Indoor Air Quality and Office Property Value

Authors Kwame Addae-Dapaah, Tham Kok Wai, Mohd Jaafar Bin Dollah, and Yvonne Foo

Abstract Urbanization and technological advancement have resulted in many urbanites working in window-sealed high-rise office buildings. Many researchers have found that indoor air quality (IAQ) affects tenant-landlord relationships, workers' health and productivity, and building elements and systems. This may imply that IAQ could affect, positively or negatively, the value of buildings. This paper examines the impact of IAQ on the value of office buildings in Singapore. The results show that the return on investment in IAQ could be substantial (78.56%) while property values could increase by 1.28% to 3.85%. The findings could be of interest and usefulness to valuers and investors in office properties in Singapore and thus, help to promote sustainability in office property developments.

Environmental concern over the past decades, vis-à-vis the publication of ''Our Common Future'' by the World Conference on Environment and Development (WCED, 1987), has given sustainability worldwide currency. This is mainly due to the link that has been established between sustainability and economic, social, and environmental benefits. According to Cohen-Rosenthal and Smith (2003), sustainable buildings can be tagged as a ''wave of the future,'' and ''value, value, and value'' should be the developers' and owners' motto.

In Singapore, the quality of air and the work environment in office buildings has received much publicity since the introduction of the Guidelines for Good IAQ in Office Premise by the Ministry of Environment (ENV) in October 1996. The Green Mark Scheme (similar to the Green Building Rating by LEED in the United States), under which the Building Construction Authority of Singapore awards the Green Mark to buildings that satisfy certain criteria (including IAQ), has given further impetus to sustainability.

Studies have shown that indoor air quality (IAQ) has a direct impact on workers' health and job performance (Djukanovic, Wargocki, and Fanger, 2002; Fisk, 2002; Wargocki, 2002; Olsen, 2005; Tanabe, Haned, and Nishipana, 2007). A good IAQ improves production qualities and helps to increase worker productivity by maintaining a healthy work environment (Martin, 1999). Poor IAQ and its concomitant sick building syndrome cause health problems, as well as uncomfortable workplace environments (Czubaj, 2002; Fisk, 2002).

This paper is motivated by the fact that in view of the several research findings showing the importance of IAQ on health and productivity, IAQ may affect

property values. However, no study has been done to relate IAQ *per se* to property value. Furthermore, although people laud the ideals of IAQ, green buildings, etc., little appears to be done simply because developers cannot see (in quantifiable monetary terms) how IAQ affect the value of their office buildings. In other words, developers/investors do not find the benefit-cost aspects of IAQ attractive enough to invest in it. Therefore, this paper is aimed at: (1) ascertaining (in monetary terms) the impact of IAQ on the rental value of office buildings in Singapore; (2) carrying out an IAQ audit to determine how the office IAQ complies with the stipulated guidelines; (3) determining office property owners'/tenants' willingness to finance/pay premium rental for improvement in office IAQ; and (4) ascertaining the role of IAQ in tenant's selection of an office space in Singapore.

The paper therefore proceeds as follows. The next section will deal with a review of the relevant literature. This is followed by data sourcing and management after which is presented the results, interpretation, and discussion of the data analysis. The last section is devoted to concluding remarks.

Literature Review

According to RICS (2005), green properties earn higher rents, attract tenants and buyers more quickly, and cost less to operate. Similarly, the Vancouver Valuation Accord (2007) highlights the need to recognize how inextricably intertwined are economic and environmental issues. The contributions of sustainable development (such as economic, health, ecological, etc. benefits) to the social well-being of occupants of such buildings are documented in the OCED, CaGBC, and USGBC reports (Lucuik, Trusty, Larsson, and Charette, 2005; Roper and Beard, 2006). A 15% reduction in absenteeism and a 90% decline in energy cost have been attributed to sustainable development (Morton, 2002). Cohen-Rosenthal and Smith (2003) state that higher real estate valuation can occur because of higher net income, higher productivity of money invested in real estate assets, higher productivity from the workforce, and positive company image as a result of lower operating costs for green buildings.

Gottfried (2003) observes that buildings with green rating may receive a superior capitalization rate than non-green buildings while Kats (2003) find that 72% of respondents to an extensive American office tenant survey would be willing to pay additional rent to have green features in their offices. According to Von Kempski (2003), investors and tenants demand a performance-based building, which goes well beyond traditional methods of addressing the well-being of building occupants to create building environments resulting in enhanced productivity, and reduced absenteeism and health risks. Physiological and neuro-physiological research shows that air quality and the perception of air encompassing both olfactory and thermal comfort play an important role in affecting human comfort. In mergers and acquisitions, corporate real estate values are tied more closely to the performance of the individual buildings. The differentiation between 'normal' and higher quality buildings is becoming more important (von Kempski, 2003).

Other studies have shown a positive relationship between sustainable buildings and productivity, and rent and occupancy premia, including Miller, Spivey, and Florance (2008), Fuerst and McAllister (2009), Miller, Pogue, Gough, and Davis (2009), and Eichholtz, Kok, Quigley (2010), Wiley, Benefield, and Johnson (2010). Similarly, Bako-Biro, Wargocki, Weschler, and Fanger (2004), Wyon (2004), and Seppanen, Fisk, and Lei (2006) have found a positive relationship between IAQ per se and productivity.

EPA (2000) suggests that given the relevant magnitude of operating cost, labor cost, and rental value in most buildings, it is possible that a modest investment towards improved IAQ would generate substantial returns. Gerard de Vries (2004) states that the provision of good office IAQ results in substantial savings in maintenance and replacement costs. Any such savings in operating expenses increases the net rental income and the related capital value of the building.

According to Lam (2004), air conditioning and mechanical ventilation (ACMV) account for more than 30% of the operational cost of a building. Deterioration of the ACMV system would, [apart from resulting in poor IAQ which, among other things, causes sick Building Syndrome (Raw, 1993) with its attendant absenteeism, which affects office productivity], increase repair costs for the aging mechanical and electrical system. Judge (2003) finds that absenteeism costs the U.K. economy 12 billion pounds sterling per annum—a significant proportion of this figure is attributed to poor environmental conditions in buildings, which give rise to Sick Building Syndrome. All these factors are potential sources of a net rental loss to the building owner, which ultimately affects the economics of letting office space to tenants (Gan, Tan, and Premas, 2003). As observed by Dixon, Scura, Carpenter, and Sherman (1994), economic action, which includes environmental actions, generates two effects: benefits and costs. It is noted that there is a useful symmetry in benefits and costs: a benefit forgone is a cost while a cost avoided is a benefit.

The extant literature does not specifically relate IAQ to rental or property values. Given the effects of IAQ on buildings and the occupants thereof, which are lauded by most people, it appears paradoxical that both landlords/investors and tenants are somewhat reluctant to ''commit'' themselves to it. It is therefore hypothesized that IAQ does not affect office rental values in Singapore. This will be operationalized through statistical tests.

Data Sourcing and Management

The paper is based on rental data obtained from an international property consultancy firm in Singapore, data from an IAQ audit of an office, and three surveys that were conducted at different times from December 2004 to January 2008. Thus, both qualitative and quantitative analyses are employed for the study.

First Survey

The first survey, which was conducted in December 2004, focused on a sample population of 133 high-rise office buildings at Marina Centre, Raffles Place,

Shenton Way, Tanjong Pagar, and Beach Road (i.e., CBD of Singapore). Both the owners and tenants of these office buildings were interviewed during the survey. The entire building owners' population constitutes the building owners' sample size as the owners are few (133). In contrast 10% of the office tenants' population (4,730) constitutes the sample size for the tenants (Tan, 2002). The sample population and size for both building owners and tenants are reported in Exhibit 1. Stratified random sampling was used for the office tenants to reduce sampling error (Mangione, 1995).

Two sets of questionnaires were used for this survey: one set each for building owners and tenants. Each set of questionnaires had three sections that solicited similar information from both groups. Section A investigated the degree of importance that the respondents attach to the management of IAQ of the office buildings. Section B explored the relationship between good IAQ and office rental value. In addition, the section solicited information on how much the respondents are willing to invest in (building owners), or pay for (i.e., payment of premium rental by tenants) improving the existing IAQ. The respondents were further asked to state their views on tenants' office selection preferences/criteria using a 9-point ordinal rating scale with ''1'' signifying the most important and ''9'' the least important.

Self-addressed postage-paid return envelopes and questionnaires were hand-delivered to the 133 building owners and 615 office tenants. This was followed by emails. The whole exercise (collection of rentals for the office buildings and the survey) took two months (i.e., November and December 2004) to complete. A total of 475 tenants' and 129 owners' questionnaires were duly completed and found suitable for analysis. The data were coded as shown in Exhibit 2 to facilitate the use of SPSS for the analysis.

The variables in Exhibit 2 are used for the hedonic model (Equation 1), which is the basis for testing the hypothesis that IAQ has no impact on office rental. Thus, the hedonic model is specified as follows:

Exhibit 1 | Population and Sample Size of the Building Owners and Office Tenants

	Population		Sample	
Office Location	Building Owners	Office Tenants	Building Owners	Office Tenants (10% of Population)
Marina Centre	9	900	9	90
Raffles Place	30	1250	30	125
Shenton Way	60	1380	60	138
Tanjong Pagar	23	680	23	68
Beach Road	11	520	11	52
Total	133	4730	133	473

Exhibit 2 | Variable Codes for Hedonic Model

Variables	Codes	Types	Descriptions
Rental Value	RENTAL	Numeric	Singapore Dollars
Age	AGE	Numeric	Years
Carpark Facilities	CARPARK	Dummy Variable	1–with carpark facilities 0–without carpark facilities
Improvement of IAQ	IAQ	Dummy Variable	1–with IAQ improvement 0–without IAQ improvement
DISTANCE	DISTANCE	Dummy Variable	1–≤ 1 km from Mass Rapid Transit (MRT) station 0–≥ 1 km from MRT station

$$\text{Office Rental} = \beta_0 + \beta_1 AGE + \beta_2 DISTANCE + \beta_3 IAQ + \beta_4 CARPARK + \varepsilon.$$

The variables in the model are extremely few. This is intentional as the model is mainly aimed at exploring the effect of IAQ on office rental rather than the explanatory power of office building characteristics on rental. The model suffices for the purpose of this inquiry.

Furthermore, the analysis is based on rental instead of sale price as a block of offices in Singapore is rarely sold and bought. Thus, there is a dearth of sales data for office buildings. In contrast, data on office rentals abound in the market albeit difficult to obtain as the data are shrouded in confidentiality. This implies that an analysis based on rental value will reflect the market more than that based on market values (if they can be obtained), which are appraisal-based.

IAQ Audit and Second Survey

The objective of this exercise is to determine the impact of IAQ on the productivity of an office building in Singapore. The exercise took place in December 2006 and January 2007. It includes a walk-through inspection of the office areas, a survey of the 90 workers in the office (Exhibit 3), and an IAQ audit by an accredited IAQ consultant. The ENV Guidelines for Good IAQ in Office Premise were the criteria for the inspection and audit. The walk-through audit occurred on December 11, 2006 while the questionnaire for the IAQ survey was sent via email to the 90 office workers on December 15, 2006. This was followed by phone calls to ensure speedy return of the completed questionnaires. It took two weeks to complete the survey. The questionnaire covered environmental conditions, nature of occupation, health complaints, demographic factors, and importance of IAQ.

The questions relating to environmental condition are aimed at discovering the possible source of discomfort (if any) due to the workplace environment. The

Exhibit 3 | IAQ Survey: Population Size and Number of Respondents

#	Location	# of Occupants	# of Respondents	Percentage of Response
1	Zone 1	18	13	72.2%
2	Zone 2	24	22	91.7%
3	Zone 3	16	13	81.3%
4	Zone 4	32	29	90.6%
5	Total	90	77	85.6%

nature of occupation deals with physical and psychological problems attributable to exposure to pollutants from work. Health complaints are due to the exposure to the discomfort, pollutants, etc., while the absenteeism rate will help to determine the cost of labor due to an IAQ problem. Questions on demographic factors were meant to solicit information on the salaries of the respondents so that monetary loss due to absenteeism and/or savings due to improvement in productivity as a result of IAQ could be calculated. Similarly, questions on IAQ were meant to gauge the office workers' perception of IAQ. The distribution of respondents (85.6% of the office workers) among the office zones are presented in Exhibit 3.

The objective IAQ audit was done on January 8 and 9, 2007. The second survey preceded the IAQ audit to ensure that the respondents were not influenced by the results of the IAQ audit. This is meant to preempt any accusation of priming the survey results. It is possible that the results of the second survey might have been different if it had been done after the IAQ audit.

The office space was divided into four zones for the audit (details are available from the authors). Measurements were taken twice daily (morning and afternoon) from 28 sampling locations comprising 25 locations within the four zones and three outdoor locations. The IAQ audit was done after the IAQ survey to ensure that the survey results were not biased by the audit.

Third Survey

The third survey, which was conducted in December 2007 and January 2008, was aimed, among other things, at ascertaining the probable impact of sustainability (of which IAQ was found to be a major component according to the survey results) on rental and capital values of real estate. Both random sampling (for the general public) and snowball sampling (for real estate professionals) were used for the survey. A questionnaire was used for the survey that involved 150 interviewees from the general public and 71 respondents who are real estate professionals. A 5-point Likert scale, with ''1'' being least significant and ''5'' most significant was given to the respondents to indicate the impact of sustainability on rental and capital values of real property. SPSS was used to analyze the data.

Results

The results of the IAQ survey and audit are presented first to provide a systematic development of discussion.

Results of Walk-through Audit

The salient observations during the walk-through audit are as follows:

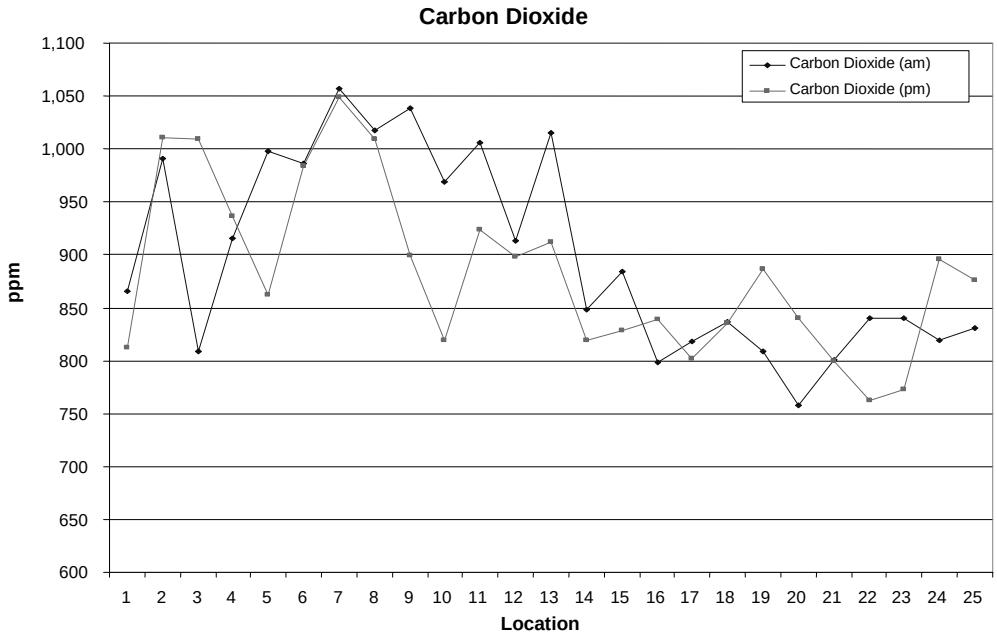
- The main doors to all the respective zones were left open. Some occupants complained of stuffiness in their workplace environment.
- Some of the occupants were wearing jackets, which was an indication of overcooling. This is symptomatic of thermal discomfort.
- The carpeted flooring was stained in some areas.
- There was an unpleasant odor in certain areas.
- There was an accumulation of dust at the supply and return air grilles, indicating that the air-conditioning ducts were dirty.
- Some ceiling boards were badly stained due to leaks.
- The offices were supplied by a constant air volume air-conditioning system. Except for Zone 1 that was using a chilled water system and having a fresh-air intake, the others were using an air-cooled system with no fresh air supply.

It is apparent from the above observations that there are some IAQ problems to be resolved if these observations could be supported by objective facts through a formal audit and a survey of the workforce. Similarly, the overcooling of the workplace is a potential source for energy and cost saving.

Results of the IAQ Audit

The relevant significant results are presented in Exhibits 4a, 4b, and 5 (detailed results are available from the authors). The results generally show that apart from carbon dioxide (18% above guidelines), bacterial count (16% above guidelines), and temperature (26% below guidelines), the rest of the parameters were within the ENV Guidelines. However, the level of carbon dioxide in two sampling locations in Zone 1(Exhibit 4) was quite harmful. The trend shows that the carbon dioxide level was high for both morning and afternoon. Even though only 18% of the readings were above the limits, this is a cause for concern as 90% of the readings were above 800 ppm, which is close to the allowable limit of 1000 ppm. It must be noted that the audit was conducted with the office doors open to comply with the office workers practice of leaving the doors open. Thus, the carbon dioxide level could reach dangerous levels if the doors are closed as they are designed to. These findings are in consonance with Akbar (1999). Furthermore, Zone 1 is found to be problematic as far as temperature is concerned as its mean temperature (22°C and 21.9°C) is below the Guidelines minimum of 22.5°C. Moreover, every zone exhibits bacterial counts in excess of the 500 CFU/m^3 maximum limit, although the frequency is relatively low (Exhibit 5).

Exhibit 4a | IAQ Audit: Trend of Carbon Dioxide in Air



Zone 1—Location 1 to 8; Zone 2—Location 9 to 13; Zone 3—Location 14 to 19; Zone 4—Location 20 to 25.

Exhibit 4b | Mean Carbon Dioxide Content

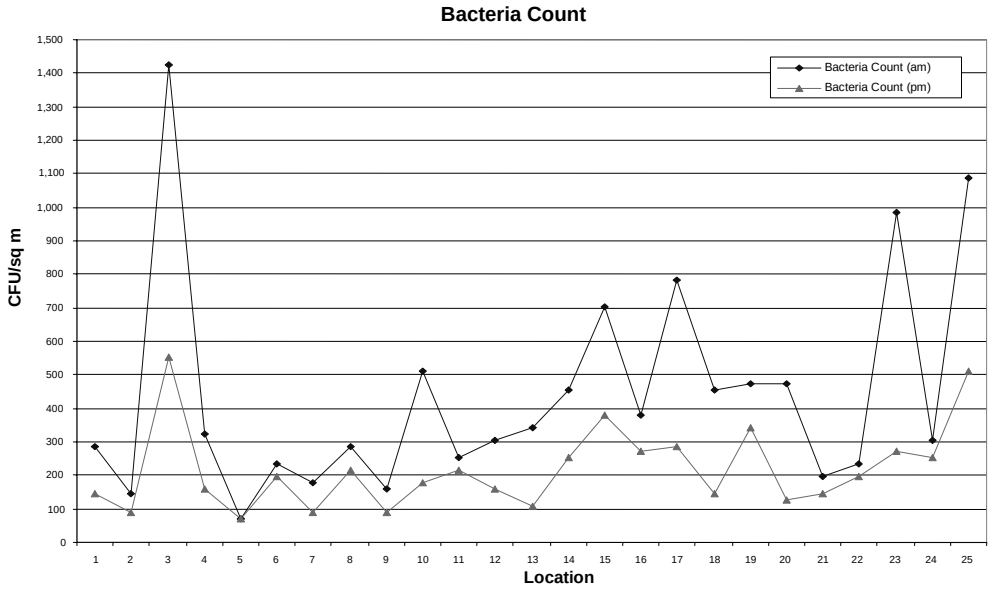
ENV Guidelines (1000 ppm)	Zone 1		Zone 2		Zone 3		Zone 4	
	AM	PM	AM	PM	AM	PM	AM	PM
Mean	955	959	988	890	832	835	806	824
N (1)	2	4	3	0	0	0	0	0
N (2)	8	8	5	5	6	6	6	6

Notes:
N (1): Number sampling locations exceeding ENV Guidelines.
N (2): Number of sampling locations.
AM: Readings taken in the morning.
PM: Readings taken in the afternoon.

Results of IAQ Survey of Workforce

The results of the above survey are presented in Exhibit 6. Taking 80% (ASHRAE62-1989R) response of ''just right'' as the standard of acceptability, it may be concluded that ''lighting'' is not problematic. To some extent, ''noise''

Exhibit 5 | Bacteria Count



and ''humidity'' (both with 77.9% just right response) are not much of a problem. However, ''air movement'' and ''temperature,'' with an acceptance rate of 51.9% and 44.2% respectively, are problematic. The unsatisfactory air movement, vis-à-vis concentration of carbon dioxide above 800 ppm in 90% of the office environment, causes stuffiness and unpleasant odor; 88.3% and 63.6% of the respondents complained of stuffiness and bad smell respectively.

The response rate of 55.8% that the office areas were either cold or too cold is rather surprising since only Zone 1 had temperature readings below the limit and only about 16% of the respondents are from Zone 1. However, it is worth noting that 50% of the readings were 23.1°C and below. This could mean that the 22.5°C minimum under the ENV Guidelines could be too low. The overcooling of the work environment was attested by 89.7% of the respondents, who wear extra clothing to keep warm in the office. This may negate productivity to controvert Seppanen, Fisk, and Lei (2009), who conclude that the highest productivity is at a temperature of about 22°C.

The end result of all these is health complaints (Exhibit 7), with its attendant 140 days of absenteeism per year, with managerial/professional and secretarial/clerical staff accounting for 98 and 42 days respectively. According to the results of the survey, only 14.3% of the respondents did not have any health complaint. Of the 85.7% who had health complaints, 31.2% and 41.4% found relief when they left their workstations or building respectively while 13% did not find any relief at all. These results imply the existence of Sick Building Syndrome (ASHRAE62-1989R). Given that only 10.7% of the respondent workforce was on medication, it could be concluded that the health complaints are due to the workplace

Exhibit 6 | Percentage of Acceptable Environmental Conditions

		Zone 1	Zone 2	Zone 3	Zone 4	Total
	Noise					
Just Right	Count	8	15	12	25	60
	Total respondents per zone	13	22	13	29	77
	% Within Location	61.5%	68.2%	92.3%	86.2%	77.9%
	Lighting					
Just Right	Count	10	18	12	26	66
	Total respondents per zone	13	22	13	29	77
	% Within Location	76.9%	90.9%	92.3%	89.7%	88.3%
	Humidity					
Just Right	Count	9	18	10	23	60
	Total respondents per zone	13	22	13	29	77
	% Within Location	69.2%	81.8%	76.9%	79.3%	77.9%
Dry	Count	2	2	3	4	11
	Total respondents per zone	13	22	13	29	77
	% Within Location	15.4%	9.1%	23.1%	13.8%	14.3%
	Air Movement					
Just Right	Count	7	11	7	15	40
	Total respondents per zone	13	22	13	29	77
	% Within Location	53.8%	50.0%	53.8%	51.7%	51.9%
	Temperature					
Just Right	Count	5	13	4	12	34
	Total respondents per zone	13	22	13	29	77
	% Within Location	38.5%	59.1%	30.8%	41.4%	44.2%

Exhibit 7 | Health Complaints by Ranking

Ranking	Health Complaints	Percentage of Complaint
1	Headache	80.5%
2	Dry Throat	79.2%
3	Stuffy Nose	74.0%
4	Eye Irritation	72.7%
5	Lethargy	72.7%
6	Drowsiness	67.5%
7	Skin Rash	63.6%
8	Dizziness	57.1%
9	Short of Breath	48.1%
10	Nausea	46.8%

environment (office) rather than to the respondents' medical conditions. It must be noted that the survey was conducted before the IAQ audit. Thus, the results could not be influenced by the IAQ audit. The cost and benefits of these results and their impact on property rental and capital values are discussed in the next sections.

Result of the Hedonic Model

The results are presented in Exhibit 8. The problem is that the increase in rental of S$0.16[1] per square foot attributable to improvement in IAQ is not statistically significant at any of the conventional levels. The same result is replicated by the general public survey (i.e., the third survey); the increase in rental value attributable to sustainable development has a *p*-value of 0.156. This is not good news for IAQ, although a positive correlation exists between IAQ and office rental. However, statistical insignificance does not necessarily mean that the impact on rental and capital value is not substantial. For, example, for an office space of 300,000 square feet (which is common in Singapore), the S$0.16 per square foot translates to a mean incremental rental value of S$48,000 per annum which, at a capitalization rate of 5%, adds S$960,000 to the capital value. This may not be statistically significant but it is nonetheless substantial. Furthermore, given a standard error of S$0.227 per square foot (Exhibit 8), a good IAQ can add a maximum[2] of S$0.49 per square foot to the rental value. Thus, on the basis of 300,000 square feet of office space and a 5% capitalization rate, a good IAQ could increase rental and capital values (assuming the good IAQ can be perpetuated) by S$147,000 per annum and S$2,940,000 respectively. Moreover, improvements in IAQ lead to savings in energy consumption and other benefits to tenants, as evidenced by the cost-benefit analyses of an improvement in IAQ of the office space, which was the subject of the IAQ audit and survey (Exhibits 9a & 9b).

The analyses in Exhibit 9a show that an investment (S$41,800) in IAQ improvement for the office space (about 26,900 square feet), which was the subject of the IAQ audit and survey, provides an internal rate of return (IRR) of 78.56% and a net present value ((NPV) of S$159,770 based on a discount rate of 12%. Certainly, this is a very good investment by any standard. It must be noted that the analyses are based on the mean incremental rental of S$0.16 per square foot attributable to IAQ. The IRR and NPV increase to 100.51% and S$220,102 respectively if the analyses are based on the maximum incremental rental of S$0.49 per square foot attributable to IAQ improvement. These figures clearly reveal that accounting for all the benefits attributable to IAQ improvement provides a totally different (attractive) picture from that (dismal) provided by analyses solely based on rental value. However, it must be cautioned that the foregoing analyses assume an owner-occupier. Unfortunately, the position of an owner/investor who lets the property to tenants is not very attractive, as evidenced by figures in Exhibit 9b.

Such an owner/investor has to share the benefits from IAQ improvements with the tenants. Although it is the owner/investor who pays for the IAQ improvement, the major proportion of the benefits accrues to the tenant. The owner/investor

Exhibit 8 | Results of Hedonic Model

Variable	Unstandardized Coefficients β	Std. Error	Standardized Coefficients Beta	t	p-value Significant	95% Confidence Level for β	
						L-bound	U-bound
Constant	3.329	0.403		8.351	0.000	2.530	4.127
Age	−0.031	0.071	−0.131	−1.750	0.083	−0.065	0.004
Distance	0.911	0.227	0.301	4.024	0.000	0.463	1.360
IAQ	0.159	0.226	0.053	0.704	0.483	−0.289	0.607
Carpark	1.244	0.230	0.406	5.404	0.000	0.788	1.700

Exhibit 9a | Cost-Benefit Analysis of IAQ Improvement[a]

Year	0	1	2	3	4	5	6	7	8	9	10
Total Savings & Incremental Rental Value											
Absenteeism[b]	0	19,600	19,894	20,192	20,495	20,802	21,114	21,431	21,753	22,079	22,410
Medical Fee[c]	0	4,200	4,263	4,327	4,392	4,458	4,525	4,592	4,661	4,731	4,802
Electricity[d]	0	6,690	7,294	7,954	8,673	9,457	10,312	11,244	12,261	13,369	14,578
Increase in Rent (S$0.16/ft^2)	0	4,300	4,515	4,740	4,977	5,226	5,488	5,762	6,050	6,353	6,670
Total	0	34,790	35,966	37,213	38,537	39,943	41,439	43,029	44,725	46,532	48,460
Expenditure[e]											
Improvement Works	41,800										
Annual Maintenance		3,000	3,045	3,090	3,137	3,184	3,231	3,280	3,329	3,379	3,430
5 yearly Cleaning of Ducting						8,491					
Total Expenditure	41,800	3,000	3,045	3,090	3,137	11,675	3,231	3,280	3,329	3,379	3,430
Net Income	−41,800	31,790	32,921	34,123	35,400	28,268	38,208	39,749	41,396	43,153	45,030

Exhibit 9b | Cost-Benefit Analysis of IAQ Improvement (Owner's Viewpoint Only)

Year	0	1	2	3	4	5	6	7	8	9	10
Savings in Electricity Consumption	0	6,690	7,294	7,954	8,673	9,457	10,312	11,244	12,261	13,369	14,578
Increase in Rent (S$0.16/ft^2)	0	4,300	4,515	4,740	4,977	5,226	5,488	5,762	6,050	6,353	6,670
Total Income		10,990	11,809	12,694	13,650	14,683	15,800	17,006	18,311	19,722	21,248
Expenditure[c]											
Improvement Works	41,800										
Annual Maintenance		3,000	3,045	3,090	3,137	3,184	3,231	3,280	3,329	3,379	3,430
5 yearly Cleaning of Ducting						8,491					
Total Expenditure	41,800	3,000	3,045	3,090	3,137	11,675	3,231	3,280	3,329	3,379	3,430
Net Income	−41,800	7,990	8,764	9,604	10,513	3,008	12,569	13,726	14,982	16,343	17,818

Notes:

Exhibit 9a: NPV (12%) = S$159,770 (based on mean incremental rental of S$0.16/ft^2). IRR = 78.56%.

Exhibit 9b: NPV (12%) = S$17,803. IRR = 20.21%

[a]Cash flow is over 10 years as ACMV is expected to last for 10 years according to IAQ Consultant.

[b]Based on 140 days absence per year and average salary of S$140 per day (based on 3 years' salary statements). Salary is projected to increase at 1.5% inflation rate.

[c]Based on figures obtained from clinics- Projected to increase at 1.5% p.a.to account for inflation.

[d]Based on average consumption over 3 years and projected to increase at 9.04% p.a. computed from 3 years' tariff.

[e]Figures were provided by the IAQ Consultant who did the audit. Figures are projected to increase at 1.5% p.a. to account for inflation (See Appendices 1 & 2 for detail).

only reaps benefits from savings in utility bills (if the owner/investor is responsible for the bills) and the incremental rental value, both of which provides an IRR of 20.21% compared to the overall IRR of 78.56% and NPV of S$17,803 compared to S$159,770 based on a discount rate of 12% (Exhibits 9a and 9b and Appendices 1 and 2). The IRR and NPV accruable to the owner/investor increase to 44.31% and S$78,141 (compared to 100.51% and S$220,102) respectively when analyses are based on the maximum incremental rental of S$0.49 per square foot. Although the analyses from the owner/investor's viewpoint show that the investment in IAQ improvement is financially feasible, the figures imply that the owner/investor's share of the NPV for all the benefits from improved IAQ is 11.14%.

In a situation where the tenant is responsible for the utility bill, the owner/investor's return on the invested capital in IAQ improvement reduces to minus S$35,302 and plus S$25,036 (IRR of minus 13.53% and plus 24%) when analyses are based solely on the mean and maximum incremental rentals of S$0.16 and S$0.49 per square foot. This inequitable ''natural'' allocation of the benefits between the owner/investor and tenants could undermine IAQ improvement unless a satisfactory apportionment of the benefits and/or costs between the two groups could be found.

Results of Owners' and Tenants' Survey

The results of the owners' and tenants' survey reported below are in consonance with the statistical insignificance of the impact of IAQ on rental (see Results of Hedonic Model above). The results reported in Exhibit 10 show that the overwhelming majority of both owners (about 95%) and tenants (about 96%) agree that it is important/very important to maintain good IAQ in office space. Similarly, 100% and 96.21% of owners and tenants acknowledge the impact of IAQ on workers' productivity. This is reinforced by 68.20% of owners and 80.60% of tenants agreeing that good office IAQ increases workers' productivity (Exhibits 11a & 11b). These results are in consonance with the extant literature. It is noteworthy that only 19.40% of the tenant respondents do not think that good office IAQ increases workers' productivity (Exhibit 11b). Furthermore, 71.40% of the tenant respondents agree that good office IAQ reduces absenteeism. These results are concurred by the general public survey in which 82.4% of the respondents agree to health, etc. benefits of sustainable developments.

These results imply that tenants do know the beneficial effects of good IAQ. In contrast, owners are not very sure that good IAQ will bring them commensurate monetary rewards through increased rental value. Only 49.60% (vs. 50.40%) of owners think that improvement in IAQ will lead to higher rental. Given the tenants' awareness and acknowledgement of the benefits to them of good office IAQ, one would have expected IAQ to feature prominently on their office selection preferences. With a mean rank of 4.78 according to the Friedman test (Exhibit 12), IAQ is not considered to be a very significant factor in their selection preferences. Similarly, one would have expected tenants to be willing to pay higher rent for good office IAQ. Paradoxically, the majority of tenants (54.70%) do not

Exhibit 10 | Importance of IAQ to Owners and Tenants (Tenants' Response Bracketed)

Upkeep of Office IAQ			Effect of IAQ on Workers' Performance			Condition of Current IAQ		
Response	Frequency	%	Response	Frequency	%	Response	Frequency	%
Very Important	61 (229)	47.29 (48.21)	Yes	129 (457)	100 (96.21)	Excellent	0 (4)	0 (0.84)
Important	62 (226)	48.06 (47.58)				Good	79 (152)	61.24 (32)
Neutral	6 (19)	4.65 (4)	No	0 (18)	0 (3.79)	Neutral	27 (114)	20.93 (24)
Not Important	0 (1)	0 (0.21)				Satisfactory	17 (141)	13.18 (29.68)
						Very Poor	6 (64)	4.65 (13.47)

Exhibit 11a | Owners' Views on Factors Favoring IAQ Improvement

Response	Yes (%)	No (%)
Increased workers' productivity	68.20	31.80
Recognition from building authority	59.70	40.30
Reduced maintenance cost	58.90	41.10
Higher efficiency in building system	57.40	42.60
Fewer tenant complaints	50.40	49.60
Higher office rental can be reaped from improved IAQ	49.60	50.40
Increased lifespan of building elements and system	38.80	61.20

want to pay higher rent for improvement in office IAQ; they want the owner to absorb the cost of IAQ improvement (Exhibit 13b). The weighted average percentage increase in rental value that the 45.30% of the ''willing'' tenant respondents want to pay for improvement in IAQ is 2.99%. Another paradox is that more owners (59.70%–Exhibit 13a) are willing to spend a relatively higher weighted percentage increase (5.47%) in funding for improvement in IAQ vis-à-vis their uncertainty about a commensurate return via increased rental value.

It is evident from the foregoing analyses that the tenants want to have their cake and eat it too. They want the owners/investors to pay for improvement in, and maintenance of, good office IAQ for them (the tenants) to reap the bulk of the monetary rewards. This may prove to be the greatest hindrance to improving IAQ in offices. The analyses presented in Exhibits 9a and 9b reveal that 88.86% of the monetary benefits (NPV) from improved IAQ accrues to the tenants. The owner/investor who pays for the improvement receives a paltry 11.14% of the resultant NPV.

The Way Forward

According to the results of the general public survey, the main obstacles to achieving sustainable developments in Singapore are: difficulty in quantifying benefits (4.30), higher construction cost (4.24), lack of awareness of benefits (4.20), and pay-back period being too long (4.0). The mean scores are out of 5 with ''1'' being very insignificant and ''5'' very significant. As far as IAQ is concerned, it has been shown that:

- The benefits can be quantified;
- The cost is not very high;
- The parties are aware of the benefits; and
- The pay-back period is relatively short: it is less than two years if all benefits are accounted for in the analysis (Exhibit 9a) and about seven

Exhibit 11b | Tenants' Views on Benefits of IAQ Improvement

Response	Yes (%)	No (%)
Increased workers' productivity	80.60	19.40
Reduction in absenteeism	71.40	28.60
Increase tenants' annual profit	13.70	86.30
Enhance landlord-tenant relationship	28.20	71.80
Landlords owe a duty of care to tenants to provide good IAQ	52.80	47.20
Other: enhance tenants health	0.60	0

Exhibit 12 | Owners' and Tenants Selection Preferences for Office Unit (Owners' Ranking Bracketed)

Factors	Mean Rank	Rank
Location of Building	2.10 (1.78)	1 (1)
Rental Rates	2.45 (1.95)	2 (2)
Accessibility	2.93 (2.84)	3 (3)
IAQ of the Building	4.78 (5.83)	4 (5)
Age of Building	5.90 (7.15)	5 (9)
Flexible office layout/column-free concept	6.04 (5.43)	6 (4)
Prestige of building & availability of high-tech facilities	6.82 (6.61)	7 (7)
Availability of car parking facilities	6.92 (6.49)	8 (6)
Nearness to similar business types	6.96 (6.96)	9 (8)

years for the owner/investor who receives the incremental rental and savings in utility bills attributable to improved IAQ if he is responsible for utility bills (Exhibit 9b).

Thus, the main impediment to improvement in office IAQ could be the unwillingness of tenants to pay a premium rent for it when they enjoy most of the benefits accruable from IAQ improvement. It must be noted that notwithstanding the tenants' acknowledgement that good office IAQ reduces absenteeism and increases productivity, they argue that it is the building owner's

Exhibit 13a | Owners Willingness to Increase Funding for IAQ Improvement

Response	%		%
Yes	59.70%	% Increase in Annual Fund for IAQ Improvement	
		20% more	3.10%
		15% more	12.40%
		10% more	15.50%
		5% more	27.10%
		Less than 5%	1.60%
No	40.30%	Reasons for Unwillingness to Increase Annual Fund for IAQ Improvement	
		IAQ is not an important factor	24.0%
		Satisfied with the present IAQ	11.60%
		Current rent does not justify IAQ	4.70%

Exhibit 13b | Willingness to Pay Higher Rent for Improved IAQ

Response	%		%
Yes	45.30%	% Increase in Rental Tenants are Willing to Pay	
		20% more	0.60%
		15% more	1.10%
		10% more	10.50%
		5% more	23.40%
		Less than 5%	9.70%
No	54.70%	Reasons for Unwillingness to Pay Higher Rent for IAQ Improvement	
		Current rental is too high	7.20%
		Landlord should absorb the cost of IAQ improvement	43.40%
		Not essential to have good IAQ in working environment	3.80%
		Others	0.40%

responsibility to provide a healthy working environment. If the current condition of office IAQ is causing absenteeism and reduced productivity (both of which are costs to tenants) and the building owner concedes to it, the tenants could go to court to seek redress. Although the legal implications are beyond the tenets of this paper, such action could cause the owners to incur more costs. Thus, the tenants may argue that the benefits from improved IAQ directly (through increased rental value and reduction in maintenance cost) and indirectly (through preempting possible litigation) accrue to the owners of the building to make the cost of IAQ improvement the sole responsibility of the owners.

Notwithstanding the fact that the increased rental attendant to IAQ improvement does not justify the investment (as it results in negative NPV), the inclusion of savings in utility bills makes the investment in improved IAQ financially feasible—it provides a positive NPV. Recall that the analyses do not take into

account the savings in maintenance and repair costs that may result from improved office IAQ. Since maintenance and repair costs are operating expenses, any savings in these costs increase net income from the property (and therefore capital value) to increase the financial returns from IAQ investment. Thus, an increase in rental value (though important) should not be the sole justification for investment in improved office IAQ. Savings in operating expenses are equally important as they increase the net income to make the investment economically viable. After all, it is net income, not merely an increase in rental value, which determines the value of the property if the capitalization rate is held constant.

According to the results of the general public survey, the respondents gave a mean score of 3.16 and 3.71 respectively on the impact of sustainable development on the rental and market values of such buildings. The difference between the two means is statistically significant at the 0.05 level. This implies that while the general public expects sustainable development to have a muted impact on rentals, it expects the impact on capital values to be relatively substantial. This paradox is explained by the fact that savings in utility bills and maintenance costs (operating expenses) will increase net income and thus, capital value but not rental value. For example, if the benefits (total income of S$10,990 for Year 1) in Exhibit 9b can be perpetuated at 5% yield, they would add an average of S$219,800 (or S$695,800 if the analysis is based on all the benefits from IAQ—Exhibit 9a) to capital value. These figures translate into S$8.17/S$25.87 per square foot more in capital value, which amount to 1.22%/3.85% of the capital value (S$672 per square foot) at the time of the survey. Even if the analysis is solely based on Exhibit 9b (benefits likely to accrue to the owner/investor), the increase in capital value per square foot could be S$14.77 (2.20%) on the basis of the maximum incremental rental value of S$0.49 per square foot. In contrast, the incremental rental of S$0.16 (mean) and S$0.49 (maximum) per square foot amounts to a 0.48% and 1.46% increase in capital value. Moreover, Gottfried (2003) states that green buildings could have a superior capitalization rate to ''normal'' buildings. If account is taken of any reduction in capitalization rate vis-à-vis reduction in maintenance and repair costs attributable to IAQ improvement, the increase in capital value could be substantial.

Given that the cost per square foot for the IAQ improvement is S$1.55 (i.e., 0.23% of capital value), the increases in capital value per square foot presented above are quite attractive, especially to the owner-occupier, who enjoys all the benefits from IAQ improvement; the incremental capital value-IAQ improvement cost ratio is 16.69 (S$25.87/1.55). The ratio for owner-investor is 5.27 (i.e., S$8.17/1.55).

Furthermore, the results of the survey show that both parties share the same views on the importance and benefits of good office IAQ, especially in relation to increased productivity and reduced absenteeism. What is required is a common understanding between the two parties that improved office IAQ benefits both of them so that they can come to a win-win agreement for ''equitable'' sharing of the costs and/or benefits of IAQ to promote investment in improving office IAQ.

Conclusion

The paper set out to investigate the impact of IAQ on office property values. In view of this, three surveys were conducted. There was also an IAQ audit of an office space, as well as a hedonic analysis of the impact of IAQ on office rental. The results of the survey show that while both office building owners and tenants acknowledge the benefits of improved office IAQ, the majority of the tenants (54.70%) is not willing to pay additional rent for improved IAQ. This gives credence to the results of the hedonic model that the increased rental value attributable to improved IAQ is not statistically significant. Notwithstanding the statistical insignificance of the increase in rental value, the results show that the increase in capital value is relatively high. Even without accounting for a possible superior capitalization rate and savings from reduced maintenance and repair costs, the results show that improved IAQ could increase capital value by 1.28% (mean) and 2.29% (maximum) on the basis of net income from the property. Capital value could increase by 3.85% if all benefits from improved IAQ are taken into account. Moreover, it was found from an investment analysis of a test case that the return on investment in improved IAQ is substantial (78.56% if all benefits are included in the analysis). Even when analyses are based solely on incremental rental value and savings in operating expenses, the return on investment was found to be 20.21%. Given that the bulk (about 89%) of the monetary benefits from improved IAQ accrues to the tenants vis-à-vis the unwillingness of most tenants to pay a premium rent for improved IAQ, what is required is a common understanding between the two parties that improved office IAQ benefits both of them so that they can come to a win-win agreement for ''equitable'' sharing of cost and/or benefits of IAQ to promote investment in improving office IAQ. As the market becomes more familiar with the benefits of sustainable development, the impact of good IAQ on property value will be enhanced.

Appendix 1

Cost of IAQ Improvement

The cost of improving the IAQ for the office which is the focus of the IAQ audit is as shown below.

Scope of Work

- To seal off the 3 DX AHU rooms with 2″ polyurethane panel and seal off all infiltration from the roof.
- Install fresh air inlet grilles with damper for all the 3 DX AHU rooms.
- Optimize the DX unit refrigeration system for all the 3 AHU/CDU units.
- Optimize the chilled water AHU units.
- Relocate one set of return air duct.
- Clean the ductwork.

- Install a fresh air treatment unit for the chilled water AHU unit. This comprises 2 chilled water coils with the ductwork connected to the suction end of the AHU unit.
- To re-commission all the AHU units.

Estimated Cost Provided by the IAQ Consultant

- PU ceiling work: S$20,000
- Fresh air coils: S$4,000
- Ductwork modification: S$3,800
- Installation: S$6,000
- Duct Cleaning: S$8,000
- Total: S$41,800

Annual Expenditure

1. Annual Cost of Replacement of Air-Filters and Maintenance of Filtration System is estimated at S$3,000.00. This is projected to increase at the average annual inflation rate of Singapore of 1.5% per annum.
2. The Air-conditioned Duct needs to be cleaned in Year 5 at a cost of S$8,000.00. Given an inflation rate of 1.5% per annum, this cost will increase to S$8,491.

Appendix 2

Savings Resulting From IAQ Improvement

Savings

1. Absenteeism: The number of days absenteeism per annum, according to the second survey relating to the IAQ audit, is 140 as follows:
   - 4 managerial staff were absent for a total of 19 days.
   - 20 professional staff were absent for a total of 79 days.
   - 2 secretarial staff were absent for a total of 10 days.
   - 4 clerical staff were absent for a total of 32 days.

   Staff cost (salaries) for the 145 workforce were:

   - Financial Year 2003/04 = $6,960,080
   - Financial Year 2004/05 = $7,400,784
   - Financial Year 2005/06 = $7,204,826

Based on the 2005/06, the cost of absenteeism (which becomes a saving when there is no absenteeism is S$136.12 per day (i.e., [S$7204826/(145 staff $\times$ 365

days)]). This is based on a conservative and pessimistic assumption that employees, at least, earn their salaries and thus, contribute that amount to production. This implies that employees' absence due to medical leave attendant to poor IAQ costs the company (to reduce profit) the employees' salaries paid during medical leave. Thus an improved IAQ that reduces such absenteeism to zero improves profitability by the cost (which becomes a saving) of the absenteeism. The result of the DCF is therefore likely to be the minimum savings as employees normally produce more than they earn in salaries. Ideally, the analysis should be based on productivity for which accurate figures are not accessible to us.

Given that managerial and professional staff with a relatively higher salary account for 98 of the 140 days absenteeism, savings from absenteeism is based on a conservative estimate of S$140 per day to give an annual savings of S$196,000. This is projected to increase at an average annual inflation rate of 1.5%.

An average staff cost is used for the DCF analysis as the company's accounts only provide total staff cost. There is no indication of salaries for different categories of employees.

2. Medical Fee: An annual medical fee of S$4,200.00 (140 days × S$30) is used in the DCF calculations. The S$30 medical fee per visit was obtained via telephone interviews of clinics where employees on medical leave receive medical treatment. This is projected to increase by 1.5% per annum to account for inflation.
3. Electricity Bills = (S$10,000 × 66.9%*) = S$6,690.00. This is projected to increase by 9.04% annually based on Singapore Power's electricity tariffs from January 2004 (S$0.1544) to January 2007 (S$0.2002).
    - Based on Ng (1993) that 66.9% of the energy consumption in a typical high-rise office building is attributed to the ACMV system.

Endnotes

[1] At the time of writing, US$1 = S$1.384.

[2] Given a mean of S$0.16 and a standard error of 0.227, the minimum impact of IAQ is minus S$0.07 per square foot. A good IAQ certainly will not have adverse effect on rental value, as attested by the results of the survey. It is therefore meaningful to base the analyses on the mean and maximum impact.

References

Akbar, M. An Indoor Air Quality Audit of a Commercial Building. School of Building and Real Estate. National University of Singapore, 1999.

Bako-Biro, Z., P. Wargocki, C.J. Weschler, and P.O. Fanger. Effects of Pollution from Personal Computers on Perceived Air Quality. SBS Symptoms and Productivity in Offices. *Indoor Air,* 2004, 14, 178–87.

Czubaj, C.A. School Indoor Air Quality. *Journal of Instructional Psychology,* 2002, 29:4, 317–21.

Cohen-Rosenthal, E.S. and M. Smith. *Eco-Industrial Strategies: Unleashing Synergy between Economic Development and the Environment*. Chapter 14. Sheffield, England: Greenleaf Publishers, 2003.

de Vries, G. A Key Factor for Energy Efficiency. *Journal of Southeast Asia Facility & Property Management*, 2004, 6–8

Dixon, J.A., L.F. Scura, R.A. Carpenter, and P.B. Sherman. *Economic Analysis of Environmental Impacts*. London: Earthscan, 1994.

Djukanovic, R., P. Wargocki, and P.O. Fanger. Cost-benefit Analysis of Improved Air Quality in An Office Building. The 9th International Conference on Indoor Air Quality and Climate, *Proceedings of Indoor Air 2002*, 1, 808–13.

Eichholtz, P.M.A., N. Kok, and J.M. Quigley. Doing Well by Doing Good: Green Office Buildings. *American Economic Review,* 2010, forthcoming.

ENV. Guidelines for Good Indoor Air Quality in Office Premises. Ministry of the Environment, Singapore, 1996.

EPA. Energy Cost and IAQ Performance of Ventilation Systems and Controls. United States Environmental Protection Agency, Washington, D.C., 2000.

Fisk, W.J. How IAQ Affects Health, Productivity. *ASHRAE Journal*, 2002, 44, 56–60.

Fuerst, F. and P. McAllister. An Investigation of the Effect of Eco-Labeling on Office Occupancy Rates. *Journal of Sustainable Real Estate*, 2009, 1:1, 49–64.

Gan, C.C., M.H. Tan, and I.L. Premas. Life Cycle Costing for Office Productivity. Research Report R-296-000-057-112/592, 2003.

Gottfried, D. *A Vision of Green Building Economics for the Private Sector.* World Build Technologies, San Francisco, CA, 2003.

Judge, E. Flexitime Work. *The Times*, January 6, 2003, E2 p. 7.

Kats, G. *The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force*. October 2003, from http://www.usgbc.org/Docs/News/News477.pdf.

Lam, K.C. The Importance of Better Management of Building Services Maintenance. *Journal of Southeast Asia Facility Management*, 2004, June/May, 18–22

Lucuik, M., P. Eng, W. Trusty, N. Larsson, and R. Charette. *A Business Case for Green Buildings in Canada Report.* Morrison Hershfield, 2005.

Mangione, T.W. *Mail Surveys: Improving the Quality*. *Applied Social Research Methods Series*. Vol. 40. United States of America: Saga Publication Ltd, 1995.

Morton, S. *Business Case for Green Design.* 2002, www.facilitesnet.com.

Martin, J. Addressing IAQ Concerns in Medical Facilities. *Engineered Systems*, 1999, 16:6, 53–7.

Miller, N., J. Spivey, and A. Florance. Does Green Pay Off? *Journal of Real Estate Portfolio Management*, 2008, 14:4, 385–99.

Miller, N., D. Pogue, Q.D. Gough, and S.M. Davis. Green Buildings and Productivity. *Journal of Sustainable Real Estate*, 2009, 1:1, 65–89.

Olsen, B.W. Indoor Environment—Health, Comfort and Productivity. Clima 2005 Lausanne, 8th REHVA World Congress, Switzerland, October 9–12, 2005.

Royal Institution of Chartered Surveyors. *Green Value–Green Buildings, Growing Assets.* 2005. www.rics.org/NR/rdonlyres/93B20864-E89E4641-AB11028387737058/0/GreenValueReport.pdf.

Roper, K.O. and J.L. Beard. Justifying Sustainable Buildings—Championing Green Operations. *Journal of Corporate Real Estate.* 2006, 8:2, 91–103.

Seppanen, O., W.J. Fisk, and Q.H. Lei. Effect of Temperature on Task Performance in Office Environment. Report LBNL-60946. Helsinki University of Technology, 2006, 1–9.

Smith, V.K. and J-C. Huang. Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models. *Journal of Political Economy*, 1995, 103:1, 209–27

Tanabe, S-I., M. Haned, and N. Nishipana. Indoor Environmental Quality and Productivity. *REHVA Journal*, 2007, June, 26–31.

Tan, W. *Practical Research Methods*. Singapore: Prentice-Hall, 2002.

Vancouver Valuation Accord. *An Agreement to Address the Interrelationship of Sustainability and Value.* Vancouver, British Columbia, 2007.

von Kempski, D. Air and Well Being—A Way to More Profitability. *Proceedings of the Fifth International Conference on Healthy Buildings*. 2003, 2, 348–54.

Wargocki, P. Making the Case for IAQ. *ASHRAE IAQ Applications*, 2002.

Wiley, J., J. Benefield, and K. Johnson. Green Design and the Market for Commercial Office Space. *Journal of Real Estate Finance and Economics*, 2010, 41:2, 228–43.

Wyon, D.P. The Effects of Indoor Air Quality on Performance and Productivity. *Indoor Air*, 2004, 14, 92–101.

Kwame Addae-Dapaah, National University of Singapore, Singapore 117566 or rstka@nus.edu.sg.

Tham Kok Wai, National University of Singapore, Singapore 117566 or bdgtkw@nus.edu.sg.

Mohd Jaafar Bin Dollah, National University of Singapore, Singapore 117566 or mjaafar@science.edu.sg.

Yvonne Foo, Wing Tai, Singapore.