Economic Impacts to Residential Real Estate from Small Wireless Facilities

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Study Background

Mobile telephone and data networks have existed for several decades, dating back to the late 1960s when "car phones" were first introduced. Mass-adoption began in the late 1990s, when economies of scale and Moore's Law [1] made affordable mobile handsets possible. The introduction of smartphones in the late 2000s drove mass adoption of mobile connectivity and applications we now rely on for daily life in the 21st century. The usage trends of these technologies are well-known and personally familiar. In 2015 the World Bank reported that 97.4% of the world's population have cellular phone subscriptions, but only 68% have sanitation service (i.e. toilets, sewers, etc.) [2]

In the United States, over 80% of emergency calls to 911 emergency services originate from mobile phones. [3] Per the Centers for Disease Control's bi-annual *Wireless Substitution Report* 62.5% of U.S. adults and 73.6% of U.S. children are living in households that are "wireless-only" in which they've replaced their wired telephones with wireless service. [4] For people under the age of 34, the wireless-only rate is nearly 80%, as an increasingly large percentage of the younger population have never owned — or even used — wired telephones. Mobile internet and data usage is also growing exponentially. Globally, in 2020, the amount of data that flowed *monthly* over mobile data networks exceeded 70 Petabytes. (A Petabyte is equal to 1,000,000 Gigabytes.) [5]

To serve this exponentially-increasing demand, wireless carriers are densifying their networks by deploying low-power augmentation sites known as "small cells" because they cover small areas close to population centers and areas where people congregate. Initially, the densification projects used enhanced 4G LTE technology, but are now shifting toward 5G NR (New Radio) to add additional capacity and features. This expansion of the network, and in particular the introduction of new technologies and spectrum bands, has met with a variety of concerns from a small but vociferous handful of residents, organizations, and even some local governments. The expressed concerns are primarily that electromagnetic fields from these wireless sites will cause health problems, negatively impact local aesthetics, or negatively affect real property valuations. It is this latter concern that our study sought to address.

Study Goals

There are numerous studies on the impact of wireless sites on real estate valuation that used objective and reproducible methods: Joint Venture Silicon Valley 2012, Valbridge 2018, Maennig (University of Hamburg) 2010, and others. [6], [7], [8] However, previous studies focused on wide-area coverage from large towers and monopoles (known as "macro" sites) on hilltops and buildings, rather than small cells on wooden poles and street lights near residences and population centers. None of the previous objective studies found economically-significant impacts — positive or negative — to property valuations, but nevertheless there is an extant belief (or an "urban legend") held by some real estate agents that wireless sites near residences can cause

property valuation reductions of up to 20%. A devaluation of residential real estate from proximal wireless sites does not show up in objective peer-reviewed studies, nevertheless a belief that wireless sites cause devaluation persists and is often raised as an objection during planning commission, city council, county board, and permit appeal hearings. Because the previous studies focused on macro sites, and the wireless industry's current deployment focus is on 4G and 5G small cells, the studies from JVSV, Valbridge, Maennig, etc. are challenged by appellants as not applicable to small cells. To address the gap between extant belief and evidence-based economics, our study focused on whether residential real estate valuation impacts from small cells were objectively evident in real estate sale records.

Study Methodology

Our study applied a *spatial difference-in-differences* approach, a well-regarded economic analysis method used to estimate the impacts from proposed shopping centers, liquor stores, sports stadiums, transit centers, and other contentious land uses in and near residential areas. The study examined the question, "Do wireless small cell sites have an effect, either positive or negative, on the valuation of residential real estate?" The study also examined the question of whether or not the oft-asserted 20% reduction in property valuation appeared in the results.

The study used a dataset of 1,734 small cell sites installed in the State of California over the time period from 2010 to 2020, and a dataset of 11,684,458 real estate transactions statewide over the same ten-year period.

The study looked at residential real estate valuations for properties (the study subjects) within 10 kilometers around the constructed small cell sites, compared with residential real estate valuations for similar properties (the control group) not near small cell sites. The study looked at price variation before and after construction of the small cell sites.

Using the *spatial difference-in-differences* analysis method, effects on real estate sale prices from wireless small cell sites — if they exist — will show up as variations in sale price trajectories between properties proximal to wireless sites and the non-proximal control group properties, with variation occurring during or after the time point when the small cell sites were built.

Our study methodology also controlled for variations that could affect the sale price. Controlling for variations included, but was not limited to, defining similarities in the properties based on:

- Type of Transaction: New construction, Re-sale, REO, Foreclosure, etc.
- Property Type: Single-Family Attached, Single-Family Detached, Condo, COOP, etc.
- Number of bedrooms

- Number of bathrooms
- Number of Half Bathrooms
- Square Footage (living area)
- Garage Square Footage
- Lot Size: Number of square feet of lot
- Year Built: Original construction year
- Levels: Number of property stories
- Units: Number of units on property
- Property Condition: Any internal flag/measure of property condition
- Arm's Length: Any internal indicator of arm's length transaction
- Latitude - Property latitude in decimal degrees (ISO 6709)
- Longitude - Property longitude in decimal degrees (ISO 6709)

The wireless site dataset was provided by Verizon Wireless, and included small cell sites (both 4G and 5G) constructed between 2010 and 2020 in sixteen metropolitan regions in California:

- Sacramento, Roseville, Arden-Arcade
- San José, Sunnyvale, Santa Clara
- San Francisco, Redwood City, South San Francisco
- Oakland, Hayward, Berkeley
- Santa Rosa
- Stockton, Lodi
- Fresno
- Santa Maria, Santa Barbara
- Modesto
- Salinas, Monterey
- San Luis Obispo, Paso Robles, Arroyo Grande
- Santa Cruz, Capitola, Aptos, Watsonville
- Bakersfield
- Vallejo, Fairfield
- Visalia, Porterville
- Napa

The wireless site dataset defined the latitude and longitude of the site, the date of construction, and the type of attachment structure i.e. wood pole, street light, etc.

The real estate transaction dataset was provided by Black Knight Data & Analytics, LLC, and included all residential real estate transactions in California between the years 2010 and 2020. Extensive and detailed coding of the properties in the dataset enabled accurate comparisons between sales of the study properties and sales of control group properties.

Both the wireless and real estate datasets were provided to a doctoral-level economist skilled in urban planning, policy, land use, and housing. The economist was directed to conduct the analysis objectively. The economist had no contact with the wireless industry before or during the study, and has no previous or current financial relationship with the wireless industry. The analysis was done using the Stata software package from StataCorp LLC. The economist produced a set of statistical coefficients appropriate for a third-order curve analysis of residential real estate sales near wireless sites ranging out to 10 kilometers (32,808 feet) radial distance. The analysis used radial increments of 0.1 kilometers (328 feet). The economist also calculated a coefficient of determination (denoted as R^2) which indicates how well the data fits to the calculated regression line. The analysis was conducted at the aggregate statewide level, and also at the local level for the aforementioned metropolitan regions. No adjustments were made to the real estate dataset by the Joint Venture Silicon Valley or the economist.

The coefficients and analysis results were in turn provided to Joint Venture Silicon Valley for final authorship of this report. Aside from formatting the results as necessary for report authorship production, no adjustments were made to the analysis results.

Study Findings

Statewide (California)

At an aggregate statewide level, the analysis found statistically significant increases in residential real estate valuation at all distances after construction of the proximal wireless sites. However, not all of these valuation variations were economically significant.

Coefficient of determination (R^2) for the statewide analysis was very high at 0.97 – in other words, this analysis accounts for nearly 100% of all observed effects on valuation from wireless site deployment near the subject properties.

Statewide, real estate valuation increases from proximal wireless sites ranged from +0.03% (within 0.1 kilometers of a wireless site) to +2.14% (at distances from 8.4 km to 8.9 kilometers). For purposes of illustration: California's median single-family home price in 2020 was $758,990 thus the price premia found in the analysis would result in valuation increases ranging from $228 (0.03%) to $16,242 (2.14%).

The oft-cited 20% reductions in valuation are not evident in the statewide analysis, nor in any of the metropolitan region analyses.

Statistical Significance of Metro Areas

Of the sixteen metropolitan regions analyzed, six regions showed no statistical significance; i.e. wireless sites proximal to residential real estate had no impact on valuation. The six metro regions showing no statistical significance in the analysis were:

- Stockton, Lodi
- Salinas, Monterey
- Santa Cruz, Capitola, Aptos, Watsonville
- Bakersfield
- Vallejo, Fairfield
- Visalia, Porterville
- Napa

Sacramento CA Metro Area

In the Sacramento metro area (Sacramento, Roseville, Arden-Arcade), the analysis found increases in residential real estate valuation after construction of proximal wireless sites.

Looking at 3,796,728 transactions, the valuation variation ranged from +0.01% (within 0.1 km of the wireless site) to +0.53% (at distances from 6.0 km to 6.4 km).

R^2 for the Sacramento metro area analysis was 0.92. The oft-cited 20% reductions in valuation are not evident in the Sacramento metro area results.

San José CA Metro Area

In the San José metro area (San José, Sunnyvale, Santa Clara), the analysis found no valuation effects within 0.4 km, and increases in residential real estate valuation at distances greater than 0.5 km, after construction of the subject wireless sites.

Looking at 3,612,141 transactions, the valuation variation ranged from +0.01% (beginning at 0.5 km from the wireless site) to +0.47% (at distances from 8.0 km to 9.0 km).

R^2 for the San José metro area analysis was 0.93. The oft-cited 20% reductions in valuation are not evident in the San José metro area results.

San Francisco CA Metro Area

In the San Francisco metro area (San Francisco, Redwood City, South San Francisco), the analysis found slight decreases, but also increases, in residential real estate valuation after construction of proximal wireless sites.

Looking at 3,378,178 transactions, the valuation variation ranged from -0.11% (at distances from 0.7 km to 0.9 km from the wireless site) to +3.73% (at distances from 9.1 km to 9.3 km). The decreases observed are not economically signification.

R^2 for the San Francisco metro area analysis was 0.90. The oft-cited 20% reductions in valuation are not evident in the San Francisco metro area results.

Oakland CA Metro Area

In the Oakland metro area (Oakland, Hayward, Berkeley), the analysis found increases in residential real estate valuation at all distances after construction of proximal wireless sites.

Looking at 628,836 transactions, the pricing variation ranged from +0.08% (within 0.1 km of the wireless site) to +3.25% (at 10.0 km from the wireless site).

R^2 for the Oakland metro area analysis was 0.92. The oft-cited 20% reductions in valuation are not evident in the Oakland metro area results.

Santa Rosa CA Metro Area

In the Santa Rosa metro area, the analysis found slight decreases, but also slight increases, in residential real estate valuation after construction of proximal wireless sites.

Looking at 120,937 transactions, the pricing variation ranged from -0.52% (at distances from 2.3 km to 2.7 km from the wireless site) to +0.05% (at distances from 7.5 km to 7.9 km).

R^2 for the Santa Rosa metro area analysis was 0.94. The oft-cited 20% reductions in valuation are not evident in the Santa Rosa metro area results.

Fresno CA Metro Area

In the Fresno metro area, the analysis found increases in residential real estate valuation after construction of proximal wireless sites.

Looking at 18,438 transactions, the pricing variation ranged from +0.25% (within 0.1 km of the wireless site) to +3.94% (at distances from 4.4 km to 4.6 km).

R^2 for the Fresno metro area analysis was 0.97. The oft-cited 20% reductions in valuation are not evident in the Fresno metro area results.

Santa Barbara CA Metro Area

In the Santa Barbara metro area (Santa Barbara, Santa Maria), the analysis found increases in residential real estate valuation after construction of proximal wireless sites.

Looking at 15,630 transactions, the pricing variation ranged from +0.10% (within 0.1 km of the wireless site) to +2.56% (at distances from 5.0 km to 5.5 km).

R^2 for the Santa Barbara metro area analysis was 0.98. The oft-cited 20% reductions in valuation are not evident in the Santa Barbara metro area results.

Modesto CA Metro Area

In the Modesto metro area, the analysis found increases in residential real estate valuation after construction of proximal wireless sites.

Looking at 15,123 transactions, the pricing variation ranged from +1.00% (within 0.1 km of the wireless site) to +16.22% (at distances from 3.7 km to 3.8 km).

R^2 for the Modesto metro area analysis was 0.92. The oft-cited 20% reductions in valuation are not evident in the Modesto metro area results.

San Luis Obispo CA Metro Area

In the San Luis Obispo metro area (San Luis Obispo, Paso Robles, Arroyo Grande), the analysis found slight decreases, but also increases, in residential real estate valuation after construction of proximal wireless sites.

Looking at 9,831 transactions, the pricing variation ranged from -0.27% (at distances from 1.7 km to 2.1 km from the wireless site) to +0.91% (at distances from 9.3 km to 9.5 km).

R^2 for the San Luis Obispo metro area analysis was 0.98. The oft-cited 20% reductions in valuation are not evident in the San Luis Obispo metro area results.

Discussion

Economic Significance of Pricing Variations

While some pricing variation was found to be statistically significant, not all variations were economically significant. Economic significance could be interpreted as any variation above the 1 - R^2 level, however for purposes of this study, the researchers considered pricing variations over 1% to be economically significant. Variations could be due to factors that this analysis did not consider including weather, crime trends, stock market fluctuations, or population migration trends.

Example: In our study, the maximum valuation decrease was -0.52% (Santa Rosa metro area). The median listing sold price in Santa Rosa CA (Jan 2020, per the National Association of REALTORS® website) was $571,000. A pricing variation of -0.52% would equate to a valuation decrease of $2,969.

The study found three metro areas with statistically significant valuation decreases, but no metro areas with economically significant valuation decreases. The study found six metro areas with economically significant valuation increases: San Francisco (+3.73%), Oakland (+3.25%), Fresno (+3.94%), Santa Barbara (+2.56%), and Modesto (+16.22%).

Metro Area	Lowest Variation	Highest Variation	R^2
Sacramento	+0.01%	+0.53%	0.92
San José (South Bay)	+0.01%	+0.47%	0.93
San Francisco	(-0.11%)	+3.73%	0.90
Oakland (East Bay)	+0.08%	+3.25%	0.92
Santa Rosa	(-0.52%)	+0.05%	0.94
Fresno	+0.25%	+3.94%	0.97
Santa Barbara	+0.10%	+2.56%	0.98
Modesto	+1.00%	+16.22%	0.92
San Luis Obispo	(-0.27%)	+0.91%	0.98

Table 1 : Valuation Variation Ranges and Coefficients of Determination, by Metro Area

Refutation of the "20% Reduction in Valuation" Assertion

An article appeared in The *Appraisal Journal*, (Summer 2005) authored by Sandy Bond, Ph.D. and Ko-Kang Wang that asserted wireless towers could result in a 20% reduction in residential real estate valuations. Reviewing this article reveals that Bond and Wang used a survey methodology to collect data, citing sources (including self-citations to Bond's own work) that recommended surveys as a valid methodology. In practice, surveys are poor methodologies for analyzing market economics as they are subject to respondent bias, participation bias, sampling bias, and a host of other factors. There is also evidence that Dr. Bond was consulting in 2005 for the Porirua Residents' Action Group in Wellington, NZ, and that this group was actively opposed to wireless tower deployments in the area. [9] Dr. Bond's financial relationship with the PRAG (if any) is unknown.

Despite the relative weakness of surveys compared to objective market studies (JVSV 2012, Valbridge 2018, Maennig 2010) the extant belief that wireless sites have negative impacts on real estate valuations persists in the real estate community, and is often cited by resident groups opposed to wireless site deployments. These negative valuation impacts are not evident in this study's analysis. Indeed, no economically significant valuation decreases are evident in our study.

Demographic Shifts in Attitudes toward Wireless Sites

As evidenced by the CDC's Wireless Substitution reports [4] younger people rely more heavily on wireless devices for their daily lives. Per the CDC's report as of December 2019, over 75% of U.S. adults under age 34 rely solely on their wireless devices for telephone calls. Younger generations, sometimes referred to as "Millennials" or "Generation Z", are now the dominant economic demographic in the U.S. and are increasingly the dominant economic force in real estate markets. An article in the National Association of REALTORS® magazine stated that, after the onset of the SARS-CoV-2 pandemic, 69% of real estate professionals reported that prospective buyers sought information about a home's access to connectivity, including wireless coverage. [10] The article also stated that 62% of real estate agents believe that within one to two years, 5G home internet (an alternative to DSL, fiber, or cable broadband) will be something they will advertise during the sale process. Younger buyers' attitudes towards wireless infrastructure stand in somewhat sharp contrast to members of older generations that have traditionally formed the core of opposition to wireless site deployments in and around neighborhoods.

The SARS-CoV-2 pandemic forced a major societal shift in attitudes toward remote work, distance learning, telehealth, online shopping, and delivery services. Many of these shifts will remain, and real estate professionals should expect that, going forward, residents will expect their wireless networks to support the increased levels of wireless data usage we observed during the pandemic.

Possible Distortions of the Study Data

The datasets for this study's analysis were purely objective. They comprise the entirety of one wireless carrier's small cell deployments from 2010 to 2020, and the entirety of real estate transactions in the state of California over the same time period. The R^2 values for the observed results are very high, at 0.90 or better, indicating that the observed effects on residential real estate valuation are largely explained by the spatial difference-in-differences approach. Nevertheless, for completeness, we note some possible external effects on the study data.

Carrier Operational Economics

The most likely distortion of the results is due to the operational economics of wireless carriers. As for-profit companies, wireless carriers must weigh the cost of building a given wireless site against the carrier's ability to realize a return on investment. Costs associated with wireless deployments are often significant, and realizing a return on investment from deployments in economically-challenged neighborhoods or areas with low population is challenging. If the wireless sites in the study data were deployed more in economically-advantaged neighborhoods, and economically-challenged neighborhoods in the control group were not targets for wireless site deployment, the relative strength of the economically-advantaged neighborhoods chosen for deployment could be affecting the results.

Economic Impacts of the SARS-CoV-2 Pandemic

Because the datasets covered the time period from 2010 to 2020, it is possible that the economic effects of the SARS-CoV-2 pandemic (beginning in early 2020) had some (albeit minimal) effect on the analysis. During the pandemic in 2020, people migrated away from large cities to smaller cities and suburban areas. [11] Despite massive corrections to the economy and significant unemployment due to business closures, real estate transactions rose sharply and valuations increased. It is possible that the 2020 real estate valuation increases could be affecting the results, however given that the study looked at a full decade of transactions, a statistically significant effect from pandemic-driven migration is unlikely.

Racial, Cultural, Age, and Other Factors

The real estate transaction dataset used for this study does not contain information about buyer demographics. Thus, it is impossible to determine if there are demographic effects in the study results. It may be, for example, that younger buyers (who tend to place higher value on network connectivity) will place a higher valuation on a real estate opportunity that has strong wireless coverage. And it may be that some racial, cultural, or other demographic groups will place higher or lower value on

network connectivity. To help offset this, the researchers studied a large number of metropolitan areas across the state, but in the end, we note that buyer demographics are an uncontrollable variable in this study.

Contradictory Evidence Review

We reviewed previous studies and articles that claimed to find negative impacts to residential real estate valuation. In many cases, these works were not openly available in the peer-review systems.

Bond/Wang 2005

We were able to review a copy of Bond and Wang's article, *The Impact of Cell Phone Towers on House Prices in Residential Neighborhoods*, in The Appraisal Journal (Summer 2005) although we note that this article is behind a subscriber paywall. We noted that Bond/Wang's methodology used surveys, which have inherent issues with respondent bias, participation bias, sampling bias, and a host of other factors.

Affuso/Cummings/Le 2017

We attempted to review the work of Ermanno Affuso, J. Reid Cummings, and Huubinh Le from University of South Alabama. Their paper, *Wireless Towers and Home Values: An Alternative Valuation Approach Using a Spatial Econometric Analysis,* in The Journal of Real Estate Finance and Economics (May 2018) appears (from what we could derive from the paper abstract) to be the closest approximation to our study, with the exception that Affuso et al. analyzed effects from macro towers not small wireless facilities. The National Association of REALTORS® links to Affuso et al. 2017 from their "Cell Phone Towers" subpage, but via a NAR member registration wall. [12] Requests to Affuso et al. for a courtesy/peer copy of their paper did not receive a response.

National Association of REALTORS® Website

The NAR also links to *The Impact of Cell Phone Towers on House Prices: Evidence from Brisbane, Australia* (Environmental Economics and Policy Studies, Jan. 1, 2018) which again is behind a member registration wall. NAR links to *Property values, desirability and cell towers* (EMFSA, website) an anti-EMF activist group which cites both the survey work from Bond/Wang 2005, and a survey conducted in June 2014 by the National Institute for Science, Law and Public Policy (NISLAPP) in Washington, D.C. [12]

Conclusions

Across a wide geographic area, using a decade of wireless facility and real estate transaction data, our analysis found effectively zero statistical evidence that proximal small wireless communication facilities or "small cells" negatively impact residential real estate valuations. In fact, there is some evidence that residential real estate valuations increase within 10 km after construction of a small wireless facility. In cases where there is a statistically significant negative impact, the impact is not economically significant.

We note that the body of evidence asserting to show negative impacts to residential real estate from wireless communication facilities appears to come largely from survey-based methodologies. Where previous work has claimed to find negative valuation impacts, there appears to be very little if any available for peer-review. We encourage researchers on this topic to open their work to peer-review and scrutiny.

Support for the extant belief held by some real estate agents that wireless sites near residences can cause residential property devaluations of up to 20% is not evidenced by this study.

About the Researchers

David Witkowski, Joint Venture Silicon Valley

Witkowski is an author, advisor, and strategist who works at the intersection between local government and the telecommunication industry. He is the Executive Director of the Civic Technologies Initiative at Joint Venture Silicon Valley, a Fellow in the Radio Club of America, an IEEE Senior Member, and the Founder & CEO of Oku Solutions LLC. After serving in the U.S. Coast Guard and earning his B.Sc. in Electrical Engineering from the University of California, he held leadership roles for companies ranging from Fortune 500 multi-nationals to early-stage startups. He serves as Co-Chair of the Deployment Working Group at IEEE Future Networks, Co-Chair of the GCTC Wireless SuperCluster at NIST, as a member of the Connected Communities Forum in the Wireless Broadband Alliance, and as an Expert Advisor to the California Emerging Technology Fund.

Dr. Ralph B. McLaughlin, Chief Economist and Senior Vice President of Analytics, Haus

In December 2019, McLaughlin was named Chief Economist and Senior Vice President of Analytics at Haus. He is responsible for leading economic research using data and analytics to expand the visibility of the Haus economic policy unit while enhancing research capabilities and tools for consumers, industry professionals, the public sector and news media.

McLaughlin has nearly two decades of experience in the housing and mortgage market. Prior to joining Haus, he served as Chief Economist at Trulia, as Deputy Chief Economist at CoreLogic, as an Assistant Professor in Real Estate Development at San Jose State University, and as a Lecturer at the University of South Australia. He was also recently appointed as an Adjunct Assistant Professor in the Price School of Public Policy at the University of Southern California, where he teaches a masters course in urban economics.

McLaughlin frequently appears on local and national radio and television programs, and has been widely quoted in The Wall Street Journal, New York Times, Washington Post, USA Today, and Los Angeles Times as well as numerous industry trade publications such as HousingWire and National Mortgage News. He has appeared as a regular guest on cable news channels including CNBC, Bloomberg, and Fox Business News.

McLaughlin earned a Ph.D. in Planning, Policy, and Design, specializing in Urban Economics, from the University of California at Irvine, and a B.S. in Geography and Regional Development from the University of Arizona.

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