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Using GIS to Measure the Impact of Distance to Cell Phone Towers on House Prices in Florida

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Abstract:
The siting of cellular phone transmitting antennas, their base stations and the towers that support them (*towers*) is a public concern due to fears of potential health hazards from the electromagnetic fields (EMFs) that these devices emit. Negative media attention to the potential health hazards has only fuelled the perception of uncertainty over the health effects. The unsightliness of these structures and fear of lowered property values are other regularly voiced concerns about the siting of these towers. However, the extent to which such attitudes are reflected in lower property values affected by tower proximity is controversial.

This paper outlines the results of a study carried out in Florida in 2004 to show the effect that tower proximity has on residential property prices. The study involved an analysis of residential property sales transaction data. Both GIS and multiple regression analysis in a hedonic framework were used to determine the effect of actual distance of homes to towers on residential property prices.

The results of the research show that prices of properties decreased by just over 2%, on average, after a tower was built. This effect generally reduced with distance from the tower and was almost negligible after about 200 meters (656 feet).

1. Introduction

This paper outlines the results of one of the first US-based cell-phone tower studies. The research was carried out in Florida in 2004 to show the effect that **distance** to a CPBS has on residential property prices. It follows on from several New Zealand (NZ) studies conducted in 2003.[1] The first of the earlier NZ studies examined residents' perceptions toward living near CPBSs, while the most recent NZ study adopted GIS to measure the impact that distance to a CPBS has on residential property prices using multiple regression analysis in a hedonic pricing framework. The current study was conducted to determine if US residents respond similarly to those in NZ towards living near CPBSs and hence, whether the results can be generally applied.

The paper commences with a brief literature review of the previous NZ studies for the readers' convenience as well as the literature relating to property value effects from other similar structures. The next section describes the research data and methodology used. The results are then discussed. The final section provides a summary and conclusion.

[1] Bond, S.G. and Wang, K. (2005). "The Impact of Cell Phone Towers on House Prices in Residential Neighborhoods", The Appraisal Journal, Volume LXXIII, No.3, pp.256-277, Bond, S.G., Beamish, K. (2005). "Cellular Phone Towers: Perceived Impact on Residents and Property Values", Pacific Rim Property Research Journal, vol. 11, no. 2, pp. 158-177 and Bond, S.G. and Xue, J. (2005). "Cell Phone Tower Proximity Impacts on House Prices: A New Zealand Case Study", European Real Estate Society and International Real Estate Society Conference, June 15-18, Dublin, Ireland.

2. Literature Review

2.1 Property Value Effects

First, an opinion survey by Bond and Beamish (2005) was used to investigate the current perceptions of residents towards living near CPBSs in a case study city of Christchurch, New Zealand and how this proximity might affect property values. Second, a study by Bond and Wang (2005) that analyzed property sales transactions using multiple regression analysis was conducted to help confirm the results of the initial opinion survey. It did this by measuring the impact of proximity to CPBSs on residential property prices in four case study areas. The Bond and Xue (2005) study refined the previous transaction-based study by including a more accurate variable to account for distance to a CPBS.

The City of Christchurch was selected as the case study area for all the NZ studies due to **the large amount of media attention** this area had received in recent years relating to the siting of CPBSs. Two prominent court cases over the siting of CPBSs were the main cause for this attention.[2] In summary, the Environmental Court ruled in each case that there is no established adverse health effects arising from the emission of radio waves from CPBSs as there is no epidemiological evidence to show this. However, in the court's decisions they did concede that while there is no proven health affects that there is evidence of **property values** being affected by both of the above allegations.

These court cases were only the start of the negative publicity surrounding CPBSs in Christchurch. Dr. Neil Cherry, a prominent and vocal local Professor, served only to fuel the negative attention to CPBSs by regularly publishing the health hazards relating to these structures.[3] This media attention had an impact on the results of the studies, outlined next.

2.2 The Opinion Survey

The Bond and Beamish (2005) opinion survey study included residents in ten suburbs: five case study areas (within 100 feet of a cell phone TOWER) and five control areas (over 0.6 of a mile from a cell phone TOWER). The five the case study suburbs were matched with five control suburbs that had similar living environments (in socio-economic terms) except that the former are areas where a CPBS is located, while the latter are without a CPBS. Eighty questionnaires[4] were distributed to each of the ten suburbs in Christchurch (i.e. 800 surveys were delivered in total).
After sending out reminder letters to those residents who had not yet responded, an overall response rate of 46% was achieved. Over three-quarters (78.5%) of the case study respondents were homeowners compared to 94% in the control area.

The results were mixed with responses from residents ranging from having no concerns to being very concerned about proximity to a CPBS. Interestingly, in general, those people living in areas further away from CPBSs were **much more** concerned about issues from proximity to CPBSs than residents who lived near CPBSs.

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[2] McIntyre and others vs. Christchurch City Council [1996] NZRMA 289 and Shirley Primary School vs. Telecom Mobile Communications Ltd [1999] NZRMA 66

[3] For example, Cherry, N. (2000), "Health Effects Associated with Mobil Base Stations in Communities: The Need for Health Studies," Environmental Management and Design Division, Lincoln University, June 8. Available from: http://pages.britishlibrary.net/orange/cherryonbasestations.htm.

4 Approved by the University of Auckland Human Subjects Ethics Committee (reference 2002/185).

Over 40% of the control group respondents were worried a lot about future health risks, aesthetics and future property values compared to the case study areas where only 13% of the respondents were worried a lot about these issues. However, in both the case study and control areas, the impact of proximity to CPBSs on future **property values** is the issue of **greatest concern** for respondents. If purchasing or renting a property near a CPBS, over a third (38%) of the control group respondents would **reduce price** of their property by more than **20%.** The perceptions of the case study respondents were again less negative with a third of them saying they would reduce price by only 1-9%, and 24% would reduce price by between 10 and 19%.

Reasons for the lack of concern shown by the case study respondents may be due to the CPBS being either not visible or only barely visible from their homes. Another reason may be that the CPBS was far enough away from respondent's property (as was indicated by many respondents, particularly in St Albans West, Upper Riccarton, and Bishopdale) or hidden by trees and consequently it did not affect them much. The results may have been quite different had the CPBS being more visually prominent.

2.3 Transaction-based Market Study

The Bond and Wang (2005) market transaction-based regression study included 4283 property sales in four suburbs that occurred between 1986 and 2002 (approximately 1000 sales per suburb). The sales data that occurred before a CPBS was built were compared to sales data after a CPBS was built to determine any variance in price, after accounting for all the relevant independent variables.

Interestingly, the effect of a CPBS on price (a decrease of between 20.7% and 21%) was very similar in the two suburbs where the towers were built in the year 2000, after the negative media publicity given to CPBSs following the two legal cases outlined above. The other two suburbs that indicated a CPBS was either insignificant or increased prices by around 12%, had towers built in them in 1994, prior to the media publicity. Also, given that the cell phone technology was relatively new to NZ in 1994 (introduced in late 1987) there may have been more desire then to live closer to a tower to receive better coverage than in later years when the technology became more common and the potential health hazards from these became more widely publicized.

The main limitation affecting this study was that there was no accurate proximity measure included in the model, such as GIS coordinates for each property. Instead, street name was included as an independent variable to help to control for the proximity effects. A study has subsequently been performed using GIS analysis to determine the impact that distance to a CPBS has on residential property prices. The results from this study are outlined next.

2.4 Proximity Impact Study

Bond and Xue study conducted in 2004 involved analysis of the residential transaction data using the same hedonic framework as the previous study as well as including the same data but added a further six suburbs to give a total of ten suburbs: five suburbs with CPBSs located in them and five control suburbs without CPBSs. In addition, the geographical {x, y} coordinates that relate to each property's absolute location were included. A total of 9,514 geo-coded property sales were used (approximately 1000 sales per suburb).

In terms of the effect that proximity to a CPBS has on price the overall results indicate that this is significant and negative. Generally, the closer to the CPBS a property is the greater the decrease in price. The effect of proximity to a CPBS **reduces price by 15%, on average.** This effect reduces with distance from the CPBS and is negligible after 1000 feet.

2.5 High Voltage Overhead Transmission Line Research

CPBSs are very similar structures to high voltage overhead transmission lines (HVOTLs) and their supporting structure, the pylons. Therefore, despite the limited research relating to value effects from CPBS, it is worthwhile reviewing the body of literature on the property values effects from HVOTLs and pylons.

2.5.1 New Zealand HVOTL Research

The only recently published study in New Zealand on HVOTLs value effects is by Bond and Hopkins (2000).[5] The case study area selected for the research was a low-middle income, predominantly single-family residential district in the northern Wellington suburb of Newlands that is crossed by two 110KV transmission lines with 85 foot high steel pylons **located on private land**.

The results of the sales analysis, comprising sales from 1989 to 1991 (330 of which were within 1000 feet, or 300 meters, of a HVOTL), indicate the effect of having a 'pylon' close to a particular property is statistically significant and has a **negative effect of 27%** at 33 feet (10 meters) from the pylon, 18% at 50 feet (15 meters), decreasing to 5% at 164 feet (50 meters). This effect diminishes to a negligible amount after 328 feet (100 meters). However, the presence of a 'transmission line' in the case study area has a minimal effect and is not a statistically significant factor in the sales price.

2.5.2 UK HVOTL Research

In England, the effect of HVOTLs on the value of residential property remains relatively unexplored due, in part, to the lack of available transaction data for analysis. The most recently published study is by Sims and Dent (2005).[6] They compare the results of two parallel UK studies: the first is an analysis of transaction data from a case study in Scotland where sales data are available; the second is a national survey of property appraisers' perceptions (Chartered Surveyors and members of the National Association of Estate Agents) of the presence of distribution equipment in close proximity to residential property.

The data set for the Scotland study consisted of 593 single-family houses that sold between 1994 and 1996 near Glasgow. There is a 275 kV HVOTL running through the centre of the neighborhood in a corridor of land. (Note: This scenario is akin to the US situation where HVOTLs are also situated in easement corridors).

In summary, the analysis of prices at varying distances from the HVOTL showed no clear pattern. The presence of a pylon was found to have a more significant impact on value than the HVOTL and could **reduce price by up to 20.7%.** All negative impacts appeared to reduce with distance and were negligible at around 820 feet (250 meters).

The results from the survey of appraisers and real estate agents indicate they **reduce house price by around 5-10%** when valuing a property within close proximity to a HVOTL. Comparing the

[5] Bond, S.G. & Hopkins, J. (2000)."The Impact of Transmission Lines on Residential Property Values: Results of a Case Study in a Suburb of Wellington, New Zealand". *Pacific Rim Property Research Journal*, Vol.6, No.2, pp.52-60.
[6] Sims, S. and Dent, P. (2005), “High-voltage overhead power lines and property values: A residential study in the UK”, Urban Studies, Vol.42, No.4, pp. 665-694.

results from both studies suggests that appraisers and real estate agents underestimate the impact of proximate HVOTLs on value.

2.5.3 US and Canadian Research

There have been a number of HVOTLs studies carried out in the US and Canada. A major review and analysis of the literature by Kroll and Priestley indicated that in about half the studies carried out, HVOTLs had not affected property values and in the rest of the studies there was a loss in property value between 2-10%.[7]

Kroll and Priestley were generally critical of most valuer type studies because of the small number of properties included and the failure to use econometric techniques, such as multiple regression analysis. They found that the Colwell study was one of the more careful and systematic analysis of residential impacts.[8] This study was carried out in Illinois and found that the strongest effect of the HVOTLs was within the first 50 feet (15m) but with this dissipating quickly further away, disappearing beyond 200 feet (60m).

A Canadian study (Des Rosiers, 2002) based on a sample of 507 single-family house sales in the City of Brossard, Greater Montreal that sold between 1991-1996 showed that the severe visual encumbrance due to a direct view of either a pylon or lines exerts a significantly negative impact on property prices of between 5% to well in excess of 20%. The extent of value diminution depended on the degree of set back of the homes with respect to the HVOTL easement. The smaller the set back the greater the reduction in price (for example, with a setback of 50ft price was reduced by 21%).

However, the study also showed that a house located adjacent to a transmission corridor may increase values. The proximity advantages include enlarged visual field and increased privacy. The decrease in value from the visual impact of the HVOTLs and pylons (between, on average, 5-10% of mean house value) tends to be cancelled out by the increase in value from proximity to the easement.[9]

A study by Wolverton and Bottemiller[10] utilized a paired-sale methodology of home sales occurring in 1989-1992 to ascertain any difference in sale price between properties abutting rights-of-way of transmission lines (subjects) in Portland, Oregon; Vancouver, Washington; and Seattle, Washington and those located in the same cities but not abutting transmission line rights-of-way (comparisons). Their results did not support a finding of a price effect from abutting an HVTL right-of-way. In their conclusion they warn that the results cannot and should not be generalized outside of the data. They explain that

> "limits on generalizations are a universal problem for real property sale data because analysis is constrained to properties that sell and sold properties are never a randomly drawn representative sample. Hence, generalizations must rely on the weight of evidence

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[7] Kroll, C. and Priestley, T. (1992), "The Effects of Overhead Transmission Lines on Property Values: A Review and Analysis of the Literature", Edison Electric Institute, July.

[8] Colwell, P. (1990), "Power Lines and Land Value", *The Journal of Real Estate Research*, American Real Estate Society, Vol. 5, No. 1, Spring.

[9] Des Rosiers, F. (2002), Power Lines, Visual Encumbrance and House Values: A Microspatial Approach to Impact Measurement, *Journal of Real Estate Research*, Vol.23, No.3, pp. 275 – 301.

[10] Wolverton, M.L. & Bottemiller, S.C., (2003), "Further analysis of transmission line impact on residential property values", *The Appraisal Journal*, Vol.71, No.3, pp. 244.

from numerous studies, samples, and locations," p. 250.

Thus, despite the varying results reported in the literature on property value effects from HVOTLs, each study adds to the growing body of evidence and knowledge on this (and similar) valuation issue(s).

2.5.4 Summary

This literature review shows that the price effect of proximity to a HVOTL-pylon is generally consistent between studies (i.e. negative and significant) ranging from between 12 to 27% depending on the distance to these. The closer the home is to a pylon, the greater the diminution in price. The effect diminishes to a negligible amount after 820 feet (250 meters), on average.

The effect of proximity to CPBSs is similar to that caused by proximity to HVOTL-pylons and **reduces price by around 21%.** Taking actual distance into account (using GIS analysis) the effect is a reduction of price of 15%, on average (but up to 25% depending on the neighborhood). This effect reduces with distance from the CPBS and is negligible after 1000 feet (300 meters).

The literature on property value effects from HVOTLs, pylons and cell phone towers adds to the growing body of evidence and knowledge on this (and similar) valuation issue(s). The study reported here is one such study.

3. Market Study

3.1 The Data

Part of the selection process for finding an appropriate case study area was to find one where there were a sufficient number of property sales in suburbs where a tower had been built for analysis to provide statistically reliable and valid results. Sales were required both before and after the tower was built to study the effect of the existence the tower had on the surrounding property's sale prices.

Cellular phone tower information was obtained from the Federal Communication Commission (FCC). Approximately sixty-percent (60%) of the towers located in Orange County were constructed between the years 1990 and 2000. Additionally, twenty of the towers have the greatest potential for impact on the price of residential properties, based on the greatest number of residential properties close to each tower. These twenty towers were selected to construct a dataset for the study.

Residential properties that sold between 1990 and 2000, the years during which the towers were constructed and were closest to the twenty towers were selected. Parcel data was collected from the Office of the Property Appraiser for Orange County, Florida.[11] Overall, 5783 single-family, residential properties were selected from northeast Orange County (see Appendix I: Location Map).

The study investigates the potential impact of proximity to a tower on the price of residential property, as indicated by the dependant variable: SALE_PRICE.[12] The study controls for site and structural characteristics by assessing the impact of various independent variables. The independent data set was limited to those available in the dataset and known, based on other well-

[11] As reported to the Florida Department of Revenue.

[12] Model 1, Model 2, and Model 3 estimate the Log of the SALE_PRICE.

tested models reported in the literature and from valuation theory, to be related to property price. The independent variables selected include: lot size in square feet (LOT), floor area of the dwelling in square feet (SQFT), age of the dwelling in years (AGE), the time of construction (AFTER-TWR), the closest distance of each home to the associated tower (DISTANCE), and the dwelling's absolute location is indicated by the Cartesian coordinates (XCOORD) and (YCOORD).[13]

The effect of construction of a tower on price is taken into account by the inclusion of the dummy, independent variable AFTER_TWR. By including AFTER_TWR property prices prior to tower construction can be compared with prices after tower construction.[14] Frequency distributions indicate that, among the residential properties that sold between 1990 and 2000, approximately eighty percent (80%) of the residential properties were sold after tower construction.

The mean SALE_PRICE of single-family, residential property that sold between 1990 and 2000 is $113,830 for northeast Orange County. The mean square footage of a dwelling is 1535 sq. ft., the mean lot size is 8525 square feet and the mean age is 14 years. The mean DISTANCE from residential property to a tower is 1813 feet.[15]

Based on the parcel and tower data for Orange County, descriptive statistics for select variables are presented in Table 1, below.

Table 1: Orange County, Florida: Select Descriptive Statistics (n= 5783)[16]

VARIABLE	MEAN	STD. DEV.	MIN	MAX
SALE_PRICE	113830.6	58816.68	45000	961500
SQFT	1535.367	503.8962	672	5428
LOT	8525.193	4363.28	1638	107732
AGE	13.92755	10.03648	0	35
XCOORD	664108.9	6130.238	640460	671089
YCOORD	511489.4	2422.946	506361	531096
DISTANCE	1813.077	725.5693	133	6620

3.2 Methodology

The method selected for this study was a hedonic house price approach. GIS was also adopted to aid the analysis of distance to the towers. The null hypothesis states that tower proximity does not explain any variation in residential property sales price.

To address the many difficulties in estimating the composite effects of externalities on property price an interactive approach is adopted.[17] To allow the composite effect of site, structural and

[13] See Fik, Ling and Mulligan (2003) for further discussion of the significance of the absolute location in the form of {x, y} coordinates.
[14] Dummy variables for each year of residential sales were also incorporated into each of the model specifications to control for the potential effects of time on the price of residential property.
[15] Initially, the HEIGHT of the tower was also included among the explanatory variables. However, the HEIGHT variable provided no significant explanatory power.
[16] Polynomial expansions of the independent variables, identified by the *VARIABLE***2** were included in the interactions in the three model specifications discussed in the methodology.
[17] Externalities include influences external to the property such as school zoning, proximity to both amenities and dis-amenities, and the socio-economic make-up of the resident population.

location attributes on the value of residential property to vary spatially they are interacted with the Cartesian coordinates that are included in the model.

Unless the hedonic pricing equation provides for interaction between aspatial and spatial characteristics the effects of the explanatory variables on the dependant variable will likely be underestimated, misspecified, undervalued or, worse, overvalued. Including the Cartesian coordinates in the model is intended to increase the explanatory power of the estimated model, and reduce the likelihood of model misspecification (i.e. inaccurate estimates of the regression coefficients, inflated standard errors of the regression coefficients, deflated partial t-tests for the regression coefficients, false non-significant p-values, and degradation of the model predictability, etc.) by allowing the explanatory variables to vary spatially and by removing the spatial dependence observed in the error terms of aspatial, non-interactive models.

Adhering to the methodology proposed by Fik, Ling, and Mulligan (2003), empirical models were selected and progressively tested. The models were based on other well-tested hedonic housing price equations reported in the literature, to derive a best-fit model.

The methodology progresses from an interactive model specification which controls for site and structural attributes of residential property as well as the effects of absolute location and then proceeds to a model specification that measures the effects of discrete location characteristics based on distance intervals. The final model incorporates the impact of explicit location to measure the effects of the proximity to towers (as indicated by DISTANCE) on the sales price of residential property.

Preliminary tests of each model, proceeding from interactive aspatial and spatial estimates, were executed to identify an appropriate polynomial order, or a model that provided the greatest number of statistically significant coefficients and the highest adjusted R-squared value (Fik, et al., p. 633). Like the study by Fik, et al., sensitivity analyses suggested the use of a fourth-order model, at most. Similarly, the following model specifications are estimated with a stepwise regression procedure to ensure that the potential for model misspecification due to multi-collinearity is minimized and that only the independent variables offering the greatest explanatory power are included in the final model.

Model 1 was utilized as a benchmark for the remaining two models. The SALE_PRICE is estimated using the following independent variables: lot size (LOT), square footage of the dwelling (SQFT), age of the dwelling in years (AGE), and the dwelling's absolute location (XCOORD) and (YCOORD). To investigate the effect of tower construction on the price of homes the dummy variable (AFTER_TWR) was also included. Residential sales prices prior to tower construction, BEFORE (=0), were compared to sales prices after tower construction, AFTER (=1). With the addition of the absolute location Model 1 was used to provide a sound model specification, to maximize the explanatory value of the study and minimize the potential for misspecification in the estimated models.

Model 2 integrated the base-model with distance intervals akin to discrete locations. Residential properties within the discrete intervals were then coded according to the interval in which each property was located. The distance intervals, adopted are: 500MTRS (500 to 451 meters), 450MTRS (450 to 401 meters), 400MTRS (400 to 351 meters), 350MTRS (350 to 301 meters), 300MTRS (300 to 251 meters), 250MTRS (250 to 201 meters), 150MTRS (150 to 101 meters), 100MTRS (100 to 51 meters), 50 MTRS (50 meters, or less, to the tower). These distance rings are within the range of distances used in other similar proximity studies of detrimental features on property values (see for example: Des Rosiers 2002; Reichert 1997; Colwell 1990, and Bond and Hopkins 2000).

Model 3 includes distance-based measures indicating the property's explicit location, with respect to the closest tower. Model 3 integrated the base-model (Model 1) with the distance from the tower to the property. Model 3 introduces the independent variable DISTANCE and interacts this variable with the variables from Model 1. The final model, Model 3, is used to assess the variation in sale price due to proximity to a tower.

3.4 Empirical Results

Tables 2, 3 and 5 are shown in Appendices II and III. The Tables show the progressive development of a spatial and fully interactive model specification to estimate the effects of the proximity to towers on the price of residential property, according to the base-model, Model 1.

In the semi-logarithmic equation the interpretation of the dummy variable coefficients involves the use of the formula: $100(e^{bn} -1)$, where bn is the dummy variable coefficient (Halvorsen & Palmquist).[18] This formula derives the percentage effect on price of the presence of the factor represented by the dummy variable.

Results in Table 2 (Appendix II) suggest that the price of residential properties sold after the construction of a tower increases by 1.47% (i.e. AFTER_TWR = 1.46E-02). Interactions with AFTER_TWR and other variables also suggest an increase in the price for single, family residential properties sold after tower construction. This may reflect residents' preference to live near a tower to obtain better cell phone coverage.

Among the control variables SQFT increases price by 0.039% with each additional square foot of space (i.e. SQFT = 3.88E). AGE reduces price by 0.25% for each additional year of age. The t-statistics for the explanatory variables SQFT, AGE, XCOORD and YCOORD suggest significant explanatory power within the specification (i.e. SQFT = 47, AGE2 = 7, XCOORD = -7.105 and YCOORD = 6.799). Model 1 accounts for 82% of the variation in the SALE_PRICE (i.e. Adj. R-Square = .08219987).

The results of Model 2 (in Table 3, Appendix II) indicate the estimated effect that proximity to a tower has on residential property prices. Although the SALE_PRICE of single-family, residential properties may appear to increase after the construction of towers as indicated by Model 1, the discrete intervals created in Model 2 suggest that the value of residential properties also increases as the distance from towers increases. That is, if the distance from the residential property to the tower decreases, then the price of the residential property likewise decreases.

Model 2 indicates that the influence of the proximity of towers on the price of residential properties increases inversely with the distance. Under 200MTRS from the towers, the negative signs of the estimate coefficients suggest a decrease in the value of residential properties with an increased proximity or decreased distance to towers. The price of a property located between 101 and 150 meters of a tower decreases by 1.57% $(1- e^{-0.0156})$ relative to properties that sold prior to the tower being built when holding other explanatory variables constant. The price of properties

[18] Halvorsen, R. and Palmquist, R. "The Interpretation of Dummy Variables in Semilogarithmic Equations," *American Economic Review*, (70:3, 1980): 474-475.

that are located between 151 and 200 meters from a tower is reduced by 2.71% (1- $e^{-0.0275}$). Thus, a tower has a statistically significant, albeit minimal, effect on prices of property located within 200 meters of a tower.

From 300MTRS to 400MTRS, the price of residential property increases with the distance from the tower. Between 400MTRS and 500MTRS, the price continues to increase with the distance from the tower. These price increases vary from between 1.045% at 350 meters to 2.32% at 500 meters. Additionally, the t-statistics increase with the distance, further suggesting the impact indicated by the increase in estimate coefficients. Although the general trend in the data suggests a positive relationship between the price of residential properties and distance, anomalies exist within the distance intervals.

Having provided a preliminary assessment of the impact of the proximity of towers on residential property prices, Model 3 introduces the independent variable DISTANCE to better assess the variation in sale price due to the external effect of a tower.

Table 4 provides a summary of the distance-based results from Models 2 and 3. While the results of Model 2 present minor anomalies within the data intervals, the results of Model 3 suggest a greater consistency in the results. The results from Model 3 are presented in Table 5 (see Appendix III).

Table 4: A Comparison of Distance-Based Location Coefficients ***(% impact on price)***

DISCRETE LOCATION	**ADJ. R^2 = 0.826257**
500-450MTRS	2.30E-02 ***(2.33%)***
450-400MTRS	1.91E-02 ***(1.93%)***
400-350MTRS	2.17E-02 ***(2.19%)***
350-300MTRS	1.04E-02 ***(1.045%)***
200-150MTRS	-2.75E-02 ***(-2.71%)***
150-100MTRS	-1.56E-02 ***(-1.57%)***
EXPLICIT LOCATION	**ADJ. R^2 = 0.8282641**
DISTANCE	5.69E-05 (5.69-03%)
DISTANCE2	-1.49E-08

The results of Model 3 clearly show that the price of residential property increases with the distance from a tower. The independent variable, DISTANCE, estimates a coefficient with a positive sign, that increases with increasing distance from the tower (i.e. Distance = 5.69E-05). Moreover, the t-statistic associated with the estimated coefficient indicates the significance of the explanatory power of the variable (i.e. *t*-Stat = 10.751).

DISTANCE presents significant interactions with the other independent variables. The t-statistics associated with these interactions provide strong evidence that the price of residential property, while highly associated with site and structural characteristics, may be significantly impacted by proximity to towers (i.e. AFTER_TWR*DISTANCE = 3.519; DISTANCE2 = -12.258; DISTANCE*AGE = 4.829).

Further, although the estimated effect of the explanatory variable AFTER_TWR continues to suggest that the value of residential property increases with the distance from towers, the interactive nature of AFTER_TWR with DISTANCE2 suggests that the effect of AFTER_TWR may vary due to varying distances from the tower. Indeed, the estimated coefficient for AFTER_TWR from Model 1 is diminished in Model 2 and Model 3 as discrete and explicit, distance-based locational attributes are included in the model specification (i.e. Model 1, AFTER_TWR = 1.46E-02 ***(1.47%),*** Model 2, AFTER_TWR = 1.1495-02 ***(1.156%)*** and Model 3, AFTER_TWR = .012722 ***(1.28%)***).

3.5 Limitations and Comparison with the NZ Study

This study analyzed residential property sales drawn from a number of different, but neighbouring, suburbs in Orange County, Florida as an entire dataset (the suburbs were grouped together and analyzed as a whole). While the Location Value Signature was included in the model to take into account composite externalities as well as to allow these and other independent variables in the model to vary spatially, and therefore preclude the need to analyse neighbourhoods separately, it is possible that not all neighbourhood differences were accounted for when these results are compared to those from the NZ study.

The NZ study (2004) included an analysis of the whole dataset but also of the separate suburbs. The analysis of the whole dataset indicates that CPBSs have a significant, but minimal, effect on the prices of proximate properties. The same general result was obtained for the current US study. However, what the NZ study showed by analyzing the suburbs separately was that substantive differences exist in the effect that CPBSs have on property prices between suburbs, since the distribution of the property sales prices is quite different in each.

The analysis showed that the most significant variables and their effect on price were similar between the four suburbs: St. Albans, Beckenham, Papanui, and Bishopdale. This indicates the relative stability of the coefficients between each model. The overall results indicate that the presence of a CPBS has a significant and negative effect on property prices. This effect is not very strong when the variable *TOWER* is included in the model fitted to the **entire dataset**. However, the effect in each suburb is quite pronounced. It is possible that if the current study had analyzed suburbs separately that similar differences would have been found. Table 6, below, summarizes the results.

Table 6: Coefficients of TOWER, inv.dist and DIST

Model & Date Tower Built		TOWER	Inv.dist	DIST1	DIST 2	DIST 3
All Suburbs	Coefficients	-2.29e-02	-3.68e-01	-2.78e-02	-2.91e-02	-3.98e-03
	Value Effects	**-2.3%**	**50m @ -5.07%** **100m@ -3.61%**	**-2.7%**	**-2.87%**	Insignif.
St Albans 1994	Coefficients	1.48e-01	8.99e-01	1.45e-01	1.53e-01	1.44e-01
	Value Effects	**+16%** **(+12%)**	**50m@ +13.6%** **100m@ +9.4%**	**+15.6%**	**+16.5%**	**+15.5%**
Beckenham 2000	Coefficients	-1.81e-01	-2.85e+00	-1.74e-01	-1.74e-01	-2.03e-01
	Value Effects	**-16.56%**	**97m @-25.13%**	**-15.9%**	**-15.9%**	**-18.37%**
Bishopdale 1994	Coefficients	-9.86e-02	1.62e+00	-1.34e-01	-9.18e-02	
	Value Effects	**-9.39%**	**50m @-20.4%** **100m@ -15%**	**-12.54%**	**-8.96%**	

Papanui 2000	Coefficients	-8.17e-02	-2.24e+00	-7.02e-03	-1.55e-01	-6.70e-02
	Value Effects	**-7.85%**	**177m @-15.5%**	**Insignif.**	**-14.36%**	**-6.48%**

Other factors that could affect the results are the style and appearance of the CPBSs and how visible they are to residents.

4. Summary and Conclusions

This paper presents the results of a study carried out in Florida in 2004. The study involved the analysis of market transaction data of single-family homes that sold in Orange County between 1990 and 2000 to investigate the affect on the price of property in close proximity to a tower. The results showed that while a tower has a statistically significant effect on prices of property located near a tower, this effect is minimal. The price of properties within 200 meters (656 feet) decreased, on average, by just over 2%.

Each geographical location is unique as evidenced by the difference in results from the NZ and US studies. These observed differences are partly due to the manifold factors that influence the degree of negative reaction to towers. Residents' perceptions and assessments of risk vary according to a wide range of processes including psychological, social, institutional, and **cultural**. In addition to the potential heath, aesthetic and property value impacts from towers, other factors that may impact on the degree of negative reaction from residents living near these structures and that may be reflected in price are listed below:

- The kinds of health and other risks residents associate with towers, and the level of risk perceived;
- The height, style, and appearance of the towers, how visible these are to residents and how they perceive such views;
- The marketability of homes near towers;
- The extent and frequency of negative media attention to towers;
- The socio-economic make-up of the resident population (prior research indicates that social class is an important variable influencing people's response to environmental detriments, Thayer *et al*. 1992, and Dale *et al*. 1999);
- The distance from the towers residents feel they have to be to be free of concerns.

As the results reported here are from a case study conducted in 2004 in a specific geographic area (Orange County, Florida) the results should not be generally applied. Wolverton and Bottemiller[19] explain that:

> "…limits on generalizations are a universal problem for real property sale data because analysis is constrained to properties that sell and sold properties are never a randomly drawn representative sample. Hence, generalizations must rely on the weight of evidence from numerous studies, samples, and locations," p. 250.

Thus, to determine if the results are consistent across time and space many similar studies in different geographic locations would need to be conducted over time. Further, to allow valid comparison between them, such studies would need to be of similar design. As suggested by Bond

[19] Wolverton, M.L. & Bottemiller, S.C., (2003), "Further analysis of transmission line impact on residential property values", *The Appraisal Journal*, Vol.71, No.3, pp. 244.

and Wang (2005), the sharing of results from similar studies would aid in the development of a global database to assist appraisers in determining the perceived level of risk associated with towers and other similar structures from geographically and socio-economically diverse areas.

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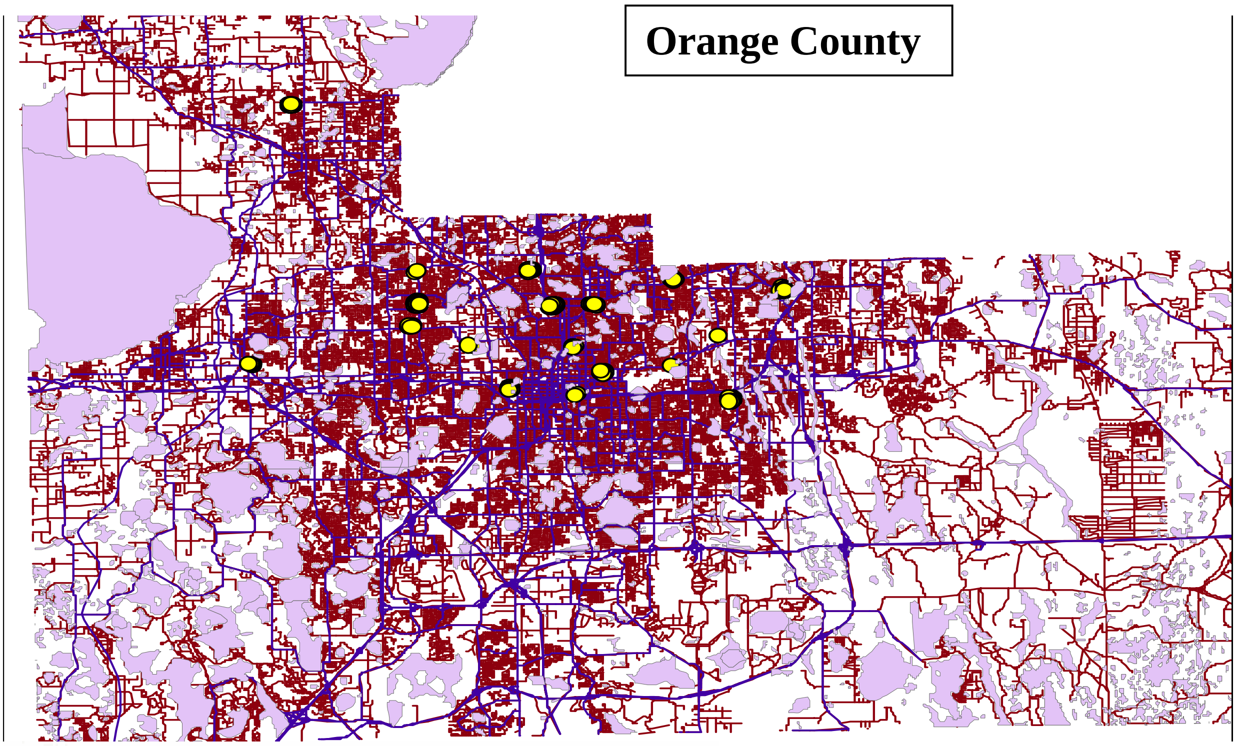
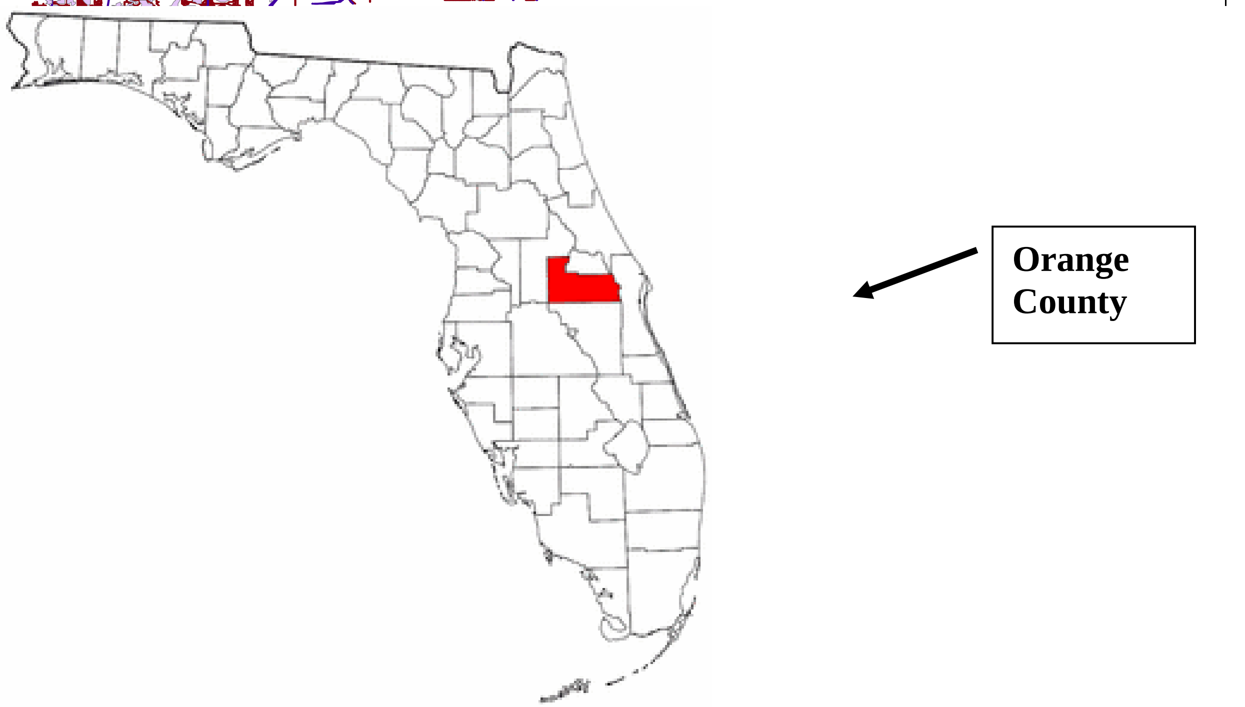
Appendix I - Location Map





Appendix II – Model 1 & 2 Results

Table 2: Model 1 (*n* = 5783); Adjusted R-Square = .8219987					
Variables	**Est. Coefficient**	**Std. Error**	**Std. Coefficient**	***t-Stat***	**Significance**
Constant	3.689244	0.257416		14.332	0.0000
AFTER_TWR	1.46E-02	5.08E-03	0.0353	2.867	0.0042
AFTER_TWR*AGE	5.99E-04	2.62E-04	0.0395	2.29	0.0221
AFTER_TWR*LOT	8.79E-07	2.91E-07	0.0272	3.018	0.0026
SQFT	3.88E-04	8.20E-06	1.2072	47.368	0.0000
SQFT2	-3.02E-08	1.90E-09	-0.3779	-15.912	0.0000
SQFT*AGE	3.52E-07	1.78E-07	0.0429	1.982	0.0475
AGE	-2.81E-03	5.17E-04	-0.1739	-5.429	0.0000
AGE2	7.12E-05	9.94E-06	0.1527	7.165	0.0000
XCOORD	-1.14E-06	1.61E-07	-0.0432	-7.105	0.0000
YCOORD	3.05E-06	4.48E-07	0.0456	6.799	0.0000

Table 3: Model 2 (*n* = 5783); Adjusted R-Square = .826257					
Variables	**Est. Coefficient**	**Std. Error**	**Std. Coefficient**	***t-Stat***	**Significance**
Constant	3.9082	0.2556		15.291	0.0000
AFTER_TWR	0.011495	5.05E-03	0.0279	2.275	0.0230
AFTER_TWR*AGE	5.57E-04	2.59E-04	0.0367	2.151	0.0315
AFTER_TWR*LOT	1.25E-06	2.91E-07	0.0387	4.301	0.0000
SQFT	3.98E-04	7.78E-06	1.2385	51.236	0.0000
SQFT2	-3.21E-08	1.89E-09	-0.4011	-16.994	0.0000
SQFT*AGE	--				
AGE	-2.29E-03	4.36E-04	-0.1418	-5.247	0.0000
AGE2	7.11E-05	9.81E-06	0.1524	7.245	0.0000
XCOORD	-1.67E-06	1.65E-07	-0.0633	-10.134	0.0000
YCOORD	3.26E-06	4.45E-07	0.0487	7.324	0.0000
500MTRS	2.30E-02	2.94E-03	0.0699	7.835	0.0000
450MTRS	1.91E-02	3.97E-03	0.0344	4.813	0.0000
400MTRS	2.17E-02	4.04E-03	0.0376	5.364	0.0000
350MTRS	1.04E-02	4.30E-03	0.0162	2.415	0.0158
200MTRS	-2.75E-02	6.12E-03	-0.0271	-4.489	0.0000
150MTRS	-1.56E-02	7.16E-03	-0.0128	-2.177	0.0295

Appendix III – Model 3 Results

Table 5: Model 3 (*n* = 5783); Adjusted R-Square = .8282641

Variables	Est. Coefficient	Std. Error	Std. Coefficient	*t-Stat*	Significance
Constant	3.097387	0.268028		11.556	0.0000
AFTER_TWR	0.012722	4.42E-03	0.0309	2.877	0.0040
AFTER_TWR*AGE	---				
AFTER_TWR*LOT	1.26E-06	2.86E-07	0.0389	4.4	0.0000
AFTER_TWR*DISTANCE2	2.72E-09	7.73E-10	0.055	3.519	0.0004
SQFT	4.01E-04	8.45E-06	1.2464	47.46	0.0000
SQFT2	-3.04E-08	1.93E-09	-0.3797	-15.726	0.0000
SQFT*AGE	--				
AGE	-2.80E-03	3.95E-04	-0.1731	-7.077	0.0000
AGE2	6.72E-05	9.70E-06	0.1442	6.931	0.0000
XCOORD	-1.61E-06	1.63E-07	-0.061	-9.911	0.0000
YCOORD	4.70E-06	4.80E-07	0.0702	9.798	0.0000
DISTANCE	5.69E-05	5.29E-06	0.2548	10.751	0.0000
DISTANCE2	-1.49E-08	1.22E-09	-0.2927	-12.258	0.0000
DISTANCE*AGE	6.20E-07	1.28E-07	0.0909	4.829	0.0000
DISTANCE*SQFT	-5.43E-09	2.71E-09	-0.0568	-2.002	0.0453