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Health in Office Buildings: A Research Methodology

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Preface

This report summarises the methodology for a research project aimed at determining how healthy New Zealand office buildings are and what physical factors contribute to their health performance.

Preliminary New Zealand research suggests that office buildings in this country are performing similar to overseas buildings, in particular those in the UK. That research suggests that Sick Building Syndrome (SBS) is present in a significant number of New Zealand buildings.

The intended outcome of this research methodology is to enable the industry to improve the health performance of New Zealand office buildings beyond the current level.

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Note

This report is intended for Building Research.

Health in Office Buildings: A Research Methodology

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ABSTRACT

This report summarises the methodology for a research project aimed at determining how healthy New Zealand office buildings are and what physical factors contribute to their health performance. Preliminary New Zealand research suggests that office buildings in this country are performing similar to overseas buildings, in particular those in the UK. That research suggests that Sick Building Syndrome (SBS) is present in a significant number of New Zealand buildings. The intended outcome of this research methodology is to enable the industry to improve the health performance of New Zealand office buildings beyond the current level.

KEYWORDS

Health, office, sick building syndrome, methodology.

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1. EXECUTIVE SUMMARY

This report outlines a research methodology for identifying the prevalence of Sick Building Syndrome (SBS) and other building related factors affecting occupant health in New Zealand office buildings. The methodology is aimed to provide an indication of potential building related factors responsible for SBS in New Zealand.

SBS has been identified overseas as a significant issue in the built environment. Research goes back for more than 25 years. In 1984 the World Health Organisation reported a cluster of symptoms occurring "with increased frequency in buildings with indoor climate problems" — a collection of symptoms later known as SBS. These symptoms were associated with a particular building by their reoccurrence, often in several people when in the building, and their decrease or disappearance when not in the building.

There is a series of other indoor air pollutants which are not directly associated with SBS, but which have detrimental affects on occupant health, specifically environmental tobacco smoke, other combustion products, biological pollutants, volatile organics and heavy metals. A good overview is published by the US Consumer Product Safety Commission, the American Medical Association, the Environmental Protection Agency and the American Lung Association (Colome et al).

A small number of studies have also been conducted in New Zealand. These suggest that the prevalence and severity of SBS in this country is similar to overseas.

The field of SBS research is complex and has a long history. One common theme is that it requires close collaboration between researchers of different disciplines including building research, air quality and health. The project outlined in this report would lay the foundation to allow future more specifically targeted research to be undertaken.

The proposed research project has been discussed with a number of potential research collaboration partners and industry stakeholders. In general there is widespread support for the research concept and a number of companies indicated that they would volunteer their office places for conducting such a study. However, none of the approached stakeholders indicated that they would be prepared to commit significant funding to this type of project.

The proposed research methodology suggests a three stream data collection methodology. One stream consists of a large set of buildings in which low cost audits will be applied, the other two streams concern buildings in which detailed monitoring is conducted. One group of the monitored buildings will have no intervention measures applied to them; the second one will be monitored before and after the buildings have been modified to reduce the risk of SBS.

This report is intended to serve as a discussion document to build a collaborative research project on the health performance of New Zealand office buildings. Thus the suggested research methodology is seen as an integrated approach addressing most of the experimental issues. However, the type of stakeholders and collaborators may have different priorities and capabilities which could be accommodated in the research approach.

2. BACKGROUND AND NEW ZEALAND CONTEXT

SBS is an occupational health description associated with certain symptoms in a building's occupants. These may include acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints may be localised in a particular room or zone, or may be widespread throughout the building. A 1984 World Health Organisation Committee report suggested that up to 30% of new and remodelled buildings worldwide may be the subject of excessive complaints related to indoor air quality (IAQ) (quoted in EPA Guideline: *Indoor Air Facts*). In a nationwide random sampling of US office workers, 24% perceived air quality problems in their work environments and 20% believed their work performance was hampered thereby (Kreiss 1990).

Tell-tale signs of SBS are that building occupants complain of symptoms associated with acute discomfort e.g. headaches; eye, nose or throat irritations; dry cough; dry or itchy skin; dizziness and nausea; difficulty in concentrating; fatigue; and sensitivity to odours. The occupants perceive improvements soon after leaving the buildings.

A pilot study was recently conducted by the Wellington School of Medicine and Health Sciences and Massey University (Gale et al 2005). The study evaluated the Wellington Medical School building and found similar SBS prevalence as found in UK office buildings. The study concluded that a "detailed systematic study is required to elucidate environmental causes of SBS in New Zealand".

A 1999 cross-sectional study of 360 office workers in Palmerston North conducted by Massey University (Phipps et al 1999) found that more than 80% of the subjects experienced some building related symptoms, with lethargy, stuffy noses, dry throat and headache reported to occur regularly. Effects were similar to results found in the UK with affected subjects making up over 40% of the samples in buildings associated with SBS. New Zealand subjects experienced comparable or slightly higher levels of symptoms, except for itchy eyes, which were significantly more prevalent. The study concludes that SBS was found to be sufficiently prevalent in both surveys to warrant concern. There were sufficient similarities between the two populations to suggest that the conclusions from the UK survey are applicable to the New Zealand context.

Another Massey University study (Fleming 2002) investigated the effects of lighting quality on worker health and satisfaction and found that:

- women reported they were more affected than men
- office workplace density is a factor
- day-lighting affects health
- middle aged people are most affected
- physiological differences affect reaction to lighting quality.

All this suggests that there is a need to better understand the prevalence and causes of SBS in New Zealand office buildings. This document outlines the research questions and suggests a methodology to do that.

2.1 Possible causes for SBS

A number of causes have been connected with SBS. The most common ones relate to IAQ:

- inadequate ventilation
- chemical contaminants from indoor sources (VOCs including formaldehyde)

- chemical contaminants from outdoor sources (pollutants from motor vehicle exhausts, plumbing vents and building exhausts etc)
- biological contaminants (bacteria, moulds, pollen etc).

A 1999 meta study (Seppanen et al 1999) on causes of SBS found that in 16 studies using measured ventilation rates, 20 of 27 comparisons of different ventilation rates found increased symptoms associated with lower measured office ventilation rates. Also 9 of 18 studies using CO_2 measurements as simpler, but less accurate, indicators of ventilation rate also found such associations.

In addition to these air quality related issues research also suggests that other environmental conditions lead to the lack of occupant well-being (Clements-Croome et al 2000). Typical factors include:

- extreme high and extreme low air temperatures
- radiant temperatures and their directional balance
- air movement (draughtiness)
- relative humidity
- noise
- lighting levels and quality (day-lighting, lighting levels and direction etc).

Several articles on associations between temperature and symptoms in offices, published between 1989 and 2004, show overall that symptom prevalence increased systematically as temperatures increased between about 21 and 24.5ºC. Also temperatures at the lower end of the scale are associated with reduced worker well-being. There is, however, an association between increasing temperature, overcrowding, and inadequate ventilation which makes it difficult to pinpoint the causative factor.

Other recent international studies (Mills et al 2007) have shown that individuals working under fluorescent light sources with a high correlated colour temperature (17000 K) showed a significant improvement in self-reported ability to concentrate compared to those within a control group. This suggests that high correlated colour temperature fluorescent lights could provide a useful intervention to improve wellbeing and productivity in the corporate setting.

This indicates that not only IAQ affects worker health and well-being, but also other physical environmental factors.

3. RESEARCH QUESTIONS

The proposed research aims to address two questions:

1. *How healthy are New Zealand office work stations and office buildings?*
2. *What physical changes can be made to the building and to the building's services to improve the indoor environment, and how effective are these changes to make them healthier?*

The first question is to be answered in absolute terms i.e. how frequently do New Zealand office workers experience SBS symptoms, but also in comparison to overseas occurrences.

The second question requires the evaluation of the chain of influences leading to health experiences by office workers. The simple diagram below shows the three stage link between the built and natural environment, the internal office environment and the resulting effects on office worker health.

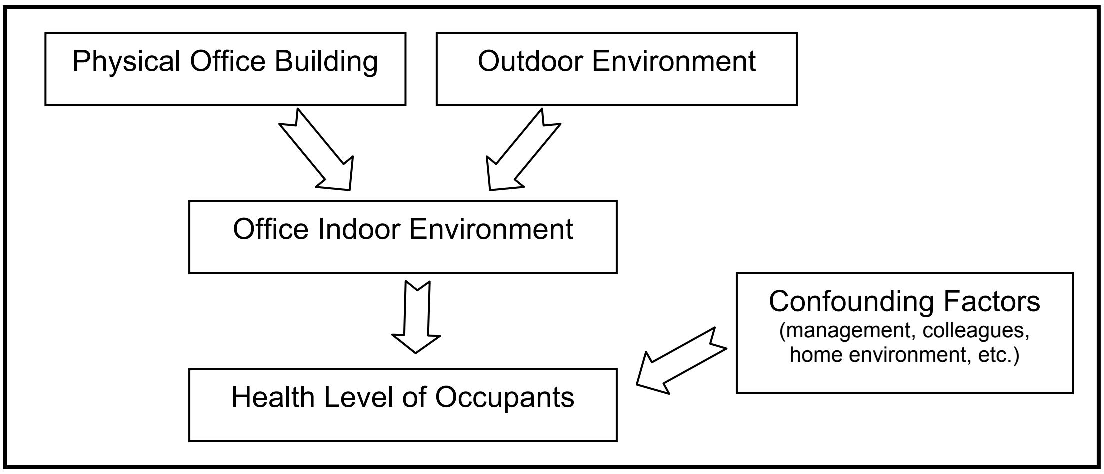

Figure 1. Influence chain.

The proposed research methodology will help understand this relationship.

4. METHODOLOGY

4.1 Overview

The suggested project is designed to run for four years and includes three data sets. Year 1 will mainly cover literature review, statistical sample design, case study selection, instrument development (survey and technical) and piloting of the methodology. Monitoring (including data logging) will be conducted during Years 2 and 3. Data analysis and technology transfer will be covered in Year 4. Some preliminary results will be available earlier.

It should be noted that although a large number of consultations were held between researchers of different research fields, the research design and interpretation in terms of health outcomes will require further guidance from health research professionals.

4.2 Year 1

The literature review will collect relevant overseas data on both the expected prevalence of SBS in this country and on research instruments being used in overseas and existing New Zealand research. The statistical sample design will, based on literature values, determine the required sample size and type, as well as the best methodological approach to achieve reliable representative results (see also Section 4.6.1).

The sample selection will depend on willingness of businesses to participate in the research. Discussions so far indicate that a number of businesses would be interested in participating by making their office spaces available for surveys and data logging.

It is suggested to target two groups of offices, one with known SBS histories (assuming these data are available from independent consultants) and one without known SBS issues. Discussions were held with one indoor air consultant (Len Stratton from Healthy Environments Ltd) who suggested that there are a reasonably large number of buildings in New Zealand which have been investigated for IAQ problems. It may be possible to get access to contact some of the lessees of these buildings indirectly by using the corresponding consultants.

It is intended that the sample will include a cross-section of:

- building types (openable windows and sealed façade, low rise and high rise, open plan and individual office etc)
- sophistication of HVAC services (fully automated HVAC and personal control and naturally ventilated)
- building age
- location (major city CBD and regional centres)
- occupation type (owner occupied, public sector or private sector occupied).

The survey instruments will build on overseas used questionnaires which will be adapted to New Zealand conditions.

BRANZ – with funding from Building Research – has recently developed a low cost integrated environmental monitoring system which can be operated from any workstation computer. This equipment will be available to collect a series of environmental parameters including amongst others temperature, RH, air movement and noise levels. Additional sensor types such as CO_2 and VOC sensors can be added relatively easily (Stoecklein and Wood, 2007). More specialised logging equipment for IAQ is available through Massey University, but may require to be customised for this particular study.

4.3 Years 2 and 3

Unless the statistical survey design conducted in Year 1 suggests otherwise the data collection will occur using three different data streams. Streams A and B will consist of about 50% of buildings with known or anticipated SBS issues and 50% of buildings without. Stream C will consist only of buildings with SBS histories.

Stream A: Representative – low level: A large number of offices will be evaluated using walk-through audits and a limited number of critical one-off measurements (i.e. dust sampling from air supply ducts etc). The sample should be designed to be representative of the New Zealand office stock as a whole. Health of office occupants will be captured through questionnaire surveys (one-off and repeated) and company level Key Performance Indicators, such as sick days and absenteeism.

Stream B: Case studies without intervention: A small number of offices will be measured using environmental metering technology including temperature, CO_2, etc. Health of the occupants will be assessed through self-reporting of symptoms during the metering period, one-off questionnaires, and company level Key Performance Indicators.

Stream C: Case studies with intervention: This group will consist of offices with known or anticipated SBS problems which will be retrofitted during the study. The same measurement methods as Stream B will be applied. The measurements will be conducted twice, once pre- and once post-retrofit. If practical the type of retrofit intervention will depend mainly on the building analysis during the pre-retrofit period. Where evidence is found that a part of the building or building services are contributing to a problematic environment then these will be addressed in the case study and the results monitored. It is anticipated that the problems identified include issues such as fouled cooling coils and components of the HVAC system, ingress or entrainment of pollutants, off-gassing of solvents from building materials, removal of fungi from water damage or leaks, or changes to the lighting. Most of these will be possible to address at little cost. The intervention type will also depend on participation of suitable office tenanting businesses and on contributions and partnerships with suppliers of suitable technologies such as HVAC suppliers, office outfit providers etc.

It is currently estimated that the total number of individuals included in the monitoring will be approximately 2000 occupying approximately 200 offices. This is broadly in line with other overseas studies into SBS. The exact numbers will need to be confirmed by the statistical project design conducted in Year 1 of the project.

4.4 Year 4

During this phase the data collected in Years 2 and 3 will be analysed. The analysis will follow two approaches:

- The "representative – low level" sample will be analysed by comparing office design features, walk-through survey results and one-off measurement results with the reported health level of the office occupants. By comparing different offices and the corresponding health levels of their occupants (ANOVA analysis) the influence of the physical office environment will be determined. The large number of survey subjects will prove a statistically useful data set.
- The "case studies without intervention" will be used to understand causal relationship chains between the identified office environmental features and the impact of occupant health. This will be achieved by measuring the two-stage relationship. 1. The impact of office features on the physical environment (example: impact of window size and layout on the lighting level and quality at the working surface). 2. The impact of the physical environment on the health of the occupant (example: impact of low natural lighting levels and unsuitable artificial light direction on worker well-being). Since the sample size will be small, conclusions will be of a more exploratory nature unless clear medical causal linkages can be referred to.
- The "case studies with intervention" will be analysed comparing direct before/after health measures. The advantage of this approach is that most of the other confounding factors (such as company culture, work stress etc) are eliminated since the two compared samples include the same workplaces before and after the treatment. Also this sample is small, limiting the statistical validity of the findings. However, because of the nature of the before/after intervention methodology the findings will be more reliable than those from Stream B.

4.5 Sample overview

The following table shows an overview of the three sample streams.

Table 1. Overview of three stream sampling methodology

Stream	**A**	**B**	**C**
	Representative – low level	Case studies without intervention	Case studies with intervention
General			
Sample size (number of offices each with approximately 10-20 subjects per office)	200	10	10
Intervention i.e. HVAC changes, office layout changes etc			X
Performance Evaluation Methods			
Walk-through audit and visual inspection (building features such as lighting type and quality, open-plan vs individual offices, HVAC types, level of individual control etc)	X	X	X
One-off sampling: respirable particulates, CO, viable fungi counting and identification, pollen, dust analysis and count, visual inspection of building or services defects that could cause poor indoor environments	X[1]	X	X
Continuous sampling: CO_2, CO, temperature, RH, particulates, formaldehyde, lighting, noise		2 weeks	2 x 2 weeks pre/post
Survey evaluation (one-off)	X	X	X
Ongoing self-reporting of symptoms during the monitoring period (SF-36)	X	X	X
KPIs (sick days, voluntary overtime etc)	X	X	X
Analysis			
Statistical correlations: design vs health	X		
Causal relationships between physical environment and health		X	X
Statistical intervention analysis (before/after)			X
Approximate Budget			
Intervention cost		(to be third party funded: 10x$40k = $400k)	
Equipment cost	$20k (survey development)	20 sets @ $5k per set = $100k	20 sets @ $5k per set = $100k
Data collection cost	$100k	$160k	$110k
Analysis cost	$50k	$90k	$90k
Project management	$80k	$50k	$50k
Total cost	$250k	$400k (+$400k)	$350k

[1] Sampling may be conducted only on an office level rather than a workplace station level.

4.6 Methodology aspects to consider

4.6.1 Statistical design and robustness

International SBS studies generally cover sample sizes of between 500 and 3000 individuals. Therefore this seems to be an appropriate sample size for this study as well. However, once the type of potentially available office spaces in the three sampling streams is confirmed it is important to conduct a more detailed statistical design. A power analysis will provide essential guidelines on the sample sizes necessary, also enabling appropriate office stations to be selected.

The case studies with intervention will require very careful consideration. The reference data can be collected via two methods:

- Capturing baseline data via use of sample Stream C before the intervention occurred: advantage of elimination of other factors, static sample group; disadvantages include small sample size, Hawthorne effect.
- A control group via use of sample Streams A and B: advantages are large representative sample size; disadvantages are not monitored data, only surveyed for Stream A, different subject groups between streams, other confounding factors (carry-over effects …).

Medical studies traditionally use double blind intervention methods. However, in the intervention stream of this project (Stream C) it will probably be impossible to use a double blind methodology because at least some of the intervention measures will be visible to the subjects. Also the fact that the subjects are aware of the monitoring bears the risk of unintentionally modifying their behavior (Hawthorne effect). Richard E Clark and Timothy F Sugrue (Clark et al 1991 p333) in a review of educational research say that uncontrolled novelty effects cause on average 30% of a standard deviation (SD) rise, which decays to a small level after 8 weeks (50% of a SD for up to four weeks; 30% of SD for 5-8 weeks; and 20% of SD for >8 weeks).

The necessary monitoring timeframe will be governed by the statistical requirements, the practicality of the interactions with the subjects, and the type of the monitoring equipment. Current intention is to conduct one 2 week monitoring period in Stream B and two 2 week monitoring periods in Stream C. This is based on experience from previous similar air quality studies, but more detailed statistical design might suggest that longer monitoring periods are required. The alternatives are to either increase the logging time and in return to reduce the number of workstations which can be covered within the anticipated four year project length. Alternatively, more logging equipment would have to be used in parallel. Our initial assessment is that the 2 x 2 week timeframe will be sufficient to detect any important building and SBS issues, but we recommend confirming this in a small pilot project.

Another potential issue is the “between-subject-variability” which may be substantial, and overwhelm other effects. Also this is a consequence of the limitation of the sample size. There are two alternative solutions: either the study could focus on a subset of subjects with well-known characteristics (non-smokers, 30-45 years old, male etc) and thereby remove at least some of the confounding factors and thus reduce the variability; or the alternative is to have a sufficiently large sample size to control for these other factors. Because the objective of this study is to identify how healthy the New Zealand office environment is in general the study cannot be limited to a subset of subjects if its intention is to be representative for the office population in general. It is anticipated that the “representative – low level surveys” in Stream A will provide a sufficiently large sample set (about 2000 individuals) to control for some of the other factors. Most of the research in the literature uses similar sample sizes suggesting that it is suitable to statistically control for much of the between-subject-variability.

One issue which cannot be dealt with in this sampling approach are time related effects i.e. there is no practical way to conduct a cross-over sampling methodology in Stream C, since any changes to the building are generally irreversible. Should there be time related influences (warm weather vs cold weather, changes in management structure, etc) which are potentially confounding SBS reporting, this will not be captured in this study.

4.6.2 Surveys

The occupational health and safety resource centre at Canada's University of Western Ontario has devised a routine 5-point survey for occupational hygienists to follow when investigating air quality complaints (Federal Facilities Council 2002). Features include:

- a walk-through inspection to look for sources of contamination, such as photocopiers, insulation and cleaning materials
- measurement of temperature, humidity, air movement and other comfort parameters
- measurement of carbon dioxide to assess ventilation efficiency
- measurement of formaldehyde, carbon monoxide, ozone and respirable particles
- examination of the ventilation system for causes of poor distribution, including tests for biological organisms in any water in the system.

From these measurements it will be possible to predict the health complaints of people working in the building; conversely, people's rating of environmental conditions usually correlates well with the measurements obtained with instruments (Burge et al 1987). But this is not always the case: air monitoring tests may show nothing 'abnormal'. This does not mean, however, that people are not sick or that their symptoms are not real. Instruments do not measure things in the same way as humans: they can only measure the 'here and now' and cannot provide a summary of the long-term performance of the building environment as humans can. Also, instruments cannot measure interactions between the various parameters that determine environmental comfort.

A major problem can arise when people look to instruments to validate health complaints (Vischer 1989). If people are too hot and the thermometer shows the temperature to be 25°C, then they are 'right' in complaining. But if a sound level meter gives a reading of only 32 decibels in an office where people complain about noise levels then they are 'wrong' and are told to stop complaining. The assumption is that the instrument tells the 'truth' and people's experience is dismissed as 'subjective' and 'unreliable'.

4.6.3 Questionnaires

In all three data collection streams short daily surveys will capture self-perceived symptoms including eyestrain, lethargy, headache, office environment satisfaction and perceived productivity.

The survey instrument could be a modified SF36 questionnaire and/or one of several publicly available surveys which have been used in other research. Two examples are given in Sections 6.2.1 and 6.2.2.

One-off questionnaires will collect demographic and biographic data which is related to people's health (smoking, blood pressure etc). These questionnaires will also try to capture a series of other job satisfaction related factors which will allow a statistical correction for non-building related factors impacting on staff health and well-being.

The *Indoor Air Pollution: Introduction for Health Professionals* handbook (Colome et al) suggests the following diagnostic checklist to analyse diurnal and other patterns that may provide clues to an occupant's link with indoor air pollution. A diary or log of symptoms correlated with time and place may prove helpful.

- When did the (symptom or complaint) begin?
- Does the (symptom or complaint) exist all the time, or does it come and go? That is, is it associated with times of day, days of the week, or seasons of the year?
- (If so) Are you usually in a particular place at those times?
- Does the problem abate or cease, either immediately or gradually, when you leave there? Does it recur when you return?
- What is your work? Have you recently changed employers or assignments, or has your employer recently changed location?
- (If not) Has the place where you work been redecorated or refurnished, or have you recently started working with new or different materials or equipment? (These may include pesticides, cleaning products, craft supplies etc.)
- What is the smoking policy at your workplace? Are you exposed to environmental tobacco smoke at work, school, home, etc?
- Describe your work area.
- Have you recently changed your place of residence?
- (If not) Have you made any recent changes in, or additions to, your home?
- Have you, or has anyone else in your family, recently started a new hobby or other activity?
- Have you recently acquired a new pet?
- Does anyone else in your home have a similar problem? How about anyone with whom you work? (An affirmative reply may suggest either a common source or a communicable condition.)

4.6.4 Key environmental measurements

Research in SBS has shown that the environmental factors relating to SBS reporting need to be tightly defined. A good overview of the most relevant data parameters is given by Mark Mendell and William Fisk in an electronic letter to the Editor of the *Occupational Environmental Medicine* (Mendell et al 2006). The recommendations are summarised below:

- Different VOC compounds need to be measured separately because irritancy and odour vary among specific volatile organic compounds by orders of magnitude.
- Metrics based on counts of culturable airborne fungi and bacteria do not detect most indoor microbial matter and "provide little information about the microbial status of an indoor environment". Recent research suggests that visible dampness and mould, but not traditional airborne mould counts, are consistently associated with asthma exacerbation and respiratory symptoms in building occupants (Institute of Medicine Committee on Damp Indoor Spaces and Health 2004, Park 2004).
- It is important to record environmental values at a suitable range:
    - relevant CO_2 levels are levels above 500ppm
    - temperatures below 16°C and above 21 or 22°C.[2]

[2] This seems a rather low threshold. Temperatures up to 25°C are generally considered to be within the comfort range in New Zealand.

- A distinction should be made between both extremes on either side of the accepted parameter band i.e. extreme high temperatures should not be treated in the same group as extreme low temperatures.
- Presence of passive tobacco smoke has been shown to be an important factor in SBS reporting.
- In buildings with air-conditioning or humidification measurements of the additional psycho-social variables are important.

The prevalence of SBS should separately evaluate outcomes of biologically related symptom subgroups – rather than using the very non-specific SBS metric (for instance, lumps rash/itch together with cold/flu) which may be sensitive to stress related over-reporting but insensitive to specific biologic effects.

As discussed in other sections of this report one issue with measuring SBS causes and symptoms is the large number of variables and possibly confounding factors. It is therefore important to make the sample size as big as possible. However, this comes at a high capital and operational cost. Building Research has recently funded a project to develop low cost environmental data logging packages which can be applied on office workstations utilising the existing workplace computers. This data logging system is able to log various temperatures, diffuse and directional lighting levels, RH, noise levels and occupancy of the workstation. Most of the environmental sensors are low cost. However, the CO_2 sensors are more complex instruments which come at a significant price ($1000-$2000 each). VOC levels – as indicators of air quality – do not generally vary highly between individual work stations within one open plan office space. It is therefore possible to only record VOC levels at a smaller number of selected workstations and infer the air quality distribution across the whole floor plan from this. Lighting levels, temperatures and background noise levels are more locally isolated and need to be monitored for each workstation separately.

4.6.5 Study participation

It is intended to offer small incentives to encourage participation. The incentive might have to be different for those participating in the more intrusive workstation monitoring Streams (B and C) compared to the simple questionnaire stream participants (A).

Incentive options which were successfully applied in other studies include:

- Lotto scratch tickets
- end of year/study bash with any staff 'compensation' matched by the study organisers
- competition between offices for largest donation to worthy cause
- donation to staff fund/retirement/holiday or similar fund
- free health check-up service at the end of the study.

The free detailed office health check would also be of value to the management. Given that New Zealand has at the moment a very high employment rate social staff services should be valued highly.

Experience from other research (Fleming 2002) suggests that that there will be a high attrition rate, implying that a significant over-sampling is necessary.

A number of potential partner organisations also subscribe to sustainability strategies and specifically to Triple Bottom Line reporting. Investments in the study of staff well-being are a tangible contribution to the social component of corporate sustainability. If the study uses one of the compensations above or similar, it would support staff morale which is desirable from a management point of view.

4.6.6 Other than building factors

Recent work at the University College London suggests that buildings are only responsible for part of the symptoms associated with SBS (Marmot et al 2006). According to this research work related stresses are responsible to a larger degree than the built environment. However, the majority of literature over the last years has confirmed the importance of building environment factors. Literature has repeatedly reported that both factors are relevant. This research will therefore need to capture other than building related factors in its data collection and identify their significance in comparison to the building related factors. Multi-correlation analysis will be a useful statistical tool to quantify the importance of building environment related factors compared to psychosocial factors.

Many variables vary across the office floor. This provides the opportunity to assess workstation impacts while leaving other confounding factors (company culture, management, etc) constant.

Due to data logging cost and availability of equipment each case study can be monitored only for a short period of time (approximately two weeks). However, the impact of the building on occupant health is often seasonally dependent (cold temperatures and drafts during the winter, availability of natural ventilation through window openings in the summer etc). Due to cost reasons it is suggested to apply statistical correction methods rather than re-sampling during different weather conditions, in order to correct for these factors.

5. STATUS OF NEGOTIATIONS WITH POTENTIAL RESEARCH PARTNERS

5.1 Massey University

Several meetings were held with Dr Robyn Phipps from Massey University. Her input into the design of the research methodology was vital and her participation in the research proved to be critical. Massey University has a long history of air quality research. The level of expertise and the access to suitable air quality logging equipment will offer significant benefits in terms of research quality and project cost.

5.2 ESR

A meeting was held with Dr David Slaney and Tammy Voice from ESR and Dr Robyn Phipps from Massey University. ESR’s most relevant current research focus is environmental epidemiology. ESR had conducted ecological studies (exposure-disease associations among groups of people), exposure assessment of chemicals/substances and tested associations for measured exposures in the built, natural and occupational environments with a variety of health outcomes.

Standard methods for environmental epidemiology include those used in clinical studies and infectious disease epidemiology, as well as those specific to occupational studies, and a variety of new and emerging methods to study large populations and diffuse exposures.

Another relevant area of expertise is exposure and risk assessment identifying exposure to environmental chemicals and natural agents using detailed sampling techniques specific to the medium being tested. Because in most cases available data (or the funding available to collect the data) is insufficient to describe the exposure of interest with complete certainty, ESR applies statistical methods describing hypothesised exposure pathways and concentration ranges to derive intake values for individuals.

This expertise will be a valuable contribution to this research project. Dr Slaney was interested in participating in the research project. Although ESR is generally a research provider rather than a research funder, one identified opportunity is to use an ESR PhD scholarship program to fund a PhD student to work on this research project.

5.3 Marie Fleming, MEFDesign Ltd.

Marie Fleming was the lead researcher of a New Zealand study on the associations between health symptoms, environmental satisfaction and productivity of data entry personnel (Fleming 2002). We asked Marie for a peer review of the draft research methodology. A number of helpful issues were highlighted by her.

Although lighting is generally not considered one of the core factors causing SBS the study found that office personnel perceived that their productivity and work satisfaction were strongly affected by the eyestrain, headache and lethargy symptoms they experienced. Further, their perceived productivity was significantly associated with satisfaction with the air circulation, lighting, temperature, job satisfaction and the overall work environment. The actual productivity of participants was related to eyestrain and lethargy symptoms experienced in the workplace.

Marie offered to function as a peer reviewer for the healthy office research project. Given her extensive practical experience in that field it is strongly recommended to include her in the research team.

5.4 Gilmour McGregor and Associates Limited

A brief discussion with Ross Gilmour from Gilmour McGregor and Associates Limited (consultant psychologists) regarding physiological and psychological measurement methodologies of performance in workplaces suggests that specifically workplace fatigue has recently been identified overseas as a health and safety workplace issue. Methodologies for measuring fatigue are now being further developed and can possibly be applied in this research project.

5.5 FRST/VUW/Opus

The intention of this research was to align with a simultaneous study funded by FRST on productivity in the workplace. This would have offered a range of opportunities to align data collection and reduce cost. However, FRST declined funding of the productivity research proposal.

The FRST productivity research proposal was developed by a group of scientists from BRANZ, Victoria University and Opus. This group still believes that there is significant benefit in researching this topic and that there is an opportunity to combine the health research with the investigation of productivity. In the Appendix is a copy of the productivity research project as it was proposed to the Foundation. This can be used as a starting point for a project design should Building Research be interested in broadening the research objective.

BRANZ has also applied for a new FRST project aimed at investigating energy performance in office buildings (Building Energy Efficiency Project – BEEP). The achieved indoor environment is an important aspect of this research and there are clear alignments with the objective of this research.

5.6 Ministry for the Environment (MfE)

In a discussion with Chris Wood from MfE in mid-2006 he suggested that they were generally very interested in this topic. A 2006 report, *Value Case of Sustainable Buildings* (Fullbrook 2005), addressed some of the issues of added benefits of good sustainable design touching on the issue of healthy office buildings. However, at the time MfE did not have any significant funds available which could support a large research project into this topic. Chris Wood suggested that MfE's role is to facilitate the set-up of such a project. The Gov3 initiative might offer an opportunity to access a large number of office buildings and might provide contrasting office performances for the monitoring,

Chris also suggested two industry contacts (New Zealand Post and Westpac) which have been followed up.

5.7 ACC

Discussions were also held with Daryn Jemmett and Michael Wilson from ACC regarding SBS claims. A brief analysis of the cost of claims related to occupational activities which are related to chest or lung treatment only make up less than 0.2% of the ACC claims (ACC 2006). The impact of the office environment on occupant health is obviously much more subtle and the ACC statistics would only capture the most extreme cases. However, health in buildings does therefore not seem to be a significant issue and hence there is little likelihood of getting co-funding from ACC.

One option to possibly attract ACC's interest might be to extend the research brief and include physical accident hazards in the study, which make up a larger proportion of the ACC claims. This would obviously add another research component and increase the corresponding cost.

5.8 Treasury

A brief discussion was held with Hamish Grant-Fargie of the Social Policy Branch at The Treasury.

Hamish expressed interest in any findings of the research. However, this issue was not an area identified as a priority for resources in 2006/07. Hamish referred to the Department of Building and Housing and MfE as having primary responsibility for the areas involved in the research.

5.9 Westpac

Discussions were held with John Baldwin, Manager, Building Facilities at Westpac Properties. Westpac had some years earlier commissioned a study on worker productivity associated with lighting quality. The results of the study suggested some benefits from good lighting but no further action has followed the work. John Baldwin was prepared to consider participating in the project by allowing access to Westpac offices. Also the possibility of co-funding of the study was discussed, but a clear commercial case would have to be made for this.

5.10 New Zealand Post

A meeting with Patrick Homan, Manager, Facilities Management at New Zealand Post, also concluded general interest from them in participating in a healthy office project, but no firm agreements were reached.

5.11 Waitakere City Council

Waitakere City Council is interested in having their new council buildings evaluated for health (and productivity) benefits. The council would allow in-kind access to any health and productivity KPI records, and may possibly contribute a small amount of co-funding.

6. APPENDICES

6.1 FRST research proposal on productive workplaces

Productivity improvements in the well designed office work environment

Short Title:	Productive Workplaces
Proposal No:	CONC-11342-SET-VICLINK
Total funding per annum (GST inclusive)	$475,000
Total funding (GST inclusive)	$1,900,000
Number of years funding requested:	4 years
Contractor:	Victoria University of Wellington
Contract Manager:	Mr Hew Norris
Science Leader:	Mr Michael Donn
Contact Person:	Mr John Gibson
Contact Email:	John.Gibson@vuw.ac.nz
Contact Phone:	04 463 5121
Special Flags:	New proposal (not linked to previous FRST contract(s))

Concept summary

Research overview:

This research project investigates the hypothesis that the effect of office workplace environments on productivity can be quantified. The project will produce a tool that building procurers renting or buying a new or existing workplace building can use as input to their investment decisions which provides quantitative information on the impact on workplace productivity of building design features such as windows, shades and controls that affect workplace environmental quality. This will make workplace environmental quality and the associated productivity gains an integral part of 80% of building procurement investment strategies for new and existing buildings within 10 years of project completion.

This programme of research will adapt and apply existing building and productivity evaluation methodologies for office buildings and quantify productivity improvements as a function of building design contrasted against three social influences on workplace productivity: perceptions of management, the effect of co-workers, and the policies and visions of the employer.

Outcome benefits to New Zealand

Most economic activity takes place in buildings and structures of some sort. This applies especially to the service industries which account for about 25% of New Zealand's GDP. The impact of buildings on national productivity is therefore significant. Property Council figures for typical New Zealand workplaces suggest energy use during operation and the energy investment in buildings is some 2 to 5% of the cost of running a business whereas personnel costs are over 80%. Yet investment in the services and systems to provide quality environments within which this resource can work productively is where costs are cut first in building construction. This is largely because the impact is seen as affecting the enterprise only marginally in terms of energy use. The connection to productivity is not transparent to decision makers.

The outputs from this research will provide investors with the information linking their investments in premises to productivity. The immediate outcome will be to alter radically investment in new owner-occupied buildings. The longer term effect will be on the rental market as firms look to rent buildings that provide work environments that have a positive effect on productivity.

International research suggests that workplace design features such as controllability of personal environment, view, daylight, and natural not mechanical ventilation lead to productivity gains between 1 and 3%. Some literature indicates gains can be as high as 5 to 10%. In the mid-range of these, at 3%, the effect on New Zealand's GDP in service industries alone would be an increase of over $1b, with additional environmental benefits such as a reduced loading on national electricity demand. Even assuming a conservative 1% increase in productivity in only 50% of the service industries will result in an annual $170m GDP increase.

There are many competing proponents of building design features for improved comfort and hence productivity. Evidence that actually links productivity to some of these is urgently needed. This project uses a leading edge research methodology that goes beyond short-term evaluation of individual case studies and thus requires a coordinated long-term commitment. Although there are significant national and commercial benefits to a number of stakeholders, neither the construction industry nor the services industry have suitable frameworks or mandates to support such a research project. Building Research is interested in a small project on health in commercial buildings, but this is motivated more by regulatory and public liability issues than commercial drivers such as productivity. The research team is involved in this effort and will ensure close alignment of the projects should they both eventuate.

Pathway to implementation

Members of the team have used FRST funded research in recent years to: advise the development of national standards for energy efficiency in buildings; assist DBH and EECA to formulate the energy efficiency parts of the Building Code for houses and for non-residential buildings; contribute to the Wellington City Council formulation of comfort and safety criteria for wind tunnel tests of Central Business District buildings; develop building design tools such as the Annual Loss Factor method used as the NZBC Verification Method for the energy efficiency Clause H1; publish numerous BRANZ industry publications and educational services.

Clearly VUW has significant multiplier effects through its teaching. The team leader was contracted in 2000 to write a book on solar house design which has influenced the writing of two standards, plus the current review of the Building Code. BRANZ's core business is to provide technical advice and education to the construction industry, building owners, users and policy makers, and does that through its comprehensive network into the construction industry. Opus is not only a 'research provider', but has extensive expertise in architectural and environmental consultancy which these research results would affect directly. eCubed Building Workshop work to provide sustainable buildings and regularly use workplace assessment tools similar to those proposed here. Current clients include the Department of Labour and Inland Revenue.

The biggest barrier to good quality workplace environments at present is the lack of information connecting investment in building design to productivity. The team has identified and approached a number of key stakeholders and international research partners. These have provided valuable input into the research design and indicated there is a strong likelihood that the type of tool we are planning to produce is highly likely to change investment decisions in building. They have also indicated a strong interest in participating in the research in reference groups, the selection of the case study participants and eventually in tech transfer activities. This close end-user integration guarantees that the research is outcome focused and will provide practical outputs to the end-users. Our international collaborators are interested to gain further case studies for their own researchers and to learn from the team's unique combination of social science and building physics approaches.

The output of the work is practical and transferable across most service industries that use buildings. The research clearly has national importance and can be adopted nationwide and across even wider economic sectors such as government, education and health. The effect of providing quantitative evidence of links between building environment and productivity/ performance can bee seen in the USA, where school design has changed radically since the publication of research linking daylight quality to school test scores by the Heschong Mahone group, one of our international collaborators.

Specific organisations that have agreed to be involved include: *Business New Zealand, FINSEC, Property Council of NZ, Wellington Chamber of Commerce, Department of Labour, and call centre organisations such as 'AM PM Calling Centre'.*

Research, science and technology benefits to New Zealand
The objective of this research is to answer the following question which has not been answered in all studies of workplace environments over the past 20 years: *What is the magnitude of potential productivity gain from specific building design strategies?*

There are numerous international empirical studies that prove a general link to design in general. This project, however, attempts to demonstrate: (1) the causal link between workplace design and the indoor environment; and (2) the impact of the environment on staff productivity.

The research approach will use established surveys and measurement processes developed by our partner organisations in North America and the UK in order to align with international norms for New Zealand. Productivity will be defined by integrating subjective impressions of workplace performance, objective measures correlated with productive output (e.g. health and well-being of workers), objective measures of activity, and external observations of activity/productivity. Physical monitoring of the environment (temperature, day-lighting, noise, etc) will take place contemporaneously using office workers' personal computers providing the opportunity to measure worker activity, obtain perceived influence of social context and to monitor the physical environment. Managing the 'confounding' productivity influences is the single most challenging aspect of this research project and requires significant scientific 'stretch'.

The project integrates the team's experience in direct measurement of building performance, social science based studies of human comfort and attitudes, and energy performance studies of workplaces. This unique mix of skills and experience, together with the already initiated international collaborations will quantify productivity as a function of building design for the first time. Our initial inquiries with international peers have already led to three specific expressions of interest for collaborative work and exchange of research students with world-leading research organisations. This will significantly increase the team's future research capabilities in this field.

Ability to deliver research
This will be the fourth major FRST project involving members of the team. OPUS and VUW collaborated on two projects in the late 1990s on sustainable urban buildings and environments. BRANZ and VUW collaborated more recently on the Zero and Low Energy House project.

Not only do all parties have direct experience of working within the FRST funding guidelines, but they also have 45+ years combined experience of working as research contractors for outside bodies. Also BRANZ and VUW have experience of contributing to International Energy Agency collaborative research projects.

Two methods will be applied to control or measure within-group and between-subject variance: (1) a repeated measures design of the same office workers (N=500) in new physical locations; and (2) a case-control design (N=1000) to assess the generalisability of the findings established for office workers to other similar productive sectors (e.g. education) by examining different industries. For the first of these, the planned research strategy is to work with eCubed Building Workshop, a firm of building design practitioners who are involved in design and analysis of advanced sustainable buildings and systems. They will identify organisations which are constructing and moving into new buildings. They currently administer international standard “before and after” Post Occupancy Evaluation surveys to their clients.

Specific international links have been discussed with colleagues in the USA and the UK. These people have through their publications defined the current state-of-the-art in the general understanding of the effect of buildings on people’s well-being. They have expressed a strong interest in the contribution of the proposed work to their work investigating productivity benefits and costs of environmental qualities of offices. The project budget at present includes an allowance for managing the relationships with international research collaborators. This will be fully costed if the proposal proceeds to the next stage. The proposal envisages regular reciprocal exchange between Wellington and laboratories in the USA and the UK of a significant number of researchers to the benefit of both teams.

6.2 Sample questionnaires

6.2.1 Questionnaire Sample 1

A typical office work environment survey aimed at identifying SBS symptoms is given below (London Hazard Centre 1990).

Part 1: Demographic information
Name: (please leave blank if preferred)
Building/Floor/Room: (as appropriate)
Job type:
Smoking habits:
Hours per day spend in building:
Office equipment used:

Part 2: Subjective evaluation of working environment
Do you experience the following conditions in your working environment?

	Always	Often	Sometimes	Never
Too little air				
Too much air				
Too dry				
Too moist				
Too hot				
Too cold				
Too bright				
Too dim				
Glare on surfaces				
Too noisy				
Too quiet				
Smoky				
Stuffy				
Unpleasant odours				

Part 3: Health-impaired symptoms

Do you experience any of the following complaints in your workplace? Also, please indicate if the problem is consistently more common in the afternoon than in the morning.

	Always	**Often**	**Sometimes**	**Never**	**More common in the afternoon**
Dry or sore throat					
Skin dryness					
Skin rashes					
Eye irritation					
Contact lens problem					
Runny nose					
Stuffy nose					
Difficulty in breathing					
Chest tightness					
Flu-like symptoms					
Headache					
Dizziness					
Nausea					
Drowsiness					
Lethargy					
Aches in arms					
Chest pain					
Backache					
Menstrual problems					
Impotence					

Part 4: Degree of control over environment

	None	A little	Some	Mostly	Complete
Temperature					
Ventilation					
Humidity					
Lighting					
Noise					

Please add any additional comments: ……………………………………………

6.2.2 Questionnaire Sample 2

This questionnaire was published by the Federal Facilities Council (Federal Facilities Council 2002).

Welcome to the Building-In-Use Assessment Survey!

This questionnaire is for all staff. We want to find out more about how you feel about the facility you work in, and how you feel this environment affects your work.

Below you will find a checklist of items about your workspace. Please answer these questions as soon as you receive the questionnaire. It will take you less than 10 minutes to complete. **When you have filled it out, please return it immediately**.

Please do not fill out the ID number on this survey form. It is used for analysis purposes. However, please provide your office location in the space provided, as this will help us understand the building conditions at your work location. Your name is not necessary on the questionnaire and your answers will remain confidential.

We really want to hear from you. Thank-you for participating!

PLEASE FILL OUT THE FOLLOWING: **Office or cube number _________________**

Floor _________ Workgroup or department name _______________________

Please rate your comfort level in your primary workspace on the following scales, where **1** is poor or uncomfortable and **5** is good or comfortable, and **2-3-4** are inbetween, with **3** being neutral. **Your task is to circle the number on each scale that best represents your experience of working in this building**.

1. Temperature comfort:				
1	2	3	4	5
GENERALLY BAD				GENERALLY GOOD
2. How cold it gets:				
1	2	3	4	5
TOO COLD				COMFORTABLE
3. How warm it gets:				
1	2	3	4	5
TOO WARM				COMFORTABLE
4. Temperature shifts:				
1	2	3	4	5
TOO FREQUENT				GENERALLY CONSTANT
5. Ventilation comfort:				
1	2	3	4	5
GENERALLY BAD				GENERALLY GOOD
6. Air freshness:				
1	2	3	4	5

STALE AIR				FRESH AIR
7. Air movement:				
1	2	3	4	5
STUFFY				CIRCULATING
8. Noise distractions:				
1	2	3	4	5
DISTURBING				NOT A PROBLEM
9. General office noise level (background noise from conversation and equipment):				
1	2	3	4	5
TOO NOISY				COMFORTABLE
10. Specific office noises (individual voices and equipment):				
1	2	3	4	5
DISTURBING				NOT A PROBLEM
11. Noise from the air systems:				
1	2	3	4	5
DISTURBING				NOT A PROBLEM
12. Noise from office lighting:				
1	2	3	4	5
BUZZ/NOISY				NOT A PROBLEM
13. Noise from outside the building:				
1	2	3	4	5
DISTURBING				NOT A PROBLEM
14. Furniture arrangement in your workspace:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE
15. Amount of space in your workspace:				
1	2	3	4	5
INSUFFICIENT				ADEQUATE
16. Work storage:				
1	2	3	4	5
INSUFFICIENT				ADEQUATE
17. Shared (team) file storage:				
1	2	3	4	5
INSUFFICIENT				ADEQUATE
18. Personal storage:				
1	2	3	4	5
INSUFFICIENT				ADEQUATE
19. Visual privacy in your workspace:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE
20. Voice privacy in your workspace:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE

21. Telephone privacy in your workspace:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE
22. Electrical lighting:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE
23. How bright lights are:				
1	2	3	4	5
TOO MUCH LIGHT				DOES NOT GET TOO BRIGHT
24. Glare from lights or windows:				
1	2	3	4	5
UNCOMFORTABLE				COMFORTABLE
25. Natural lighting from windows:				
1	2	3	4	5
INSUFFICIENT LIGHT				GOOD NATURAL LIGHT
26. Not enough light:				
1	2	3	4	5
TOO DARK				COMFORTABLE
27. Please rate how this space affects your ability to do your work:				
1	2	3	4	5
MAKES IT DIFFICULT				MAKES IT EASY
28. How would you rate your satisfaction with this building?				
1	2	3	4	5
DISSATISFIED				VERY SATISFIED

PLEASE COMMENT:

29. What I **like best/find most useful** about this building as a place to work:

30. What I **dislike most/have most trouble** with in this building as a place to work:

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