Valuation of the Effects of Asbestos on Commercial Real Estate

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Abstract. This study develops a valuation procedure and a model for estimating the impact of the presence of asbestos-containing materials (ACMs) on real estate income property. A key aspect of the valuation procedure is that the value of a property with asbestos, and hence the value adjustment for the presence of asbestos, depends on the optimal strategy for dealing with the asbestos. Value-maximizing conditions are derived from the model for determining if and when removal should occur. Information obtained from a survey of real estate appraisers provides data for parameterizing the model for the purpose of simulating the effects of ACMs on the value of different categories of property.

Introduction

Appraisers are being asked to estimate the effect of the presence of asbestos-containing materials (ACMs) in buildings on the market value of properties. The purpose of this paper is to develop a theoretically sound valuation process for assessing the impact of asbestos on market value.

In well-functioning markets, the market value of a property with asbestos at the time of valuation should reflect the optimal strategy for dealing with the asbestos. In this paper, we develop a value maximization model for a property with asbestos-containing materials (ACMs) that incorporates the timing of removal of the ACMs as a key determinant of the value of the property. With this model, we show how, on the one hand, the timing and the cost of removal and, on the other hand, the cost of safely containing the asbestos plus possible reductions in property net operating income (NOI) and increases in the property discount rate as a consequence of adverse market reactions to buildings with asbestos, interact to determine the value-maximizing strategy for dealing with the ACMs. That value-maximizing strategy, in turn, is incorporated in the valuation of the property such that its market value reflects the optimal strategy for dealing with the ACMs.

Relatively few articles systematically attempt to assess the impact of asbestos on real estate values. Koehn, MacAvoy and De Silva [7] report the results of an empirical study of the effects of asbestos on commercial property values in Los Angeles. That study found no significant effect of the presence of asbestos on the value of the properties.

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included in the study, a finding that is controversial. The leading work on the economic effects of asbestos on buildings is Dewees [3]. In addition to addressing the issue of the cost effectiveness of asbestos regulations, existing and proposed, Dewees develops a present value framework for assessing the impact of asbestos on property value and for evaluating alternative approaches for dealing with the asbestos. Yet the general models developed by Dewees do not address the key trade-offs developed in this paper, specifically the trade-off between the cost to remove and the reactions of the marketplace to buildings with asbestos.

Wilson [11] uses a case study to illustrate a discounted cash flow procedure for assessing how the reduction in value is affected by alternative removal strategies. His objective is to determine the financially optimum strategy for dealing with asbestos in a commercial property and to assess the effect of removal cost assumptions on the selection of that strategy. However, Wilson does not develop a general model to solve for the optimal time to remove the asbestos. Ramsland [9] identifies important market value issues relating to estimating the impact of asbestos on property value. He also suggests, in broad outline, a property-specific asbestos assessment model to estimate the loss in value caused by ACMs. Ramsland calculates the loss in value as the present value of abatement-associated costs, which assumes that the asbestos is removed immediately. He does not allow for the possibility that the highest and best use of the property may be to contain, rather than remove, the asbestos. He also does not explicitly consider how the timing of asbestos removal affects the loss in value.

The approach utilized in this article is linked to research dealing with the relationship between investment decisions and property value. Like research on issues relating to the highest and best use paradigm [4], the approach we take examines how property value is affected by decisions about what to do with a property. In our case, the value of the property is maximized, not by selecting the value-maximizing combination of land use and improvements, but rather by selecting the optimal strategy for dealing with the asbestos contained in the property. Another strand of research to which the approach taken in this study relates is research concerning the optimal holding period for a real estate investment [2], [6]. In that literature, property value is shown to be maximized by selecting the optimal tax-induced holding period.

The following section of the paper, section two, describes the valuation procedure that we use to estimate the market value of a property with asbestos. The third section presents the general valuation model for estimating the value of a property with asbestos as well as some general propositions derived from the model. Section four derives optimal timing decisions for removal of the asbestos. In the fifth section we simulate market values of buildings with ACMs using information obtained from a survey of commercial real estate appraisers. The sixth and final section is the conclusion.

Valuation Procedure

A simple three-step procedure can be utilized for determining the loss in property value because of the presence of asbestos. The steps in this valuation procedure are, first, to estimate the market value of the property as if it were asbestos-free, second, to estimate the market value of the property with asbestos, and third, to subtract the market value of the property with asbestos from the market value of the property as if
clean to find the estimated loss in market value due to the presence of asbestos. The most difficult of the above three steps is step two, estimating the market value of the property with asbestos.

**Value of the Property "As If Clean"**

The first step of the valuation procedure is to estimate the value of the property "as if clean" (i.e., as if it did not contain asbestos). The estimated value "as if clean" provides a reference point from which the effects of the asbestos on value can be estimated.

The "as if clean" value conceivably can be estimated by valuation methods under any or all of the three approaches to value, that is, by means of the sales comparison approach, the cost approach, and the income approach using either the direct capitalization or discounted cash flow method. However, given the available information, the effects of asbestos on property value will generally have to be estimated by means of the income approach using the discounted cash flow (DCF) method. Therefore, to be consistent with the other steps of the valuation procedure, the value of the property "as if clean" should also be estimated with discounted cash flow analysis. The "as if clean" value would be estimated by developing a forecast of the expected NOI of the property based on income and expense assumptions appropriate for comparable properties that never had asbestos and then discounting that NOI with a discount rate also appropriate for such properties.

**Value of the Property with Asbestos**

The ways in which property value can be lowered by the presence of asbestos are summarized in Fisher, Lentz and Tse (FLT) [5]. To assess the value of a property with ACMS using DCF analysis, estimates of each of the following would generally have to obtained:

- the NOI expected each year of the holding period or economic life of the property,
- the expected net selling price of the property at the end of the holding period,
- the expected containment and/or removal costs,
- the appropriate discount rate, or rates, for capitalizing each of the above into a value estimate (i.e., a present value).

The expected NOI stream of a property with asbestos can be reduced by both the loss of rental income and higher building operating expenses. The loss of rental income can result from a decline in occupancy and/or in rent levels. Higher operating expenses can result in part from the costs of implementing an operations and maintenance (O&M) plan for safely controlling the asbestos. The analysis in this study assumes that the building owner/operator follows an O&M plan as long as the building is operated while the ACMs are present. Operating expenses may also increase as a result of higher insurance costs, higher legal expenses, and higher personnel expenses attributable to the presence of asbestos.
Insofar as the presence of asbestos reduces NOI levels, the expected NOI stream will be affected by the timing of removal. There may be one expectation of NOI levels prior to removal, and a different (i.e., a higher) expectation following completion of removal.

The expected selling price of a property with ACMS may be discounted relative to that of a clean property to the extent that prospective buyers anticipate a reduced NOI from the property and possibly increased economic risks. The net selling price may also be adversely affected by higher transactions costs, notably requirements for costly environmental audits/surveys prior to sale. For the purposes of this study, however, we assume that the selling price is a direct function of the NOI stream expected by the new owner, and thus we assume that the impact of asbestos on the selling price is captured by expectations about the future NOI.4

Containment costs include the cost of treating the asbestos or installing devices designed to prevent the asbestos from becoming airborne, and thus becoming potentially dangerous to building occupants. The cost of safely containing the asbestos is generally considerably less than the cost of removal. The analysis in this study assumes that the asbestos in the building is safely contained if it is not removed immediately.

The cost of removing the asbestos includes both direct and indirect costs. The direct costs of removal include the expenditures for removing and disposing of the asbestos. The indirect costs of removal include the costs of moving and temporarily relocating tenants and the loss of rental revenue due to building “down time” while the asbestos is being removed.

An essential part of the process of estimating the value of a property with asbestos within the present value framework is the selection of a property discount rate. Selection of a discount rate entails an estimate of the extent to which the asbestos in the building increases the riskiness of the expected NOI. If the future NOI of properties with ACMs is expected to be riskier to the suppliers of capital (the equity investors and the lenders) than comparable properties without asbestos, then a higher discount rate should be used to discount the NOI. Moreover, if the riskiness of the future NOI is expected to change (i.e., decrease) after removal of the ACMs is completed, two discount rates would be needed, one for the NOI before removal and one for the NOI after removal.

The Value Loss Due to Asbestos

The final step in the valuation procedure for estimating the loss in value due to the presence of asbestos is to subtract the estimated value of the property with asbestos (estimated in step 2) from the estimated “as if clean” value (estimated in step 1) to arrive at an estimate of the loss in value. This estimate also represents the adjustment that would be made to the value of a comparable property without asbestos (i.e., a “clean” property) to make it similar in value to a property with asbestos.

Decision Rules for Removal

Theoretically, as mentioned, the property’s market value at the time of the valuation should reflect the optimal strategy for dealing with the ACMs. Therefore, the alternatives for dealing with the ACMs must be considered before the impact of the ACMs on
the market value of the property can be estimated. The main alternatives for dealing with the ACMs examined in this paper are as follows: (1) immediate removal, (2) no removal until demolition of the building, and (3) postponement of removal until a time in the future intermediate between immediate removal and demolition of the building.5

Although immediate removal generally entails a large initial expenditure not required by the other alternatives, it nonetheless may be the most cost effective alternative for dealing with the asbestos if market resistance to buildings with ACMs is taken into account. Expectations of lower occupancy and rental rates, higher operating expenses, and a reduced selling price—resulting from adverse tenant and buyer reactions to buildings with ACMs, resistance of lenders and insurers to buildings with ACMs, and legal and regulatory risks arising from uncertain regulatory and judicial actions—may combine to provide incentive for early removal. A strategy of containment and control typically has lower up-front costs relative to removal; but with this strategy the future net cash flows may be lower and the mortgage rate and the equity discount rate higher than if the asbestos had been removed.

Clearly, then, there are trade-offs among these alternative asbestos control strategies. The basic trade-off is between the cost of removal, on the one hand, and the costs of having ACMs remain in the building, i.e., a lower NOI, containment costs, and an increase in the property discount rate, on the other. Determining the optimal strategy for dealing with the ACMs involves analyzing this trade-off.

A property may continue to experience asbestos-related problems after total removal of the ACMs has been completed. Such lingering problems may prevent a complete adjustment of the NOI and the property discount rate to “clean” levels.6 The effect of any anticipated post-removal problems is to increase the costs associated with the decision to remove the asbestos by reducing the anticipated benefits from removal.

From the trade-offs identified above we can formulate a decision rule for the removal of the ACMs. In general, if the present value of the cost of having the ACMs in the building is lower than that of the removal costs, then do not remove; but if the present value of the costs of having the ACMs in the building is higher than the present value of the removal costs, then remove. More specifically, if the negative value adjustment for the expected adverse effects on property NOI of the continued presence of ACMs exceeds the cost of immediate removal plus any value adjustment for expected adverse lingering effects (i.e., lags in revenue and expense adjustments and/or the costs from any residual “taint”), then the optimal strategy would be to remove the asbestos immediately following acquisition of the property. If, on the other hand, the value adjustment for the expected adverse effects of the presence of asbestos on the property’s NOI is less than the total cost of immediate removal plus the value adjustment for expected adverse lingering effects, then some form of a deferred removal strategy is the optimal strategy. As the costs of retaining the ACMs increase relative to the costs of removal, the time to remove is accelerated, ceteris paribus. The relationships discussed in this section are developed formally below.

Valuation Model

The valuation model employed in this study is as follows:
\[ V = \int_{0}^{T} NOI_1 e^{g_1t} e^{-(k_1)T} dt + \int_{0}^{T} NOI_2 e^{g_2t} e^{-(k_2)T} dt - Re^{-(k_1 - c)T} - \int_{0}^{T} C e^{c} e^{-(k_1)T} dt, \] 

where

\( V \) = the property value in the presence of asbestos,

\( NOI_1 \) = the initial net operating income after acquisition prior to removal,

\( NOI_2 \) = the initial net operating income following removal,

\( g_1 \) = the growth rate \( NOI_1 \),

\( g_2 \) = the growth rate \( NOI_2 \),

\( R \) = the current removal cost, defined as a percentage of the "clean" property value,

\( r \) = the growth rate of the removal cost,

\( C \) = the continuous expenditure equivalent to the present value of the expenditures on containment (e.g., by means of encapsulation or enclosure) in one or more years in the interval \([0, T]\),

\( c \) = the growth rate of the containment cost,

\( k_1 \) = the property discount rate before removal,

\( k_2 \) = the property discount rate after removal,

\( T \) = the time of removal, and

\( N \) = final year of the economic life of the property, and the year of demolition.

\( NOI_1 \) and \( NOI_2 \) are defined in terms of percentage changes from what the \( NOI \) would be if the property were clean of asbestos. More specifically,

\[ NOI_1 = ("\text{As if clean" value}) \cdot (\text{as if clean" cap rate}) \cdot (1 - \% \text{ decrease in NOI because of the presence of asbestos}), \]

\[ NOI_2 = ("\text{As if clean" value}) \cdot (\text{as if clean" cap rate}) \cdot (1 - \% \text{ decrease in NOI after removal resulting from any lingering effects}). \]

Furthermore, \( k_1, k_2 \geq 0, k_1 > g_1, k_2 > g_2, 0 \leq T \leq N, \) and \( N > 0.7 \).

Simply put, the model expresses the property value as the present value of the \( NOI \) before removal of the ACMs plus the present value of the \( NOI \) after removal minus the present value of the removal cost when removal takes place at time \( T \) and the present value of the containment costs incurred until removal at time \( T \). The model allows different levels for \( NOI_1 \) and \( NOI_2 \), different discount rates to be applied to the property \( NOI \) before and after removal (i.e., to \( NOI_1 \) and \( NOI_2 \)), and different growth rates for \( NOI_1 \), \( NOI_2 \), and the containment and removal costs. Moreover, the year of removal of the asbestos is an endogenous variable. The model calculates the present value of the property at removal times for the interval of time from year 0 to year \( N \). The time that gives the highest value is the optimal time to remove.

The closed-form solution for \( V \) after integration of (1) is

\[ V = NOI_1 \left[ 1 - e^{-(k_1 - g_1)T} \right] / (k_1 - g_1) + NOI_2 \left[ e^{-(k_2 - g_2)T} - e^{-(k_2 - g_2)N} \right] / (k_2 - g_2) - Re^{-(k_1 - c)T} - C \left[ 1 - e^{(k_1 - c)T} \right] / (k_1 - c). \]
To examine the behavior of \( V \) with respect to the time of removal, \( T \), we take the first derivative of \( V \) with respect to \( T \) and obtain (3):

\[
\frac{\delta V}{\delta T} = NOI_t e^{-(k_1 - g_1)T} - NOI_s e^{-(k_2 - g_2)T} + (k_1 - r)Re^{-(k_1 - r)T} - Ce^{-(k_1 - c)T}.
\] (3)

The optimal time of removal, \( T^* \), if it exists in \([0, N]\), can be found from the first-order condition by setting \( \frac{\delta V}{\delta T} \) in (3) equal to zero.

From the first-order condition, we can observe that if \( \frac{\delta V}{\delta T} \) is greater than zero for all \( T \in [0, N] \), then

\[
NOI_t e^{-(k_1 - g_1)T} + (k_1 - r)Re^{-(k_1 - r)T} - Ce^{-(k_1 - c)T} > NOI_s e^{-(k_2 - g_2)T},
\]

and the optimal time of removal is the end of the economic life of the property because the current NOI and the saving of the removal cost minus the containment costs outweighs the higher NOI after removal in terms of present value. Therefore, the asbestos would not be removed prior to the end of the building's economic life.

Similarly, if \( \frac{\delta V}{\delta T} \) is negative for all \( T \in [0, N] \), then

\[
NOI_t e^{-(k_1 - g_1)T} + (k_1 - r)Re^{-(k_1 - r)T} - Ce^{-(k_1 - c)T} < NOI_s e^{-(k_2 - g_2)T},
\]

and the optimal time of removal is immediately following purchase because the increase in NOI following removal outweighs the removal cost in terms of present value.

If for some \( T \in (0, N) \), \( \frac{\delta V}{\delta T} = 0 \), then

\[
NOI_t e^{-(k_1 - g_1)T} + (k_1 - r)Re^{-(k_1 - r)T} - Ce^{-(k_1 - c)T} = NOI_s e^{-(k_2 - g_2)T},
\]

and either an interior solution for the optimal time of removal exists in \((0, N)\) or the property value is invariant to the removal time.

The second-order condition for \( T^* \) to maximize \( V \) is

\[
\frac{\delta^2 V}{\delta T^2} = -(k_1 - g_1)NOI_t e^{-(k_1 - g_1)T^*} + (k_2 - g_2)NOI_s e^{-(k_2 - g_2)T^*} + (k_1 - c)Ce^{-(k_1 - c)T^*} - (k_1 - r)^2Re^{-(k_1 - r)T^*} < 0.
\] (4)

From the first-order condition (3), we can see that the optimal solution for the removal time is a complex function of the interaction of the discount rates, growth rates, NOI before and after removal, and the removal cost.

To obtain a closed-form solution, we must impose restrictions on the model parameters. Without restrictions, the optimal solution must be derived iteratively by using numerical analysis.

**Optimal Time of Removal**

In this section, we first impose restrictions on the model parameters to obtain closed-form solutions for the optimal time to remove the asbestos. Three propositions are
developed from three different sets of restrictions. The propositions identify the key
economic trade-offs affecting the removal timing decision. The customary comparative
statics follow the propositions. Then later in the section many of the restrictions imposed
to develop the propositions are relaxed. The Newton-Raphson algorithm is employed to
maximize property value with respect to removal time \( T \) with the more general parameter assumptions.

**Proposition 1**

Assume (1) \( k_1 = k_2 = k \) and (2) \( g_1 = g_2 = r = c = g \). Then,

(a) if \( R > [\text{NOI}_2 - (\text{NOI}_1 - C)]/(k - g) \), \( T^* = N \),

(b) if \( R < [\text{NOI}_2 - (\text{NOI}_1 - C)]/(k - g) \), \( T^* = 0 \), and

(c) if \( R = [\text{NOI}_2 - (\text{NOI}_1 - C)]/(k - g) \), the property value is invariant to the
removal time \( T \).

For proof of proposition 1, see Appendix B.

The results here are quite intuitive. The result in (a) implies that if the removal cost
required today, \( R \), is larger than the present value derived from the gain in \( \text{NOI} \) (i.e., the
benefit derived from removing the asbestos), the decision is to postpone the removal of
asbestos until \( N \). Similarly the result in (b) says that if the benefits that could be derived
from removing the asbestos are larger than the removal cost today, then the asbestos
should be removed immediately. The result in (c) is that if the benefits derived from
removing the asbestos are equal to the removal costs, the property value, \( V \), is invariant
to the time of removal.

We are able to obtain an interior solution for \( T^* \) in the open interval \((0, N)\) if we allow
either the property discount rates to differ while holding the growth rates of the \( \text{NOI} \)
equal, or the growth rates of the \( \text{NOI} \) to differ while holding the discount rates equal.
That is, \( k_1 > k_2 \), \( g_1 = g_2 \), or \( g_1 > g_2 \), \( k_1 = k_2 \). The results that obtain from these assumptions
are summarized below in propositions 2 and 3.

**Proposition 2**

Assume that (1) \( k_1 > k_2 \) and (2) \( g_1 = g_2 = r = c = g \). Then,

(a) if \( R \leq [\text{NOI}_2 - (\text{NOI}_1 - C)]/(k_1 - g) \), \( T^* = 0 \),

(b) if \( [\text{NOI}_2 - (\text{NOI}_1 - C)]/(k_1 - g) < R < [\text{NOI}_2 e^{k_1 - k_2 N} - (\text{NOI}_1 - C)]/(k_1 - g) \).

\( T^* \) exists in the interval \((0, N)\) and is given by

\[
T^* = \left[ \frac{1}{k_1 - k_2} \right] \ln \left[ \frac{\text{NOI}_1 - C + (k_1 - g)R}{\text{NOI}_2} \right]
\]

and

(c) if \( R \geq [\text{NOI}_2 e^{k_1 - k_2 N} - (\text{NOI}_1 - C)]/(k_1 - g) \), \( T^* = N \).

For proof of proposition 2, see Appendix B.
By imposing an equality restriction on the property discount rates and relaxing the assumptions on the \( NOI \) growth rates, another set of simple results emerges.

**Proposition 3**

Assume (1) \( k_1 = k_2 = k \), (2) \( g_1 < g_2 \), and (3) \( r = c = g_2 \). Then,

(a) if \( R \leq [NOI_1 + C - NOI_1]/(k - g_2) \), \( T^* = 0 \),
(b) if \([NOI_2 + C - NOI_1]/(k - g_2) < R \leq [NOI_2 + C - NOI_1(e^{-(g_2 - r)N})]/(k - g_2)\), \( T^* \) exists between \((0, N)\) and is given by

\[
T^* = \left[ \frac{1}{g_2 - g_1} \right] \ln \left[ \frac{NOI_1}{NOI_2 + C - (k - g_2)R} \right],
\]  

(6)

(c) if \( R \geq [NOI_2 + C - NOI_1(e^{-(g_2 - r)N})]/(k - g_2) \), \( T^* = N \).

For proof of proposition 3, see Appendix B.

**Comparative Statics**

The following partial derivatives derived from equations (5) and (6) above express the key comparative statics results:

(a) \( \delta T^*/\delta (k_1 - k_2) < 0 \),
(b) \( \delta T^*/\delta (NOI_2 - NOI_1) < 0 \),
(c) \( \delta T^*/\delta (g_2 - g_1) < 0 \),
(d) \( \delta T^*/\delta C < 0 \), and
(e) \( \delta T^*/\delta R > 0 \).

Summarizing, the greater the degree to which the removal of asbestos brings about a decrease in the size of the property discount rate, an increase in the level of the \( NOI \), and an increase in the growth rate of the \( NOI \), the shorter the waiting time to remove. Moreover, the greater the containment cost, the shorter the waiting time to remove. Conversely, the larger the removal cost, the longer is the waiting time to remove.

**Valuation Procedure Using Numerical Analysis**

To assess the impact of asbestos on property value, the values of key parameters of the valuation model must be able to differ between properties with ACMs and properties without ACMs. In particular, we want to relax the assumptions employed for propositions 1, 2, and 3 above to allow for the more general situation in which \( K_1 \geq K_2 \) and \( g_2 \geq g_1 \). With this more general specification, the solution for the optimal time to remove \( (T^*) \) must be solved iteratively using numerical analysis. We obtain the optimal time to remove with the Newton-Raphson algorithm by evaluating the ratio of the first- and second-order conditions as given by equations 3 and 4, respectively, at different
values of $T$. The iteration begins with an initial value for $T_0$. The algorithm then generates new values for $T$ with each successive iteration. The iteration continues until the percentage difference between two successive values for $T$ is smaller than some pre-specified tolerance limit, $\varepsilon$. The algorithm is expressed formally as follows:

$$T_{i+1} = T_i - \frac{\delta V/\delta T}{\delta^2 V/\delta T^2} \bigg|_{T=T} \quad i=0,1,2,3, \ldots$$

where $T_i$ and $T_{i+1}$ are the values of $T$ obtained in the $i$th and $(i+1)$th iteration. The iteration stops whenever $|T_{i+1} - T_i|/T_i < \varepsilon$, and $T^*$ is given by $T_{i+1}$.

Finally, this value of $T^*$ is then inserted into the valuation equation, equation (2), to obtain the maximum value of the property with asbestos.

Data and Simulation Analysis

In the remainder of the paper we simulate the loss in value due to the presence of asbestos. The Newton-Raphson algorithm as described by equation (7) is used to compute the optimal time of removal, and the valuation model specified in equation (2) is used for simulating the value of a property with ACMs. The valuation model is parameterized wherever possible with values taken from a survey of selected members of the Appraisal Institute conducted during June and July 1990. The objective of the survey was to obtain information from this select group of appraisers about the effects of asbestos on commercial real estate values.

Table 1 in Appendix A presents the average estimates obtained from questions in the survey that are used as inputs for the simulation analysis. Table 2 in Appendix A contains additional assumptions about model parameters for the simulation.

Table 3 in Appendix A presents the simulation results. Displayed in Table 3 is the optimal year to remove the ACMs, the value adjustment if the ACMs are removed at the optimal time (shown as a percent of the value “as if clean”), the value adjustment if the ACMs are removed immediately, and the difference between these two adjustments. The difference between these two adjustments represents the additional loss in value from removing the ACMs immediately rather than at the optimal time.

The results in Table 3 employ the following assumptions about the differences in the growth rates of the property $NOI$ before and after removal of the asbestos: (1) no difference, (2) the differences for each property type implied by changes in the rental and vacancy rates for the different property types stated in Table 1 as explained in Table 2, and (3) twice the differences of (2). Discount rates for property with asbestos are assumed to be successively 1%, 2% and 3% higher than the “as if clean” discount rate. Two percent (199 basis points) was indicated by the survey results to be the average increase in the discount rate because of the presence of asbestos. Sensitivity analysis was done on the values of $k$ and $g$ since these are obviously difficult to estimate.

The results going down the table reveal the impacts of the change in the discount rate on the optimal removal time and on the property value for each property type, holding differences in the $NOI$ growth rate fixed. As we fix the discount rate difference and move across the table, we can see the effects of the $NOI$ growth rate differences on the optimal time and the property value. Moving down the table diagonally allows us to see the
simultaneous effects of the NOI growth rate and discount rate differences on the optimal time and property value for each property type. The block in the center of the table corresponding to “2% discount rate difference” and “NOI growth rate differences indicated by survey” represent the set of results implied by the survey data supplemented with the additional assumptions stated in Table 2 of Appendix A.

The additional reduction in property value if removal occurs immediately following purchase rather than at the optimal time can be viewed as the implicit value of the option to remove at the optimal time. The option to remove the asbestos at the optimal time clearly gives the property owner the ability to affect the value of the property.9

Conclusion

In this study we develop a model for estimating the effect of asbestos on the market value of commercial real estate. The value of the contaminated property is shown to be a function of the timing of the removal of the ACMs. The timing decision in turn is affected by the cost of removal, the cost of containment, and the effects of the asbestos on the future income stream. In an informationally efficient market, the market value of property with asbestos would reflect the optimal time to remove the asbestos.

We have also shown that removing the asbestos other than at its optimal time increases the loss in property value. This result has implications for policymakers. The additional loss in value resulting from immediate or early removal of the asbestos relative to the optimal removal time because of governmental compulsion can be viewed as an implicit cost of regulation. This cost should be weighed against the potential health benefits of early removal. Unless there is sufficient risk to the health of building occupants to justify the cost, regulations compelling property owners to remove the asbestos prematurely may cause a needless decline in the value of real estate resources, thus resulting in a deadweight loss of societal wealth.
Appendix A

Table 1
Average Numerical Adjustments Indicated by the Survey

<table>
<thead>
<tr>
<th>Adjustment to Property Value (Decrease):</th>
<th>Adjustment to Net Operating Income (Decrease):</th>
</tr>
</thead>
</table>
| 1. Mean Range of Decrease: 13–34% | 1. Office Buildings:  
|                                          | b. Low-Rise: 10% decrease  
|                                          | 2. Retail Buildings:  
|                                          | a. Free-standing Store: 8% decrease  
|                                          | b. Neighborhood Center: 7% decrease  
|                                          | c. Regional Center: 8% decrease  
|                                          | 3. Industrial Buildings:  
|                                          | a. Warehouse: 6–7% decrease  
|                                          | b. Light Industrial: 6–7% decrease  
|                                          | c. Heavy Industrial: 6–7% decrease  
|                                          | Removal Cost as a Percentage of Clean Property Value (Total of Direct and Indirect Removal Costs)  
|                                          | 1. Office Buildings:  
|                                          | a. High-Rise: 32%  
|                                          | b. Low-Rise: 28%  
|                                          | 2. Retail Buildings:  
|                                          | a. Free-standing Store: 26%  
|                                          | b. Neighborhood Center: 26%  
|                                          | c. Regional Center: 28%  
|                                          | 3. Industrial Buildings:  
|                                          | a. Warehouse: 21%  
|                                          | b. Light Industrial: 21%  
|                                          | c. Heavy Industrial: 23%  
|                                          | Increase in the Discount Rate (Increase):  
|                                          | 1. Mean Range of Increase: 1.99%  
|                                          | 2. Median Range of Increase: 1.50%  

Source: Authors
Appendix A

Table 2
Input Values of Model Parameters

1. Hypothetical property value if the building were clean = $1,000,000.
2. Assumed growth rate of NOI if the building were clean ($g_2$) = 3%.
3. The NOI growth rate before removal ($g_1$) is estimated as follows:
   ("as if clean" growth rate) (1 − the average adjustment to the rental rate) (1 − the average adjustment to the vacancy rate).
   The average adjustments to the rental and vacancy rates for each property type indicated by the survey respondents are presented in Table 1.
4. Assumed discount rate for the 'clean' building ($k_2$) = 12%.
5. Economic life ($N$) = 100 years.
6. The containment cost ($C$) is assumed to be 5% of the removal cost.
7. The growth rates of the containment cost ($c$) and removal cost ($r$) are assumed to be the average inflation rate for the year of the survey of 5%.
8. The cap rate for the clean building as implied by equation 2 is
   
   \[
   \frac{(k - g)}{[1 - e^{-(k-g)}N]} = \frac{(.12 - .03)}{[1 - e^{-(.12 - .03)100}]} = 9%. 
   \]
9. NOI before removal ($NOI_1$) = ('Clean' property value) ('clean' Cap Rate) (1 - Adjustment to NOI).
10. NOI after removal ($NOI_2$) = ('Clean' property value) ('clean' Cap Rate). We assume here that the NOI level adjusts to the 'clean' level right after the removal of asbestos.

*estimates based on surveys reported by Real Estate Research Corporation
Source: Authors
### Appendix A

**Table 3**

**Value Adjustments**

<table>
<thead>
<tr>
<th></th>
<th><strong>NOI growth rate before removal</strong></th>
<th><strong>NOI growth rate differences indicated by survey</strong></th>
<th><strong>Twice NOI growth rate differences indicated by survey</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimal year of removal</td>
<td>% Adj. optimal time</td>
<td>% Adj. if removal is now</td>
</tr>
<tr>
<td><strong>Office Buildings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. High-rise</td>
<td>18.2</td>
<td>-34.2</td>
<td>-43.0</td>
</tr>
<tr>
<td>b. Low-rise</td>
<td>15.9</td>
<td>-30.9</td>
<td>-38.0</td>
</tr>
<tr>
<td><strong>Retail Buildings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Free-standing Store</td>
<td>14.6</td>
<td>-27.7</td>
<td>-34.0</td>
</tr>
<tr>
<td>b. Neighborhood Center</td>
<td>14.4</td>
<td>-26.8</td>
<td>-33.0</td>
</tr>
<tr>
<td>c. Regional Center</td>
<td>15.6</td>
<td>-29.0</td>
<td>-36.0</td>
</tr>
<tr>
<td><strong>Industrial Building</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Warehouse</td>
<td>11.8</td>
<td>-23.1</td>
<td>-27.5</td>
</tr>
<tr>
<td>b. Light Industrial</td>
<td>11.8</td>
<td>-23.1</td>
<td>-27.5</td>
</tr>
<tr>
<td>c. Heavy industrial</td>
<td>12.8</td>
<td>-24.4</td>
<td>-29.5</td>
</tr>
</tbody>
</table>

A. 1% discount rate difference:

1. Office Buildings
   a. High-rise
   b. Low-rise
2. Retail Buildings
   a. Free-standing Store
   b. Neighborhood Center
   c. Regional Center
3. Industrial Building
   a. Warehouse
   b. Light Industrial
   c. Heavy industrial
B. 2% discount rate difference:

1. Office Buildings
   a. High-rise    10.7  -35.6  -43.0  -7.4   8.7  -36.7  -43.0  -6.3   7.3  -37.5  -43.0  -5.5
   b. Low-rise     9.4   -32.1  -38.0  -5.9   7.6  -33.0  -38.0  -5.0   6.4  -33.7  -38.0  -4.3

2. Retail Buildings
   a. Free-standing Store 8.6   -28.9  -34.0  -5.2   7.2  -29.5  -34.0  -4.5   6.2  -30.0  -34.0  -4.0
   b. Neighborhood Center 8.5   -27.9  -33.0  -5.1   7.2  -28.6  -33.0  -4.4   6.2  -29.1  -33.0  -3.9
   c. Regional Center    9.2   -30.2  -36.0  -5.8   7.6  -31.0  -36.0  -5.0   6.5  -31.6  -36.0  -4.4

3. Industrial Building
   a. Warehouse      7.0   -24.0  -27.5  -3.5   6.1  -24.4  -27.5  -3.1   5.4  -24.7  -27.5  -2.8
   b. Light Industrial 7.0   -24.0  -27.5  -3.5   6.1  -24.4  -27.5  -3.1   5.4  -24.7  -27.5  -2.8
   c. Heavy Industrial 7.6   -25.4  -29.5  -4.1   6.5  -25.9  -29.5  -3.6   5.6  -26.3  -29.5  -3.2

B. 3% discount rate difference:

1. Office Building
   a. High-rise    8.2   -36.0  -43.0  -7.0   7.1  -36.7  -43.0  -6.3   6.3  -37.3  -43.0  -5.7
   b. Low-rise     7.2   -32.4  -38.0  -5.6   6.2  -33.1  -38.0  -5.0   5.5  -33.7  -38.0  -4.5

2. Retail Buildings
   a. Free-standing Store 6.6   -29.2  -34.0  -4.8   5.9  -29.6  -34.0  -4.4   5.3  -30.0  -34.0  -4.0
   b. Neighborhood Center 6.6   -28.2  -33.0  -4.8   5.8  -28.7  -33.0  -4.4   5.2  -29.0  -33.0  -4.0
   c. Regional Center    7.1   -30.2  -36.0  -5.5   6.2  -31.1  -36.0  -5.0   5.6  -31.5  -36.0  -4.5

3. Industrial Building
   a. Warehouse      5.4   -24.2  -27.5  -3.3   4.9  -24.5  -27.5  -3.0   4.5  -24.7  -27.5  -2.8
   b. Light Industrial 5.4   -24.2  -27.5  -3.3   4.9  -24.5  -27.5  -3.0   4.5  -24.7  -27.5  -2.8
   c. Heavy Industrial 5.8   -25.6  -29.5  -3.9   5.2  -26.0  -29.5  -3.5   4.8  -26.3  -29.5  -3.3

Source: Authors
Proof of Proposition 1:
The first and the second assumption require respectively that \( k_1 = k_2 \) and \( g_1 = g_2 = r = c = g \). Imposing these two restrictions on the first-order derivative as given by equation 3 yields

\[
\frac{\delta V}{\delta T} = NOI_i e^{-(k_1 - g)T} - NOI_i e^{-(k_2 - g)T} + (k_1 - g)Re^{-(k_1 - g)T} - Ce^{-(k_1 - g)T}.
\]

Equation (1') implies that \( \frac{\delta V}{\delta T} > 0 \) for all \( T \in [0, N] \) whenever \( R > (NOI_i - NOI_i - C)/(k - g) \), which is the result in (a). On the other hand, if \( R < (NOI_i - NOI_i - C)/(k - g) \), then \( \frac{\delta V}{\delta T} < 0 \) for all \( T \in [0, N] \), and the result in (b) obtains. Finally, if \( R = (NOI_i - NOI_i - C)/(k - g) \), then both the first-order derivative, \( \delta V/\delta T \), and the second-order derivative, \( \delta^2 V/\delta^2 T \), equal zero for all \( T \in [0, N] \), and the result in (c) obtains.

Proof of Proposition 2:
The assumptions require that \( K_1 > k_2 \) and \( g_1 = g_2 = r = c = g \). These two restrictions lead to the following first-order condition:

\[
\frac{\delta V}{\delta T} = NOI_i e^{-(k_1 - g)T} - NOI_i e^{-(k_2 - g)T} + (k_1 - g)Re^{-(k_1 - g)T} - Ce^{-(k_1 - g)T} = 0.
\]

Solving for the optimal time yields equation (5) above,

\[
T^* = [1/(k_1 - k_2)]^* \ln [(NOI_i - C + (k_1 - g)R)/NOI_i].
\]

First of all, let us prove the result in (a). Under the current assumptions, the first-order derivative in (3) can be rewritten as:

\[
\frac{\delta V}{\delta T} = e^{-(k_1 - g)T} [NOI_i - C - NOI_i e^{(k_1 - k_2)T} + (k_1 - g)R].
\]

Note that \( R < (NOI_i - NOI_i - C)/(k_1 - g) \) implies that \( [NOI_i - C - NOI_i + (k_1 - g)R] \) is negative. Since \( k_1 > k_2 \), \( NOI_i e^{(k_1 - k_2)T} \) is greater than \( NOI_i \) for all \( T > 0 \). Therefore, \( \delta V/\delta T \) is negative for all \( T \in [0, N] \) and \( T^* = 0 \). This establishes the result in (a).

Next, we prove the result in (b). Note that \( R > (NOI_i - NOI_i - C)/(k_1 - g) \) is equivalent to \([NOI_i - C - NOI_i + (k_1 - g)R] > 0 \). The natural log argument in equation (5) is greater than one. Hence \( T^* > 0 \). To show that \( T^* < N \), whenever \( R < [NOI_i e^{(k_1 - k_2)T} N - NOI_i - C]/(k_1 - g) \), we substitute the upper bound \([NOI_i e^{(k_1 - k_2)T} N - NOI_i - C] \) for \( R \) in equation 5, and we obtain \( T^* = N \). Since \( T^* \) in equation 5 is an increasing function of \( R \), it follows that \( T^* < N \) whenever \( R < [NOI_i e^{(k_1 - k_2)T} - NOI_i - C]/(k_1 - g) \).

To show that \( T^* \in (0, N) \) is indeed the maximizing solution, we need to check the second-order condition. Under the current assumptions, the second-order derivative in equation (4) becomes

\[
\frac{\delta^2 V}{\delta T^2} = -(k_1 - g)e^{-(k_1 - g)T} [NOI_i - C - (k_1 - g)NOI_i e^{(k_1 - k_2)T} + (k_1 - g)R].
\]
From the first-order condition in (2'), we know that at $T = T^*$

$$[NOI_i - C - NOI_i e^{(k_1 - k_2)T} + (k_1 - g)]R = 0. \quad (5')$$

Since $k_1 > k_2$, it is easy to see that $(k_2 - g)/(k_1 - g)NOI_i e^{(k_1 - k_2)T}$ in the second term of equation (4') is smaller than $NOI_i e^{(k_1 - k_2)T}$. Therefore the second term is positive and $\delta^2 V/\delta T^2 < 0$. Hence, under the stated assumptions, the $T^*$ as given by equation (5) is optimal as the removal cost $R$ lies between $(NOI_i - NOI_i - C)/(k_1 - g)$ and $(NOI_i e^{(k_1 - k_2)N} - NOI_i - C)/(k_1 - g)$. This completes the proof for (b).

To prove the result in (c), note that as $R$ is larger than or equal to $(NOI_i e^{(k_1 - k_2)N} - NOI_i - C)/(k_1 - g)$, the first-order derivative as given by equation (2') is positive for all $T$ less than or equal to $N$, that is, the present value of the property is monotonically increasing for all $T$ in $[0, N]$. Hence, the maximizing value of $T$ is $T^* = N$ in this case. Thus the result in (c) obtains.

**Proof of Proposition 3:**

The assumptions require that $k_1 - k_2 = k$ and $g_i > g_j = r = c$. The restrictions here lead to the following first-order condition:

$$\delta V/\delta T = NOI_i e^{(k_1 - k_2)T} - NOI_2 e^{-(k_2 - k_1)T} + (k - g)Re^{-(k_2 - k_1)T} - Ce^{-(k_2 - k_1)T} = 0. \quad (6')$$

Solving for the optimal time yields

$$T^* = [1/(g_2 - g_1)] * \ln[NOI_i/[NOI_i + C - (k - g_2)R]],$$

as given in the proposition.

To prove the result in (a), first of all, note that the current assumptions allow us to express the first-order derivative in (3) as:

$$\delta V/\delta T = e^{-(k_2 - k_1)T} [NOI_i e^{-(g_2 - g_1)T} - NOI_2 - C + (k - g_2)R]. \quad (7')$$

Note that $R < (NOI_2 + C - NOI_1)/(k - g_2)$ implies that $[NOI_i - NOI_2 - C + (k - g_2)R]$ is negative. Since $g_2 > g_1$, $NOI_i e^{-(g_2 - g_1)T}$ is smaller than $NOI_i$ for all $T > 0$. This implies that $\delta V/\delta T < 0$ for all $T$ in $[0, N]$, and that $T^* = 0$ in this case. This establishes the result in (a).

Next, let us show the result in (b). Note that $R < NOI_2 + C - NOI_1)/(k - g_2)$ is equivalent to $[NOI_i - NOI_2 - C + (k - g_2)R] > 0$, which implies that the natural log argument in equation (6) is greater than one. Hence $T^* > 0$. Also, it is simple to demonstrate from equation (6) that if $R < [NOI_2 + C - NOI_1 e^{-(g_2 - g_1)N}]/(k - g_2)$, then $T^* < 0$. To show that $T^*$ in $(0, N)$ is indeed the maximizing solution, we need to check the second-order condition which is given, under the current set of assumptions, by

$$\delta^2 V/\delta T^2 = -(k - g_2)e^{-(k_2 - g_1)T^*}$$

$$*[NOI_i - (k - g_2)/(k - g_1)(NOI_i + C)e^{(k_2 - k_1)T^*} + (k - g_2)R]. \quad (8')$$
From the first-order condition in (7'), we know that at $T - T^*$

$$[NOI_1 e^{-(k-g)T} - NOI_2 - C + (k-g)R] = 0. \quad (9')$$

Since $g_2 > g_1$, it is easy to see that $(k-g_2)/(k-g_1)(NOI_2 + C)e^{(k-g)T}$ in the second term in equation (8') is smaller than $(NOI_2 + C)$, the second term in (9') and the $NOI_1$ in the second term of (8') is larger than the first term $NOI_1 e^{-(k-g_2)T}$ in (9'). Therefore the second term of (8') is positive and $\delta^2 V/\delta T^2 < 0$. Hence, under the stated assumptions, $T^*$ as given by equation (6) is optimal as the removal cost $R$ lies between $(NOI_2 + C - NOI_1)/(k-g_2)$ and $(NOI_1 + C - NOI_1 e^{-(k-g)N})/(k-g_2)$. This completes the proof for (b).

To prove the result in (c), note that as $R$ is larger than or equal to $(NOI_2 + C - NOI_1 e^{-(k-g)N})/(k-g_2)$, the first-order derivative as given by equation (7') is positive for all $T < N$. Therefore, the property value is a monotonically increasing function for all $T$ ranging from 0 to $N$. This implies that the optimal time of removal that maximizes the property value is $T^* = N$ in this case. Thus the result in (c) obtains.

Notes

1See [4] for a good review of the literature relating to the highest and best use paradigm in real estate research.

2If appraisers had sufficient information on comparable sales of properties representing a wide spectrum of structural, design, and locational characteristics, and containing varying amounts of asbestos (including some sales of properties without asbestos), then the sales comparison approach would probably provide the most reliable indicators of the effects of asbestos on building value. Unfortunately, however, this type of market data is generally not available. As a consequence of the lack of adequate market transactions data, the sales comparison approach to estimating the effects of asbestos on property values (using, for example, either a paired sales or a regression estimation method) must often be rejected.

The cost approach is clearly inadequate to estimate the value adjustment that should be made to reflect the impact of the presence of asbestos. The reason is that determining the cost of removing or otherwise containing the asbestos is not sufficient to capture all of the loss in property value as a result of the presence of asbestos in a building; and, thus, an estimation of costs will generally not be equivalent to the adjustment to value to reflect the presence of asbestos. The loss in value due to both a lower NOI and a higher discount rate must be considered in addition to expenditures for removal and/or containment. Such adverse income effects could, at best, be only obliquely considered within the cost approach (through an estimate of the functional and/or physical obsolescence attributable to the presence of asbestos).

3An operations and maintenance (O&M) plan entails establishing procedures designed to insure that the asbestos remains in a safe (i.e., nonfireable and nonairborne) condition. O&M procedures involve periodic inspections of the condition of ACMs, occasional air sampling to check levels of possible airborne asbestos, regular cleaning of areas containing ACMs to ensure that loose asbestos does not collect or lay around, and that areas containing asbestos are otherwise maintained in a safe condition. The current legal and regulatory environment essentially require that O&M procedures be developed and implemented once ACMs have been found in a building, and also that these procedures continue to be implemented as long as the building is operated while ACMs remain in the building. For all practical purposes, the alternatives other than immediate complete removal of the asbestos require the development and implementation of an O&M plan.
for the building. Realistically, however, in the absence of credible enforcement or a credible threat of tort action, many building owners can be expected to skimp on their O&M efforts. Thus, the extent to which O&M procedures and precautions are implemented is open to question.

Support for this approach is to be found generally in the finance literature where the selling price of an investment (a bond, a stock, or some other investment asset) at any one time is conceptualized as the present value of the anticipated future benefits from the investment. Our approach is also supported by Wang, Grissom and Chan [10], which shows how terminal cap rates, and hence expected selling prices, are a function of the growth expectations for the NOI and the riskiness of the NOI (as reflected in the property discount rate).

As Dewees [3] points out, if removal of the asbestos occurs at the time of a major renovation of the building, the costs of the installation of substitute materials to perform the functions previously fulfilled by the ACMs, the costs of a reduction in rental income due to building "down time," and the costs associated with dislocating building tenants can, at least in part, be charged to the renovation rather than removal, making the costs of removal lower than if it were done on its own. Moreover, scheduling the renovation and removal to coincide with the expiration of building leases, and possibly other contracts negotiated to account for the presence of asbestos in the building, may minimize any post-removal costs in the form of lags in the adjustment of property NOI to levels appropriate for properties without asbestos.

These lingering effects are described more fully in Fisher, Lentz and Tse (FLT) [5].

The assumption \( k > g \) is necessary for the implied capitalization rate to be positive.

The details of this survey are explained in FLT [5].

This idea of an implicit option value is suggested in the Magna Charter example in chapter 10 of Brealey and Myers [1]. However, an option pricing model must be used to explicitly price the option value of alternative courses of action available to a property owner to deal with hazardous materials, as explained in Lentz and Tse [8].

References


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