplied by the highest unit price mentioned or listed in the Encinitas study—as always, this study seeks to err on the side of excessive conservatism. To this were added the $150,000 worst-case labor and machinery rental costs, which are undoubtedly overestimates even after adjustment with the BEA’s Regional Price Parities index. This is particularly likely because the Encinitas crossings require far more complex reengineering and alteration than the Quiet Zones advocated by this study. The contingency, mobilization and demobilization (i.e., movement of all equipment and materials to the site and removal of whatever remains after completion), and “traffic handling” percentages were multiplied by the costs of materials and labor, and the flat “traffic flagging” fee was also listed. The following were then summed: the cost of all materials and labor, the percentage-based items, and the flat “traffic flagging” fee. The sum of these parts equals the *construction cost*.

The *project cost* associated with each SSM is larger—much larger—than the construction cost. For two reasons, a parametric approach was not used for estimating project costs. First, the differences between Richland and Encinitas values for these items (many of which are functions of government regulations) are likely far greater than the differences between the cost of materials in the two locations. Second, there is no practical way to know how much "materials testing" or "safety training" would be required at any of the jobsites that would be set up to implement the proposed Quiet Zones, so any parametric estimate derived from these would be nothing but a wild guess.

Instead of taking a parametric approach for project costs, the ratio of each of the four Encinitas crossings' total "project cost" to its construction cost was calculated. The highest such value was 2.4, so the construction cost of each of the fourteen QZs was multiplied by the same.[95] That product was then multiplied by 91.5 and divided by 116.4 to account for the California:Carolina price disparity in 2019. Lastly, a flat cost of $25,000 for an engineering study of each crossing was added to this subtotal. The resulting QZ-specific cost estimates were then totaled and that sum rounded to the nearest dollar, yielding a total estimated cost of **$14,218,730.**

A visual depiction of the process just described—a copy of the Excel worksheet used to perform the estimation calculations—can be found in Appendix C on page 126.

What does that cost buy?

The final task of this part is the comparison of the cost of QZ construction—estimated to be $14,218,730 excluding any expenses associated with crossing closures—with the estimated increase in property values that such a project would yield .[96] Unlike the process of producing the cost estimate, estimating the benefits of implementing all 14 Quiet Zones is quite simple. After the planning of the 14 proposed Quiet Zones was

[95] WSP, "Quiet Zone Feasibility Analysis," 8.

[96] Excluding the cost of private crossing closures / eminent domain / purchases (which ought to be comparatively minor expenses even if the county/authority ultimately has to purchase the two private crossings marked for closure).

completed, post-QZ estimates each of the six noise variables from Part II's regression models. Recall that the pre-QZ estimate layer was generated, in short, by the following procedure: each properties set of links to crossings was dissolved, yielding the calculated noise exposure of that property, or L_{MAX}.

To generate the post-QZ estimated sound layers, this procedure was repeated—with one additional step at the beginning. Before performing the dissolve operation that merged each property's sound model links, links to crossings slated for QZ status were deleted. This task was carried out both for individual proposed QZs (so that the noise reduction of each individual QZ could be compared with the others) and for the comprehensive plan of 14 Quiet Zones. Appendix B contains area-specific before-and-after peak exposure maps for each of the 14 proposed Quiet Zones, plus general before-and-after maps for the combined program.

For the task of estimating the total increase in Richland property values, a copy of the layer representing estimated current noise exposure was combined with a copy of the layer representing the estimated noise exposure of each property *after* the implementation of all 14 proposed Quiet Zones. The "after" values for the "noise exposure over 65dB" variable were then subtracted from the "before" values of that variable, yielding the reduction (if any) in peak noise exposure above 65 dB(A) that each of the ~109,000 properties would enjoy upon implementation of the entire program. The differences were then summed. That sum was then multiplied by the estimated coefficient of the same variable as calculated during this study's linear regression analysis. That product represents the estimated total increase in Richland County property values if all 14 proposed Quiet Zones were implemented: $221,275,381.60

<u>PART IV: A NEW WAY FORWARD</u>

"Dum spīrō spērō"[97]
("While I breathe, I hope")

-*Motto of South Carolina*[98]

Given the substantial potential upside of implementing Quiet Zones—in the case of the fourteen proposed by this study, an upside over <u>fifteen times</u> the cost of its realization—the lack of progress on their implementation is particularly puzzling. This section will attempt to solve that puzzle.

A sound heard before

The suggestion that Columbia or Richland County implement Quiet Zones is neither new nor particularly radical. At least as early as 2003—*years* before 49 CFR § 222 was to take effect—a report on the viability of Quiet Zones in Columbia had been commissioned, produced, and delivered to the city government by a locally-based firm of consulting engineers.[99] It is unclear what became of the study, though it reportedly suggested that some 40 crossings could be silenced for $8.75 million.[100] The following February—evidently in response to the study in general and its cost estimate in particular—Columbia's then-Mayor Bob Coble ordered that a two-pronged approach be applied to further study the idea. The city government's professional staff—specifically, the Traffic Engineering Division and the Legal Department—were to analyze the

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[97] Use of macrons confirmed as correct by author with the aid of a Latin dictionary and conjugation tables. For confirmation, see Minkova and Tunberg, *Latin for the New Millennium*, 391.

[98] "Facts and Symbols | Quick Facts about South Carolina."

[99] Ellis, "Time to 'Muzzle' the Trains? Columbia Considers Becoming a Quiet Zone," 2.

[100] Ellis, 2.

proposal, while an "implementation task force to be composed of neighborhood leaders and Mr. Bud Ferrillo…[was] to review the various cost elements to determine if implementation cost could be reduced."[101] That specific focus might sound familiar.

It is unclear what became of these efforts. The consulting firm that prepared the report—Wilbur Smith Associates (WSA)—was acquired[102] in 2011, and a search of the successor firm's website turns up no results.[103] However, at least one other Quiet Zone study by WSA is still available to the public: in collaboration with another consulting firm, it prepared such a report for Berkely, California in April 2009.[104] If the Berkeley and Columbia reports were similar in their composition, it makes sense that Columbia's leadership might have decided that continuing on a path to QZ implementation was not an option. The report for Berkely is not shy about including scenarios with plans involving grade separation and costing tens of millions of dollars. It nonetheless neglects to so much as *hint* at potential sources of funding and/or financing for such an endeavor. That the South Carolina city—with its *dozens* of crossings over Berkeley's seven—would be spooked by the quoted cost of the more expensive scenarios is plausible. When Mayor Coble's prescription to Columbia staff—find a way to lower the proposal's cost—is factored in, it seems probable.

In any event, what *is* clear is that the concept of a committee formed of residents of impacted neighborhoods for the sake of studying Quiet Zones was to be revived at

[101] Erica D. Moore, City of Columbia City Council Work Session Minutes, February 18, 2004.

[102] Burris, "Water, Environmental Consulting Firm Buys Wilbur Smith."

[103] "CDM Smith."

[104] "City of Berkeley Quiet Zone Feasibility Study | Final Report."

least once, in April 2017.[105] That very same month, the very same Bud Ferrillo mentioned in the 2004 City Council session spoke to a reporter covering the latest wave of calls for action.[106] Ferrillo—a fairly well-known advertising and PR executive—was not the only notable to decry the train problem in that article.[107] Former SC Democratic Party chairman Richard "Dick" Harpootlian, a resident of one of the heavily-impacted neighborhoods, told the same reporter, "'It's like living in some two-bit, rural, redneck town where the trains wake everybody up all night long…We're supposed to be a sophisticated city."[108] Harpootlian—a former member of the Richland County Council whose wife was[109] a member of the most recent iteration of the City of Columbia's QZ study committee[110]—has advocated action on train horn noise for years.[111] If either city, county, or state had then been capable of implementing Quiet Zone, even smaller ones, then the repeated public calls for action from so persistent, impassioned, and well-connected a member of the public—who was not the only prominent advocate of QZ

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[105] February 01 and 2019, "CCN Hears about Quiet Zones | Columbia Star."

[106] Ellis, "Time to 'Muzzle' the Trains? Columbia Considers Becoming a Quiet Zone."

[107] Ferrillo most notably coined the term "Corridor of Shame" to refer to the underfunding of schools in the inland counties of the Lowcountry, some of which were using coal to heat classrooms as recently as the 2000s. See Temoney and Ullrich, "All Talk, But No Action: A Reexamination of Education in South Carolina's Corridor of Shame."

[108] Ellis, "Time to 'Muzzle' the Trains? Columbia Considers Becoming a Quiet Zone."

[109] It appears possible that the Advisory Committee is dormant; whether or not Ms. Harpootlian is still *officially* a member is therefore difficult to ascertain. However, given that she has been confirmed to an ambassadorship, it seems fair to characterize her as a "former" member of the QZAC. (See Reynolds, "Prominent Columbia Attorney Confirmed as US Ambassador to Slovenia.")

[110] "Quiet Zone Advisory Committee."

[111] "South Carolina Legislature Online - Member Biography"; Monk and Schechter, "SC Sen. Harpootlian Asks Governor, State Watchdog to Investigate 'Hidden Earmarks'"; Sarah Ellis, "It Will Cost Columbia Millions to Get Trains to Stop Blowing Their Horns."

implementation—ought to have been the tipping point for action by the thusly capable entity.

The fact that neither city, county, nor state has effected progress in the years since that 2004 work session suggests that the status quo is somehow incompatible with the successful implementation of at least one Quiet Zone. It is worth examining that gridlock in closer detail, for any new organizational approach to Quiet Zone implementation must avoid the quagmires that have impeded progress thus far.

Factors behind the lack of progress

In theory, the first place to which Richland and/or Columbia might turn for Quiet Zone funding and guidance would be the state government—the assumption being that the state is more responsive than Washington yet better-funded than local government—specifically, to the South Carolina Department of Transportation (SCDOT). Unfortunately, SCDOT is presently occupied with a frantic effort to catch up with a titanic maintenance backlog representing decades of deferred action totaling tens of billions of dollars.[112] That and other megaprojects will command the lion's share of SCDOT's budget and attention for years to come. In theory, Richland or Columbia might still obtain state funding in the form of specific legislatively-allocated grants, permitting progress on a Quiet Zone program even while SCDOT is otherwise occupied.

Promisingly, there *is* an established tradition of détente in doling out earmarks under which Democratic state senators are often able to secure substantial funding for

[112] "South Carolina Ranks Worst for Roads in the U.S."; "SCDOT Provides Update on Strategic 10-Year Plan."

favored projects in their districts despite the iron grip with which the state GOP controls the legislature. Unfortunately, such red-to-blue spending is typically directed towards nonpartisan and/or [nominally] independent entities selected by those state senators. By contrast, solidly-Democratic political subdivisions rarely benefit from state grants—and this includes Richland County and the City of Columbia.

That factor essentially eliminates both city and county as potential funders of anything more than limited areas of Quiet Zone. It is unsurprising that the city's current Quiet Zone plan calls for a slow, phased approach. Neither city nor county has any real alternative, at least under current state law. §6-1-320 of the South Carolina Code of Laws strictly limits the ability of lower levels of government to raise millage rates without the occurrence of a population rise, inflation increase, or one of a handful of exceptional circumstances.[113] Neither can support substantial infrastructure projects with its present budget—or, more precisely, neither appears to be in any hurry to do so.

For the 2018 and 2019 fiscal years (the county uses a biennial budget), Richland's combined budget for its divisions of public works and engineering was just $1.67 million—out of a General Fund budget of over $335 million. The City of Columbia funds its public works with a comparatively lavish hand: $19.3 million of its $182.6 million budget for 2020/21 is thus designated, though it should be noted that the city is custodian of a far larger collection of core infrastructure, including a drinking water plant, a sewage plant, and a maze of sewer and stormwater systems.

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[113] South Carolina Legislative Services Agency, Title 6 - Local Government - Provisions Applicable to Special Purpose Districts and Other Political Subdivisions §6-1-320(B).

Both city and county, moreover, are straining under the weight of past and present capital expenditures and the borrowing required to finance such expenditures. The county's annual debt service is over $100 million. As for the city, its acceptance in 2014 of a consent decree over alleged violations of the Clean Water Act committed it to carrying out upgrades to its stormwater management and sewerage infrastructure at the cost of hundreds of hundreds of millions of dollars—upgrades on which it is still working and spending.[114] The demands of those projects will, like SCDOT's backlog maintenance program, continue to occupy the attention and energies of the city's public works division.

Meanwhile, the county's promising-sounding "Transportation Penny" surtax was not designed to fund any substantial railroad-related improvements, let alone Quiet Zones. That, however, is only one of the reasons Richland will not be building Quiet Zones any time soon, since a South Carolina Department of Revenue (SCDOR) audit of the program found that the county misspent $32.4 million of Transportation Penny funds. The county reached a settlement with SCDOR in summer 2021. In light of that settlement, the county's reputation with outside entities that might have helped fund Quiet Zones can hardly be called spotless.

Lastly, while there are federal funds for railroad crossing improvements, they are not issued by the FRA to assist with Quiet Zones. Rather, they are disbursed by the FHWA to bankroll safety upgrades to crossings for safety's sake—*not* to make them

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[114] "The City of Columbia Consent Decree"; US Department of Justice Office of Public Affairs, "Columbia, S.C., Agrees to Major Sewer System Upgrades"; "City of Columbia FY 2021-2022 Budget Overview," 38.

eligible for Quiet Zone status. Unsurprisingly, they are typically used on the most dangerous of existing crossings—those with no safety features beyond a crossing sign and a stop sign. Despite the mounting popularity of Quiet Zones—or, more precisely, aspirations for Quiet Zones—federal appropriations specifically designated for Quiet Zone projects remain nonexistent.

In essence, there exists no entity politically and financially willing and able, respectively—to assume responsibility for Quiet Zones in the study area. Decades of demands for action by public and political elite alike have not materially changed that.

And that might not be a bad thing.

The case against direct city/county administration of Quiet Zones

In one sense, Columbia and Richland's present inability to afford Quiet Zones is unfortunate. The mitigation of train horn noise within either's borders would be that rare act of public policy that at once pleases great numbers of people and (potentially) improves the long-term fiscal viability of the government administering it. Yet that inability is arguably a lucky break. To understand why, it helps to understand why this paper utilized just one existing Quiet Zone study—the magisterial Encinitas QZ analysis—in projecting the cost of its own proposed improvements.

That exclusive reliance on Encinitas did not result from a lack of existing Quiet Zone studies. On the contrary, there are numerous such works; this study evaluated existing analyses from a list of locations including (but by no means limited to):

Bellingham, WA;[115] Columbus, IN;[116] Decatur, GA;[117] Eugene, OR;[118] Monroe, WA;[119] Rapid City, IA;[120] and Windsor, CT.[121] While much of the content of these works is quite useful, the Encinitas analysis was the only one that offered enough information to inform parametric estimation and offered enough documentation to substantiate its specific cost claims. (It should be noted that the Columbus, Indiana study was of equivalent quality, but its cost estimates were marked “DRAFT,” so it was eliminated from contention).

The Windsor study, for instance, offered virtually no breakdown of cost inputs, only the total figures across a matrix of crossing and upgrade choices.[122] The Monroe report has a wealth of information: it is some 112 pages long and includes detailed engineering plans, the inventory report of every single crossing in consideration, a breakdown of the anticipated/planned financial contributions of the city, state, and federal governments to the dollar, plus detailed notes produced during an endless series of meetings between at least a dozen individuals—but no breakdown of costs.[123] These two are not outliers; the majority of existing QZ proposals encountered in researching this study offer little to no accounting for how they arrived at their cost estimates. Worst of

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[115] HDR Engineering, “City of Bellingham Quiet Zone Report”; “Railroad Crossing Safety and Quiet Zones for Trains.”

[116] CTC Inc., “Quiet Zone Evaluation Report | Columbus, IN.”

[117] “City of Decatur Community Transportation Plan, Appendix B: Rail Road Quiet Zone.”

[118] “Implementing a Quiet Zone to Address Train Horn Noise”; City of Eugene, OR, “Required Train Horn Signals.”

[119] Para and Zukowski, “Quiet Zone Feasibility Study.”

[120] SRF Consulting, “Rapid City Quiet Zone Assessment (FINAL).”

[121] SRF Consulting, “Town of Windsor, Connecticut: Quiet Zone Assessment.”

[122] SRF Consulting.

[123] Para and Zukowski, “Quiet Zone Feasibility Study.”

all, many of these proposals seem to have obtained their cost estimates from the involved railroad itself.

While the railroads can, of course, be expected to have some working knowledge of how much Quiet Zones cost, the fact that they are often tasked with construction work and/or require compensation for their cooperation arguably constitutes a flagrant conflict of interest. What incentive—assuming there is no realistic threat of the beleaguered inhabitants of communities subjected to horn noise rising up and burning down a switchyard—other than sheer altruism might railroads be expected to have? They are for-profit businesses, and their business is decidedly *not* one of helping municipal governments navigate beyond the limits of their technical expertise.

Distorted though such estimates may be, moreover, they are far from the only red flag that the reader of Quiet Zone studies might encounter. Another analysis, this one from Decatur, Georgia, simply repeats the FRA Quiet Zone Calculator "estimates" as the site's disclaimer expressly directs users not to do.[124] To be fair to the author of the Decatur report, the Quiet Zone Calculator figures appear to be from 2007, effectively the infancy of the Quiet Zone program; the report also closes with its own disclaimer, noting that the "cost estimates have not been independently verified by the CTP." However, the Decatur study is a useful symbol of the larger pattern seen in the pages of a shockingly high percentage of Quiet Zone studies: cost estimates are opaque, questionable in their objectivity, or altogether without basis in reality.

[124] "City of Decatur Community Transportation Plan, Appendix B: Rail Road Quiet Zone."

Why *should* any of these municipalities be expected to possess substantial institutional knowledge of SSM costing methods—indeed, why expect any but the largest and most heavily-impacted of municipalities to possess substantial institutional knowledge of Quiet Zones at all? The core business of a city or county, after all, involves so much more than the implementation of Quiet Zones. What private-sector organization could be reasonably expected to collect taxes, maintain public order, run a court system, put out fires, educate the young, house the underprivileged, provide safe drinking water, and properly dispose of sewage—the latter four requiring an unfailing adherence to complex and unforgiving federal rules—*and* supervise the planning, engineering, procurement, financing, construction, and regulatory approval of a piece of specialized rail infrastructure?

The inability of either Richland County or the City of Columbia to accumulate enough funds to begin substantial efforts towards Quiet Zone implementation is an opportunity to liberate those organs of direct responsibility for that task. It offers a chance to build something better. Ideally, an alternative administrative approach to implementing Quiet Zones would not only be designed to avoid the pitfalls that trap so many doomed municipal pursuits of Quiet Zone status but would also offer advantages beyond those of even the most competent municipality. This, the final section of the study, aims to do both.

The Case for a Public Authority

The existing genus of administrative entity that arguably fits the task at hand better than any other is the public authority. Sometimes known by other names—"a public body corporate and politic" appears to be the terminology invariably utilized in the

South Carolina Code of Laws—public authorities are the nearest thing to a *tabula rasa* that democracies offer.

Public authorities vary widely in their size, powers, and constraints; in general, however, they tend to adopt the basic organizational structure of private corporations/charities, with a board of directors headed by a chair overseeing the activities of a paid professional workforce headed by an executive director. Broadly speaking, the other defining characteristic of public authorities is their embrace of private-sector practices in their internal operations, a trait both enabled and encouraged by their substantial independence from ‘conventional’ governmental bodies.

Excepting these general characteristics, there is substantial variation in the form and function of public authorities across the United States because they are creatures of individual state legislatures. This study does not delve into the analysis of these variations. Instead, it recommends a new public authority tailor-made for the task at hand. For the sake of clarity, the proposed authority will frequently be referred to the acronym of its suggested name, *MTIPIA*: the Midlands Transportation Infrastructure Planning and Improvement Authority.

MTIPIA: an Introduction

Although the quantitative portions of this study—modelling noise levels, regression modelling, Quiet Zone design, and cost estimation—were conducted only within the confines of Richland County, that restriction was imposed only to ensure that the property dataset was consistent and to limit resulting time, money, and computational needs. Use of a consistent dataset was deemed particularly important in order to prevent subsequent efforts at regression modelling from failing.

One consequence of limiting input datasets to Richland County was that the recommended crossings all lie within its borders. If this study called for the county government to supervise efforts at Quiet Zone implementation, this detail would not merit mention. Of course, this study recommends no such thing, instead arguing for the creation of MTIPIA to manage that work. This shift does not merely enable multi-county Quiet Zone implementation—it incentivizes it.

In the following subsections, the characteristics of the Authority will be contrasted with those of conventional government entities. In so doing, the aim is to illustrate the proposed authority’s ability to avoid the obstacles that have thwarted all previous attempts at Quiet Zone implementation in the study area along with its anticipated advantages along several dimensions of performance. The organization, powers, and responsibilities of MTIPIA will not be exhaustively catalogued, but its core features will be described. Attributes of MTIPIA that directly relate to its performance along the dimensions detailed will also be described, briefly and when necessary.

Practice makes perfect:

The first contrast between the proposed Authority and the municipalities and counties that, in practice, lead most Quiet Zone initiatives relates to the expertise required to successfully oversee those projects. As previously noted, identifying potential Quiet Zones, evaluating their relative utility, and shepherding them from plan to reality is a complex and multidisciplinary task.

Successfully completion of that task requires a deep familiarity with the lengthy and detailed rules of 49 CFR § 222, a comprehensive knowledge of the state laws that interact with that federal regulation, at least a working understanding of civil engineering concepts (regarding both design and cost estimation), and the ability to develop and defend a process for evaluating and comparing the viability of individual crossings and entire Quiet Zones. Choosing specific combinations of crossings and particular permutations of SSMs for those crossings is, after all, an optimization problem. There are only two approaches to solving such a problem. The first, via quantum computing, is essentially unheard of in urban planning at the moment, though it holds great promise,[125] and access to quantum computing is beginning to expand, although "quantum hardware is not yet sufficiently mature to be used to run quantum algorithms to solve real-world problems".[126] The second approach is to establish as many guiding principles as possible, then exercise human judgement where necessary. This study utilized the latter approach, as has every one of the countless Quiet Zone feasibility analyses and proposals considered in researching it.

Considering the vast quantity of background knowledge needed in order to develop and evaluate Quiet Zone proposals, it is hardly surprising that local governments attempting to do so independently might make mistakes or fail to fully develop Quiet Zone proposals; the research for this study produced examples of both. It is equally unsurprising that municipalities hire outside consultants for this task so often, or that, as

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[125] Cuomo, "Quantum Computing — How It Could Be Used."

[126] Earlier in 2021, Microsoft made Azure Quantum—which allows users to run code in *Q#* on actual quantum computers—temporarily available to the general public. (See De Simone, "Microsoft Opens up Its Azure Quantum Platform for Public Preview.") While *Q#* was not ultimately included in this study despite earlier efforts (the author determined the additional

far as could be determined, there has never been a successful implementation of a new QZ without such external assistance. In a fairer world, the FRA would counterbalance the mountain of regulations and red tape it dropped on the country's local governments with a substantial increase in the amount and quality of guidance it is able to offer interested municipalities. Unfortunately, the act ordering the U.S. Department of Transportation to create 49 CFR 222 did not include a cent of additional funding to the FRA—a detail that might have enabled the FRA to provide (via a semi-independent internal unit, of course, since the agency is also the regulator) more guidance to municipalities.[127]

The outside consultants without whose help it seems no new Quiet Zone can obtain approval are not cheap. Between planning/QZ consultants and consulting engineers, the potential cost of implementing a Quiet Zone—even one without any SSMs—can be substantial. For every consultant-assisted feasibility analysis that was identified in the research stage of this study there is no doubt there are at least several communities who abandoned their hope of obtaining a Quiet Zone when it became clear that simply determining their plan's feasibility—to say nothing of possible construction costs—would cost at least thousands of dollars.

Entrusting the task of Quiet Zone selection, design, and construction to a purpose-made entity—to MTIPIA—is a third option that promises both higher-quality work than go-it-alone attempts by municipalities *without* consultants <u>and</u> lower unit costs than the those attempts *with* the assistance of consultants. Because MTIPIA would be a functional entity rather than a geographic one its staff would work on nothing but Quiet Zone

[127] Schenk, H.R.4867 - 103rd Congress (1993-1994): An Act to authorize appropriations for high-speed ground transportation, and for other purposes.

planning and implementation. They would be able to do so without the need to juggle that task with other responsibilities. The author of this study can attest to the fact that even someone without formal training in acoustics, civil engineering, or federal transportation regulations can nonetheless develop the skills needed for QZ analysis—with enough time and determination.

Lastly, the authority's staff would be far more equipped to develop strong working relationships with counterparts at the FRA, the FHWA, Amtrak, CSX, Norfolk Southern, SCDOT, Richland County, the City of Columbia, and the myriad other public and private entities whose cooperation would be needed at least some of the time. The value of such connections is hard to overestimate. Neither municipal planners working on QZ analysis part time nor private-sector QZ consultants with their ever-changing clientele would be so well-equipped to build those relationships.

MTIPIA in the middle:

Among the counterparts with whom authority staff would be able to form those close working relationships would be Republicans and Democrats, and the ability to bridge political divides would also be indispensable in attempting to complete public works in a politically heterogeneous group of municipalities inside a safely-Democratic county, it inside a safely-Republican state. MTIPIA's political advantages would not be limited to mere collegiality, however. As a multijurisdictional entity, MTIPIA would be able to deliver quality-of-life improvements to the residents of many more State House of Representatives and Senate districts, encouraging members of both parties and both chambers to respond to any MTIPIA requests for the passage of legislation or even budgetary allocations with an appreciation for the value of the authority and its work.

Were it confined to just one county or city—as existing Richland and Columbia proposals for QZs appear to be—MTIPIA would be unable to make so many friends in high places, so to speak.

Despite the SC GOP's control of both chambers of the General Assembly and the governorship, there is a well-established tradition of bipartisanship in appropriations in the General Assembly, even when the governor opposes that consensus. South Carolina's governorship is very weak; virtually every new holder of that office attempts to claw back executive power and in so doing incurs the ire of the General Assembly. This dynamic is important to understand because it increases the chances of MTIPIA receiving the statutory power and funding required to establish it, and, if necessary, to sustain and expand it. Even if a governor is hostile to MTIPIA, the authority only needs to keep a few key legislators happy to virtually guarantee the protection of its interests—provided, at least, that the MTIPIA proposal has not become a topic of news coverage or discussion. The bipartisan earmark consensus system is most effective when, in the eyes of the public, it is as quick and quiet as possible, without floor debate or other opportunities for partisanship to resume.

At the time this study was completed, the map of power in the State Senate is too volatile to permit the identification of districts whose state senator(s) might both appreciate the need for Quiet Zones *and* be in a position to promote their implementation. That volatility follows the November 2021 death in office of State Senator Hugh Leatherman, who was chairman of the Senate Finance Committee—arguably the most powerful political entity in the state.[128] Until Leatherman's successor as chair has been formally chosen and begun to exercise the powers of that position, the distribution of power and state resources within that chamber is too unknown an input to consider.[129]

If MTIPIA already existed, the uncertainty created by Leatherman's death would, at first glance, provoke concern on the part of anyone interested in Quiet Zone implementation. Yet this moment highlights the power and resilience of MTIPIA's recommended structure. As a functional rather than geographic entity, the authority would not be tied down to any particular state senate district (even if it were still limited to the Midlands area). If the map of power changes, so can MTIPIA's plans. Schoolhouse Rock such an approach is not, but if the two choices are politicized progress and holier-than-thou stagnation, it is in the interest of South Carolinians' health, happiness, and property values that MTIPIA react as political patterns necessitate.

Precedent suggests that the tactic of structuring MTIPIA as a river-straddling bipartisan joint venture that gives the right mixture of influential entities a voice is one unlikely to fail. Specifically, MTIPIA's board ought to include representation of: Richland and Lexington counties, the municipalities (at least the more influential ones) in the Midlands, (potentially) the region's business community, and (without question) at least one seat for a representative of the region's universities. It is no accident that the boards of existing independent entities (legally, many are not public authorities) in the Midlands that have enjoyed the political and fiscal support of the legislature have boards

[128] and Emily Bohatch, "Leatherman, Powerful Budget Chairman from Florence, Dies"; Bustos, "Power Shift Coming in SC Senate as the 'Domino Effect' Begins after Leatherman's Death."

[129] Bustos, "Power Shift Coming in SC Senate as the 'Domino Effect' Begins after Leatherman's Death."

that partly or wholly align with this recommendation. For example, the Columbia Convention Center—which received $9 million from the legislature in a veto-overriding bipartisan spending spree this year—is operated by a fusion of two entities that together do business as “Experience Columbia.” [130]

They also share a board, and its membership traces the topography of power in the Midlands. The University of South Carolina has managed to install a representative despite there being no formal provision for its representation (no doubt an established practice), while Richland County, Lexington County, and the City of Columbia each receive a reserved seat.[131] The board’s secretary position is held by the executive director of the Clyburn Foundation[132]—named for and founded by the dean of the state’s congressional delegation.[133] All of the other seats are held by members of the business community. These include a handful of hospitality interests (as might be expected for a board controlling a convention center)[134] and a recent candidate for mayor[135], Sam Johnson, who was previously the outgoing mayor’s chief of staff and is now an advisor to Nexsen Pruet[136], a large regional law firm based in Columbia.

The Republican legislature’s allocation of $9 million for an expansion to a convention center—in the middle of a pandemic that slashed demand for such facilities

[130] “Board of Directors.”

[131] “Board of Directors.”

[132] “Leadership - James E. Clyburn Scholarship and Research Foundation.”

[133] “Leadership - James E. Clyburn Scholarship and Research Foundation.”

[134] “Board of Directors.”

[135] Trainor, “Tuesday Runoff Wil Decide New Mayor, Council Member.”

[136] “Board of Directors.”

and despite opposition from other Republicans and indications that the expansion was unjustified[137]—in a State Senate district held by a Democrat brought media attention when it passed.[138] The list of board members suggests that the event hardly justified the amount of coverage it received. Entertaining though the resulting war of words—largely between members of Richland's delegation in the General Assembly[139]—may have been, the composition of Experience Columbia's board suggests that the passage of appropriations for the Convention Center was virtually guaranteed.

While this study does not exhaustively prescribe the composition of MTIPIA's board, it does call for the reservation of a seat for a representative of the region's four-year colleges and universities. In practice, such a seat would likely be filled by the University of South Carolina—it dwarfs all neighboring institutions. The inclusion of such a seat is prudent because Allen University, Benedict College, and the University of South Carolina have long complained about their campuses' exposure to stratospheric levels of train horn noise; furthermore, USC pumps billions of dollars into the state's economy[140] and owns many parcels around the web of rail trackage south of its campus.[141] Those parcels might prove indispensable in the installation of SSMs, both because they could provide a cheap, convenient staging area for construction crews and because a careful rearrangement of those parcels and the area's roadways would allow for the consolidation of existing crossings into a smaller number of safer, quieter crossings.

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[137] Trainor, "Study Raises Questions about Convention Center Expansion."

[138] Bustos, "Lawmakers Battle over Columbia Convention Center Funding."

[139] Bustos.

[140] "The Economic Impact of the University of South Carolina."

[141] "Richland County, SC, Internet Mapping."

Those parcels have additional—far more dramatic, if also far more distant—potential significance to MTIPIA. At present, this study merely recommends that Quiet Zone implementation be placed under the control of MTIPIA. Its structure and name, however, leave room for expansion into related areas of activity. Should MTIPIA's performance convince Richland and Columbia to additionally delegate management of the Assembly Street Grade Separation Project, the nearby USC parcels would offer engineers and planners invaluable flexibility in designing the improvement.

That project's continuingly-glacial pace suggests that SCDOT is either uninterested in seeing the project realized in the near future (not an unimaginable circumstance given the extensive maintenance project the agency is presently running) or that Richland and/or Columbia have been unable to pressure, cajole, or otherwise persuade SCDOT to pick up the pace. If MTIPIA already existed, it would behoove both Richland and Columbia to consider inviting the Authority to join the project since (for reasons detailed earlier in this subsection) the relationship between SCDOT and MTIPIA would arguably be sunnier than that between the state agency and the two local governments. Not only might such an adjustment yield a better working relationship between SCDOT and the "counterparty" (MTIPIA, replacing Richland and Columbia), but it could encourage the General Assembly to provision funding and/or directives that might ensure that SCDOT has the funds needed for the project and is sufficiently motivated to pick up the pace, respectively.

After all, as previously noted, the Republicans who control the state's legislative and executive branches are reliably bipartisan in allocating funds to nominally-apolitical entities favored by their Democratic colleagues; that they are hardly tripping over themselves to subsidize any undertaking of either Richland or Columbia suggests that those two governments would benefit from allowing a friendlier face to take their place. The independent, technocratic, friends-with-both-parties MTIPIA fits the bill perfectly.

More for less:

By design, MTIPIA would operate faster, more efficiently, and more competently than the existing governmental entities whose powers and responsibilities pertaining to Quiet Zones it would assume. The reasons for such internal operational advantages are discussed in the first subsection of this section, which begins on page 86; in essence, MTIPIA, as a specialist authority, would develop the competencies relevant to Quiet Zone implementation well before any county or municipality. By contrast, this subsection details the ways in which the product of MTIPIA's work—the Quiet Zones under its management—would be better than that produced by traditional governmental bodies. The intent is not to denigrate county or local governments' capacity to supervise Quiet Zone implementation—on the contrary, as noted on page 84, those existing governmental entities have plenty of responsibility already.

One critical contrast between MTIPIA and existing, traditional political subdivisions is that, like sound itself, MTIPIA would have the ability to cross internal borders—county lines, for instance. That ability to straddle borders would be the single most important characteristic of MTIPIA; its domain, unlike that of the traditional governmental bodies that preceded it, must be functional rather than geographic. Accordingly, the legislation authorizing and empowering MTIPIA must include a provision that allows it to operate in any county or municipality in the state as long as it receives authorization from the governing legislative body of that entity in the form of a resolution formally inviting the Authority to work with/in its boundaries. This provision would be in addition to a clause in the core of the enabling legislation that would grant MTIPIA some powers within a defined set of “Midlands counties” from the moment of its legal creation.

MTIPIA’s ability to cross jurisdictional boundaries in this manner could potentially lower the unit cost of Quiet Zones[142]—that is, it would make them cheaper. This advantage is a function of the way the FRA determines eligibility. In evaluating an SSM-only Quiet Zone application, the agency <u>averages</u> the QZRIs (risk scores) of its constituent crossings. This creates opportunities for tactical selection of crossings when designing a Quiet Zone since the correlation between a crossing’s pre-upgrade QZRI and the downside of its horn emissions is far from constant. The greater the number of crossings a government entity can work with, the easier it is to design Quiet Zones in this manner.

This is particularly true in the Harbison/Irmo/Chapin areas of the Midlands. Like the railroad track that runs through all three, these areas straddle the Richland County – Lexington County border. Unlike other parts of that border—some of which follow the path of the Congaree River—this segment of that dividing line is utterly devoid of barriers or gaps that might at least dampen intercounty sound waves.

Furthermore, the area in question—which for simplicity’s sake, will henceforth be referred to by the name of the intercounty school district with which it is approximately

[142] The exact unit is not terribly important—it could be the number of crossings closed or the number of people whose noise exposure was brought from above a certain threshold to below it, for example. The critical point is that the average unit cost of Quiet Zones would be lower for MTIPIA than for an entity with a smaller working region.

coextensive, Richland-Lexington 5 (RL5)—is thickly settled and features relatively valuable real estate. Thanks in part to the close proximity of Lake Murray, moreover, the RL5 area has now experienced rapid, sustained population growth and real estate development for many years.[143] Additionally, the crossings along the rail trackage in question possess a low average QZRI, so a Quiet Zone in this area would incur comparatively little in the way of infrastructure costs. Indeed, the "Lake" Quiet Zone from the fourteen QZs proposed by this study would require no SSM installation, just jumping through a few bureaucratic hoops, filling out some paperwork, and, at each crossing, putting up a pair of MUTCD W10-9P ("NO TRAIN HORN") warning signs.

Without MTIPIA, however, an inter-county Quiet Zone in the RL5 area could not be implemented without at least one of the following administrative concordats:

- One of the two counties agrees to allow the other to take control of the project and simply bill it for its share of the work. This is a recipe for vicious petty bureaucratic warfare—after all, how is the 'passive' county supposed to trust that its neighbor is choosing, designing, and costing out specific crossing improvements equitably?

- All four second- or third-order governmental divisions with jurisdiction over any of the railroad track in question (Richland County, Lexington County, the Town of Chapin, and the Town of Irmo) agree to ask SCDOT to perform the work. As with the previous scenario, this is a recipe for squabbling—not that there would necessarily be enough progress to reach the point of bickering

[143] Marchant, "After Moratorium, New Lexington County Subdivision Plans Are Coming, with Some Changes."

over specific upgrades. SCDOT is, after all, preoccupied with a crushing load of maintenance backlogs on which it plans to work for years to come.[144] Helping two of the richest counties in the state avoid taking charge of their own infrastructure by serving as referee for them and the surrounding towns/cities is unlikely to become a major priority for SCDOT very soon.

- Each of the four aforementioned governments attempts to handle its “share” of the combined QZ. Coordinating such an effort would be immensely complex, the potential for delay and waste sharply elevated by that complexity. As with the two-county approach, disagreement would be far too easy. Because the two towns are *inside* the two counties, furthermore, even the absence of conflict would not guarantee against chaos. Moreover, the every-government-for-itself approach to implementing a single Quiet Zone is incompatible with the standard QZ submission procedure codified in 49 CFR § 222. The only workaround to that would be to create an inter-municipal authority or the designation as one of the participating governments as responsible (in 49 CFR § 222 parlance, the “Public Authority,” confusingly enough) for the Quiet Zone.

Each of these approaches creates novel problems, and none of them is much more than a crude knock-off of MTIPIA. The creation of MTIPIA would allow all four of the governments in question to receive a Quiet Zone without the need to haggle with their neighbors over cost sharing or the necessity of ascending the steep learning curve of

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[144] “SCDOT Provides Update on Strategic 10-Year Plan.”

Quiet Zone design and implementation. With the task of creating a multi-county, multi-town QZ entrusted to the specialists of MTIPIA, the two towns and two counties in question would—at most—simply have to write a check, and the combined political clout of Richland and Lexington might very well provoke the spontaneous appearance of state funding to dispense with even that minor responsibility. The RL5 area is far from the only Midlands locale where a Quiet Zone would clearly be beneficial but where the QZ would have to cross county and/or local government borders.[145]

Create MTIPIA, and the tangled knot of complexity at cross-boundary QZs would simply fall apart.

Create MTIPIA, and the responsibility for ensuring crossings' continued compliance with FRA regulations would fall on it rather than on the governments of the communities in question, a not-insignificant detail given the failure of other traditional governments to proactively maintain their quieted crossings' FRA approval.[146]

Create MTIPIA, and the planning and public works staffs of the Midlands' cities, towns, and counties would not have to separately endure the odyssey–of learning acoustics, federal regulatory law, civil engineering, how to solve an optimization problem without a quantum computer yet while still remaining as objective as possible—of Quiet

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[145] The Norfolk Southern track extending northward from Columbia passes in and out of that city's borders several times; the same is true of the CSX track that runs from Columbia eastward and the City of Forest Acres. The borders of those two cities are particularly chaotic, and given the possibility of these borders further changing, this paper does not include a comprehensive list of the municipal governments through whose territory any of the relevant rights-of-way pass.

[146] Mazurek, "No Longer a 'Quiet Zone'"; Pitts, "'It's Driving Me Insane,' Train Horn Back In Waltham Quiet Zone After Crossings Fail Federal Inspection – CBS Boston."

Zones' learning curve. Nor would they need to resort to hiring costly outside consultants, only to then be told that they would not be able to afford the actual construction of a QZ.

To action

In the century and a half since railroads first arrived in the Midlands,[147] the region's population has skyrocketed,[148] the potentially-devastating health effects of chronic noise exposure have become clear,[149] and trains have traded in their sonorous steam whistles for industrial pneumatic train horns that consume around seventy liters of compressed air *per second*.[150] At the same time, the regulatory regime around train horns has changed. Before 1994, that regime was one under which individual municipalities, counties, and states could make regulatory policy that reflected their relative valuation of safety and serenity. No longer.

The present system of unending universal use of train horns is inflicted on most of the country from afar by FRA officials in Washington, where there is not a single horn-producing crossing,[151] like tax officials of the Ancien Régime subjecting commoners to the *taille* and *gabelle* that they themselves did not have to pay.[152] In place of the Second Estate, there are the residents of the six-county "Chicago Region," who—much like the nobility of prerevolutionary France—exercised their relatively-greater power in order to

[147] "Railroads."

[148] Clerk of the House of Representatives, "Abstract of the Returns of the Fifth Census"; U.S.Census Bureau, "Richland County, South Carolina."

[149] Passchier-Vermeer and Passchier, "Noise Exposure and Public Health."

[150] "The Locomotive Whistle."; "Nathan Airchime Model K-5LA Five Chime Locomotive Air Horns."

[151] "FRA - Safety Map."

[152] s.v., "French Revolution"; s.v., "Taille"; s.v., "Gabelle."

exempt themselves from the unpleasantries imposed on the populace writ large. No one, of course, is suggesting a revolution on the grounds of noise pollution—the time and place offer peaceable paths to change that eighteenth-century France lacked.

Yet there is some echo of that era in the indifference, inaction, and inability to recognize an issue that characterize so many local governments' attitudes to the problem of noise pollution. That attitude belies the fact that protecting citizens' health and wealth, managing infrastructure, and maintaining order (level crossing circumvention is, after all, illegal) are the only reason government *exists* in our post-Enlightenment society. It ignores the real harm caused by chronic noise. It defies reason—in those fortunate cases, like this one, where the benefits of a response would outweigh its costs. In the case of the study area, governments have indeed, to their credit, attempted to plan Quiet Zones after seeing that popular demands and cold logic alike justified such efforts.

As of yet, they have delivered no material results, and what progress has come has done so at a pace that surely cannot be what the citizens and officials who have called for and commissioned action on the problem wanted or demanded. That disconnect—just as much as the disconnect between requiring horn use to protect human interests and the immense damage that noise pollution has caused those interests—calls for action. "The country needs and, unless I mistake its temper, the country demands bold, persistent experimentation," Franklin Roosevelt once said. "It is common sense to take a method and try it: If it fails, admit it frankly and try another. But above all, try something."[153]

Dum spīrō spērō.

[153] Roosevelt, "Franklin D. Roosevelt Speeches: Oglethorpe University Address | Pepperdine School of Public Policy."

APPENDIX A: PLAN OF PROPOSED QUIET ZONES

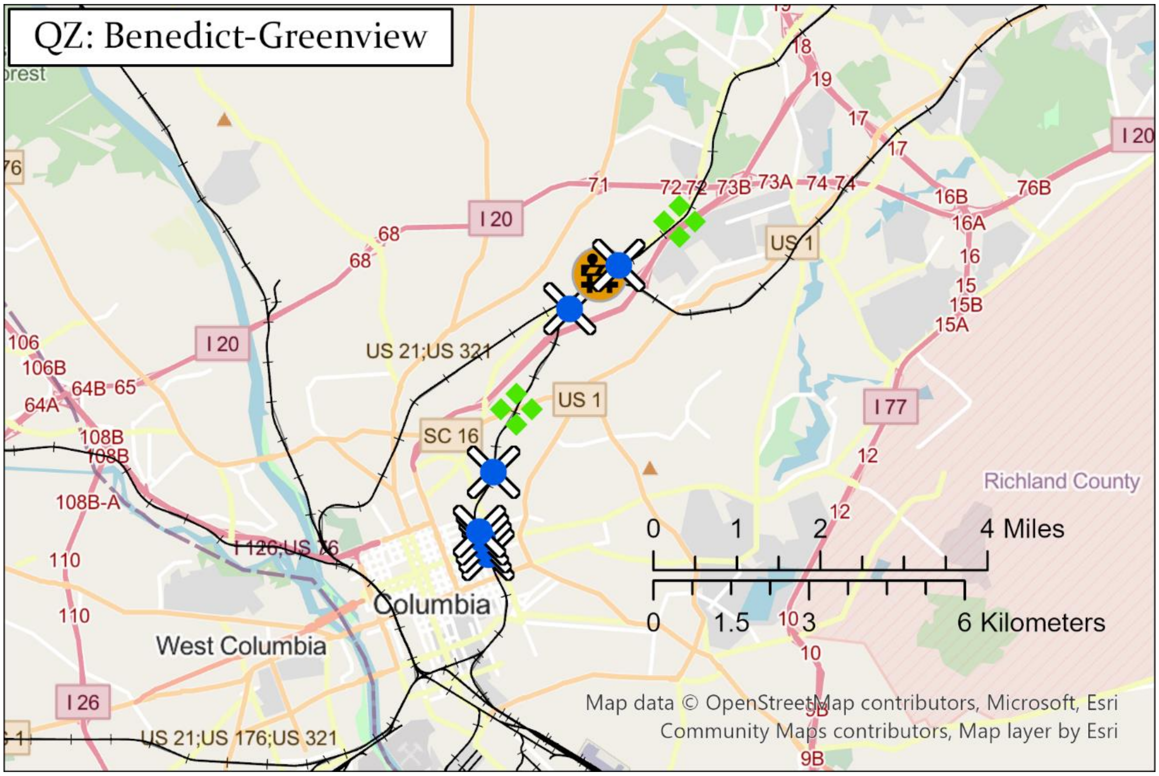
This section details the 14 proposed QZs both visually and textually.

Below each entry's overview map are three more items: a legend for the map, and two tables. The legend is the same for all fourteen maps, but a copy of it is included wit each for convenience. The tables are outputs from the FRA's Quiet Zone Calculator website; the first lists (in addition to less important details) the QZ's order-of-magnitude "costs," its RIWH, and its QZRI, along with the current NSRT (which is the same at each crossing). The second table lists all of the crossings to be included in the QZ. Crossings to be closed under this paper's plan are not included, though traffic from those crossings was redistributed to those listed in the table.

The crossing list table provides (most importantly) each crossing's FRA ID, name, traffic count (including additional traffic added as described in the preceding paragraph, the code number of the SSM to be installed (or 0 if none is required) and the post-SSM risk index of the crossing. The SSM codes are detailed in Table 5.

Code no.	SSM
0	No change (besides installation of two MUTCD W10-9P warning signs)
4	Installation of four-quadrant gates
12	"Mountable medians with Reflective Traffic Channelization Devices"
13	"Non-Traversable Curb Medians with or without Channelization Devices"

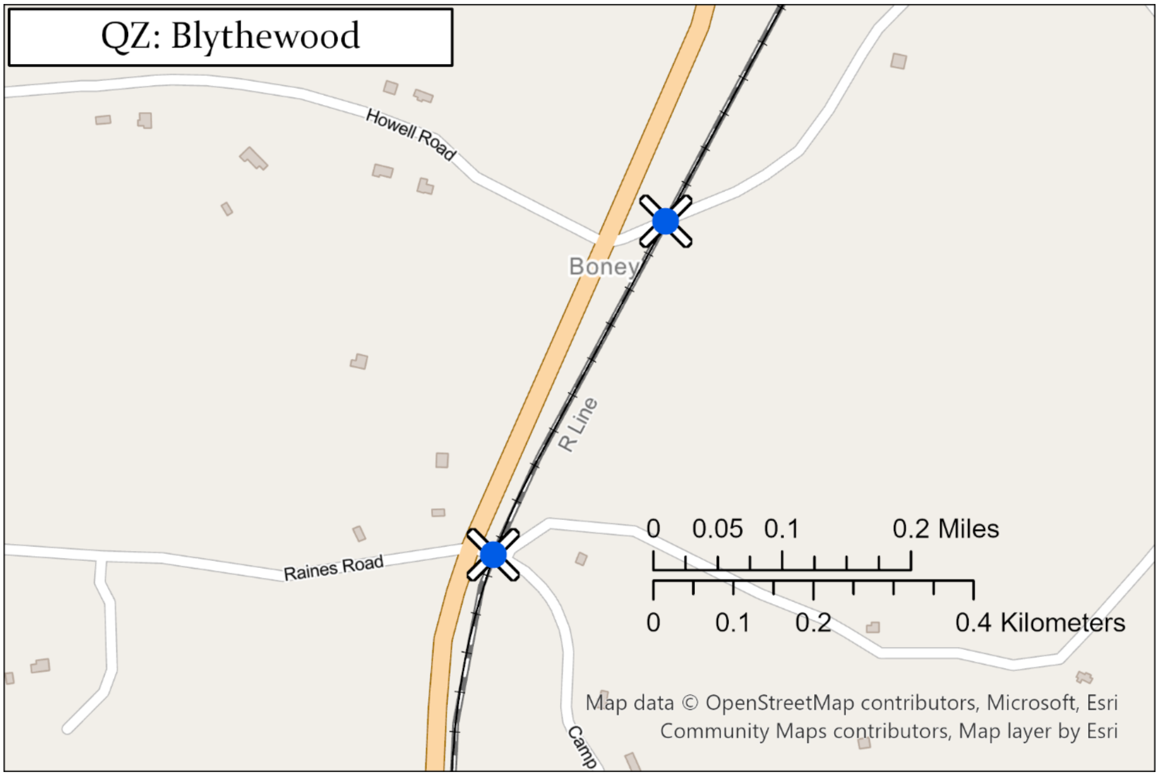
Figure 10: SSM code numbers as used on the FRA's Quiet Zone calculator website



Summary	
Proposed Quiet Zone:	BENEDICT – GREENVIEW
Type:	New 24-hour QZ
Scenario:	BENEDICT –_65517
Estimated Total Cost:	$200,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	20925.36
Quiet Zone Risk Index:	**20389.02**

Quieted w/o SSMs
Closure
Four-quadrant gates
Mountable median curb
Non-traversable curb median
Low- or no-traffic (incl. closed)
No ▲ (non-QZ)

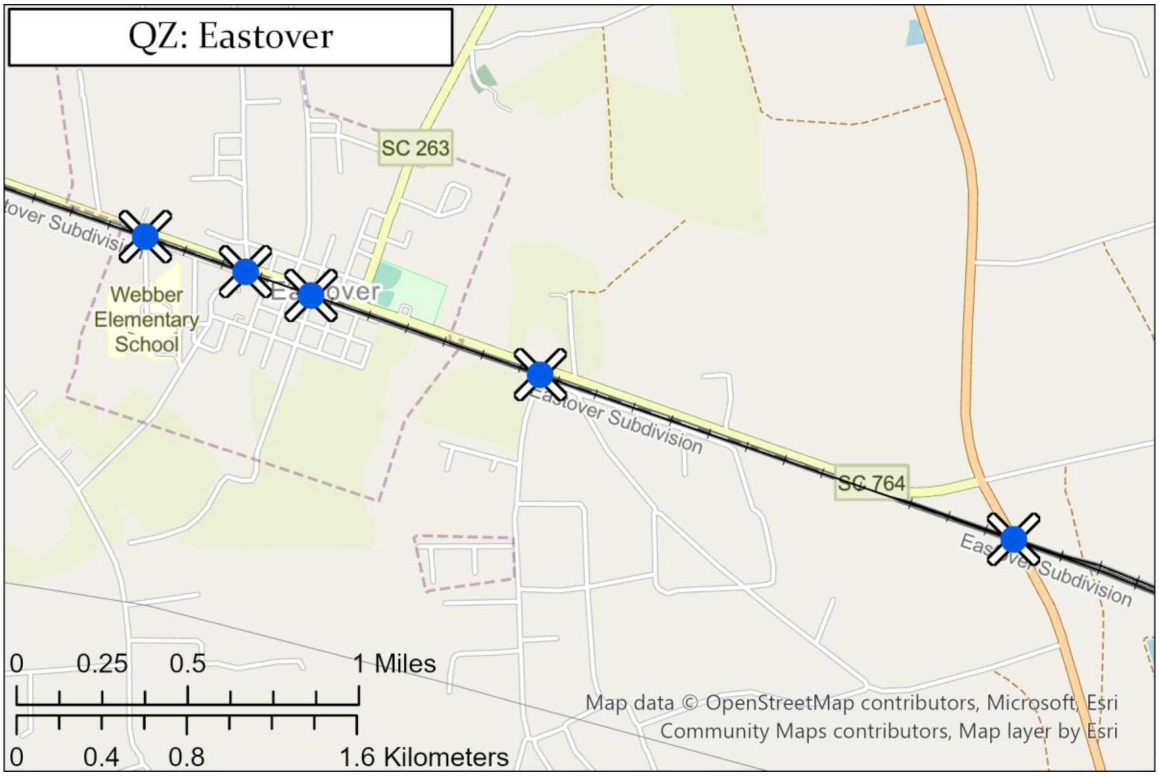
Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
715871K	**HAMPTON STREET**	**5305**	**Gates**	0	0	22,718.86	MODIFY
715872S	**TAYLOR STREET**	**18880**	**Gates**	0	0	25,481.63	MODIFY
715874F	**BLANDING STREET**	**2145**	**Gates**	0	0	16,973.61	MODIFY
715875M	**LAUREL STREET**	**7485**	**Gates**	0	0	23,515.40	MODIFY
715879P	**SLIGH ST/CHESTNUT ST**	**4501**	**Gates**	0	0	18,912.77	MODIFY
715880J	**BELTLINE BOULEVARD**	**24545**	**Gates**	0	4	15,267.07	MODIFY
715881R	**CUSHMAN DR**	**5677**	**Gates**	0	0	20,106.65	MODIFY
715883E	**FONTAINE ROAD**	**9800**	**Gates**	0	0	27,117.31	MODIFY
715884L	**WESTMORE DRIVE**	**6077**	**Gates**	0	4	13,407.87	MODIFY



Summary	
Proposed Quiet Zone:	Blythewood
Type:	New 24-hour QZ
Scenario:	BLYTHEWOOD_65086
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	4805.58
Quiet Zone Risk Index:	**8015.7**

Quieted w/o SSMs
Closure
Four-quadrant gates
Mountable median curb
Non-traversable curb median
Low- or no-traffic (incl. closed)
No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
715915H	**PORTIA ROAD**	**234**	**Gates**	0	0	8,416.52	MODIFY
715921L	**CAMP AGAPE ROAD**	**164**	**Gates**	0	0	7,614.89	MODIFY



Summary	
Proposed Quiet Zone:	Eastover
Type:	New 24-hour QZ
Scenario:	EASTOVER_65058
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	7696.75
Quiet Zone Risk Index:	**12838.19**

Quieted w/o SSMs

Closure

Four-quadrant gates

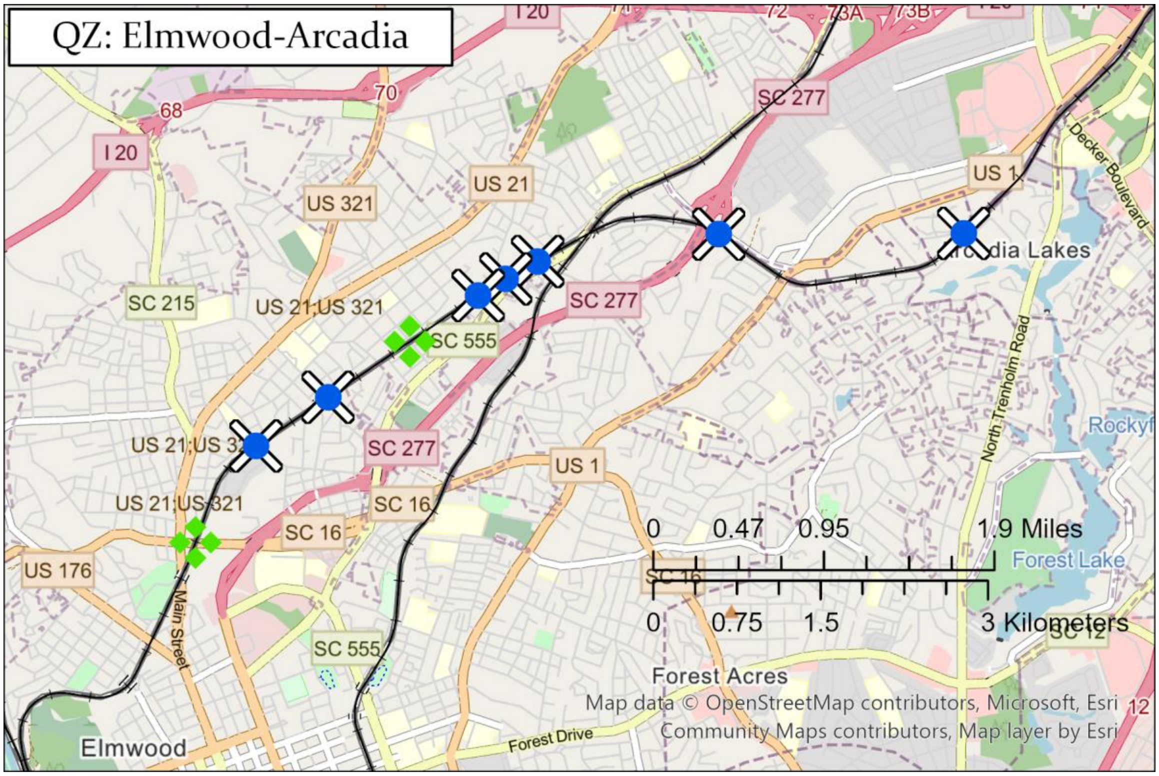
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
632635Y	**MCCORDS FERRY RD**	**1450**	**Gates**	0	0	35,813.31	MODIFY
632637M	**HICKORY HILL RD**	**950**	**Gates**	0	0	7,480.40	MODIFY
632639B	**ANDERSON ST**	**550**	**Gates**	0	0	6,410.99	MODIFY
632642J	**CHALK ST**	**1130**	**Gates**	0	0	7,854.19	MODIFY
632643R	**WEBBER SCHOOL RD**	**620**	**Gates**	0	0	6,632.04	MODIFY



Summary	
Proposed Quiet Zone:	ELMWOOD – ARCADIA
Type:	New 24-hour QZ
Scenario:	ELMWOOD – _65516
Estimated Total Cost:	$200,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	16520.63
Quiet Zone Risk Index:	**15581.92**

Quieted w/o SSMs

Closure

Four-quadrant gates

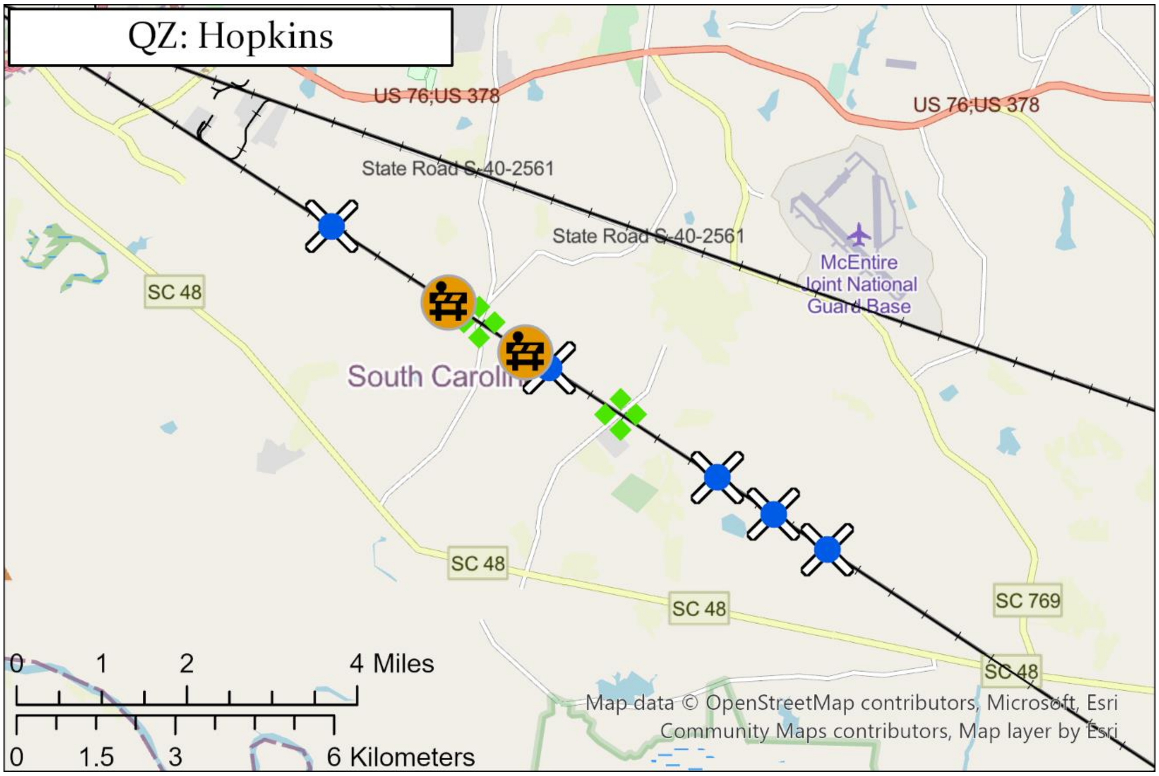
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
634297K	**ARCADIA LAKES DR**	**3300**	**Gates**	0	0	12,102.01	MODIFY
634301X	**CUSHMAN DR**	**1800**	**Gates**	0	0	12,562.49	MODIFY
634302E	**KOON RD**	**1920**	**Gates**	0	0	12,787.79	MODIFY
634303L	**GARY ST**	**1245**	**Gates**	0	0	6,312.10	MODIFY
634304T	**STANDISH ST**	**2080**	**Gates**	0	4	9,293.72	MODIFY
634305A	**COLUMBIA CLLGE BD**	**7500**	**Gates**	0	0	15,100.36	MODIFY
634307N	**LORICK RD**	**1356**	**Gates**	0	0	49,493.86	MODIFY
634308V	**SUNSET DRIVE**	**24700**	**Gates**	0	4	14,363.21	MODIFY
640941L	**FONTAINE CENTER Dr**	**513**	**Gates**	0	0	8,221.75	MODIFY



Summary	
Proposed Quiet Zone:	HOPKINS
Type:	New 24-hour QZ
Scenario:	HOPKINS_65515
Estimated Total Cost:	$200,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	15991.48
Quiet Zone Risk Index:	**14084.67**

Quieted w/o SSMs

Closure

Four-quadrant gates

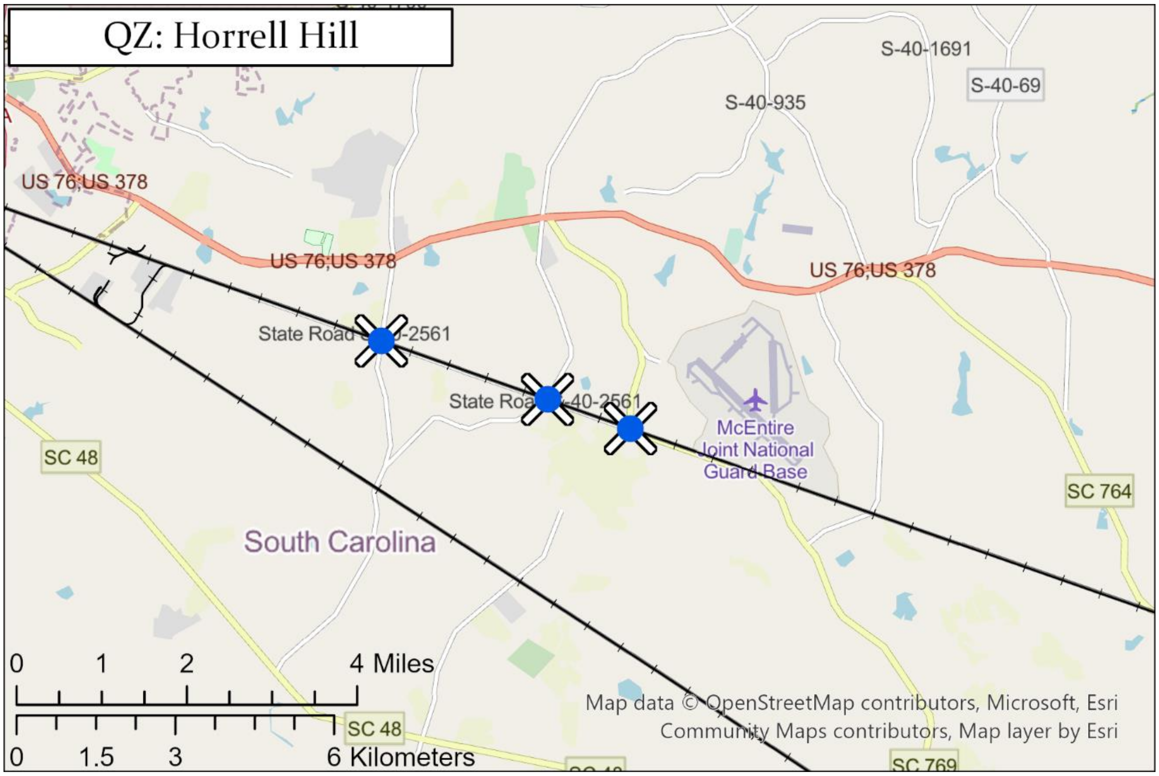
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
723723L	**DRY BRANCH ROAD**	**210**	**Gates**	0	0	14,721.61	MODIFY
723724T	**WESTON ROAD**	**152**	**Gates**	0	0	13,482.33	MODIFY
723725A	**MEETING HOUSE ROAD**	**262**	**Gates**	0	0	15,629.08	MODIFY
723727N	**MARTIN LUTHER KING BOULEVARD**	**991**	**Gates**	0	4	13,951.26	MODIFY
723728V	**JW NEAL ROAD**	**425**	**Gates**	0	0	17,792.47	MODIFY
723730W	**LOWER RICHLAND BLVD**	**4004**	**Gates**	0	4	5,392.99	MODIFY
723732K	**MONTGOMERY LANE**	**410**	**Gates**	0	0	17,622.97	MODIFY



Summary	
Proposed Quiet Zone:	Horrell Hill
Type:	New 24-hour QZ
Scenario:	HORRELL HI_65071
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	5906.75
Quiet Zone Risk Index:	**9852.47**

Quieted w/o SSMs

Closure

Four-quadrant gates

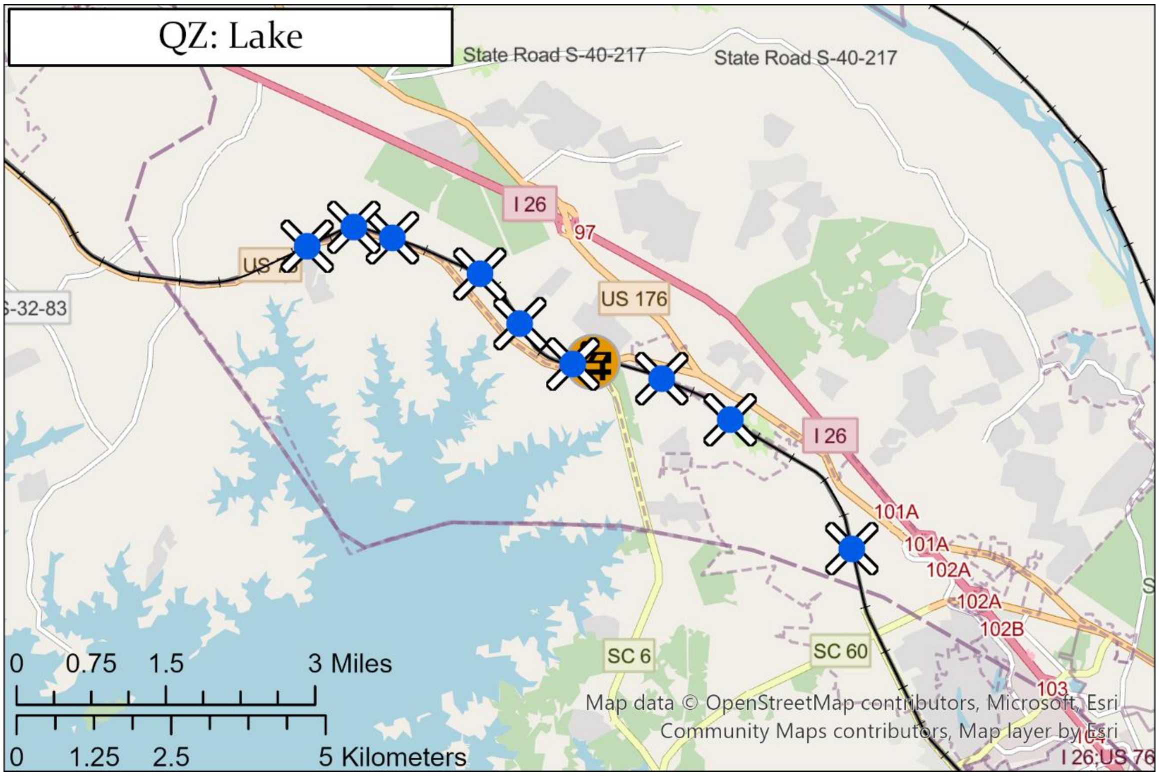
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
632190B	**HORRELL HILL RD**	**1025**	**Gates**	0	0	7,641.96	MODIFY
632194D	**LOWER RICHLAND BD**	**3405**	**Gates**	0	0	10,677.52	MODIFY
632652P	**CONGAREE RD**	**4100**	**Gates**	0	0	11,237.92	MODIFY



Summary	
Proposed Quiet Zone:	LAKE
Type:	New 24-hour QZ
Scenario:	LAKE_65521
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	7977.26
Quiet Zone Risk Index:	**13306.07**

Quieted w/o SSMs

Closure

Four-quadrant gates

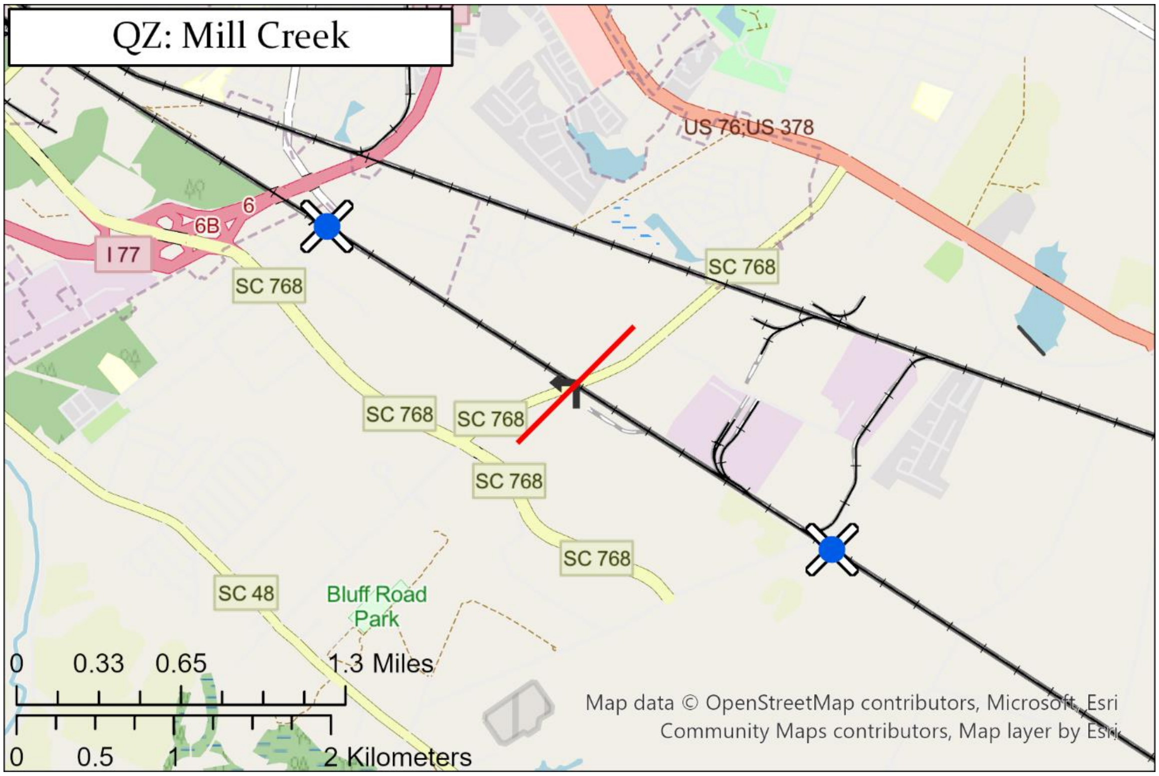
Mountable median curb

Non-traversable curb median

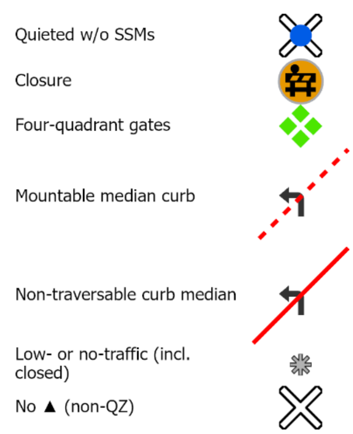
Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

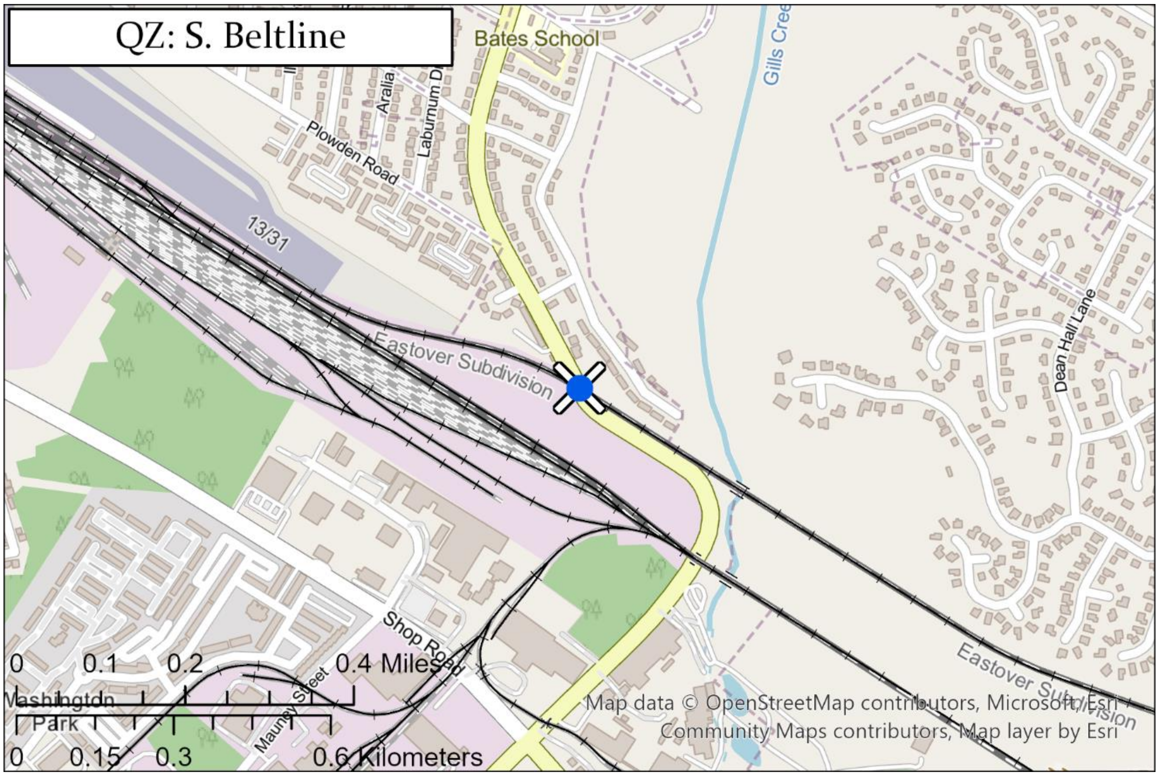
Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
843341W	**ROYAL TOWER DR**	**11085**	**Gates**	0	0	19,621.10	MODIFY
843346F	**FARMING CREEK RD**	**2680**	**Gates**	0	0	14,577.30	MODIFY
843347M	**SALEM CHURCH RD**	**1150**	**Gates**	0	0	11,565.26	MODIFY
843350V	**BICKLEY ROAD**	**4645**	**Gates**	0	0	16,904.52	MODIFY
843352J	**GATES RD**	**335**	**Gates**	0	0	8,201.56	MODIFY
843353R	**RAUCH-METZ RD**	**5240**	**Gates**	0	0	17,457.37	MODIFY
843355E	**HARVEY KILLIAN RD**	**415**	**Gates**	0	0	8,709.76	MODIFY
843356L	**MT VERNON CH RD**	**2390**	**Gates**	0	0	13,743.62	MODIFY
843357T	**THREE DOG RD**	**510**	**Gates**	0	0	8,974.15	MODIFY



Summary	
Proposed Quiet Zone:	Mill Creek
Type:	New 24-hour QZ
Scenario:	Mill Creek_65503
Estimated Total Cost:	$15,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	14410.4
Quiet Zone Risk Index:	**15206.94**



Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
723734Y	**LONGWOOD RD-SR 960**	**490**	**Gates**	0	0	15,036.27	MODIFY
723736M	**ATLAS ROAD**	**13195**	**Gates**	0	0	23,962.36	MODIFY
726282B	**PINEVIEW RD-SR 768**	**11575**	**Gates**	0	13	6,622.20	MODIFY



Summary	
Proposed Quiet Zone:	S. BELTLINE
Type:	New 24-hour QZ
Scenario:	S. BELTLIN_65522
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	4465.09
Quiet Zone Risk Index:	**7447.78**

Quieted w/o SSMs

Closure

Four-quadrant gates

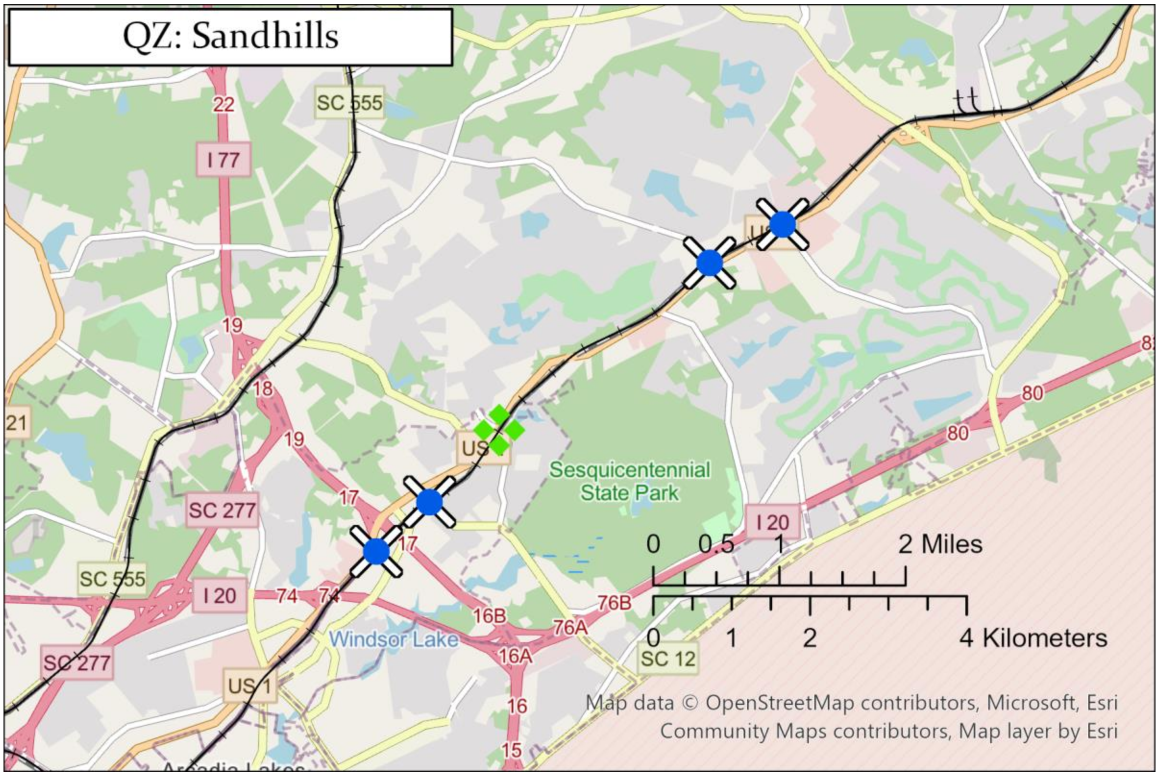
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
632205N	**S BELTLINE**	**8480**	**Gates**	0	0	7,447.78	MODIFY



Summary	
Proposed Quiet Zone:	Sandhills
Type:	New 24-hour QZ
Scenario:	SANDHILLS_65500
Estimated Total Cost:	$100,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	11878.57
Quiet Zone Risk Index:	**12167.04**

Quieted w/o SSMs

Closure

Four-quadrant gates

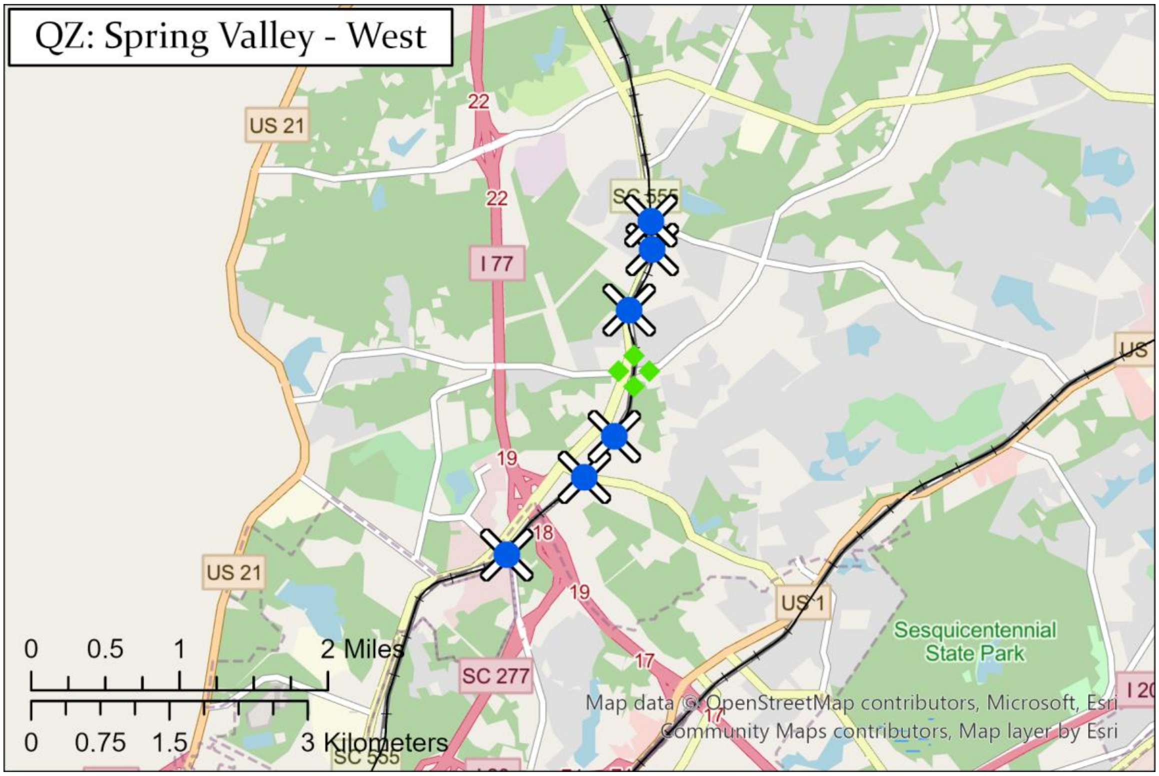
Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
634287E	**BRICKYARD RD**	**3900**	**Gates**	0	0	14,424.40	MODIFY
634289T	**WINDSOR LAKE BLVD**	**700**	**Gates**	0	4	8,392.41	MODIFY
634290M	**ALPINE ROAD**	**4200**	**Gates**	0	0	12,177.16	MODIFY
634291U	**OAKWAY DRIVE**	**80**	**Gates**	0	0	4,263.74	MODIFY
640942T	**SPARKLEBERRY LANE**	**11200**	**Gates**	0	0	21,577.51	MODIFY



Summary	
Proposed Quiet Zone:	Spring Valley West
Type:	New 24-hour QZ
Scenario:	SPRING VAL_65499
Estimated Total Cost:	$100,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	10631.19
Quiet Zone Risk Index:	**14608.51**

Quieted w/o SSMs

Closure

Four-quadrant gates

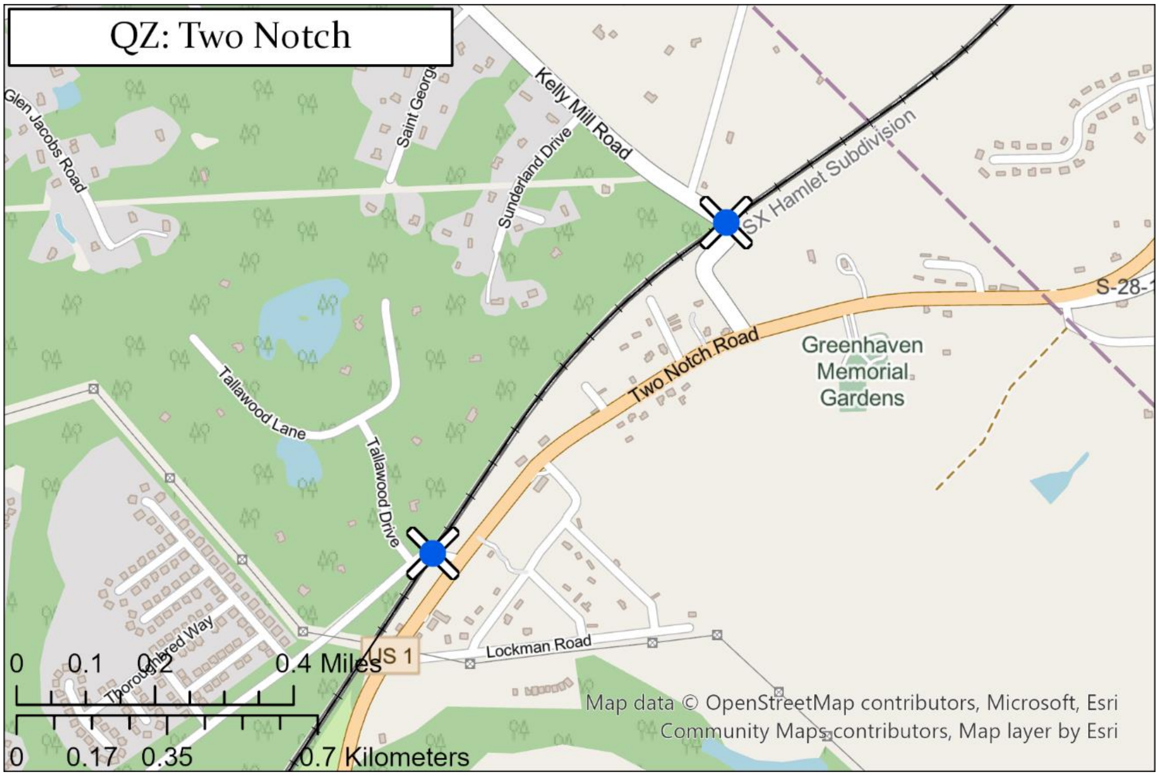
Mountable median curb

Non-traversable curb median

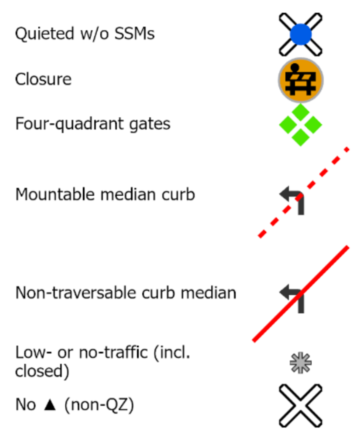
Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

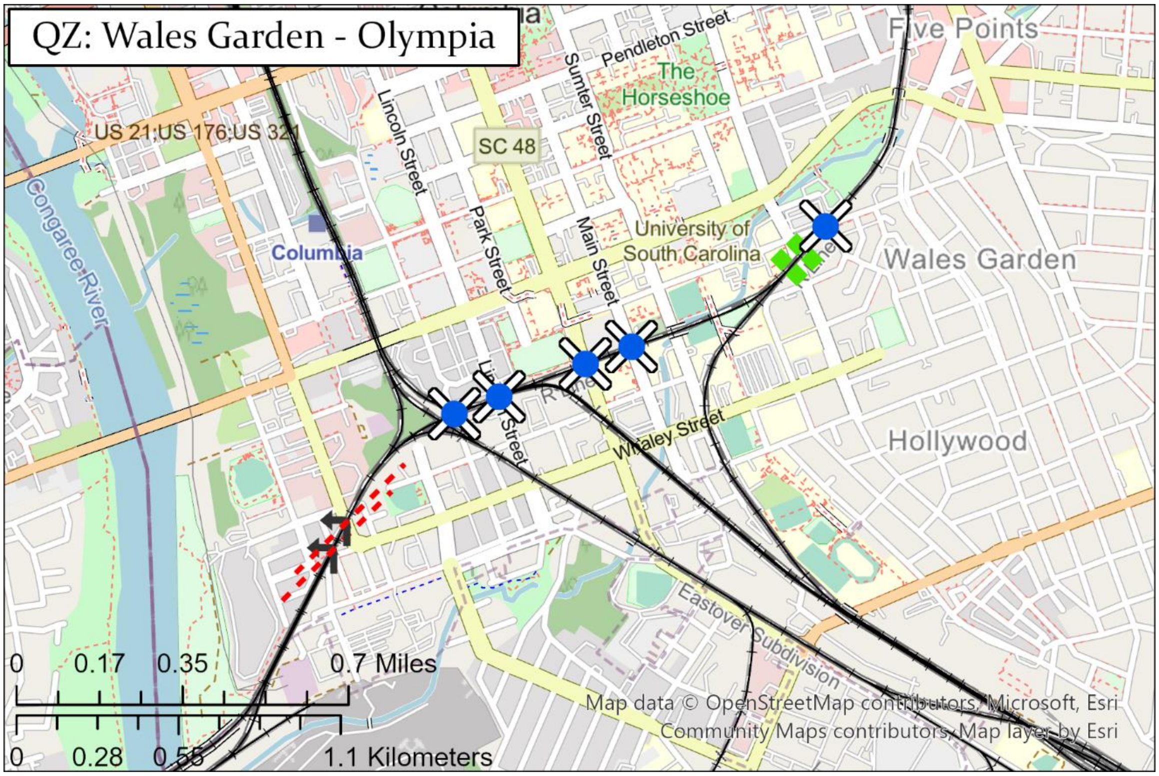
Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
715894S	**PARKLANE ROAD**	**13505**	**Gates**	0	0	26,070.01	MODIFY
715896F	**RABON ROAD**	**10070**	**Gates**	0	0	23,341.57	MODIFY
715897M	**FLINT LAKE ROAD**	**1296**	**Gates**	0	0	12,823.11	MODIFY
715898U	**HARD SCRABBLE ROAD**	**17438**	**Gates**	0	4	4,800.79	MODIFY
715899B	**PILGRIM CHURCH ROAD**	**228**	**Gates**	0	0	6,801.87	MODIFY
715900T	**OLD SLOAN ROAD**	**755**	**Gates**	0	0	11,664.32	MODIFY
715901A	**BRICKYARD ROAD**	**2858**	**Gates**	0	0	16,757.88	MODIFY



Summary	
Proposed Quiet Zone:	Two Notch
Type:	New 24-hour QZ
Scenario:	TWO NOTCH_65501
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	4393.81
Quiet Zone Risk Index:	**7328.88**



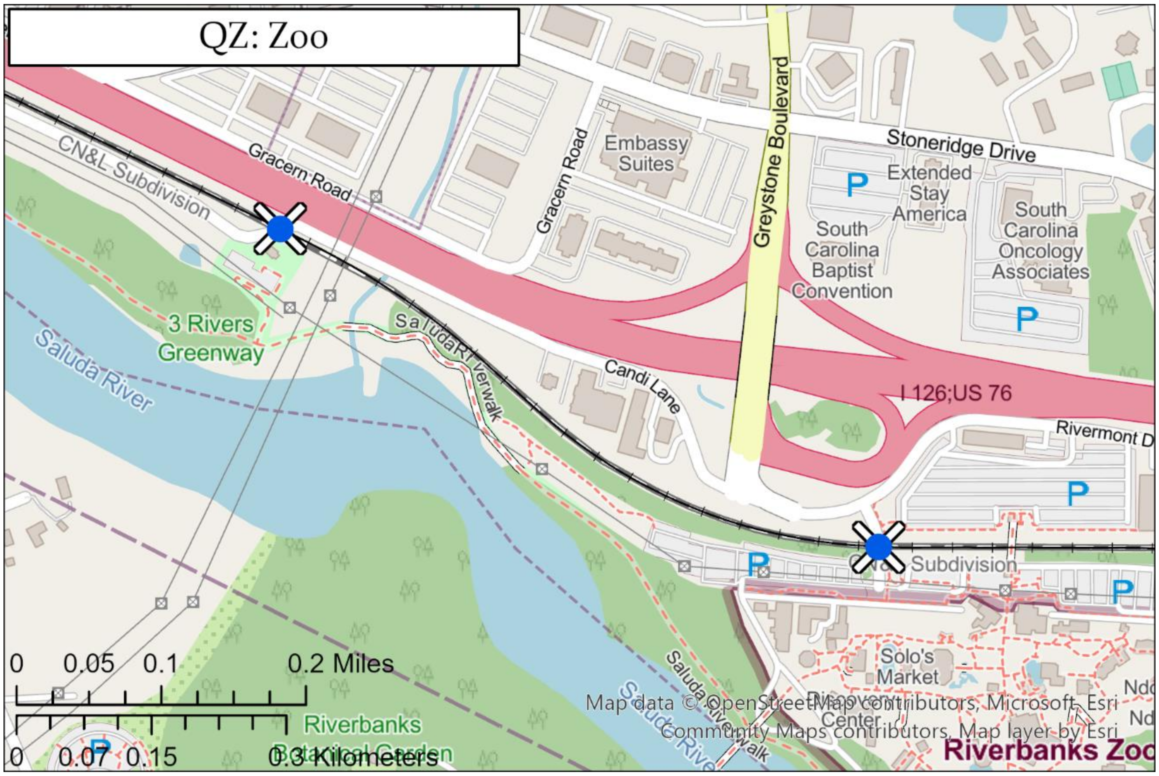
Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
634279M	**KELLY MILL RD**	**250**	**Gates**	0	0	7,229.94	MODIFY
634280G	**OLD TWO NOTCH RD**	**275**	**Gates**	0	0	7,427.82	MODIFY



Summary	
Proposed Quiet Zone:	Wales Garden – Olympia
Type:	New 24-hour QZ
Scenario:	WALES GARD_65505
Estimated Total Cost:	$126,000.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	12623.88
Quiet Zone Risk Index:	**14971.31**

Quieted w/o SSMs
Closure
Four-quadrant gates
Mountable median curb
Non-traversable curb median
Low- or no-traffic (incl. closed)
No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
715620R	**ASSEMBLY STREET**	**22180**	**Gates**	0	0	36,188.25	MODIFY
715621X	**MAIN STREET**	**12755**	**Gates**	0	0	32,449.40	MODIFY
715846C	**TRYON STREET**	**342**	**Gates**	0	12	2,397.27	MODIFY
715847J	**HUGER STREET**	**18480**	**Gates**	0	12	8,438.31	MODIFY
715866N	**PICKENS STREET**	**8106**	**Gates**	0	4	3,550.77	MODIFY
715867V	**WHEAT ST**	**2184**	**Gates**	0	0	6,794.34	MODIFY
716365M	**LINCOLN ST**	**1180**	**Gates**	0	0	19,633.38	MODIFY
716366U	**GASDEN**	**828**	**Gates**	0	0	10,318.79	MODIFY



Summary	
Proposed Quiet Zone:	Zoo
Type:	New 24-hour QZ
Scenario:	ZOO_65084
Estimated Total Cost:	$0.00
Nationwide Significant Risk Threshold:	15488 .00
Risk Index with Horns:	4583.82
Quiet Zone Risk Index:	**7645.81**

Quieted w/o SSMs

Closure

Four-quadrant gates

Mountable median curb

Non-traversable curb median

Low- or no-traffic (incl. closed)

No ▲ (non-QZ)

Crossing	Street	Traffic	Warning Device	Pre-SSM	SSM	Risk	
843290N	**WILDLIFE PRKWAY**	**1565**	**Gates**	0	0	12,448.43	MODIFY
843292C	**CANDI LANE**	**110**	**Gates**	0	0	2,843.19	MODIFY

APPENDIX B: BEFORE-AND-AFTER SOUND MAPS

This appendix contains before-and-after maps of the estimated value of L_{MAX} before and after implementation of all fourteen proposed Quiet Zones. To reconcile the competing needs for high-definition data and compatibility with the paper size of this study, a grid system was produced and used to divide the county into more manageable subparts. Figure 11 depicts the exact arrangement of that system.

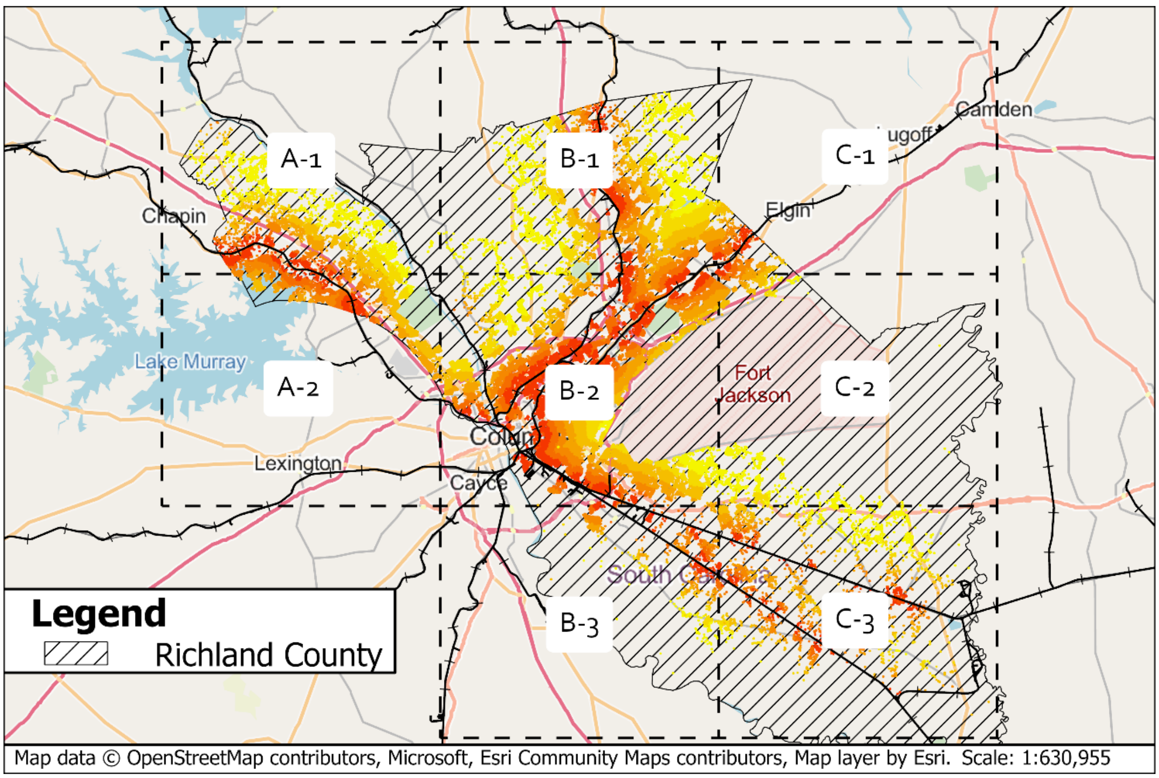
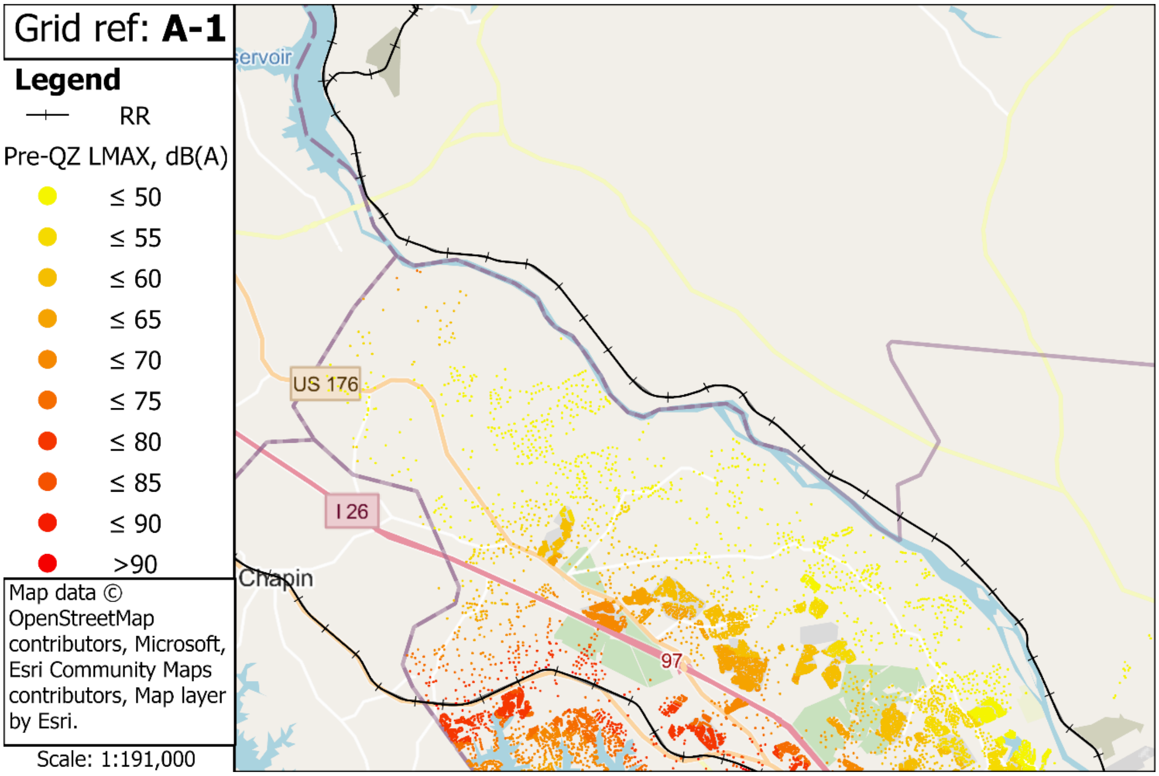
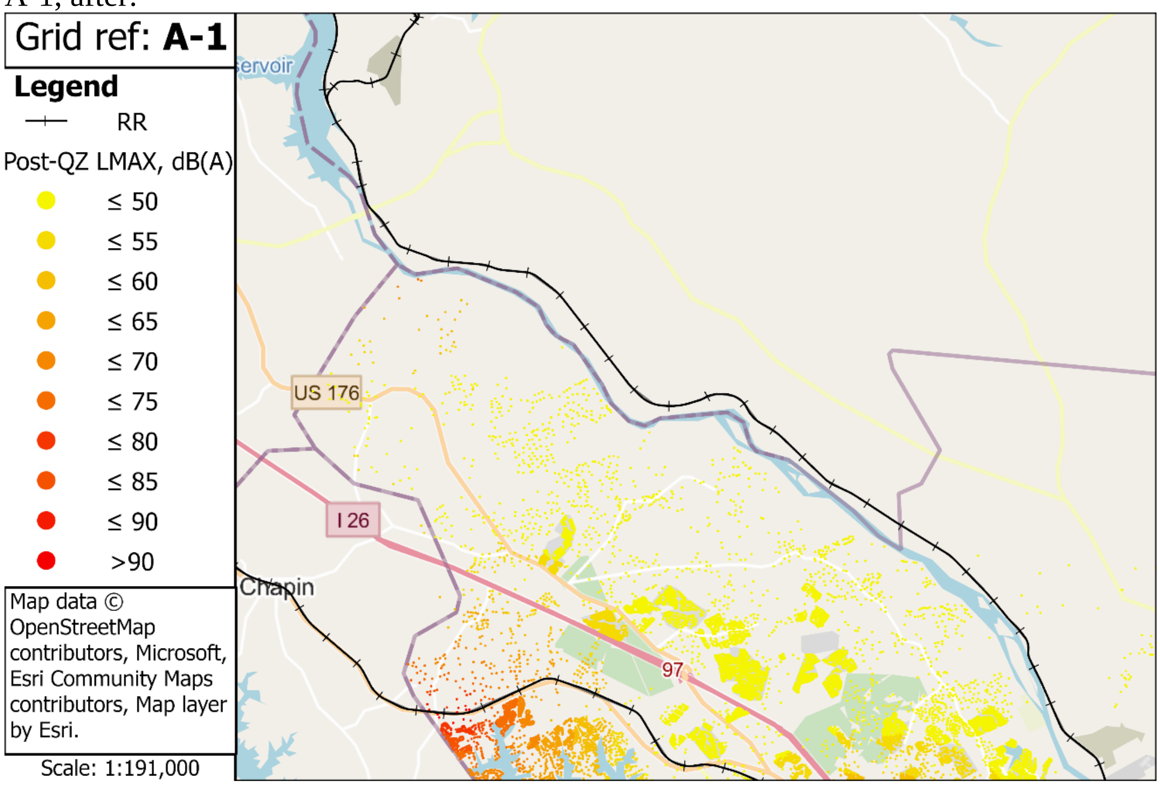


Figure 11: Overview of Richland County showing the grid system used for Appendix B's before-and-after maps. N.b. that A-3 is wholly outside Richland and was therefore omitted from this appendix's set of zoomed-in maps.

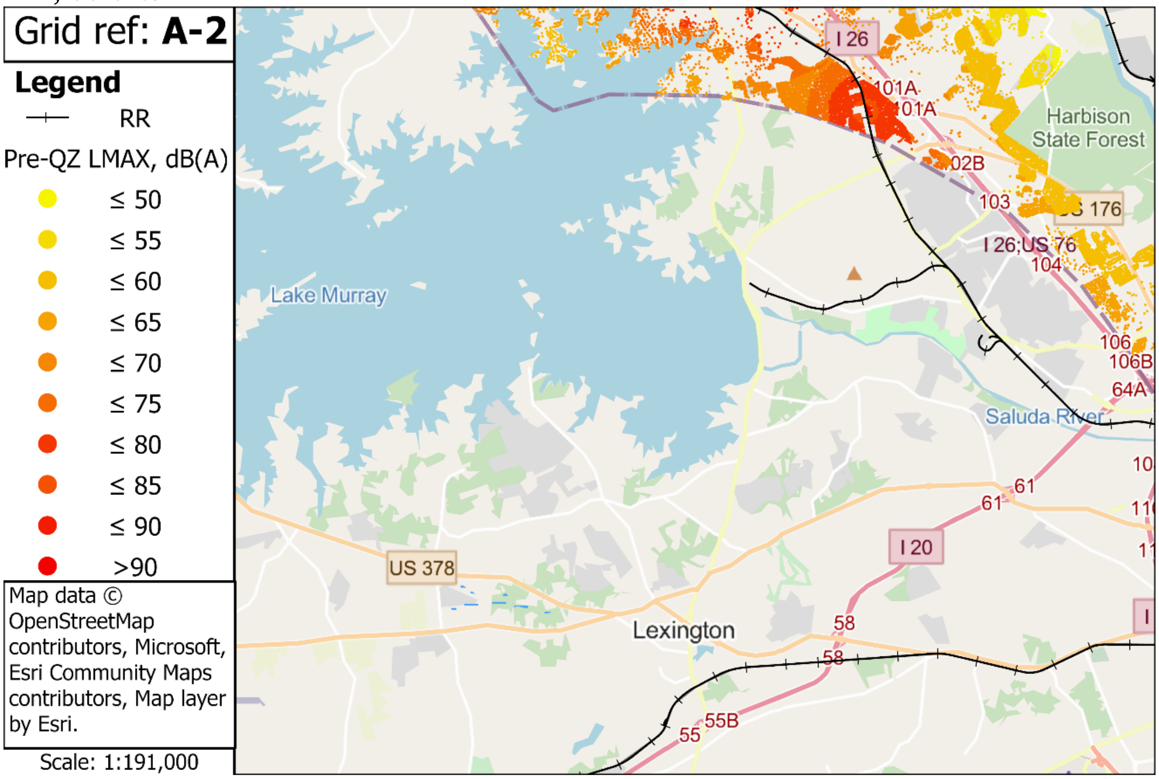
A-1, before:



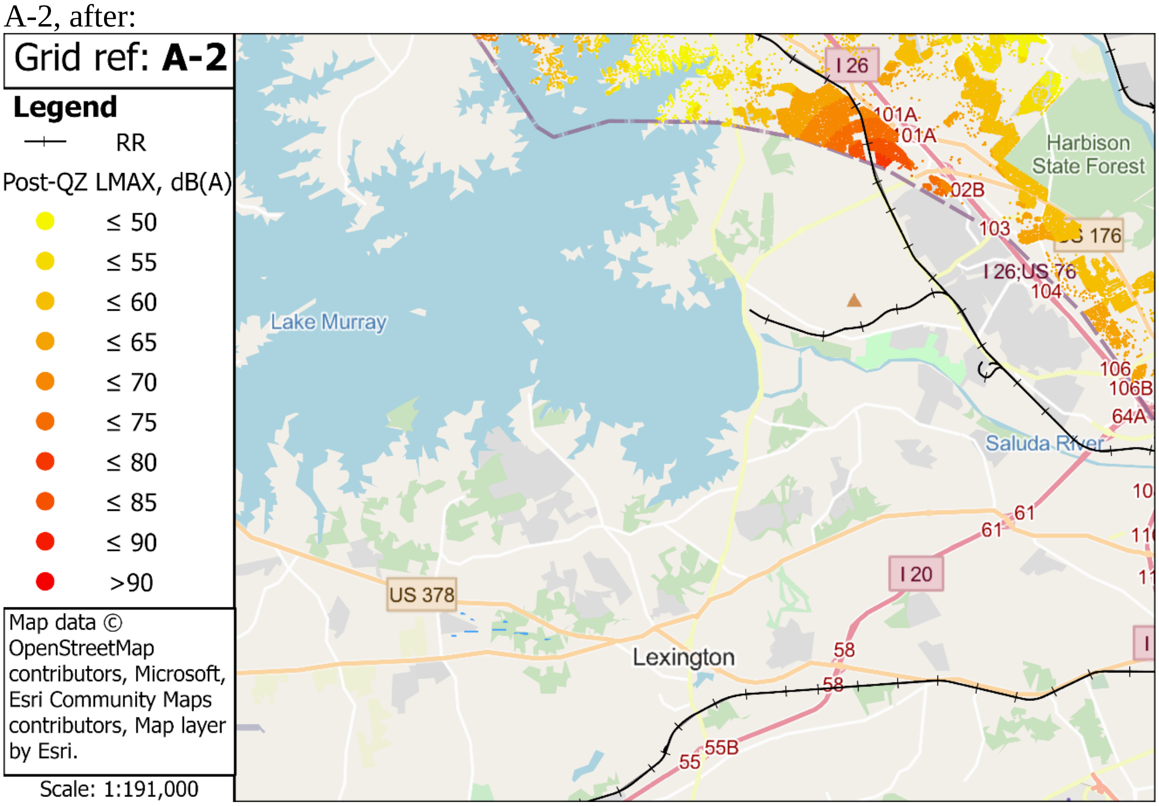
A-1, after:



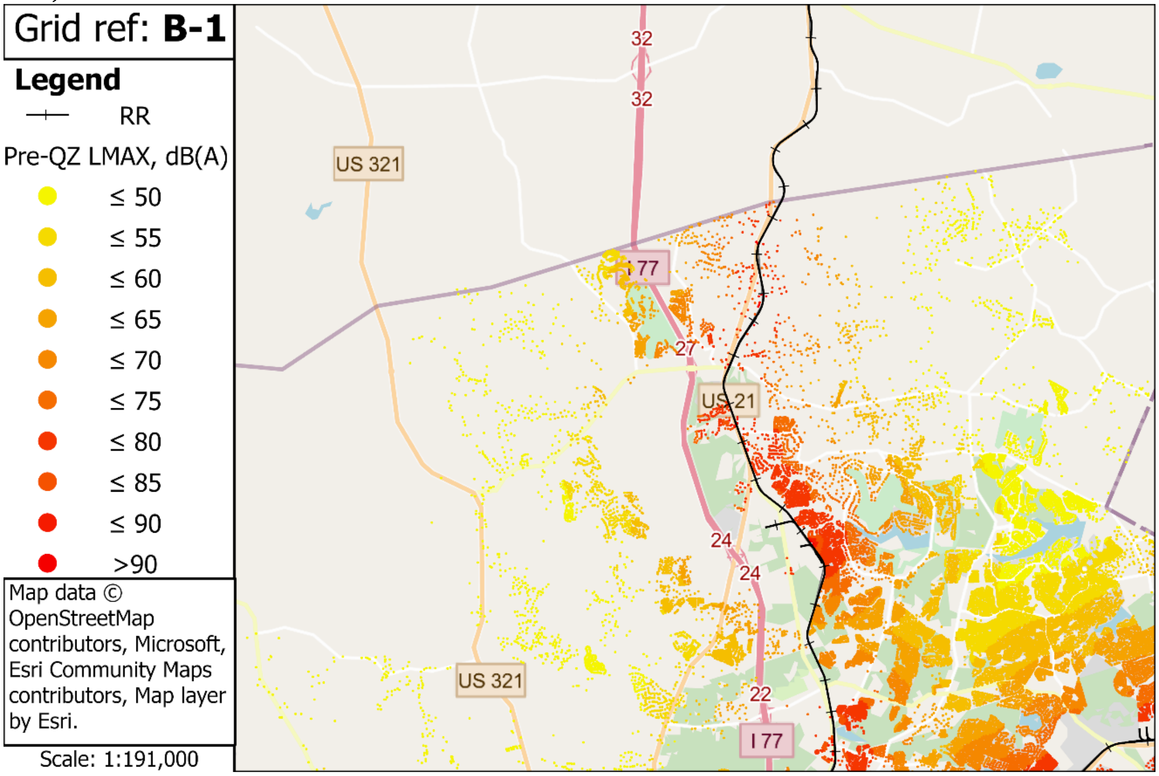
A-2, before:



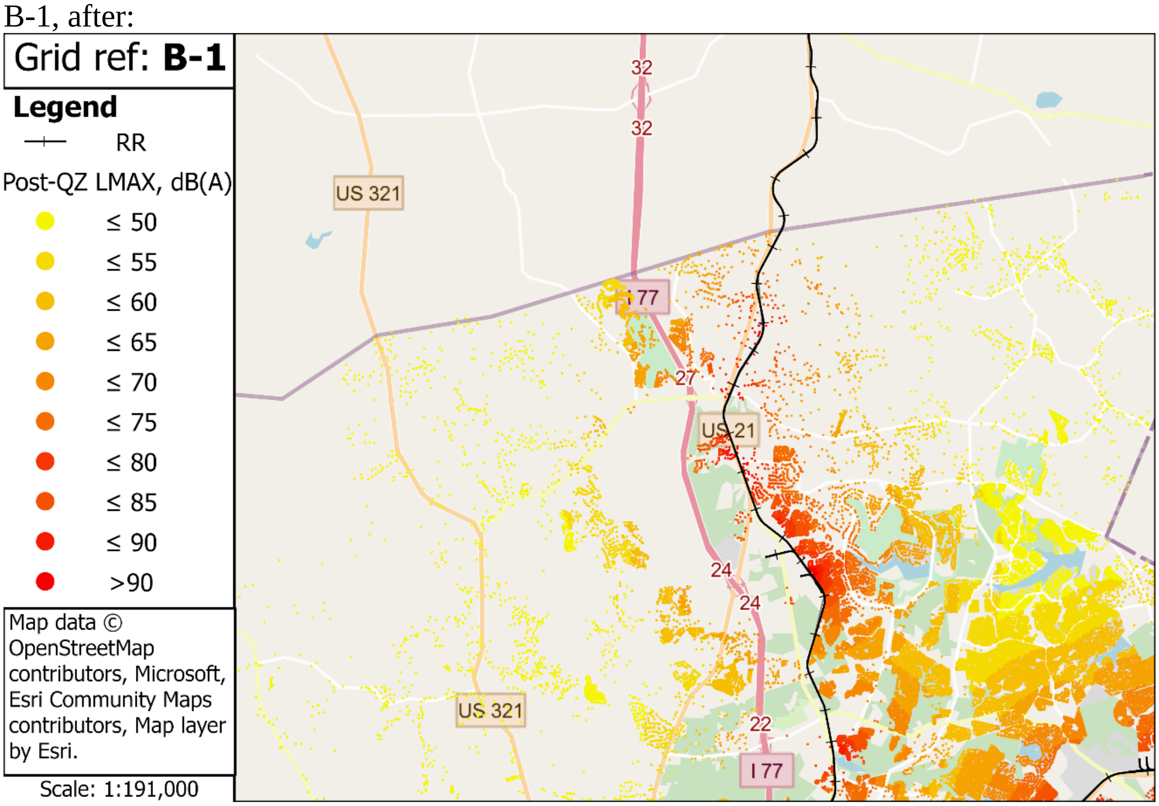
A-2, after:



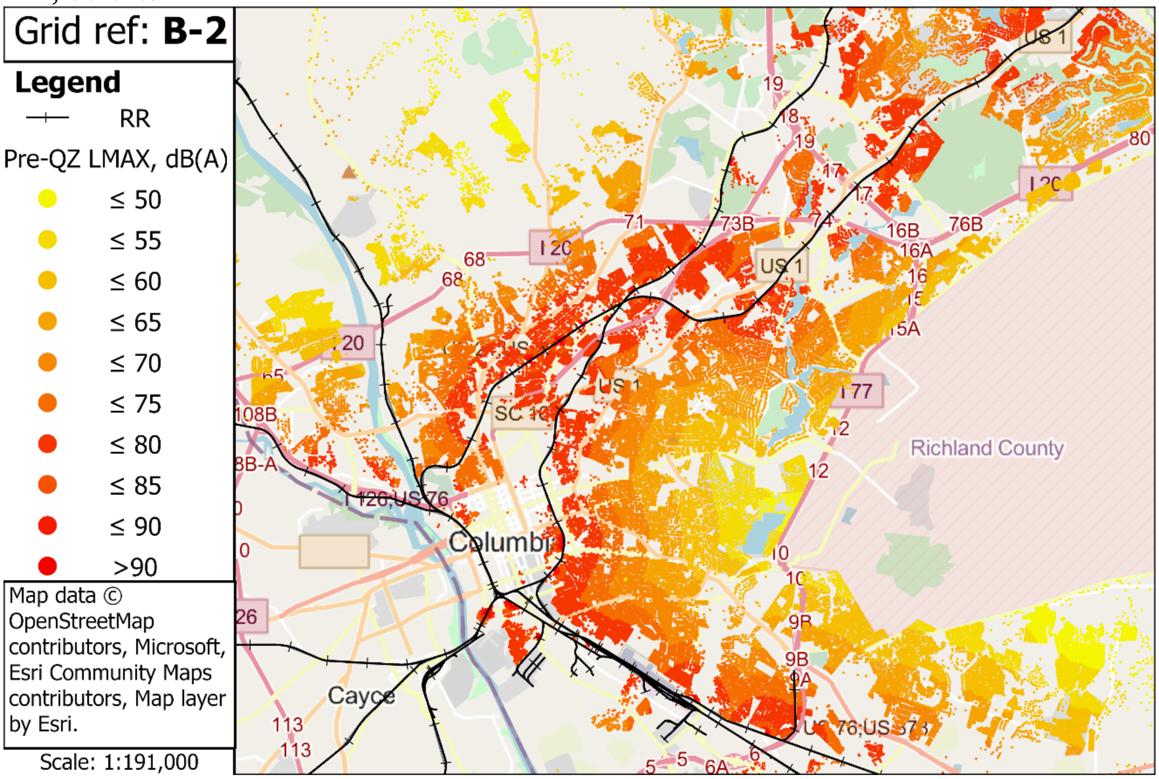
B-1, before:



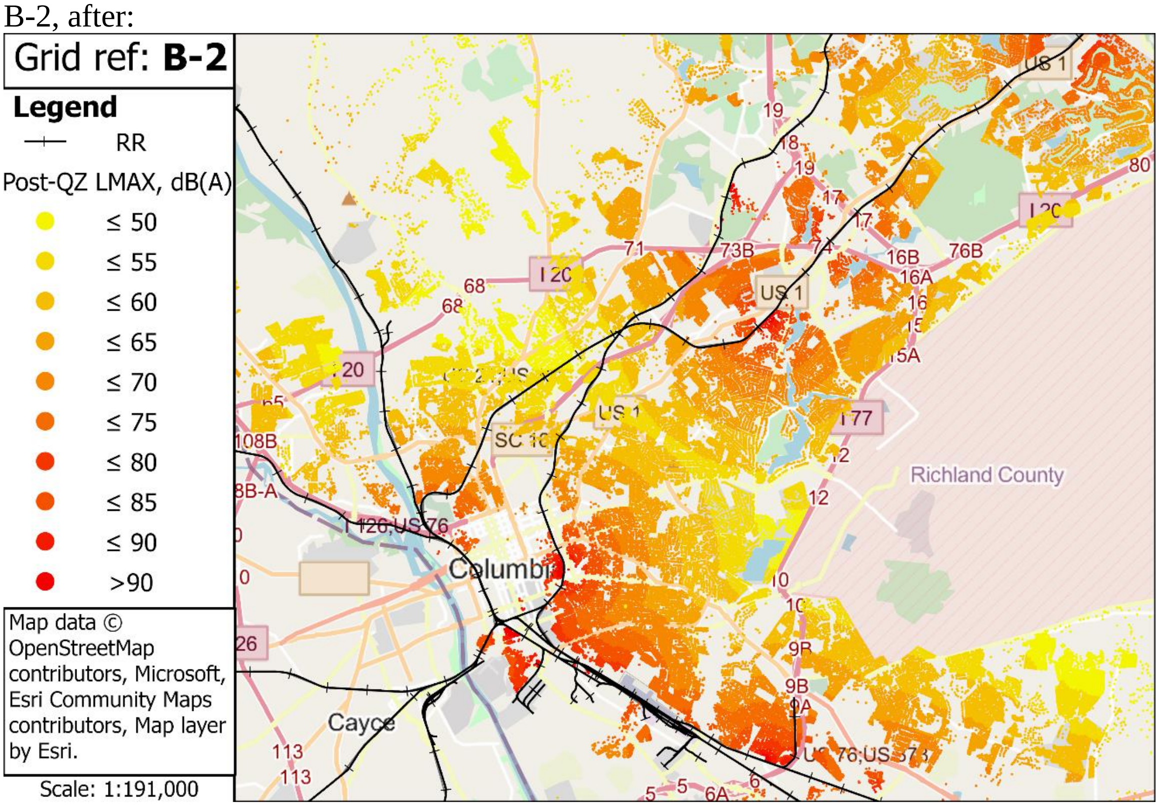
B-1, after:



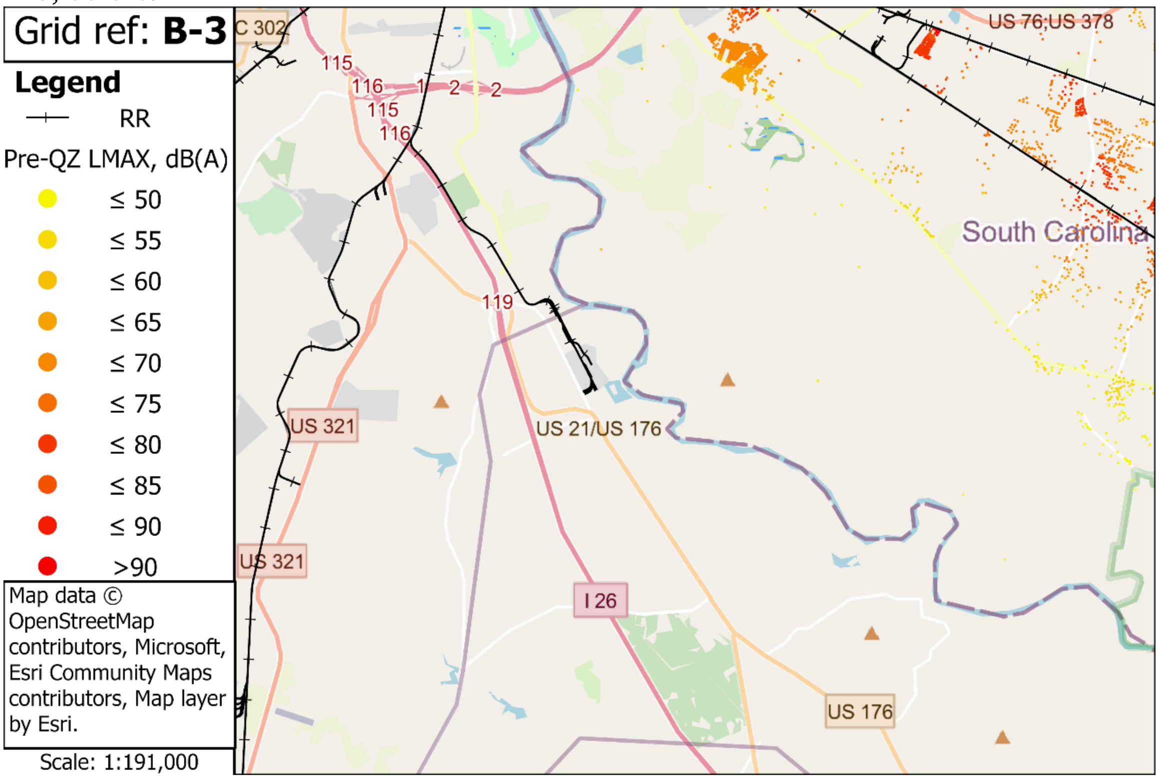
B-2, before:



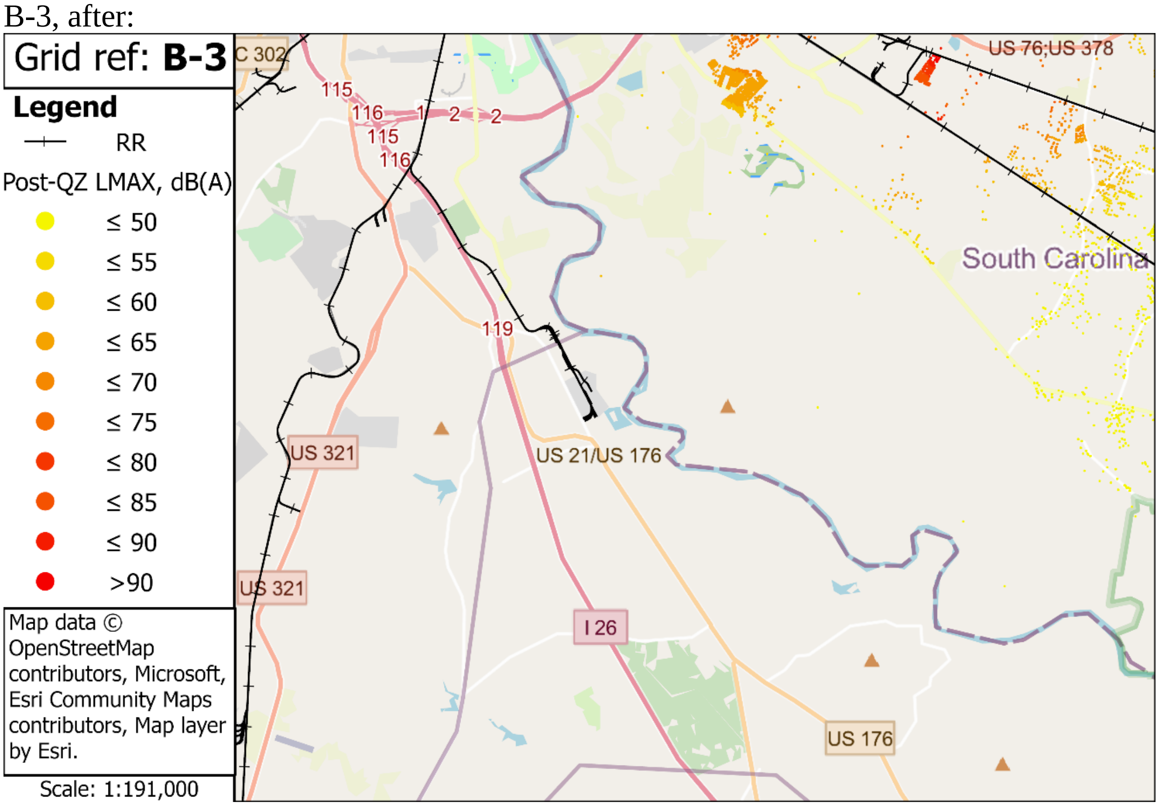
B-2, after:



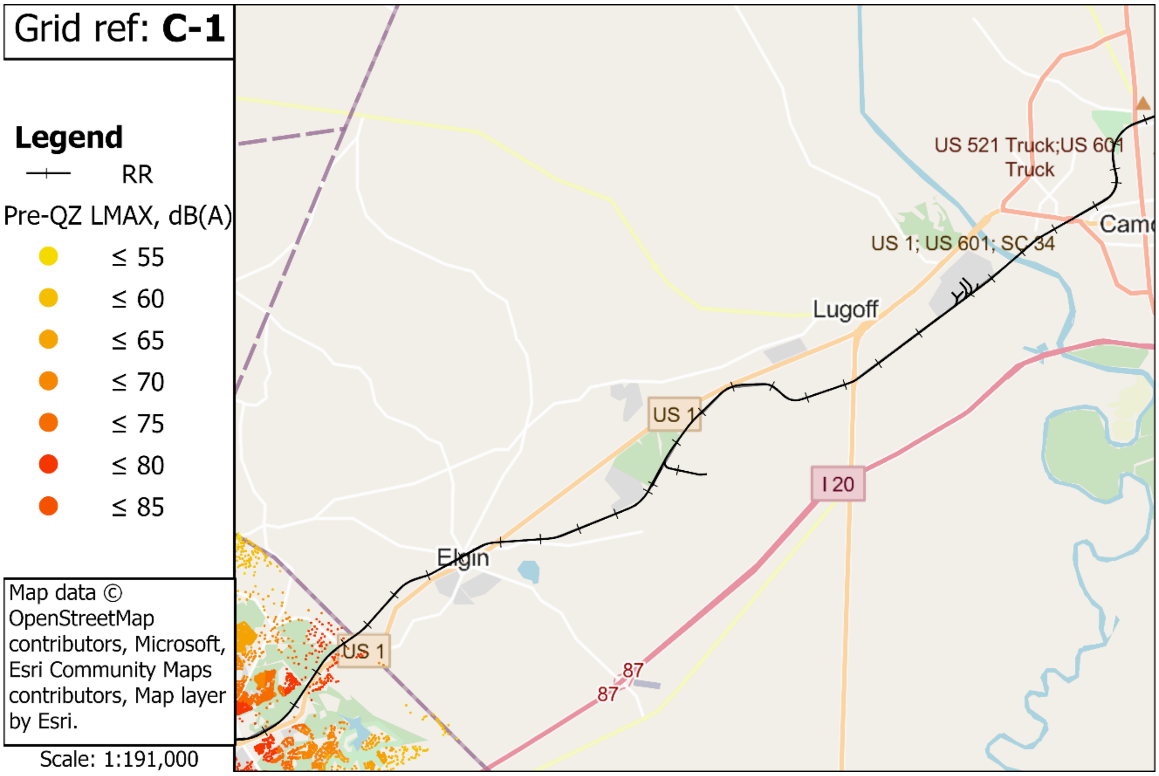
B-3, before:



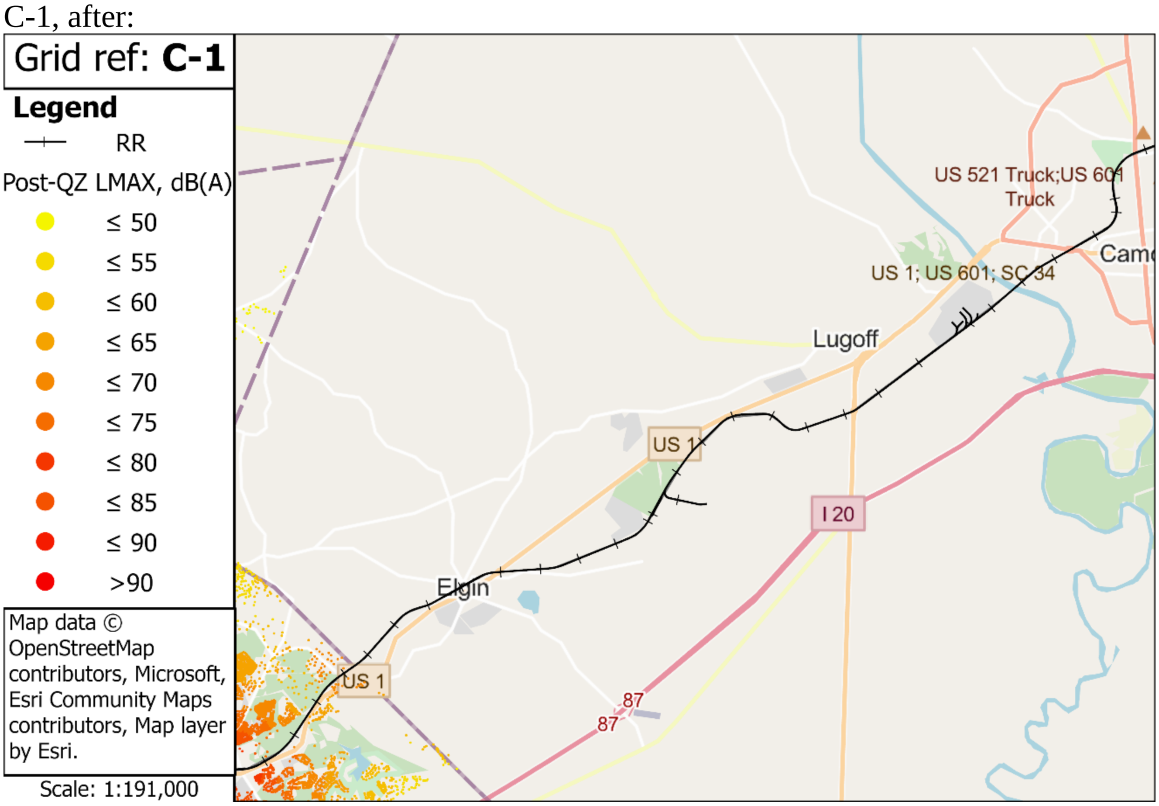
B-3, after:



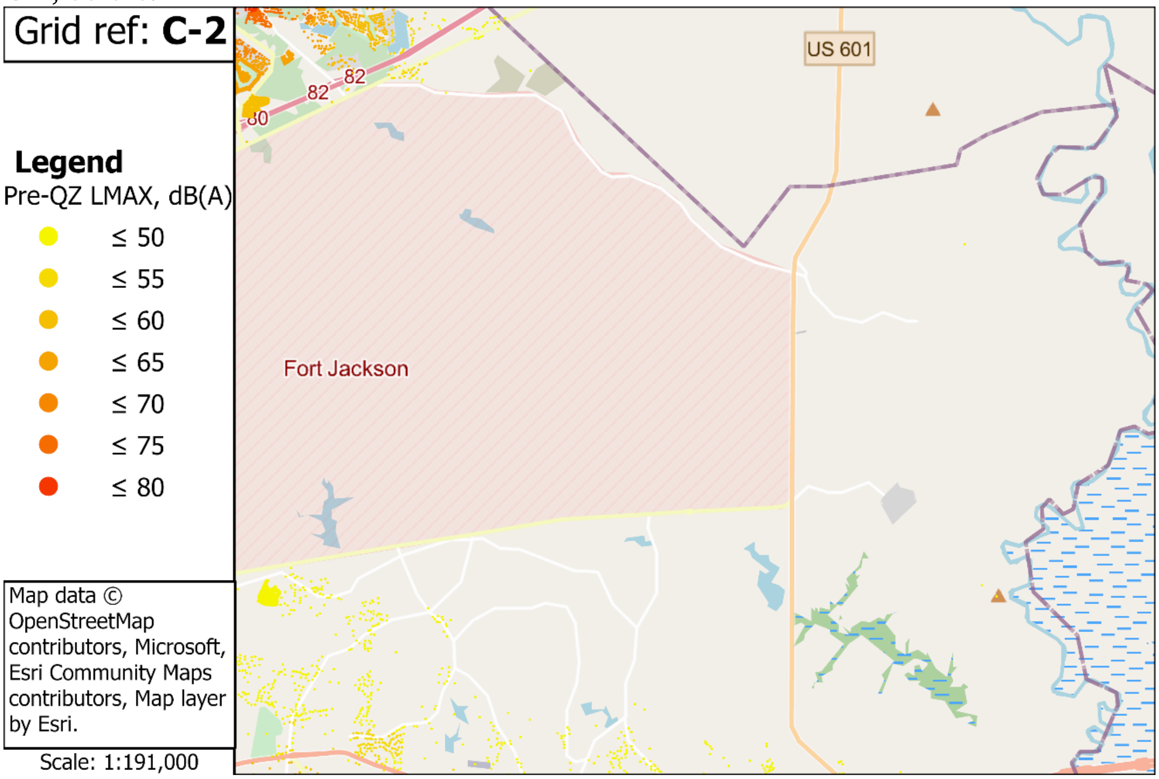
C-1, before:



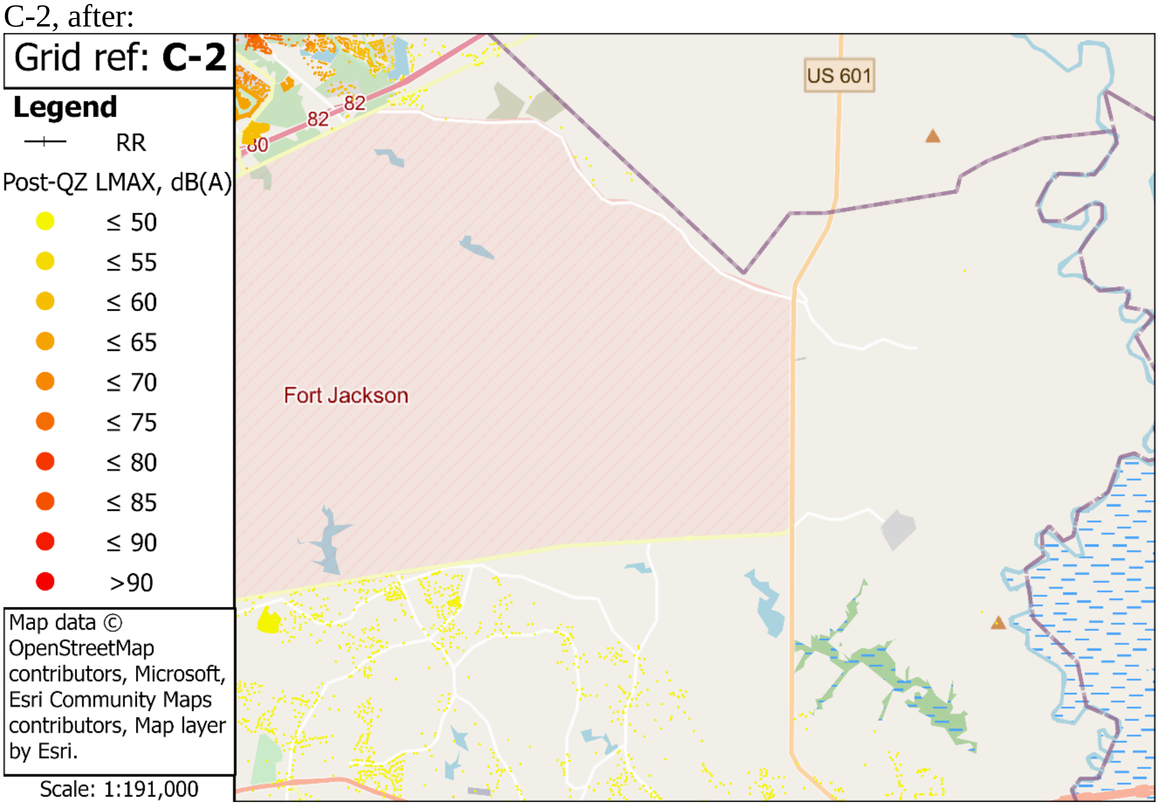
C-1, after:



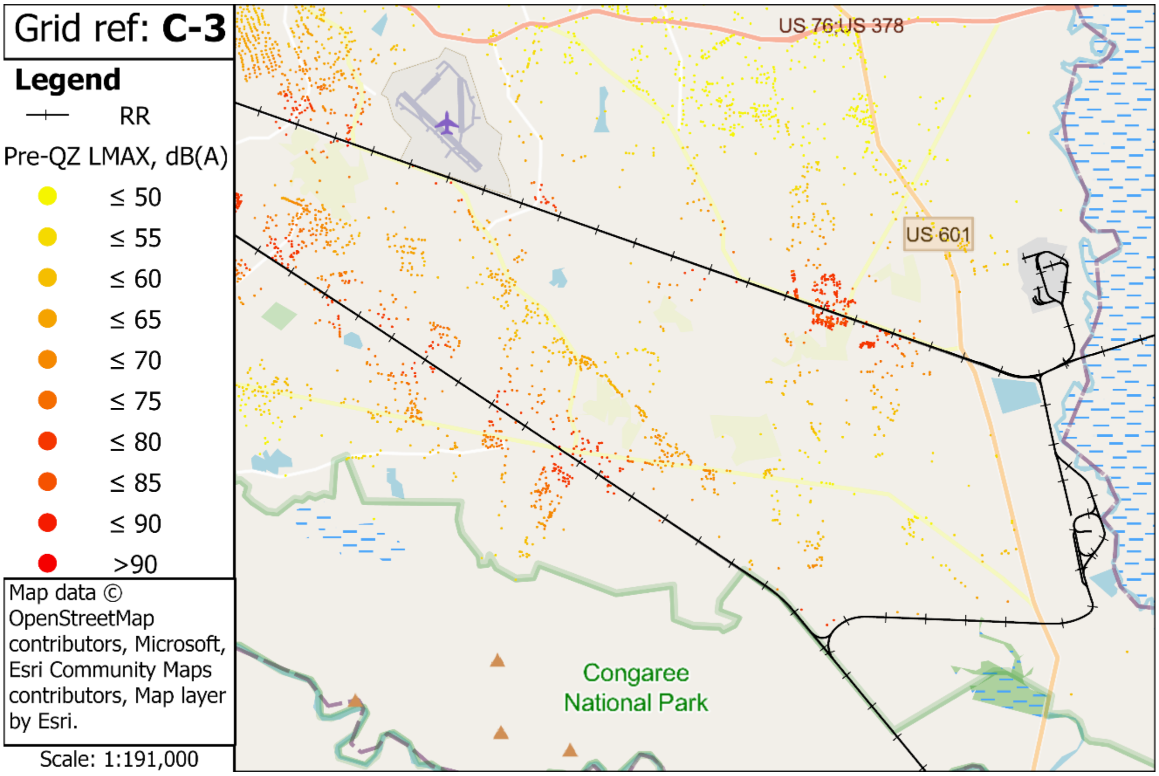
C-2, before:



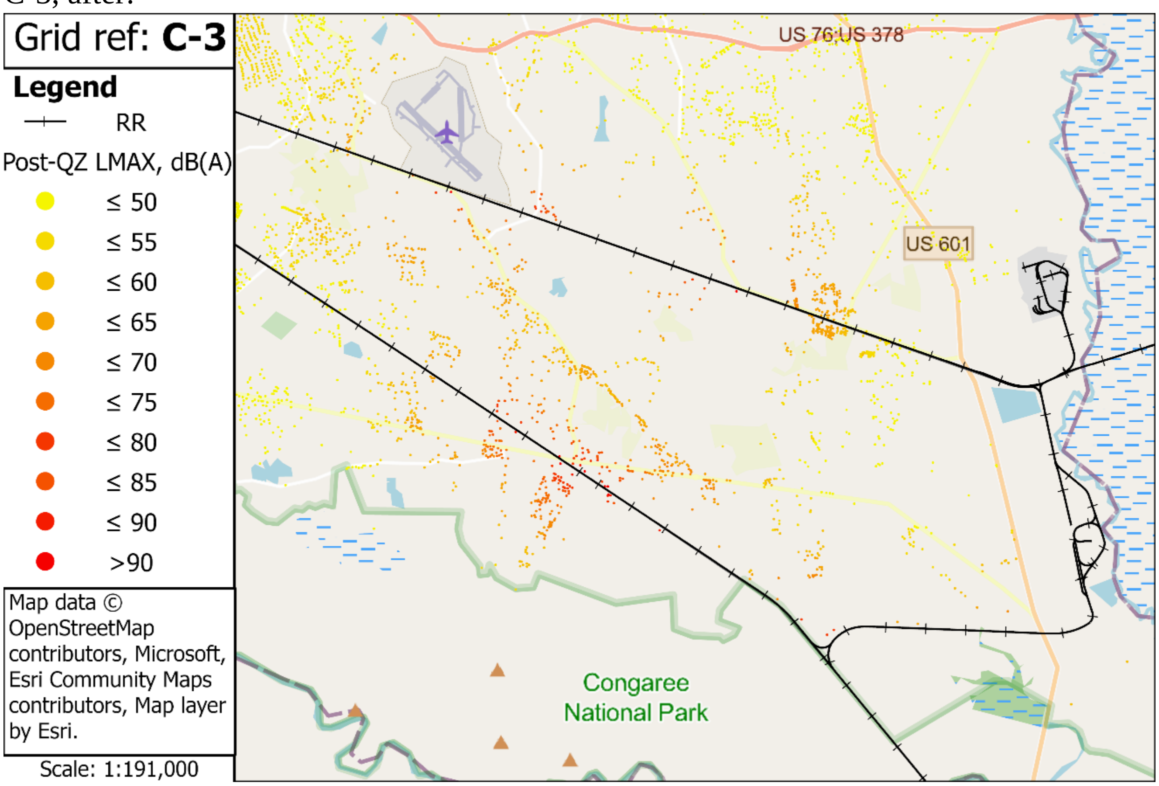
C-2, after:



C-3, before:



C-3, after:



APPENDIX C: COST ESTIMATE TABLE

	QZ name	Benedict – Greenview	Blythewood	Eastover	Elmwood – Arcadia	Hopkins	Horrell Hill	Lake	Mill Creek	South Beltline	Sandhills	Spring Valley West	Two Notch	Wales Garden – Olympia	Zoo	Categorical totals
Inputs	Total # of xings silenced (does not include those closed)	9	2	5	9	7	3	9	3	1	5	7	2	8	2	72
	Public closures	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
	Private closures	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
	Two-quadrant to four-quadrant gate upgrades	2	0	0	2	2	0	0	0	0	1	1	0	1	0	9
	Mountable median curb with channelizing devices (#)	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	Non-mountable median curb (#)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	Total LF curb needed (mountable)	0	0	0	0	0	0	0	0	0	0	0	0	400	0	400
	Total LF curb needed (NM)	0	0	0	0	0	0	0	200	0	0	0	0	0	0	200
	Gate assemblies	4	0	0	4	4	0	0	0	0	2	2	0	2	0	18
	Signs	18	4	10	18	14	6	18	6	2	10	14	4	16	4	144
	Channelization devices	0	0	0	0	0	0	0	0	0	0	0	0	64	0	64
@ Encinitas prices	Median curb, mountable, concrete, $/LF								$40.00							
	Median curb, non-mountable, concrete, $/LF								$60.00							
	Exit gate assemply (incl. flashers), ea								$20,000.00							
	MUTCD W10-9P sign, ea								$250.00							
	Curb channelization devices, ea								$60.00							
	Projected cost of materials	$84,500	$1,000	$2,500	$84,500	$83,500	$1,500	$4,500	$13,500	$500	$42,500	$43,500	$1,000	$63,840	$1,000	$343,340
"Variable" costs	Labor	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	
	Machinery rental	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	
	Subtotal: materials, equipment, general labor	$234,500	$151,000	$152,500	$234,500	$233,500	$151,500	$154,500	$163,500	$150,500	$192,500	$193,500	$151,000	$213,840	$151,000	
Construction Costs	Construction Contingency (20% of Eng. Estimate)	$46,900	$30,200	$30,500	$46,900	$46,700	$30,300	$30,900	$32,700	$30,100	$38,500	$38,700	$30,200	$42,768	$30,200	$505,568
	Mobilization/Demobilization (10% of Eng. Estimate)	$35,175	$22,650	$22,875	$35,175	$35,025	$22,725	$23,175	$24,525	$22,575	$28,875	$29,025	$22,650	$32,076	$22,650	$379,176
	Traffic Handling (10% of Eng. Estimate)	$35,175	$22,650	$22,875	$35,175	$35,025	$22,725	$23,175	$24,525	$22,575	$28,875	$29,025	$22,650	$32,076	$22,650	$379,176
	Traffic Flagging (200 hrs at $75/ hr)	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$210,000
	Total Construction Costs:	$601,250	$392,500	$396,250	$601,250	$598,750	$393,750	$401,250	$423,750	$391,250	$496,250	$498,750	$392,500	$549,600	$392,500	$6,529,600
Final adj.	Times Highest (Project Cost : Construction Cost) Ratio (2.4)	$1,443,000	$942,000	$951,000	$1,443,000	$1,437,000	$945,000	$963,000	$1,017,000	$939,000	$1,191,000	$1,197,000	$942,000	$1,319,040	$942,000	$15,671,040
	Indexed (CA → SC)	$1,134,317	$740,490	$747,564	$1,134,317	$1,129,601	$742,848	$756,997	$799,446	$738,131	$936,224	$940,941	$740,490	$1,036,874	$740,490	$12,318,730
SUM	+ est. eng. study cost = QZ COST:	$1,384,317	$790,490	$872,564	$1,359,317	$1,354,601	$817,848	$1,006,997	$874,446	$763,131	$1,061,224	$1,115,941	$790,490	$1,236,874	$790,490	
															TOTAL PROGRAM COST (G&A not included):	$14,218,730

APPENDIX D: TABLE OF SELECTED ABBREVIATIONS

ASMs	Alternative Safety Measures
BEA	Bureau of Economic Analysis
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
ESA	European Space Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FR	Federal Register
FRA	Federal Railroad Administration
GIS	Geographic Information System
NHCCI	National Highway Construction Cost Index
NSRT	National Significant Risk Threshold
QZRI	Quiet Zone Risk Index
RIWH	Risk Index With Horns
ROW	Right-of-way
SCDOT	South Carolina Department of Transportation
SSMs	Supplementary Safety Measures
USC	University of South Carolina
USDOT	United States Department of Transportation
USGS	United States Geological Survey

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