

The Effect of Previous Environmental Contamination on Industrial Real Estate Prices

abstract

This paper presents an empirical study of the effect of previous contamination on the price of industrial properties. Price effects are evaluated through two techniques. The first involves a direct comparison of previously contaminated property sales to a matched set of uncontaminated property sales. The second technique is a statistical analysis of the sales prices of industrial properties. Results from both analyses indicate that the prices of the previously contaminated properties are not adversely impacted by their environmental condition.

by Thomas O. Jackson, MAI, PhD

The central question addressed in this paper involves the effect of previous contamination on the price of industrial properties. Most empirical studies of the effects of contamination and other adverse environmental conditions have focused on single-family residential real estate. The limited empirical research on industrial property impacts appearing in *The Appraisal Journal* has not directly addressed the question of post-remediation impacts on property values due to previous contamination of the properties. Although Jackson,¹ Chalmers and Jackson,² and others have asserted that subsequent to remediation property value diminution decreases, this question has largely been addressed on a case-by-case basis. The lack of more systematic research on this issue may be due to the infrequency of transactions involving contaminated or previously contaminated properties. In addition, industrial properties are more difficult to analyze due to their relative heterogeneity in comparison to single-family houses.

Nevertheless, the question of whether or not contamination continues to affect the value and price of these properties after remediation is important for appraisers, for those involved in contaminated property transactions, and for courts that consider damages (usually estimated by appraisers) due to contamination. For appraisers, the valuation of contaminated and previously contaminated properties would have a different focus, depending on the date of value, if adverse impacts due to contamination dissipated subsequent to remediation. Many investors in contaminated properties and the environmental investment consortia that have emerged in recent years are essentially basing much of their investment strategy on the rebound in price and value subsequent to cleanup.³

Excerpt from *Papers and Proceedings*, published by Valuation 2000 in July 2000.

1. T.O. Jackson, "Mortgage-Equity Analysis in Contaminated Property Valuation," *The Appraisal Journal* (January 1998): 46-55.
2. J.A. Chalmers and T.O. Jackson, "Risk Factors in the Appraisal of Contaminated Property," *The Appraisal Journal* (January 1996): 44-58.
3. T.O. Jackson, "Investing in Contaminated Real Estate," *Real Estate Review*, (26:5, 1997): 38-43; T.O. Jackson, M.E. Dobroski, and T.E. Phillips, "Analyzing Contaminated Real Estate in a Changing Market," *The Real Estate Finance Journal* (13:2, 1997): 67-72.

This rebound provides the incentive and required rate of return for these investors.

And, lastly, courts, in numerous cases involving the allegations of property value damages due to contamination, are faced with reviewing evidence on the impact of contamination at various time points of relevance for the property, such as the date of a foregone sale or the trial date. Some courts are beginning to view property value diminution due to contamination as a temporary condition, under the assumption that remediation will “cure” the diminution. Under this theory, compensation is based on the cost to cure (remediate) the property or the diminution in fair market value, but not both. Actually, property value diminution can be attributed to both direct costs to remediate a contaminated property as well as the additional risks perceived by the market with respect to the remediation and other issues associated with the contamination. The effect of these perceived risks has been referred to as stigma, but it would be more accurately characterized more simply as additional investment and lending risk due to the environmental condition of the property.

Review of the Literature

There have been few empirical studies dealing directly with contaminated commercial and industrial properties. Most are “case studies” rather than the statistical price models that characterize most studies of the impacts of contamination and hazards on residential properties. Additionally, industrial properties are usually the source sites, and their value may be impacted by remediation costs, as well as the uncertainty and risk of investing and lending. The focus of the literature reviewed below is on these risk effects.

Page and Rabinowitz use a case study approach to evaluate the impacts of groundwater contamination.⁴ With six commercial and industrial cases from Pennsylvania, California, and Wisconsin and seven residential cases from Wisconsin, the authors found none of the presumed adverse impacts on residential property values, while the commercial and industrial properties had significant impacts from the contamination. They speculate that this is due to the levels of due diligence exercised by participants in the two markets as well as the assumption of re-

sponsibility for remediation and other liabilities involved in commercial and industrial property transactions. Although based on a limited amount of data, these findings underscore the differences between these property types, and highlight the need for additional research on the impacts of contamination on commercial and industrial real estate.

In a further application of the case study approach, Patchin reports on eight commercial and industrial transactions, finding a range of property value impacts from 20.9% to 93.7%.⁵ In addition, he notes that “properties that are in demand generally experience less stigma (reduction in value) than those with many substitutes.” Patchin’s main point, though, is that the increasing frequency of contaminated commercial and industrial properties transactions should allow for direct analysis of sales data, whereas in the past transactions were too infrequent for reliable analysis and conclusions. Thus, for these property types, Patchin finds reductions in value but also, and importantly, suggests that strong market conditions tend to mitigate the adverse effects of contamination.

The impacts of contamination on the transaction rates and financing of commercial properties have been studied by Simons and Sementelli, who compare commercial properties with leaking underground storage tanks (LUSTs) and properties with non-leaking tanks that have been registered with the State of Ohio (RUSTs) to other commercial properties (baseline).⁶ Data on sales of these properties are from Cleveland during the 1989–1992 period. With respect to transaction rates, the results show that both LUST sites and RUST sites transact at significantly lower rates than the baseline commercial properties, with 10.4% of the baseline commercial properties selling during the period and transaction rates of 3.8% for LUST sites and 4.9% for RUST sites. With respect to mortgage financing, 32.6% of the baseline commercial properties that sold had mortgages, while 29.4% of the LUST property sales had mortgages and 9.3% of the RUST sales had mortgages. Thus, there was a significant difference between the baseline commercial property sales and the RUST sites, but there was not a significant difference between the contaminated LUST sales and the baseline sales in the frequency

4. G.W. Page and H. Rabinowitz, “Groundwater Contamination: Its Effects on Property Values and Cities,” *Journal of the American Planning Association* (59:4, 1993): 473–481.

5. P.J. Patchin, “Contaminated Properties and the Sales Comparison Approach,” *The Appraisal Journal* (July 1994): 402–409.

6. R.A. Simons and A.J. Sementelli, “Liquidity Loss and Delayed Transactions with Leaking Underground Storage Tanks,” *The Appraisal Journal* (July 1997): 255–260.

of mortgage financing. Other results show that the average loan-to-value ratios (LTVRs) for the non-tank baseline properties declined from 0.95 to 0.80 during the period, while the LTVR for the RUST sales averaged 0.51 and for the LUST sites averaged 0.84. Accordingly, the reported results show LUST sales with similar rates and levels of financing to other commercial properties.

Another perspective on the Cleveland leaking underground storage tank sites is provided by Sementelli and Simons, who analyzed a sample of 429 sites over a four-year period.⁷ Among the findings of the study involved the effect of a “no further action” (NFA) letter from the State of Ohio. An NFA letter should signal the market that the site is remediated, and according to many of the previous studies this should reduce investment and lending risk and improve marketability. However, when transaction rates are analyzed, Sementelli and Simons observe that only 0.2% of the sites sold after receiving the NFA letters. This is much lower than the 10% transaction rate for non-tank commercial properties over the same period. Thus, it would seem that receiving an NFA letter from the State of Ohio increases risk and reduces marketability.

Simons, Bowen, and Sementelli provide yet another look at leaking underground storage tanks in Cleveland.⁸ In this research, the effects of LUSTs on adjacent properties are examined. The authors state that their research on sales prices is complementary to direct surveys of market participants, noting that surveys can be more detailed and specific but are difficult to employ. The main hypothesis of the research, though, is that contamination from nearby properties reduces the value of adjacent residential and commercial properties. Residential properties near LUST sites are analyzed through a hedonic modeling process whereby the model sales price predictions, based on the sales of properties not near a LUST site, are compared to the sales prices of properties near a LUST site. The actual prices averaged 14.7% less than the predicted prices.

For commercial properties near LUST sites, three other approaches are used. In the first approach, the authors compared transaction rates of commer-

cial properties near LUST sites with other commercial properties. They found that the properties adjacent to the LUST sites transacted at a rate of 2.7% per year while other properties transacted at 4.0% per year, and using a difference of means test determined that this was statistically significant. The second approach compared the incidence of seller financing and determined that properties adjacent to LUST sites had a significantly higher rate of seller financing than other properties. The third approach is based on a paired sales analysis, comparing a sale before contamination was discovered and a resale after the contamination was known. Based on an analysis of six such sales, Simons, Bowen and Sementelli conclude that the average diminution in value due to the contamination was from 28% to 31%.⁹ The authors did not use a regression-based approach to analyze the commercial sales data.

There have been few attempts to model the price of commercial and industrial properties in a statistical framework. However, multivariate statistical analysis and hedonic modeling have been used extensively in analyzing residential properties and in estimating the effects of environmental contamination or hazards on housing prices. The application of this technique to commercial and industrial properties is limited by the difficulty of assembling a sufficiently large number of transactions on relatively homogeneous properties. As noted by Epley, the small size of samples of these sales can limit the reliability of statistical techniques such as multiple regression analysis because the underlying assumptions that the error terms are normally distributed with zero mean and constant variance are usually not satisfied.¹⁰ However, Epley also notes that a “small sample does not mean that a statistical model such as regression or minimum variance does not work” but that the analyst cannot test the reliability of the underlying assumptions. It should be noted, though, that Epley’s comments are directed at a typical sales comparison analysis with four or five sales as data points.

One published example of the application of hedonic techniques to commercial real estate is by Saderion, Smith, and Smith.¹¹ Using data on apart-

7. A.J. Sementelli and R.A. Simons, “Regulation of Leaking Underground Storage Tanks: Policy Enforcement and Unintended Consequences,” *Economic Development Quarterly* (11:3, 1997): 236–248.

8. R.A. Simons, W.M. Bowen, and A.J. Sementelli, “The Price and Liquidity Effects of UST Leaks from Gas Stations on Adjacent Contaminated Property,” *The Appraisal Journal* (April 1999): 186–194.

9. Ibid.

10. D.R. Epley, “A Note on the Optimal Selection and Weighting of Comparable Properties,” *Journal of Real Estate Research* (14:1/2, 1997): 175–182.

11. Z. Saderion, B. Smith, and C. Smith, “An Integrated Approach to the Evaluation of Commercial Real Estate,” *Journal of Real Estate Research* (9:2, 1994): 151–167.

ment property sales in Houston from 1978 to 1988, the authors estimate the parameters for three models:

1. a "standard hedonic" with price as a function of property and market characteristics, including year-of-sale dummy variables,
2. an income model with income capitalization rates as a function of net operating income and the year-of-sale variables, and
3. a combined model with price as a function of property and market characteristics, year of sale, and net operating income.

The models are estimated in logarithmic form. The combined model produced the best fit with an R^2 of 0.926. The income model had the lowest explanatory power with an R^2 of 0.752, although the t -statistic for net operating income of 27.97 indicates that it is a highly significant predictor. The authors seem to imply that the first model, with the property and market characteristics and year of sale, is similar to the sales comparison approach used by appraisers. The third model specification, with property and market characteristics as well as the income data, might represent some combination of the sales comparison and income capitalization approaches.

Saderion, Smith, and Smith applied a hedonic modeling technique to uncontaminated commercial properties.¹² An application of hedonic modeling to non-residential properties for purposes of estimating environmental impacts is by Guntermann, who developed a hedonic pricing model for 183 transactions involving industrial land from 1984 to 1994.¹³ Independent variables included a variety of size and locational characteristics as well as landfill proximity. Guntermann's model estimated price as a function of parcel size, two general area locations, location in an industrial park and transportation access, as well as proximity to an open or closed landfill. Sales of non-proximate industrial properties were used to specify the proximity impact. The model explained about 70% ($R^2 = 0.71$) of the variation in price (logarithm of price). The results of the study indicated that the value of industrial property around open landfills was reduced by proximity to the landfill, while the value of industrial properties around closed landfills was not reduced. This finding is consistent with the other studies that suggest that adverse impacts are tempo-

rary, and that these effects would dissipate subsequent to closure or remediation.

Lastly, Dotzour examines real estate prices before and after the publicized discovery of groundwater contamination in Wichita.¹⁴ Dotzour looks at prices of residential properties in the contaminated area and compares them to prices in two uncontaminated control areas. Based on these comparisons, the study finds no impact on residential prices in the contaminated area. However, at the same time, Dotzour notes that lending on commercial real estate came to a nearly complete stop while residential mortgage lending continued. The finding of disparate impacts on commercial and residential properties mirrors that of Page and Rabinowitz. This may be due to greater concerns about lender liability for contaminated commercial and industrial properties.

Methodology

The methodology for analyzing the impacts of contamination on industrial properties has to date been based primarily on either the sales comparison approach or the income capitalization approach. A recent survey by Kinnard and Worzola found that the sales comparison approach was increasing in frequency of use by appraisers, although the preponderance of the literature indicated that income capitalization, and capitalization rate adjustments, was the approach most frequently deemed appropriate.¹⁵

Sales Comparison Analysis

The sales comparison approach, traditionally used by appraisers to estimate the value of many property types, has additional complications for contaminated properties. The typical sales comparison analysis involves the identification and analysis of properties comparable to the subject property. In the analysis of a contaminated property, especially where the estimate of a reduction in value due to the contamination is the central question, this process should become a two-part problem. First, a set of comparable contaminated property sales must be identified. In addition to being comparable on typical real estate criteria, such as property type, location, size, age, etc., the selection of contaminated property sales must consider the environmental condition of the comparable relative to the subject. The

12. Ibid.

13. K.L. Guntermann, "Sanitary Landfills, Stigma, and Industrial Land Values," *Journal of Real Estate Research* (10:5, 1995): 531-542.

14. M. Dotzour, "Groundwater Contamination and Residential Property Values," *The Appraisal Journal* (July 1997): 279-285.

15. W.N. Kinnard, Jr., and E.M. Worzola, "How North American Appraisers Value Contaminated Property and Associated Stigma," *The Appraisal Journal* (July 1999): 269-278.

most significant variable to be considered is the remediation status of the property. That is, the comparable property's environmental condition should be similar in terms of remediation status (before, during, or after cleanup at time of sale). The underlying theory is that there are substantial differences in the degree of risk (stigma) for an environmentally impacted property due to its remediation status at the time of sale or date of value. Thus, a subject property being analyzed in a pre-remediation condition would require comparables that sold in a similar condition. Likewise, sales comparables that had been cleaned up would be required for a subject property that was remediated on its date of value. The non-environmental factors must also be comparable. Contamination affects industrial properties differently than residential properties, for example, due to differing health risk exposure factors. In addition, market conditions could exacerbate or mitigate the effects of contamination.

Secondly, sets of uncontaminated comparable sales are identified for each of the contaminated properties. In this task, the comparable contaminated sales properties that were matched to the subject in the first step are analyzed to determine sets of uncontaminated sales properties. On the basis of each of these data, the effects of the contamination on the sales prices of the contaminated comparables can be estimated. The sales price effects extracted from the contaminated and uncontaminated comparables can then be used to evaluate the potential effects, if any, of the contamination on the subject property. This two-step process essentially controls for market and other differences that may mitigate or increase the effect of the contamination on sales price and property value. Direct comparisons of the comparables to the subject will usually be difficult due to the complex interactions between market, property, and environmental variables. The appraiser should focus on the most important question involving contaminated properties—the reduction in value due to the contamination. Once this question is answered, the value reduction, measured as a percentage or in other ways, can be applied to an unimpaired value estimate in order to determine the impaired “as is” value of the subject and any damages that may have resulted from the environmental condition of the property.

Statistical Analysis

Multiple regression analysis has been frequently used in the estimation of residential property values and environmental impacts on residential properties. As explained, it has been applied less often to industrial properties due to the relative infrequency of sales of contaminated industrial properties, as well as the generally lower number of uncontaminated commercial property sales relative to residential property sales. In addition, industrial properties are less homogeneous than residential properties such as single-family houses. The estimation of a reliable equation for properties with many differing characteristics is more difficult than it is for more uniform properties, with fewer elements of dissimilarity.

Sales Comparison Analysis

One of the most difficult tasks in developing an empirical analysis of the effect of contamination on industrial properties through either the sales comparison or hedonic modeling approaches involves the assembly of relevant data. The framework previously outlined argues that a number of uncontaminated and contaminated comparables are required in a two-step process. However, the focus of the research reported in this paper is not to estimate the effects on a single subject property, but rather to investigate the existence of effects under certain conditions for a class of properties and to determine whether there is any empirical evidence to support a claim of lingering or perpetual impacts due to contamination subsequent to remediation and cleanup.

Sales Data

In order to evaluate the impacts due to contamination on industrial properties that have been remediated, contaminated property sales from the southern California area were obtained.¹⁶ The procedure for obtaining these sales involved the identification of sales from a commercial sales data service provider based on some mention of contamination or environmental impacts in the descriptive part of the corresponding data sheets.¹⁷ After this information was reviewed in detail, 14 properties appeared to have been remediated prior to sale. These were investigated further, and another five were eliminated for various reasons. Of the remaining nine sales of contaminated or previously contaminated property, one had to be eliminated due to incomplete in-

16. These sales data were originally collected and analyzed for an environmental real estate investor based in San Francisco, California. The data are used herein by permission.

17. The COMPS, Inc., data service was used in assembling this information and the data in the hedonic price analysis discussed in the next section.

formation. The final eight sales and related property information are summarized in Table 1.

Parties to the remaining sales were contacted, as were officials at environmental regulatory agencies, in order to identify the contamination types, sources, and conveyances (underground storage tanks, petroleum hydrocarbons, chlorinated solvents, soil contamination, groundwater contamination, etc.) and the remediation status of the properties, with most having been remediated prior to sale. Also obtained was information on indemnifications provided to the purchaser against future liabilities or additional cleanup costs. This data is summarized in Table 2.

The last step was to select a set of comparable uncontaminated sales for the contaminated property sales. As explained, this step is necessary in the valuation of a contaminated property and is also an important research task for analyzing the existence of environmental impacts for a class or category of properties. Three to four uncontaminated comparables were identified for each of the contaminated properties on the basis of location, age, property type, date of sale, and other variables.

Data Analysis

These data can now be analyzed through a form of sales comparison analysis involving each of the con-

taminated sales and the sets of uncontaminated (unimpaired) comparables. This analysis is not the same as would be required by the USPAP, and it does not include all of the steps outlined in the preceding section. As noted, three to four unimpaired properties were matched to each contaminated sales property. After adjustments for such items as excess land, extraordinary tenant improvement costs, and demolition costs (for a land only sale), the per square foot prices for the unimpaired comparables and the contaminated property sales are presented in Table 3.

This data can be analyzed in a relatively straightforward manner to determine if there is evidence to suggest any impact on sales price due to the contamination or previous contamination. This is done in Table 4. The unimpaired sales price data is summarized in a range (high to low price per square foot) and then compared to the respective contaminated property (subject) price per square foot. The results in the last two columns of Table 4 indicate whether the prices for the subject/contaminated property were within the range indicated by the market. As can be seen, all of the contaminated properties were sold at unit values within or above the indicated market range. However, two of the properties sold for less than the average indicated market price. The first, a San Diego property, had previous groundwa-

Table 1 Contaminated Industrial Property Sales Data Location

Location	Property Type	Age of Structure	Building Size (Sq. Ft.)	Adjusted Sales Price	Price per Sq. Ft.	Date of Sale
Redondo Beach	Warehouse/distribution	20 years	112,000	\$6,400,000	\$57.14	03-Oct-97
San Diego	Industrial	25 years	45,414	\$1,741,720	\$38.35	30-Dec-97
Santee	Manufacturing	27 years	38,000	\$1,850,000	\$48.68	03-Sep-97
San Diego	Industrial/land	26 years	29,416	\$495,000	\$16.83	11-Jan-96
Los Angeles	Light manufacturing	Unknown	15,000	\$430,000	\$28.67	01-Aug-96
San Diego	Industrial	27 years	12,296	\$880,000	\$71.57	07-Feb-97
El Segundo	Industrial	35 years	6,375	\$460,000	\$72.16	07-Nov-96
Anaheim	Industrial	22 years	20,601	\$986,000	\$47.86	01-Oct-96

Table 2 Environmental Condition Data

Location	Property Type	Contamination Type/Conveyance	Remediation Status	Indemnification
Redondo Beach	Warehouse/distribution	Underground storage tanks	Remediated	Partially
San Diego	Industrial	VOCs/groundwater contamination	Remediated	Yes
Santee	Manufacturing	Unknown	Remediated	Yes
San Diego	Industrial/land	Oil tank	Remediated	Unknown
Los Angeles	Light manufacturing	Chlorinated solvents in soil	Remediation in process	No
San Diego	Industrial	Encapsulated asbestos	Yet to be removed	No
El Segundo	Industrial	Soil and groundwater	Remediated	Yes
Anaheim	Industrial	Unknown	Remediated	Unknown

Table 3 Industrial Property Price per Square Foot Comparisons

Location	Property Type	Subject Impaired Price per Sq. Ft.	Unimpaired Comp 1 Price per Sq. Ft.	Unimpaired Comp 2 Price per Sq. Ft.	Unimpaired Comp 3 Price per Sq. Ft.	Unimpaired Comp 4 Price per Sq. Ft.
Redondo Beach	Warehouse/distribution	\$57.14	\$35.42	\$58.14	\$48.50	n/a
San Diego	Industrial	\$38.35	\$52.00	\$40.56	\$44.58	\$37.01
Santee	Manufacturing	\$48.68	\$56.29	\$36.96	\$37.99	\$55.00
San Diego	Industrial/land	\$16.83	\$11.93	\$10.00	\$12.65	n/a
Los Angeles	Light manufacturing	\$28.67	\$28.63	\$29.96	\$38.73	\$30.33
San Diego	Industrial	\$71.57	\$68.02	\$59.31	\$73.06	\$60.95
El Segundo	Industrial	\$72.16	\$60.71	\$64.94	\$58.96	n/a
Anaheim	Industrial	\$47.86	\$42.81	\$43.83	\$51.01	n/a

Table 4 Sales Comparison Analysis of Effects of Environmental Contamination on Industrial Property Sales Prices

Location	Property Type	Unimpaired Low Price per Sq. Ft.	Unimpaired High Price per Sq. Ft.	Unimpaired Average Price per Sq. Ft.	Subject Impaired Price per Sq. Ft.	Diminution Indicated by Market Range	Diminution Indicated by Market Average
Redondo Beach	Warehouse/distribution	\$35.42	\$58.14	\$47.35	\$57.14	Within range	None indicated
San Diego	Industrial	\$37.01	\$52.00	\$43.54	\$38.35	Within range	-13.52%
Santee	Manufacturing	\$36.96	\$56.29	\$46.56	\$48.68	Within range	None indicated
San Diego	Industrial/land	\$10.00	\$12.65	\$11.53	\$16.83	Above range	None indicated
Los Angeles	Light manufacturing	\$28.63	\$38.73	\$31.91	\$28.67	Within range	-11.32%
San Diego	Industrial	\$59.31	\$73.06	\$65.34	\$71.57	Within range	None indicated
El Segundo	Industrial	\$58.96	\$64.94	\$61.54	\$72.16	Above range	None indicated
Anaheim	Industrial	\$42.81	\$51.01	\$45.88	\$47.86	Within range	None indicated

ter contamination. The second, a Los Angeles property, was in remediation at the time of sale. Thus, it had existing as well as previous contamination.

To examine this further, the last column in Table 4 compares the average unit price from the unimpaired comparables to each of the subject properties. This comparison provides a more narrow indication of any property value diminution due to the contamination or previous contamination on the basis of a point estimate of the price indication from the unimpaired sales to each of the subject property unit prices. Since the comparables have not been adjusted for any remaining elements of dissimilarity, this is not the same as a value conclusion but rather is one further quantitative indicator of potential impacts due to the environmental condition of the subject properties. As can be seen in Table 4,

only two of the contaminated subject properties had any indicated value diminution on this criterion.

The overall conclusion that could be drawn from this comparative analysis is that the environmental condition of the eight contaminated or previously contaminated properties had little or no effect on their ultimate sales price. Indeed, for most of the properties, their sales price was actually higher on a per unit basis than what would be indicated by the unimpaired comparables. Since most of these properties had been remediated prior to sale, this would suggest that subsequent to cleanup to appropriate regulatory standards the market is more comfortable with environmental risks than it would be for industrial and commercial properties that had no undiscovered contamination.

Statistical Analysis

A second type of sales price analysis can be accomplished through a multiple regression analysis sometimes referred to as hedonic modeling/price analysis. In this type of analysis, the price of industrial properties is statistically modeled as a function of the physical and/or economic characteristics of the property such that the relative contribution of each of the independent, or predictor, variables on price can be estimated. In assessing environmental impacts, the environmental condition of the property at the date of sale is added as an independent variable. The effect of environmental condition can then be tested through its estimated level of statistical significance, with a p -value of 0.05 or less indicating the probability of incorrectly rejecting the null hypothesis of no effect on prices.

The following general specification can be used for the statistical analysis of price effects of environmental contamination:

$$P = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \beta_{n+1} ENV_1 + \dots + \beta_{n+1+p} ENV_p + \varepsilon$$

where:

- P = the sales price of the property,
- β_0 = a constant term,
- $X_1 \dots X_n$ = a vector of continuous and discrete non-environmental property characteristics such as building size, lot size, age, etc.,
- $ENV_1 \dots ENV_p$ = a vector of discrete variables indicating the environmental status of the property at the time of sale, and
- ε = a random error term.

Sales Data

Sales data for this analysis includes most of the post-remediation sales discussed in the preceding pages, as well as a larger number of additional sales that will improve the reliability of the regression estimates. Of the initial group of sales, the sale that was in remediation, the land sale, and the sale involving asbestos were excluded. The remainder represents improved industrial properties that sold with previous soil or groundwater contamination. The additional data was collected through a search of a commercial data service database for Los Angeles, San Diego, and Orange counties. Key words in the descriptive information given for the sales were used to target contaminated properties. Full descriptions were then re-

viewed to identify properties that were sold with existing or previous contamination. For purposes of the analysis reported herein, only previously contaminated property sales were retained. Several unimpaired or uncontaminated comparables were then matched by property type, geography, and year of sale. For most properties, all of the sales of industrial properties for which there was no mention of contamination in the subarea were selected as unimpaired comparables. Some of the sales were eliminated due to missing data on one or more of the variables used in the regression analysis. The remaining sales data are summarized in Tables 5 and 6.

As can be seen in Table 5, there were 13 sales of previously contaminated property identified for this analysis. These sales included seven from the previous analysis (excluding the land, asbestos, and shopping center sales), as well as an additional six sales occurring from mid-1998 to mid-1999 in the southern California area, as described. The data in Table 5 also include the unimpaired improved industrial comparables from the preceding analysis and a number of additional unimpaired comparables matched to the additional contaminated property sales. The average sales price for the unimpaired properties is shown to be lower than the average price for the contaminated sales, but the average per square foot price for the unimpaired sales is slightly higher due to the larger size of the properties sold with previous contamination.

Table 6 lists descriptive statistics for all of the sales and variables to be used in the multiple regression analysis. There are two area (county) and year-of-sale categorical variables. One corresponds to sales occurring in Orange County in 1999 and the other corresponds to sales in San Diego County in the same year. These two dummy variables will account for the higher average prices in these two areas in 1999 relative to the Los Angeles County sales.

Data Analysis

The parameters for the general model described at the beginning of this section were estimated through a linear multiple regression analysis. The results of this analysis and the parameter estimates are presented in Table 7. Several important results are revealed in the statistical analysis in Table 7. First, variation in the five independent variables explains over 75% of the variation in sales price (adjusted R^2 of 0.7604). Furthermore, the model attains statistical significance at a high level, with a p -value of 0.0001. Thus, the main null hypothesis of no relationship

Table 5 Industrial Property Sales Data by Remediation Status

Variable	Uncontaminated Property Sales	Sales of Previously Contaminated Property
Average sales price	\$1,353,722	\$1,850,577
Orange County sales in 1999 (<i>n</i> = 5)	5	0
San Diego County sales in 1999 (<i>n</i> = 12)	12	0
Building square footage	29,320.47	40,291.15
Average price per square foot	\$46.16	\$45.86
Age of building in years	28.47	32.62
Land square footage	66,158.95	118,948.77
Number of sales	109	13

Table 6 Descriptive Statistics for Industrial Property Sales

Variable	Mean	Standard Deviation	Minimum	Maximum
Sales price	1,406,186	1,262,902	325,000	6,400,000
Orange County sales in 1999 (<i>n</i> = 5)	0.0410	0.1991	0	1
San Diego County sales in 1999 (<i>n</i> = 12)	0.0984	0.2990	0	1
Building square footage	30,489.48	27,596.50	2,014	120,000
Age of building in years	28.91	16.13	0	76
Land square footage	71,784.10	71,817.94	5,720	483,516
Sale after remediation of previous contamination (<i>n</i> = 13)	0.1066	0.3418	0	1

Note: Data on 122 industrial building property sales with non-missing data on all variables in regression model. Thirteen properties had previous contamination and 109 were uncontaminated.

Table 7 Statistical Analysis of the Effects of Environmental Contamination on Industrial Property Sales Prices

Variable	Parameter Estimate	t-statistic	p-value
Intercept	589,051	4.100	0.0001
Orange County sales in 1999	1,151,150	3.847	0.0002
San Diego County sales in 1999	418,712	2.088	0.0390
Building square footage	23.12	5.911	0.0001
Age of building in years	-13,289	-3.636	0.0004
Land square footage	5.53	3.594	0.0005
Sale after remediation of previous contamination	102,383	0.533	0.5949
Adjusted <i>R</i> ²	0.7604		
<i>f</i> -value	65.014		
<i>p</i> -value	0.0001		

Note: The model comprises 122 industrial property sales. Average sales price was \$1,406,186. All variables are significant at the 0.05 level, except the effect of contamination, which is not significant.

between the independent variables and sales price can be rejected.

The parameter estimates for all of the non-environmental variables are shown in Table 7 to attain statistical significance at the 0.05 level (*p*-value of 0.05 or less). Thus, the null hypothesis for each of these predictors of sales price can be rejected in favor of the alternate hypotheses that the observed effect on sales price is significant. In addition, all of the parameters have the expected signs and effects on price. Sales price would increase with building and land square footage and be reduced for each

year of age. The 1999 sales in Orange and San Diego counties were higher than the reference group consisting of Los Angeles County sales for all years and Orange and San Diego County sales prior to 1999. Other year and area combinations were tested, as well as year and area separately, but the other combinations did not attain significance and were dropped from the model. Building square footage attains the highest level of significance, with a *p*-value of 0.0001, and its estimate indicates that each square foot of space adds \$23.12 to sales price, controlling for the other factors in the model.

The variable of greatest interest to the main research question is the environmental condition of the property as of the date of sale. The effect of this variable on sales price is tested through a categorical, or dummy, variable with a value of 1 corresponding to the 13 previously contaminated properties in the data. The 109 comparable uncontaminated properties would have a value of 0 for this variable. The parameter estimate for this variable in Table 7 is not found to be statistically significant. The t -statistic of 0.533 corresponds to a p -value of 0.5949, indicating that the estimate is not statistically significant from 0 and the null hypothesis of no effect on sales price cannot be rejected. Thus, the environmental condition of the previously contaminated properties at their date of sale does not have a statistically significant effect on sales price, controlling for the other variables, location, year of sale, age, building size, land area, and building age.

Lastly, an alternative model specification is offered. Table 8 presents the estimates for a model of industrial sales price including the additional parameter of office square footage. Data on this variable was not available on some of the sales, and including it in the model reduces the number of sales with non-missing data on all variables from 122 to 90. One of the previously contaminated property sales was eliminated. The average office space for the remaining uncontaminated sales was 4,652 square feet and for the previously contaminated sales was 8,464 square feet. Again, the previously contaminated sales were larger than the uncontaminated comparables, but these size differences are statistically controlled in the multiple regression model and are not reflected in the environmental condition variable, the parameter of interest. The results of re-estimating the model in this alternative specification are presented in Table 8.

As can be seen in Table 8, the alternative model specification has an adjusted R^2 of 0.8486, indicating that the model explains nearly 85% of the variation in sales price. The coefficients for all of the parameter estimates are in the expected direction, with price increasing with building and land square footage and decreasing with age. The office space parameter estimate is statistically significant at the 0.0001 level, and its estimated coefficient indicates that on average each additional square foot of office space adds \$57.70 to sales price. The addition of the office space, despite reducing the number of sales available for analysis, improved the model. More importantly, in this alternative specification the variable of interest to the main research question, the environmental condition of the property at the date of sale, remains insignificant, and the null hypothesis of no effect cannot be rejected.

Lastly, it should be noted that in the regression analysis presented herein, several assumptions about the fitted models were tested. These assumptions concern the errors or residuals for the sales used to estimate the parameters of the models. Among these assumptions are that the residuals, or errors, ϵ_i have the following characteristics:

1. ϵ_i is normally distributed.
2. ϵ_i has a mean of zero.
3. ϵ_i values are linearly independent and uncorrelated.
4. ϵ_i has a constant variance.

Lack of violation of these assumptions was confirmed through several residual plots. The plots depict the residual, or difference between the actual and model predicted price, for each observation and for each of the two models. These included normal

Table 8 Statistical Analysis of the Effects of Environmental Contamination on Industrial Property Sales Prices, Alternative Model Specification

Variable	Parameter Estimate	t-statistic	p-value
Intercept	419,197	3.008	0.0035
Orange County sales in 1999	1,031,676	3.581	0.0006
San Diego County sales in 1999	291,162	1.567	0.1210
Building square footage	25.42	5.967	0.0001
Office space square footage	57.70	4.696	0.0001
Age of building in years	-11,203	-2.873	0.0052
Land square footage	2.96	2.005	0.0483
Sale after remediation of previous contamination	16,581	0.096	0.9239
Adjusted R^2	0.8486		
f -value	72.288		
p -value	0.0001		

Note: The model comprises 90 industrial property sales. Average sales price was \$1,493,370. Effect of contamination after remediation is not significant.

probability plots, histograms, and plots of the residuals against several of the independent variables and against the dependent variable, sales price. Analysis of these residual plots and related statistics did not reveal any patterns indicative of violations of any of the four assumptions. In addition, variance inflation factors were estimated to confirm the linear independence of the regressors. The absence of dominant outliers was confirmed through studentized residual calculations and plots and Cook's distance measures.

Conclusion

The research reported in this paper has attempted to evaluate, through a variety of techniques, the question of whether previous contamination has an effect on sales price. The question is based on the heretofore generally untested assumption that contamination may adversely affect real estate prices after remediation, as well as before and during remediation. Little empirical evidence has been brought to bear on this question in the past, and the question has not been studied in any systematic manner. Toward this end, data sets of previously contaminated industrial property sales and comparable uncontaminated sales were assembled and analyzed. Two procedures were used—sales comparison analysis and multiple regression analysis with two model specifications. The results of each of these analyses indicated that the previously contaminated properties did not sell at prices that differed from their uncontaminated comparables.

Indeed, formal statistical tests indicated that the sales prices of the previously contaminated properties were not significantly different from the prices of other comparable industrial properties. In these analyses, the null hypothesis of no difference and no effect on sales price due to environmental condition could not be rejected.

Thomas O. Jackson, PhD, MAI, CRE, AICP, is the president of Real Property Analytics, Inc. Dr. Jackson has 20 years of experience in the valuation of real property, urban planning, and real estate consulting. He holds a PhD in urban and regional science from Texas A&M University, as well as masters' degrees from the University of North Carolina at Chapel Hill and the Ohio State University. He has taught courses on real estate development at Texas A&M, and currently serves on the Appraisal Standards Board of The Appraisal Foundation. Dr. Jackson's research has been published in *The Appraisal Journal* and other leading academic and professional real estate journals. **Contact:** Real Property Analytics, Inc., 1904 Streamside Way, Bryan, TX 77807. (979) 823-5243; fax: (979) 779-2493; e-mail: tomjackson@cox-internet.com.