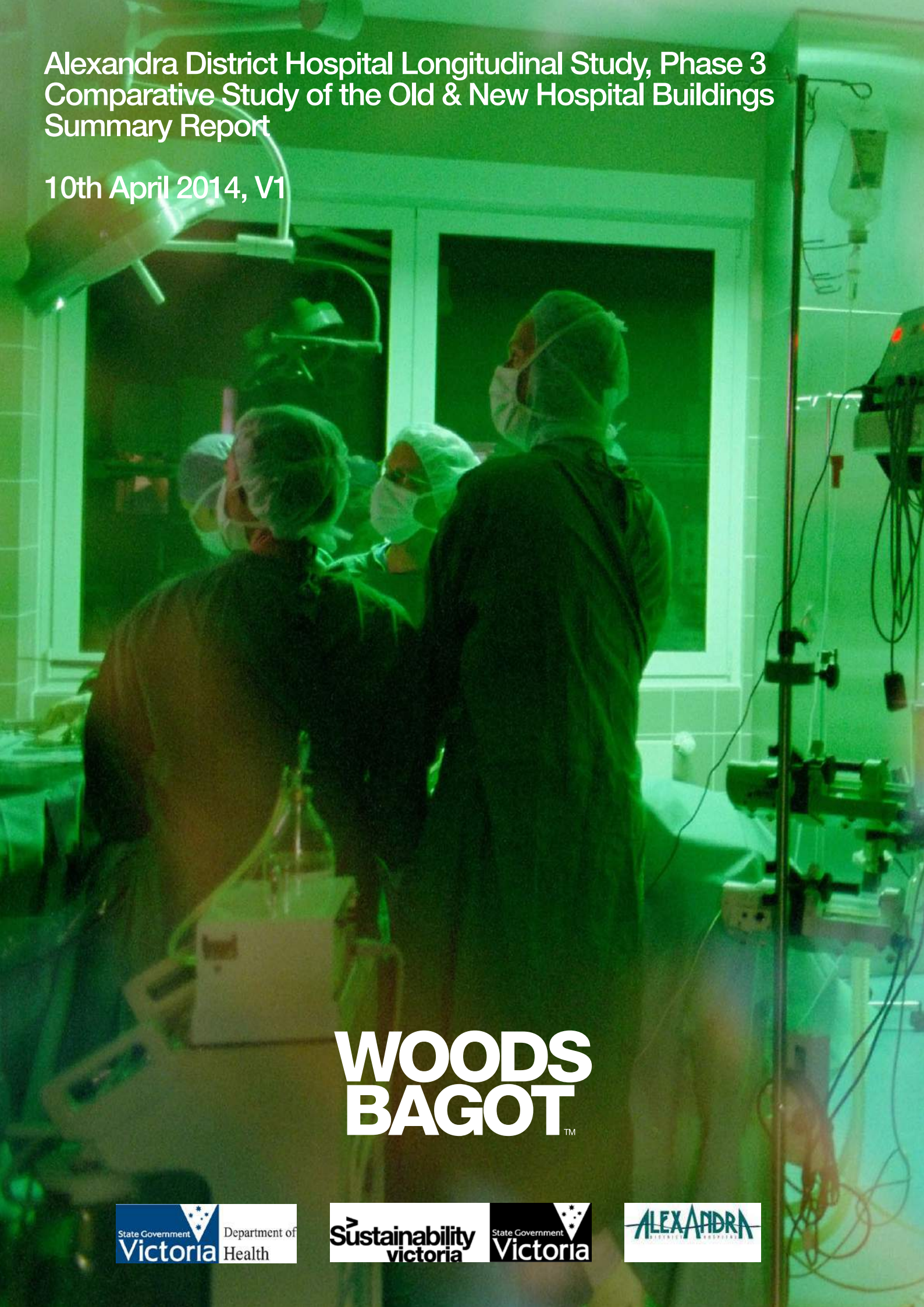
Alexandra District Hospital Longitudinal Study, Phase 3
Comparative Study of the Old & New Hospital Buildings
Summary Report

10th April 2014, V1



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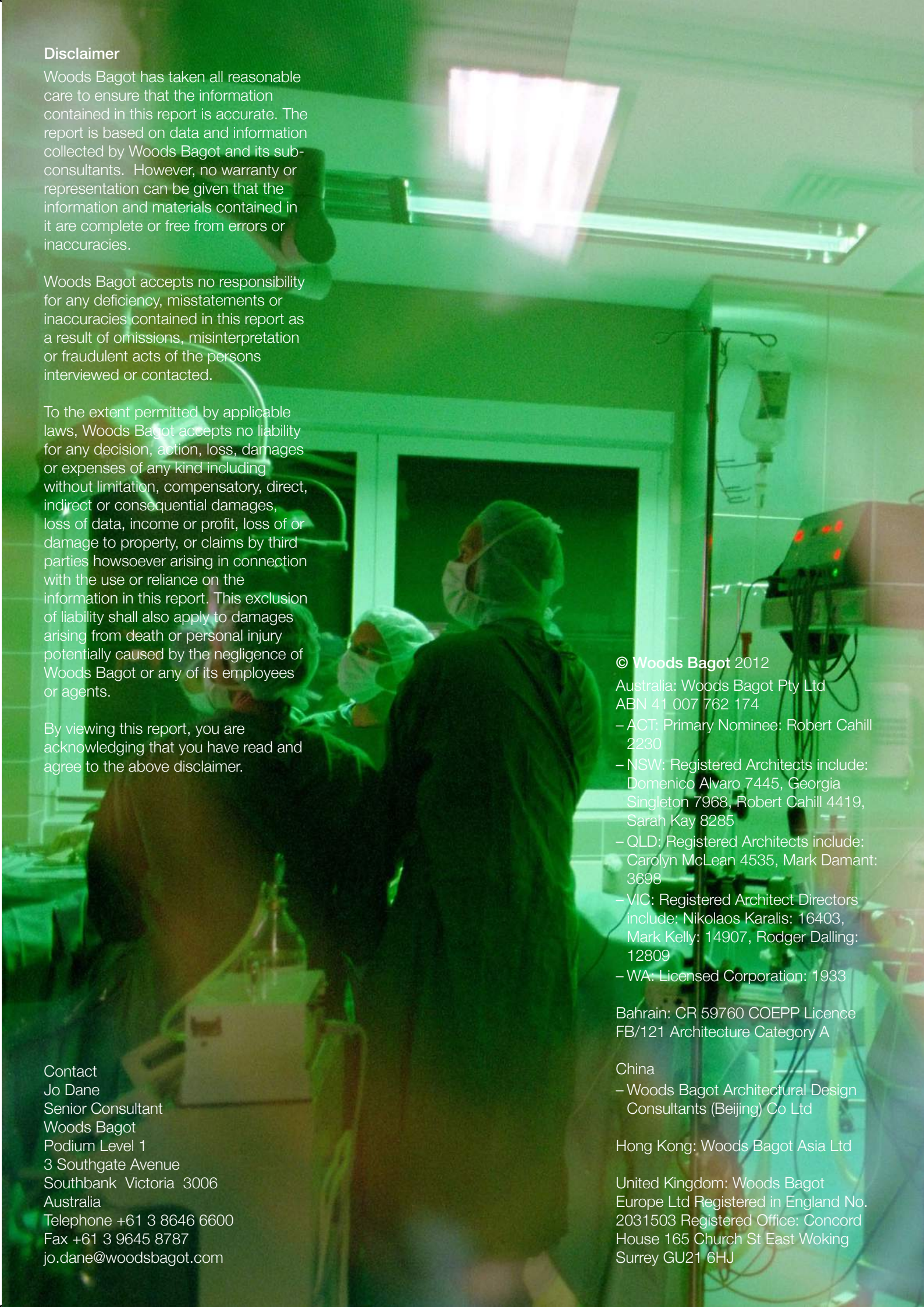

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Acknowledgements

This report draws on pre and post occupancy data collected at the Alexandra District Hospital, to investigate Indoor Environmental Quality, a study commissioned by the Department of Health and Sustainability Victoria and undertaken by Woods Bagot and CETEC.

We acknowledge the project management and direction provided by Tiernan Humphrys from the Department of Health, and the expertise of Vyt Garnys, Jack Noonan & Tim Callinan and the team from CETEC.

Finally, we thank all the staff from the Alexandra District Hospital who participated in the Study, but in particular CEO/DON Heather Byrne who provided leadership and support, and Juliana Sartori, who managed the data collection process at the Hospital. We could not have done this without such amazing cooperation.

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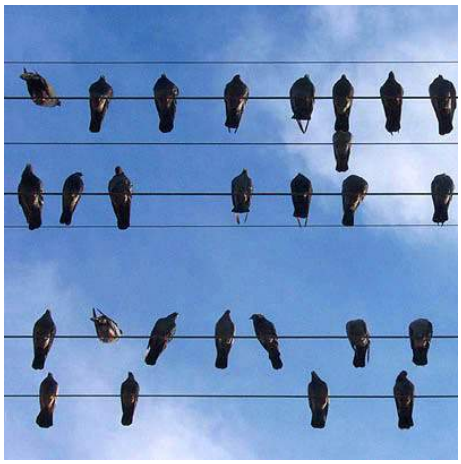
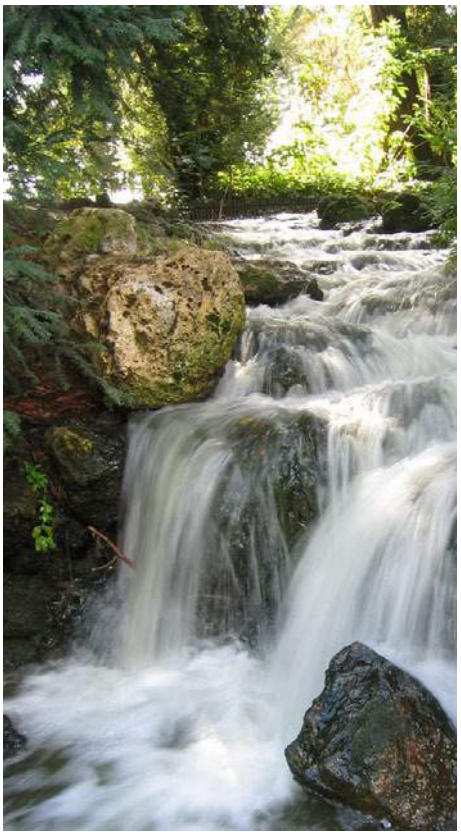




This report encompasses the findings of a longitudinal study that sought to compare quantitative IEQ data and qualitative patient and staff data between the old and new Alexandra District Hospitals. The purpose of the Study was to investigate whether or not a healthy hospital building leads to better patient outcomes and improved staff productivity. By evaluating the old Alexandra District Hospital and comparing findings with evaluations in the new hospital building, it was intended that the findings would contribute to a wider body of research that supports the healthy building / better outcomes contention.

The Study extended over four years and through three specific data collection periods. The first survey period was undertaken in the old hospital in 2011. The second survey period was undertaken in the new hospital in 2012, six months post occupancy. And the third survey period was undertaken in the new hospital in 2013 approximately two years post occupancy.

Following three periods of data collection at both the old and new Alexandra District Hospitals, the combined findings of the Longitudinal Study, comparing a variety of environmental factors, contributes significantly to the contention that a healthy building leads to better patient outcomes and greater staff productivity.

This study has interrogated Indoor Environment Quality (IEQ) through quantitative measures and qualitative responses from staff and patients, many of whom have experienced both hospital environments. Staff and patients were asked to rate their degree of satisfaction of specific conditions throughout the old and new buildings, from acoustics, lighting and air freshness to space planning and views. Staff and patient satisfaction was considered a fundamental signifier for better patient outcomes and increased staff productivity, as literature in the field of 'healthy building design' consistently reports this correlation.

It is acknowledged that staff and patients in the old Hospital building provided relatively high satisfaction ratings, with the lowest satisfaction reserved for air quality and acoustics. What is noticeable in comparing data from the old and new hospitals is the reduced levels of dissatisfaction in the new hospital building. Where the old hospital building received very positive satisfaction ratings, such as quality of natural light and staff ability to concentrate on their work, the new hospital building received even higher satisfaction ratings.

Following the second survey period (new hospital) there were two noticeable exceptions, both of which were conditions planned to be rectified prior to the third survey period (new hospital). These included:

a) thermal comfort in the new building (due to balancing issues of the HVAC system post occupancy); and
b) the lack of landscaping surrounding the new building

01.01 Executive Summary

By the time the third survey (new hospital) occured, there were still ongoing issues with the HVAC system, resulting in continued dissatisfaction by staff and patients in terms of thermal comfort. This was supported by CETEC measurements which indicated lower temperatures than recommended guidelines. It is anticipated that this issue will be fully resolved in the near future.

Landscaping had been undertaken around the hospital grounds before the third survey period, and this was noted by some patients as something that will improve with time as the plants mature.

The third survey period in the new hospital also revealed increased dissatisfaction with acoustics in the hospital, particularly by nursing staff and relational to the location and design of the nurse's station. However, it is important to note that dissatisfied respondents represented a minority of staff.

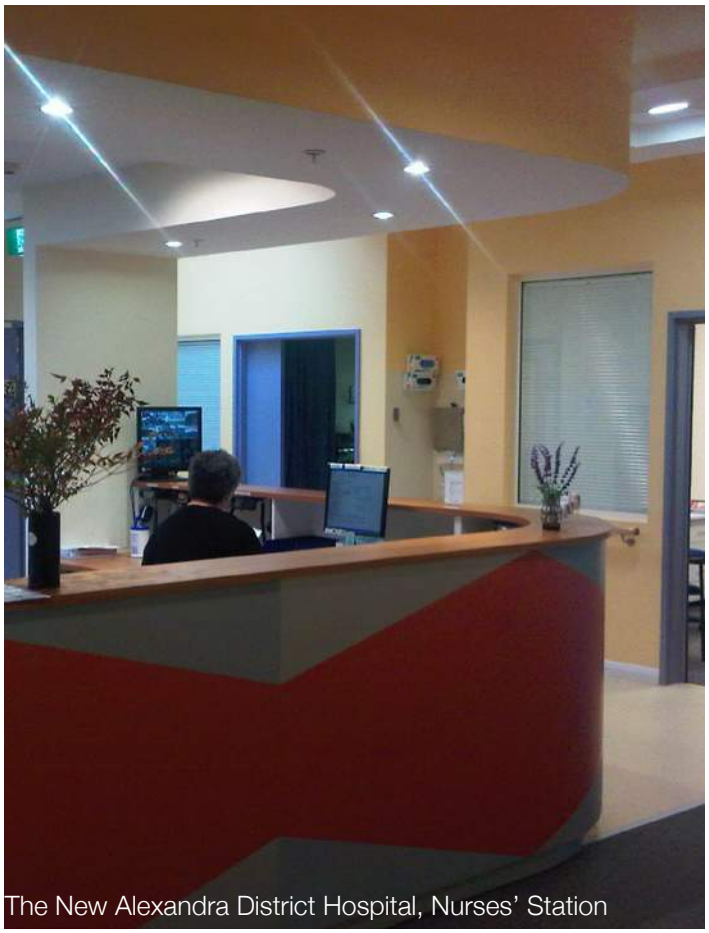
As a result of evaluations of the old and new Alexandra District Hospitals the following observations have been verified through the third survey data:

- Acoustics in the new hospital represent an improvement when compared to the old hospital, but some areas were measured above recommended sound levels.
- Patients expressed the positive influence that several IEQ characteristics have had on their recovery, for example, air freshness, quality of light and acoustic comfort.
- Staff expressed the positive influence that several IEQ characteristics have on their ability to complete their work tasks, for example, air freshness, quality of light and space planning.
- The greatest source of dissatisfaction for patients in the new building was thermal comfort.
- Some staff expressed dissatisfaction with acoustic and temperature comfort in the new building, both of which rated lower than in the old hospital.
- For patients who had experienced both the old and new hosptial buildings, they overwhelming responded that all IEQ characteristics in the new building represented an improvement on the old building.
- For staff who had experienced both the old and new hospital buildings, in most cases they responded that building characteristics had improved or significantly improved their ability to complete work tasks compared to the old hospital.

There are several indicators demonstrating how the new hospital environment is a greatly improved environment to work in. This supports the contention that a healthy hospital building does lead to increased staff productivity and improved patient outcomes. As a stand-alone study it is impossible to draw such an unequivocal conclusion, but the evidence compellingly supports the contention.

The New Alexandra District Hospital, entry


The New Alexandra District Hospital, patient bed


The New Alexandra District Hospital, Nurses' Station

02.01 Introduction
Project Background

REPORT PURPOSE AND STRUCTURE

The purpose of this report is to support the contention that a healthy building leads to increased staff productivity and better patient outcomes. While this Study alone does not unequivocally demonstrate these positive staff and patient outcomes, it will lend weight to this argument in the context of the broader existing literature on this topic.

The report has been structured to review IEQ factors, from the quantitative measures undertaken by CETEC to the qualitative responses by staff and patients in relation to the same IEQ factors. Furthermore, other topics have been explored in relation to staff productivity and satisfaction – notably patterns of sick leave and annual leave, and qualitative responses to space planning and design.

This study is unique in that it is one of the first of its kind to be undertaken in Australia and will significantly add to the body of research in this field.

METHODOLOGY

The methodology has consisted of a four part process, undertaken once at the old hospital building, repeated in the new hospital building 6 months after occupation, and again after 18 months. Firstly, each evaluation incorporated a quantitative measure of IEQ by CETEC, undertaken in multiple locations on each site, and repeated morning and afternoon.
Secondly, staff were invited to complete a hard copy or web-based survey.
Thirdly, patients were invited to complete a hard copy survey at discharge.
The fourth component of the methodology process was the collection of de-identified staff data relating to hours of sick leave and annual leave expended.

The surveys were undertaken in accordance with and the approval of the Department of Health Human Research Ethics Committee (Project number 23/10).

Collected data has been analysed in a comparative sense, but also in the context of research relating to the IEQ impact of healthcare environments.

WEB-BASED SURVEY

The web-based survey developed by Woods Bagot Consulting was designed to investigate the key research question, 'do healthy buildings lead to better patient outcomes and greater staff productivity?' Two sets of questions were developed, one for patients and the other for staff. Both sought to explore patient and staff perceptions of various aspects of the physical environment, ranging from their satisfaction with IEQ characteristics, to how other attributes may influence recovery (for patients) and ability to undertake work tasks (for staff). The literature strongly supports a correlation between productivity and staff satisfaction, hence the focus in the staff surveys to probe issues of satisfaction (Ampt et al. 2008; Mroczek et al. 2005). Similarly, research indicates a strong link between patient recovery times and physiological responses to attributes such as natural light, pleasant views and acoustic comfort (Ampt et al. 2008; Lorenz, 2007; Ulrich, 1984). Hence the structuring of questions relating to these characteristics of the hospital environment.

Questions are organised under the following categories:
Patients:
- Number of beds in a patient care room
- Length of stay
- Outlook through window
- Quality of light, temperature, air and acoustics

Staff:
- Individual work area
- Distance from natural light
- Outlook from various facilities
- Space planning & wayfinding
- Design and aesthetics
- Quality of light, temperature, air and acoustics

Patients and staff were also invited to provide qualitative statements about aspects of the environment. Both surveys were developed as hard copy surveys, but staff also had the choice of completing the survey online. The majority of questions incorporated a 5-point Likert scale.

The base line data was generated through a post occupancy evaluation of the old Alexandra District Hospital buildings and compared to an almost identical post occupancy evaluation of the new Alexandra District Hospital. It was expected that most characteristics of the new hospital building would demonstrate improved satisfaction ratings and perceptions of recovery (for patients) and ability to undertake work tasks (for staff). Together with the quantitative measurements of the Indoor Environment Quality (IEQ), and other signifiers of patient recovery and staff productivity, it was hypothesised that the findings of this Study would enable conclusions that a healthy building does lead to better patient outcomes and increased staff productivity.

02.02

Introduction
Patient demographics

Data collection period: 11th November - 21st December 2013

The data collection period of the new Alexandra District Hospital was from 11th November to 21st December 2013. During this time approximately 195 No. inpatients were admitted to the hospital. Only 12 inpatients responded in full to the survey, representing 6% of potential respondents. This low response rate is attributed to the elderly demographic of patients, many of whom may have been incapable of completing the survey. In previous surveys, there were 26 No. patient respondents in the old hospital and 19 patient respondents in the new hospital.

The demographics of inpatients in both the old and new hospitals are remarkably similar. There was a dominance of inpatients aged over 65 years. During the third survey period there were no respondents aged between 18 – 45 years. The majority of patient respondents in first two data sets were female, but in the third (most recent) data set the majority of respondents were male. The length of stay of most inpatients in both the old and new hospitals was less than one week: 84% in old hospital compared to 64% (2012) and 75% (2013) in the new hospital. In the most recent data collection period, none of the respondents had stayed in hospital for more than 3 weeks.

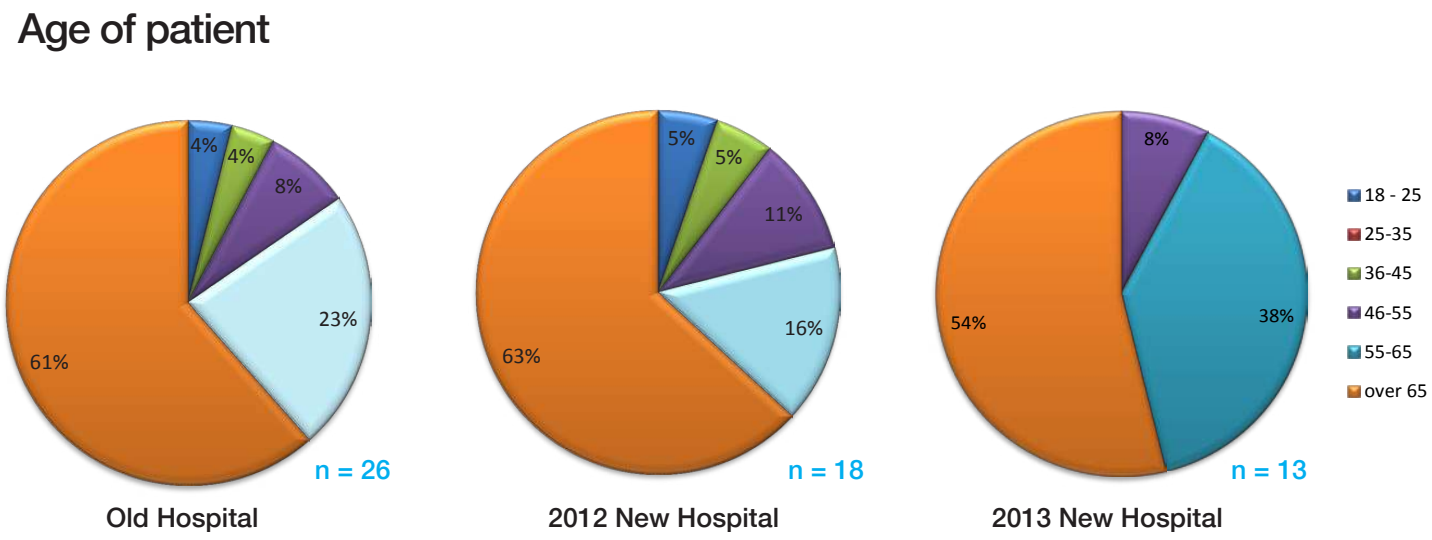


Figure 1, Age of patient respondents for old and new hospital surveys

02.02 Introduction
Patient demographics

Gender of patient

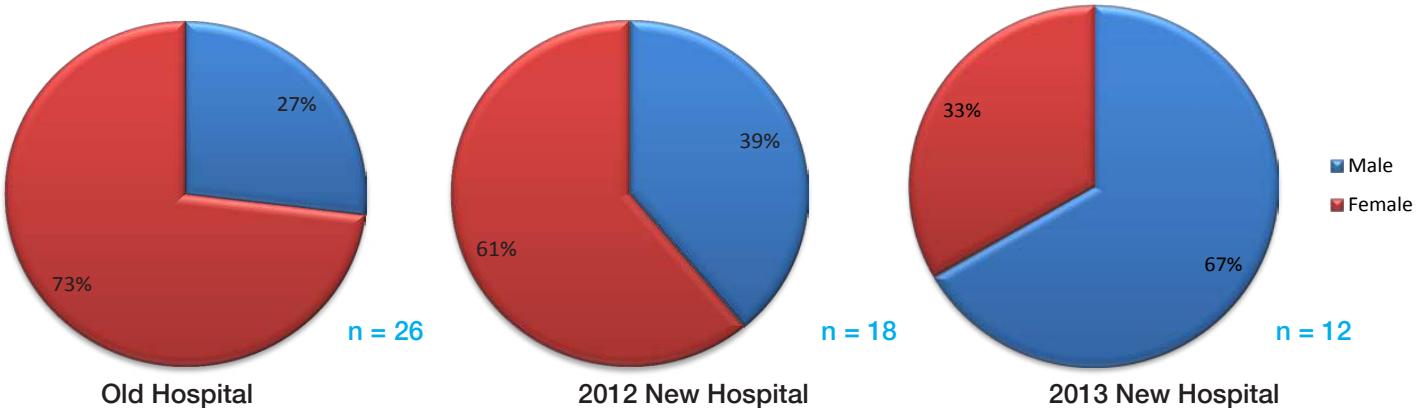


Figure 2, Gender of patient respondents for old and new hospital surveys

Length of stay

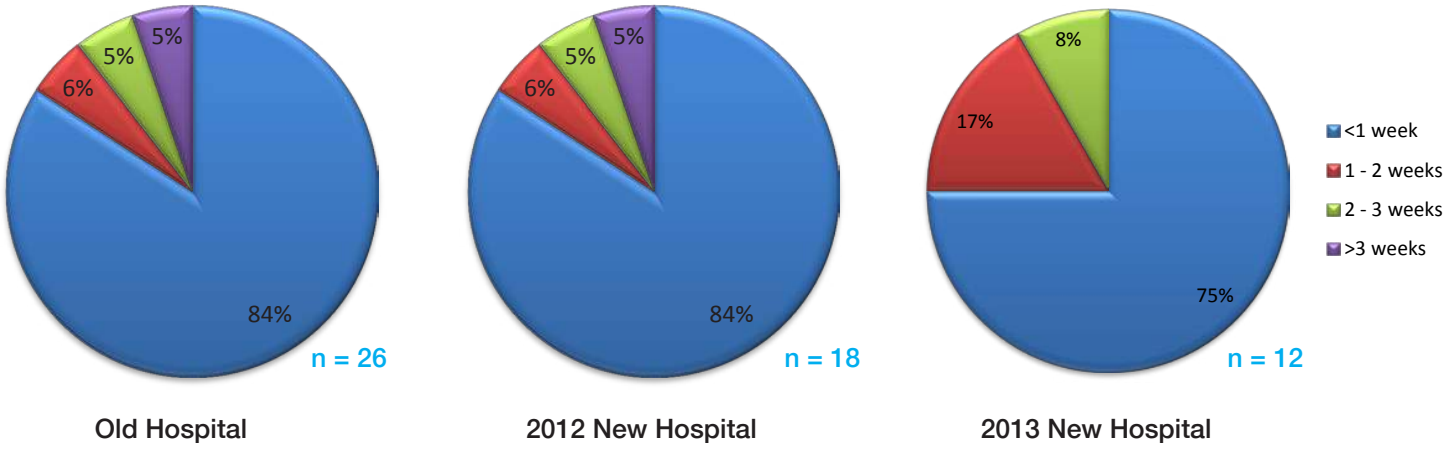


Figure 3, Length of stay for patient respondents for old and new hospital surveys

02.02

Introduction
Patient demographics

In the 2013 data set, there were less patient respondents who had not been admitted to the hospital in the prior 6 months, than the first two data sets. The percentage of patients who had been admitted to hospital more than twice in the previous 6 months was similar across all data sets, although multiple admissions appear to be higher in the new hospital 2013 data set.

There does not appear to be any statistical significance in patients who stayed in one bed rooms versus two bed rooms.

No. of previous admissions

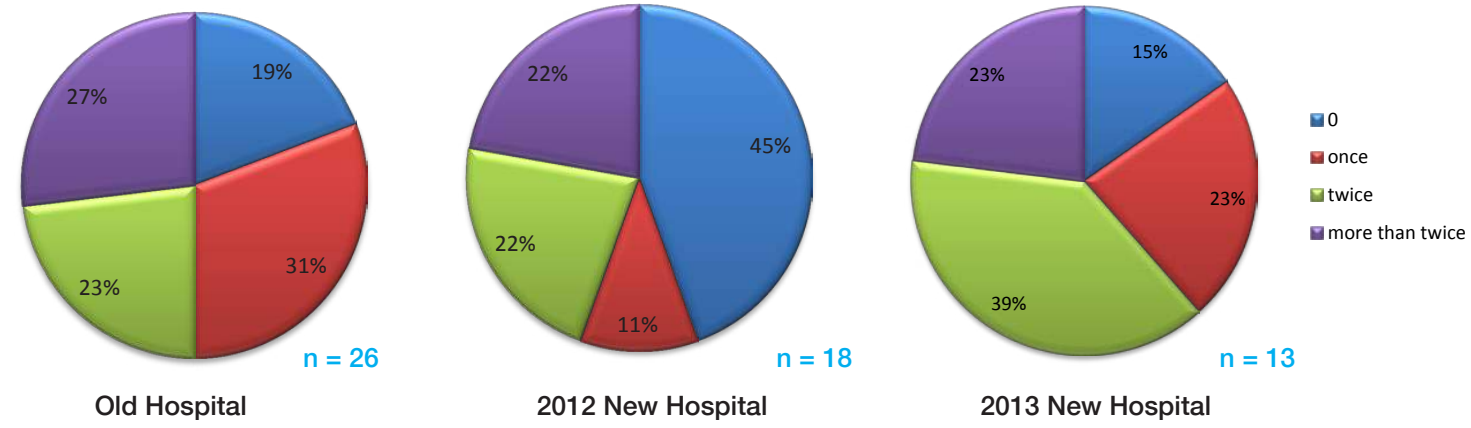


Figure 4, Number of previous admissions of patient respondents within six months for old and new hospital surveys

No. of beds in patient room

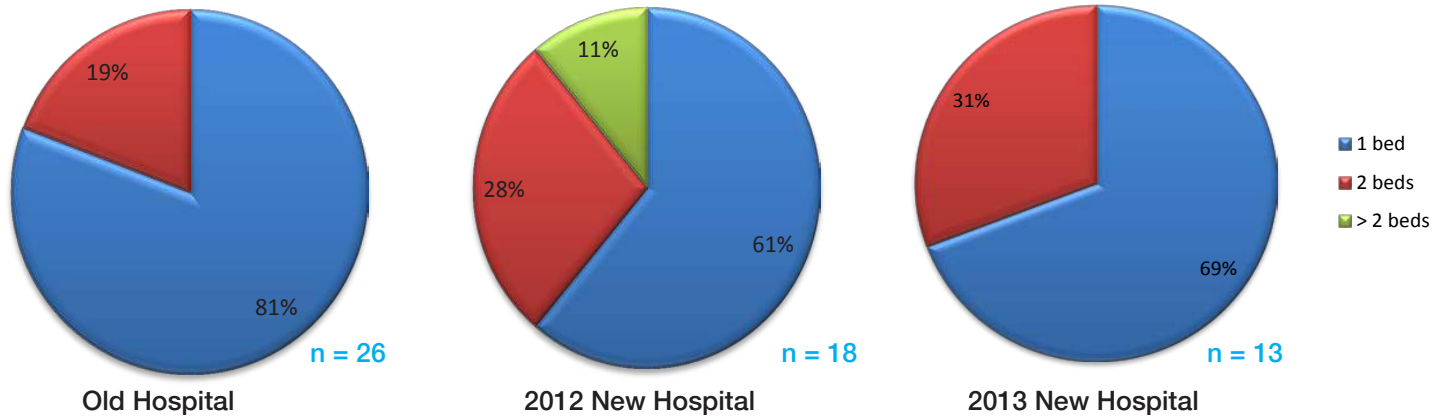


Figure 5, Number of beds in room of patient respondents for old and new hospital surveys

02.03

Introduction
Staff demographics

The numbers of staff respondents varied between the old and new hospital data sets, although the percentage of staff respondents was similar in the first two data sets despite reduced staff numbers in the new hospital. However, staff numbers appear to have increased again at the time of the third data set. The percentage of staff respondents reduced for the third data set:

74 out of 109 staff responded to the survey in the old hospital (68%)
55 out of 83 staff responded to the new hospital survey in 2012 (66%)
51 out of 102 staff responded to the new hospital survey in 2013 (50%)

Two unique aspects of the staff demographic at the Alexandra District Hospital are:
1) the majority of staff (64 – 69%) are aged over 46 years, with a third of staff aged over 55 years; and
2) The majority of staff (62 – 71%) work part time, with less than a third of staff working full time.

Age of staff

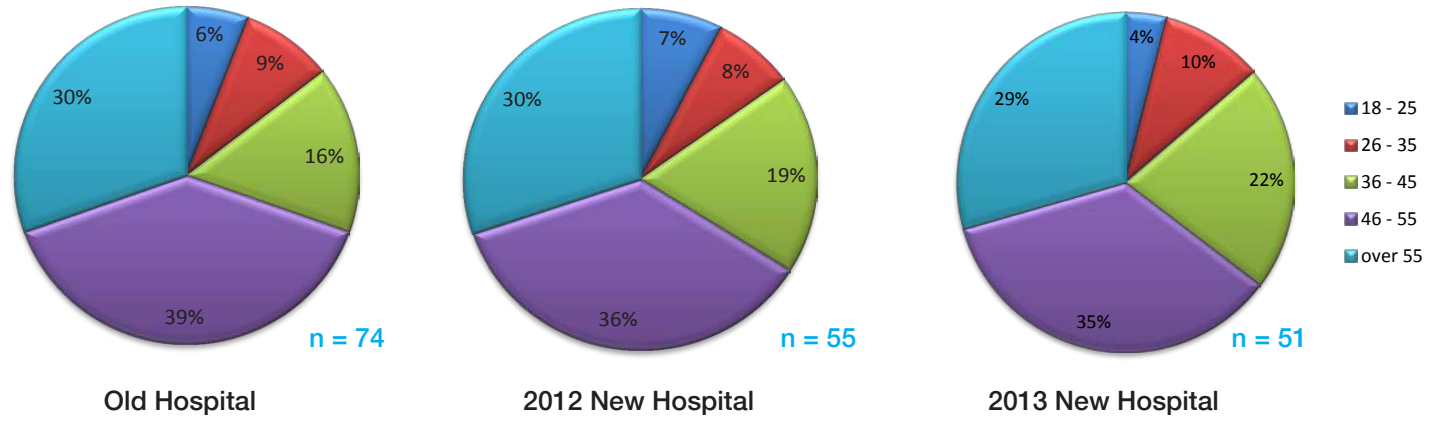


Figure 6, Age of staff respondents for old and new hospital surveys

Employment type

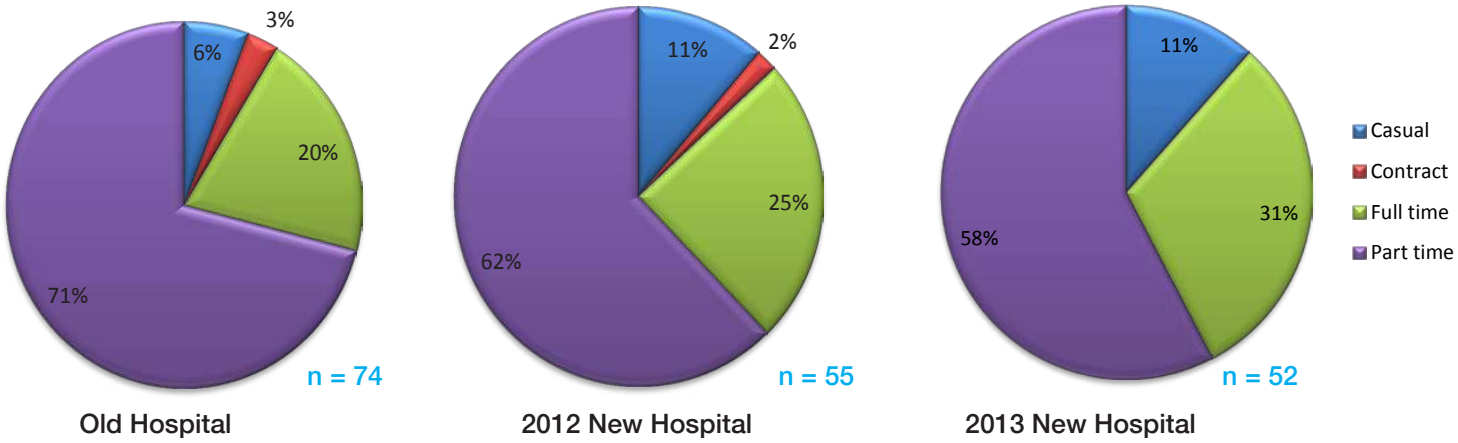


Figure 7, Employment type of staff respondents for old and new hospital surveys

02.03

Introduction
Staff demographics

This may be an outcome of a regional hospital, where there is likely to be a more stable and sustainable workforce, i.e. less employment competition for healthcare workers, and less demand for working full time. It is anticipated that the staff profile of a city hospital would be considerably different. The stability of the workforce is further demonstrated when the duration of employment is considered. Over half the staff respondents have worked at the hospital for over five years and less than a quarter of staff have worked at the hospital for less than two years. This was consistent for both the old and new hospitals across all data sets.

Of the staff respondents for the new hospital survey, 45 No. (88%) from the 2012 data set and 42 No. (88%) from the 2013 data set had also worked at the old hospital. This was crucial in enabling staff to make comparisons between the old and new hospitals, for which a dedicated section in the survey was implemented in the new hospital survey.

Duration of employment

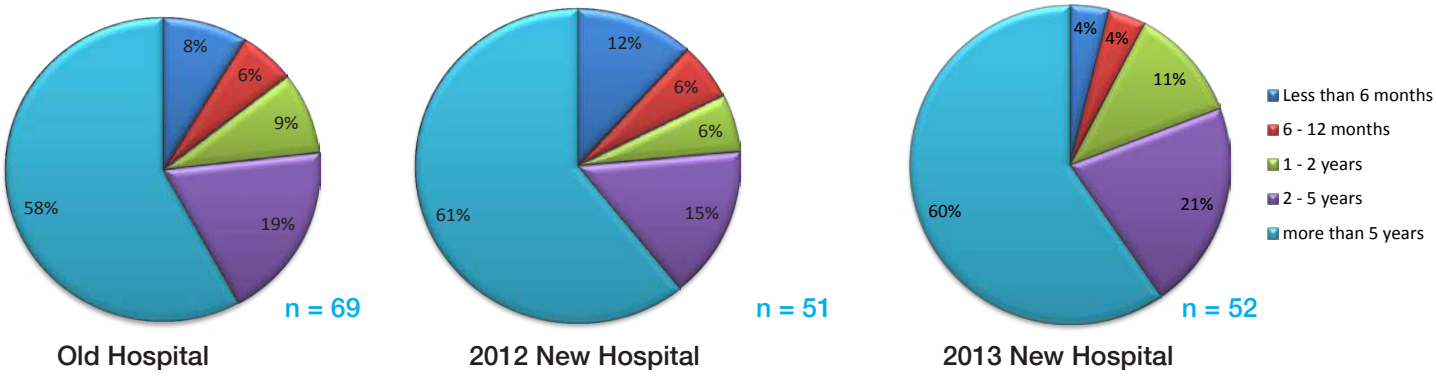


Figure 8, Length of employment of staff respondents for old and new hospital surveys

Hours of employment per week

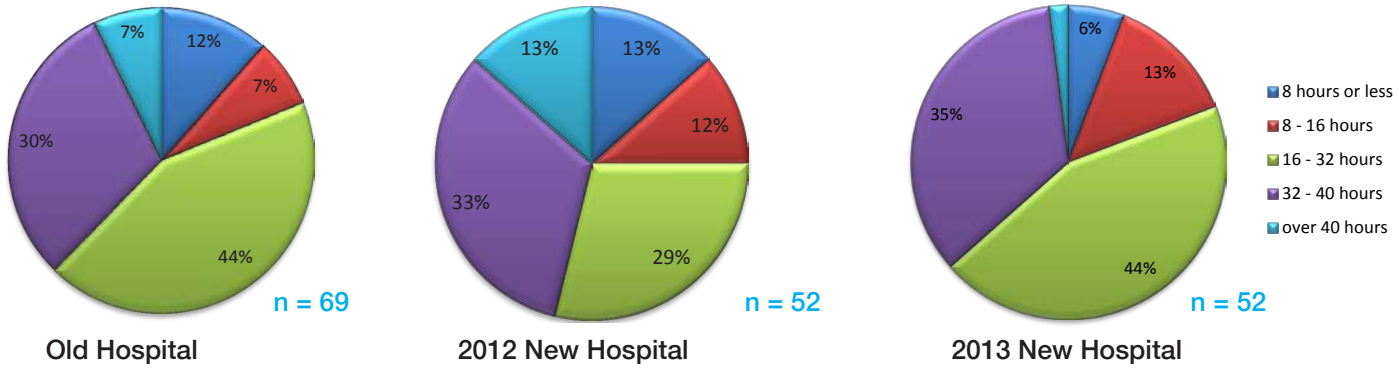


Figure 9, Hours of work per week for staff respondents at old and new hospital surveys

Percentage of staff who have worked in both old and new hospitals

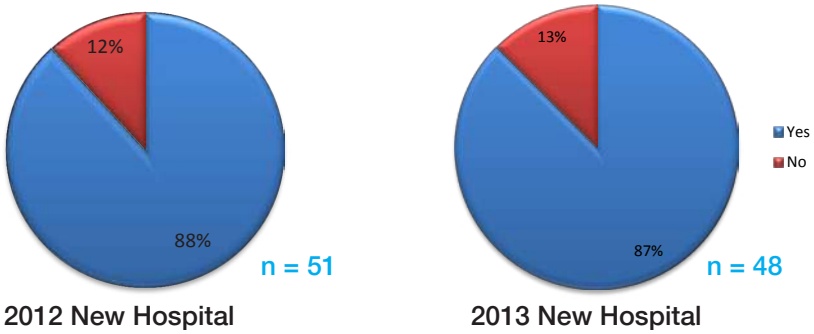


Figure 10, Percentage of staff respondents who have worked in both the old and new hospitals

02.03

Introduction
Staff organisational demographics

The hospital is organised into numerous departments, each with unique work patterns and varying interactions with patients. The majority of staff respondents in the first two survey periods were from 'acute wards' – generally nursing staff – 30% (old) and 40% (new), but this reduced to 22% in the third survey period. Good representation was also provided from 'community health' staff – 28% (old), 22% (new 2012) and 32% (new 2013), followed by 'administration' – 16% from the first two surveys and 20% from the third survey period. The remaining respondents comprised staff from catering, cleaning/maintenance, and theatre suite. This data was supported by further responses to questions relating to the nature of the work undertaken by staff (e.g. desk-based for administrative staff, roaming for catering & cleaning staff), and the nature of the staff work points (e.g. nurse's station, shared office, individual office).

Organisational Unit

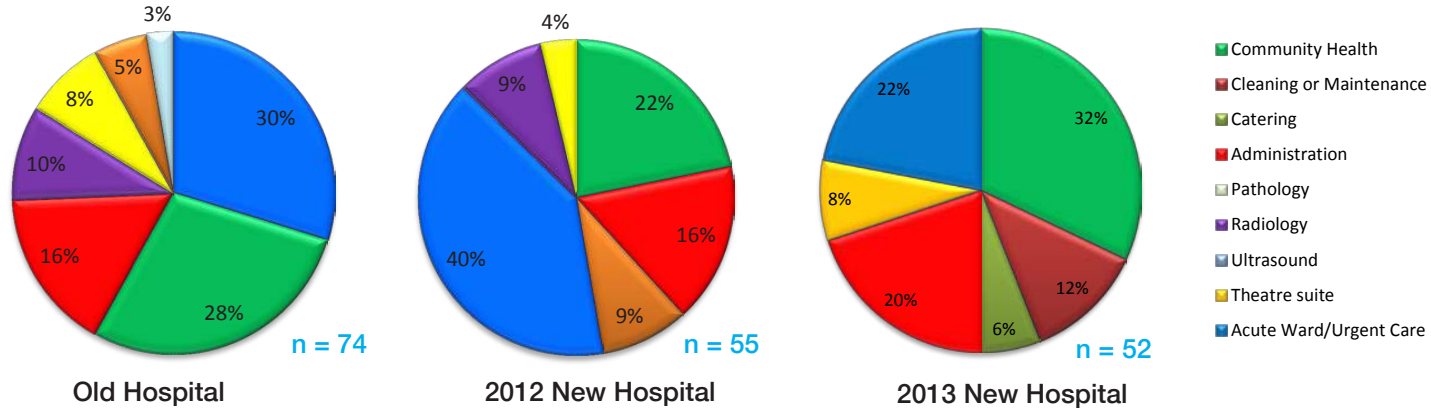


Figure 11, Organisational unit of staff respondents for old and new hospitals

Type of work

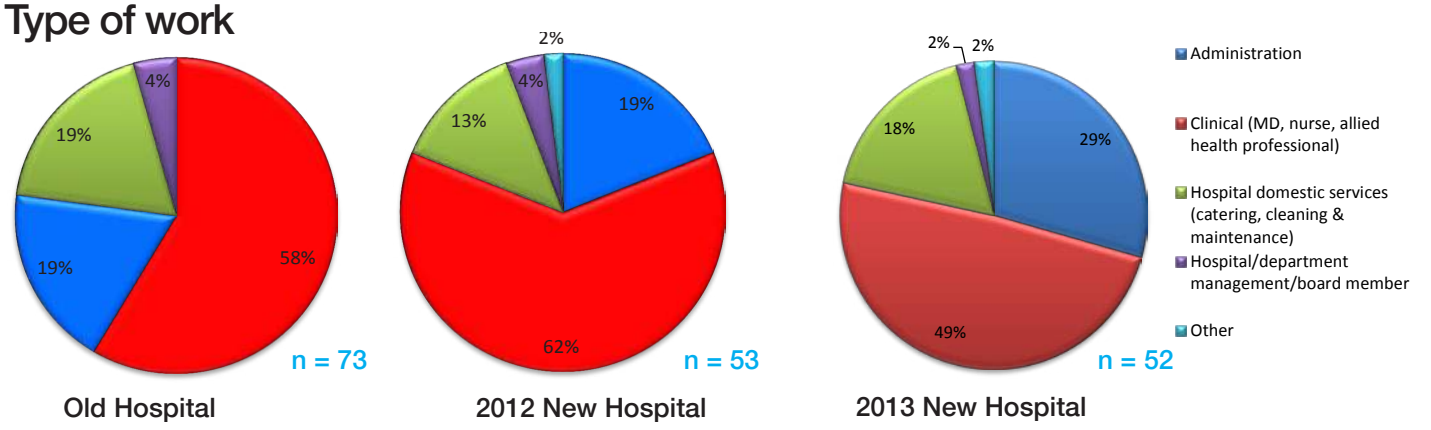


Figure 12, Type of employment of staff respondents for old and new hospitals

02.03

Introduction
Staff organisational demographics

In both the old and new hospital buildings, approximately 40% of staff spend the majority of their day at their primary work point, although a significant percentage (approximately 25%) spend the majority of their time away from their work point. This would be expected considering the mobile nature of nursing work practices, as well as catering and cleaning staff. This data was further supported by statistics on how much time staff spend inside the hospital but away from their work point.

Hours of work spent at workpoint

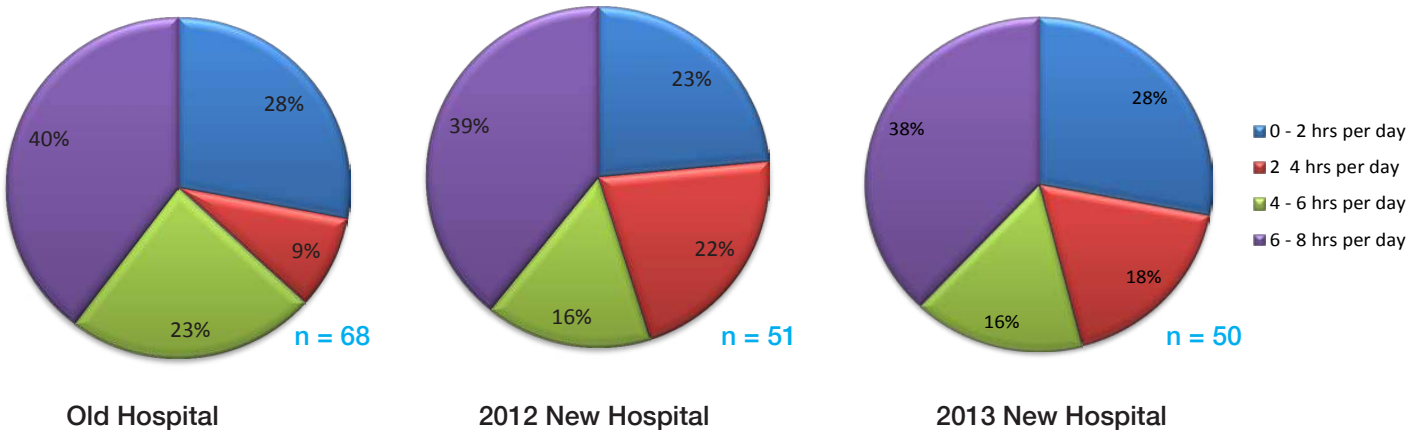


Figure 13, Hours of work per week spent by staff respondents at primary work point in the old and new hospitals

Hours of work away from workpoint

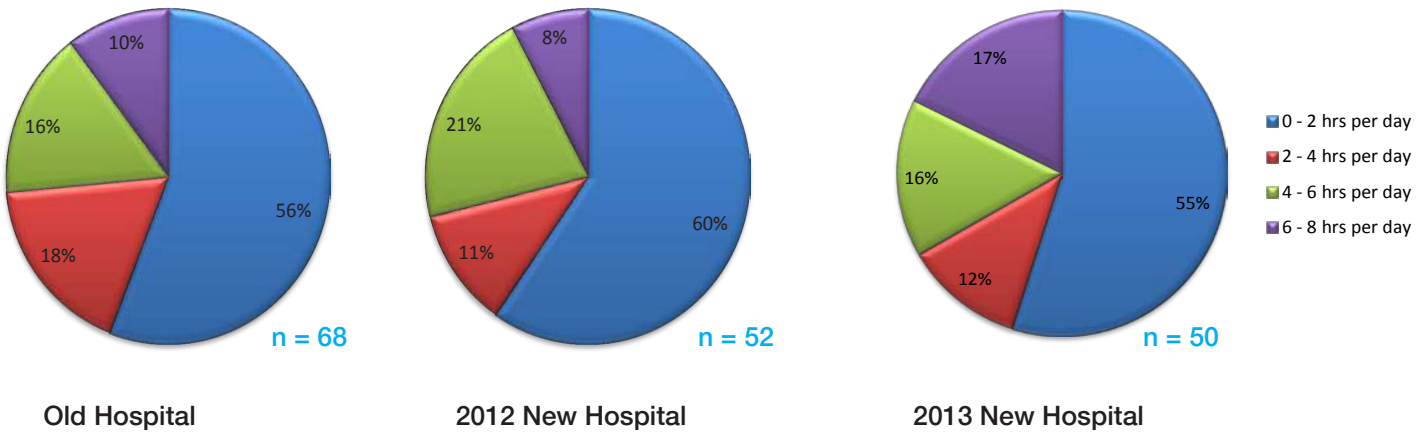


Figure 14, Hours of work per week spent by staff respondents away from their primary work point in the old and new hospitals

02.03

Introduction
Staff organisational demographics

Another crucial aspect of staff work points is that in both hospitals approximately 75% of work points were located less than 8 metres from a window. This has important implications for the Indoor Environment Quality, although proximity to a window does not equate to high quality lighting.

Distance of workpoint from daylight

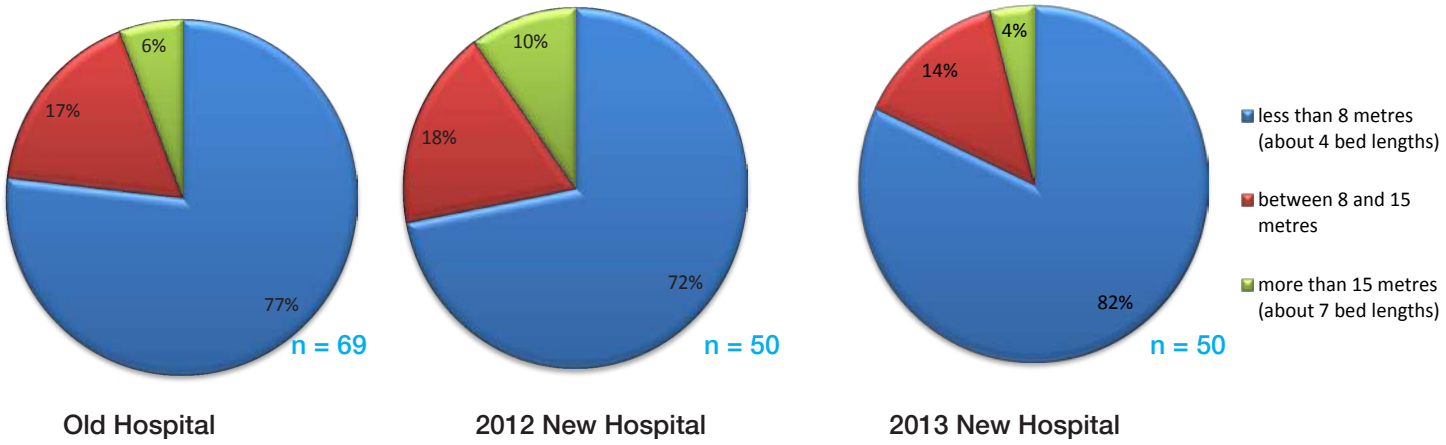


Figure 15, Distance from daylight to staff individual workpoint at the old and new hospitals

Building on the theme of staff satisfaction leading to greater productivity, staff comfort is considerably impacted by how much time staff spend on their feet, and how far they need to walk during their shift. Data from the old and new hospital buildings indicate a consistency in work patterns, in that 38 - 46% of staff spend between 80 – 100% of the day on their feet, approximately 25% of staff spend less than 40% of the day on their feet, and the remaining 30+% of staff spend between 40 – 80% of the day on their feet. This will be reported upon further in the context of walking distances investigated in the qualitative component of the surveys.

Percentage of time spent on feet

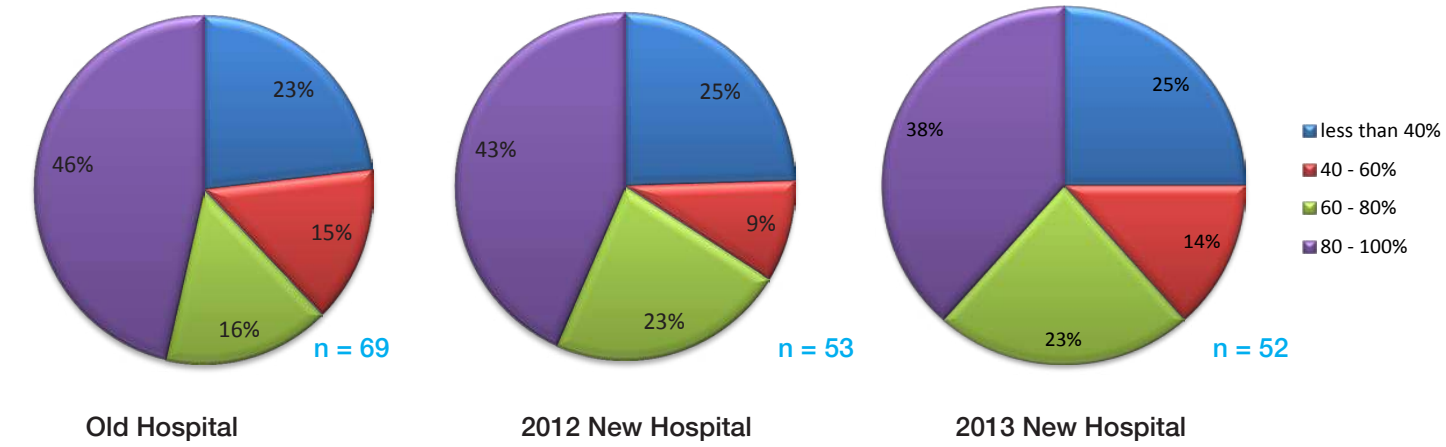


Figure 16, Percentage of time spent per week by staff respondents on their feet at the old and new hospitals

02.04

Introduction
Weather conditions during survey periods

It is acknowledged that the three survey periods were conducted at different times of the year. The survey period for the old hospital building was conducted from the end of February through to early April, through what was a particularly temperate season. During this time there were not any extreme maximum or minimum temperatures. The first survey period for the new hospital was conducted from mid-June to the end of August during the coldest time of the year, when several sub-zero minimum temperatures were recorded and low daily maximums. The second survey period for the new hospital was conducted throughout November and December, when a wide variety of temperatures were experienced including minimum temperatures of less than 5 deg and maximum temperatures over 35 deg.

As will be explained further in the context of IEQ thermal comfort, the new hospital mechanical system has continued to experience difficulties. Although the surveys were conducted six and eighteen months after occupancy the new building balancing problems were still being experienced, significantly affecting thermal comfort for staff in particular. A contention of this study is that this issue has contaminated the data and does not reflect a permanent status of the building.

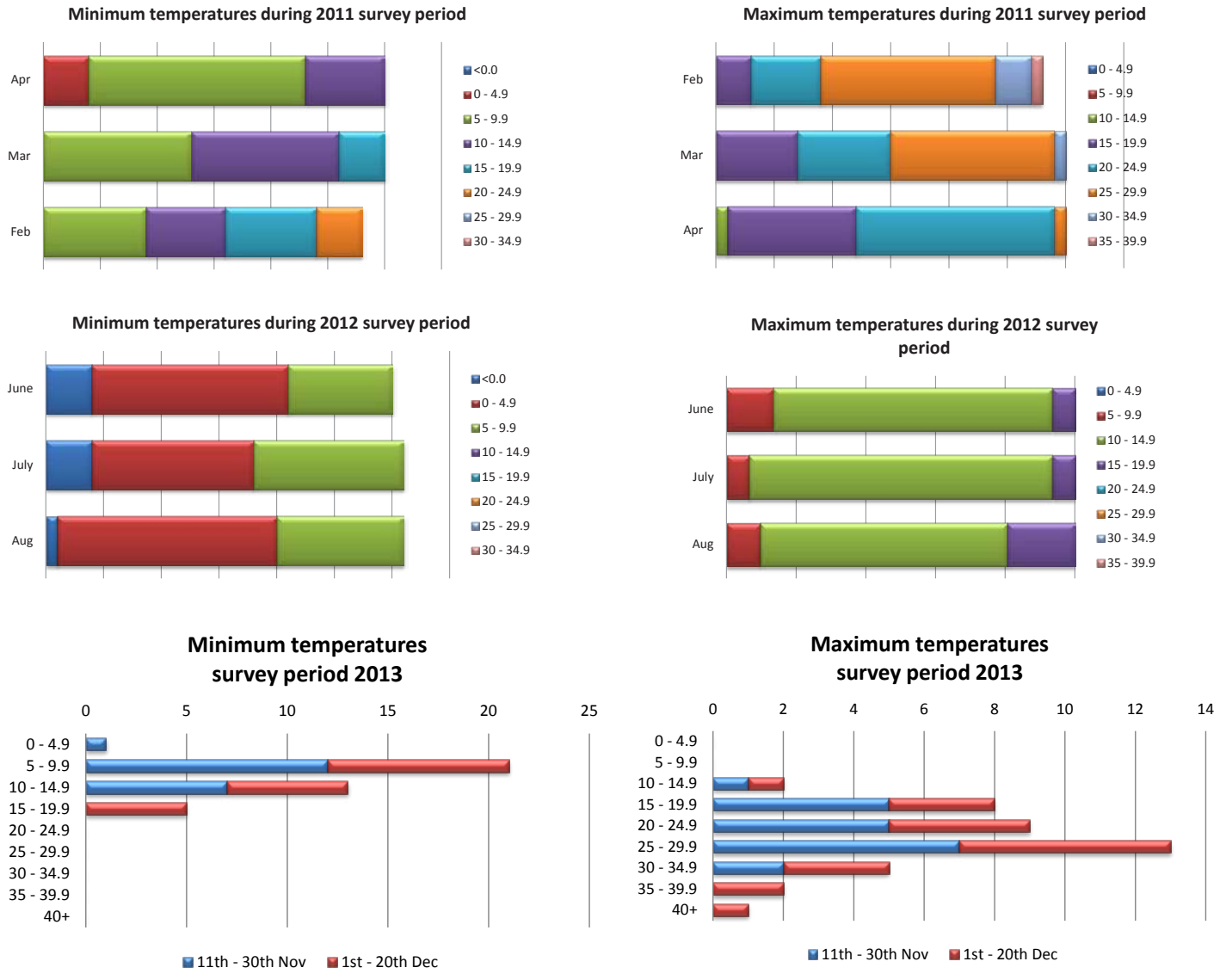


Figure 17, Minimum & maximum temperatures during survey periods in 2011 (old hospital), 2012 & 2013 (new hospital).

03.01

Findings
Indoor Environment Quality

The growing body of literature regarding the benefits of IEQ on patient recovery and staff productivity is compelling, although limited. Two key literature reviews by Umow Lai (2009) and Ampt, Harris & Maxwell (2008) explored an array of studies reporting on demonstrated benefits of thermal comfort, acoustic comfort, air quality and light quality on building occupants. Both reviews were developed in the context of healthcare, although some research was informed by workplace studies simply because none exists in the context of healthcare facilities. Some studies focused on singular aspects of IEQ, for example Ampt et al (ibid.) reported on a study indicating lower mortality rates in patients recovering from heart attacks were associated with exposure to sunlight, and reduced length of hospital stays for patients suffering depression were associated with exposure to morning sunlight. The majority of studies do not isolate specific IEQ issues, but rather the "bundled effects" of environmental variables (Ampt, et al., 2008, p. 13). Nonetheless, the collective body of literature does categorically support the contention that good quality IEQ does lead to better patient outcomes and increased staff productivity.

In the context of this Study of the Alexandra District Hospital, better patient outcomes have been explored quantitatively in terms of length of stay and number of falls, and qualitatively in terms of patient perceptions of the environment and the impact on their recovery. Increased staff productivity has been explored quantitatively in terms of amount of sick leave and annual leave expended, and qualitatively in terms of staff perceptions of the impact of the environment on their ability to undertake their work tasks. Quantitative IEQ measurements of the environment were undertaken at both the old and new hospitals and have been benchmarked against industry standards, as explained in the CETEC reports.

This study has not been undertaken with the intention of focusing on one key environmental characteristic that demonstrates better patient outcomes or increased staff productivity. Rather, this study has been undertaken to better understand the relationship between a healthy building, patient outcomes and staff productivity, and particularly in the context of a Victorian public hospital.

The Study of the Alexandra District Hospital reports upon the following four categories of Indoor Environmental Quality (IEQ):

- Thermal comfort
- Acoustic comfort
- Air quality
- Light quality

Each category is discussed in terms of the impact on staff productivity (their ability to undertake work tasks) and patient wellbeing (perceptions of recovery).

03.01

Findings
Indoor Environment Quality

CETEC measurements relating to thermal comfort, acoustic comfort, air quality and light quality were taken at six different locations within the new hospital, as per the following map. Measurements were taken in the morning and repeated in the afternoon.

A RECEPTION
B ANCILLARY SPACES (BACK OF HOUSE)
C NURSE'S STATION
D PATIENT ROOM (EAST)
E PATIENT ROOM (SOUTH)
F OPERATING THEATRE

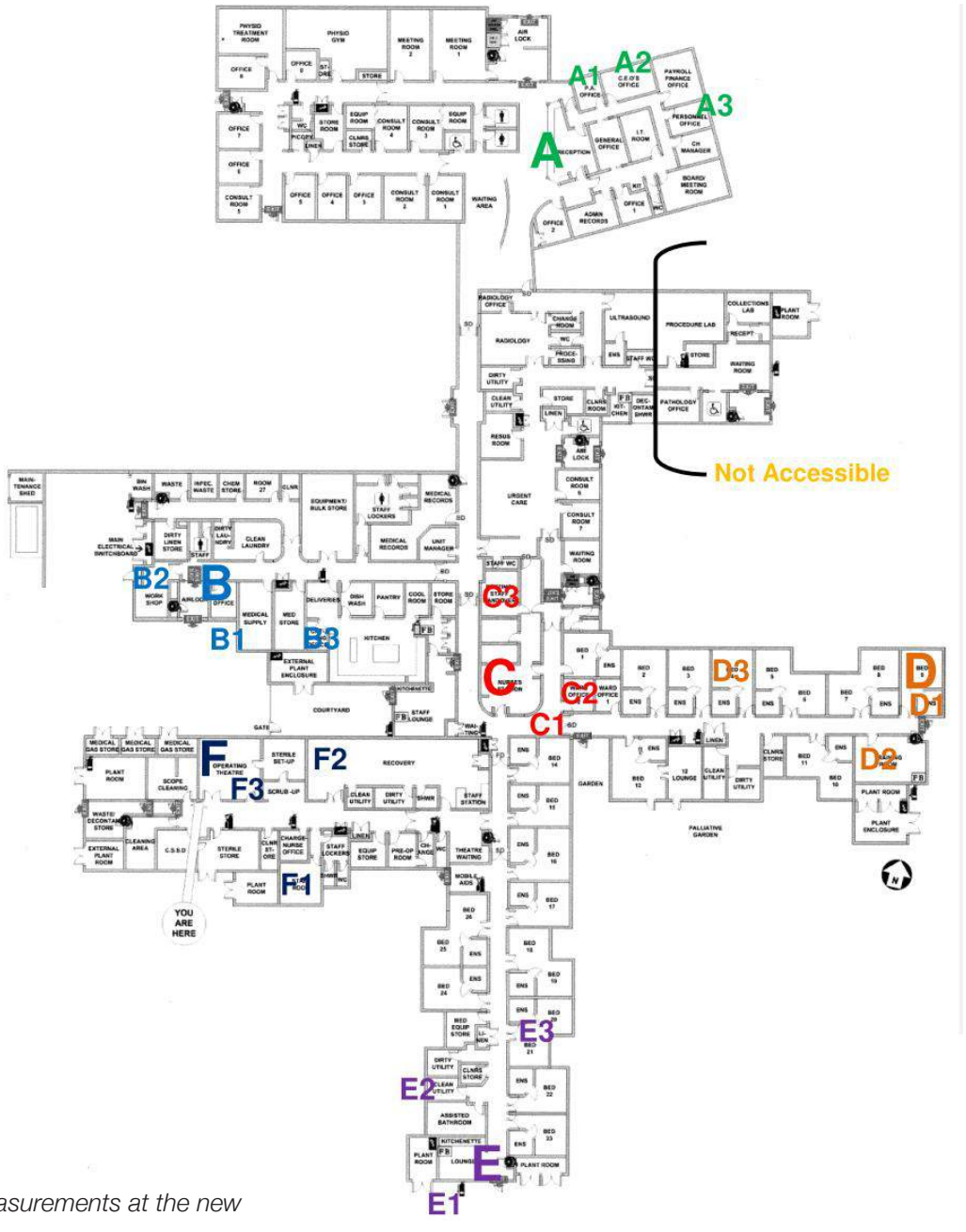


Figure 18, Locations of IEQ measurements at the new hospital. Source: CETEC

03.02

Findings
Staff General IEQ Satisfaction

The following graphs summarise staff satisfaction with IEQ characteristics of their work point in the new hospital compared to the old hospital. Satisfaction is demonstrated in these graphs by the light and dark green colours, Dissatisfaction is demonstrated by the orange and red colours. The closer the colour is to the outer ring, the higher the rate of responses, that is, the higher the rate of satisfaction or dissatisfaction. The more compressed a colour is towards the centre indicates a low response rate of satisfaction or dissatisfaction. The graph for the first survey period in the old hospital (Figure 19) indicates a high rate of satisfaction for the majority of IEQ characteristics with the (green) lines extended towards the outer perimeter of the ring. Additionally the old hospital graph also indicates some dissatisfaction with IEQ characteristics as the orange and red lines extend outwards for characteristics such as acoustic privacy, noise distraction and temperature comfort.

Old Hospital:
How satisfied are you with the following characteristics of your work point?

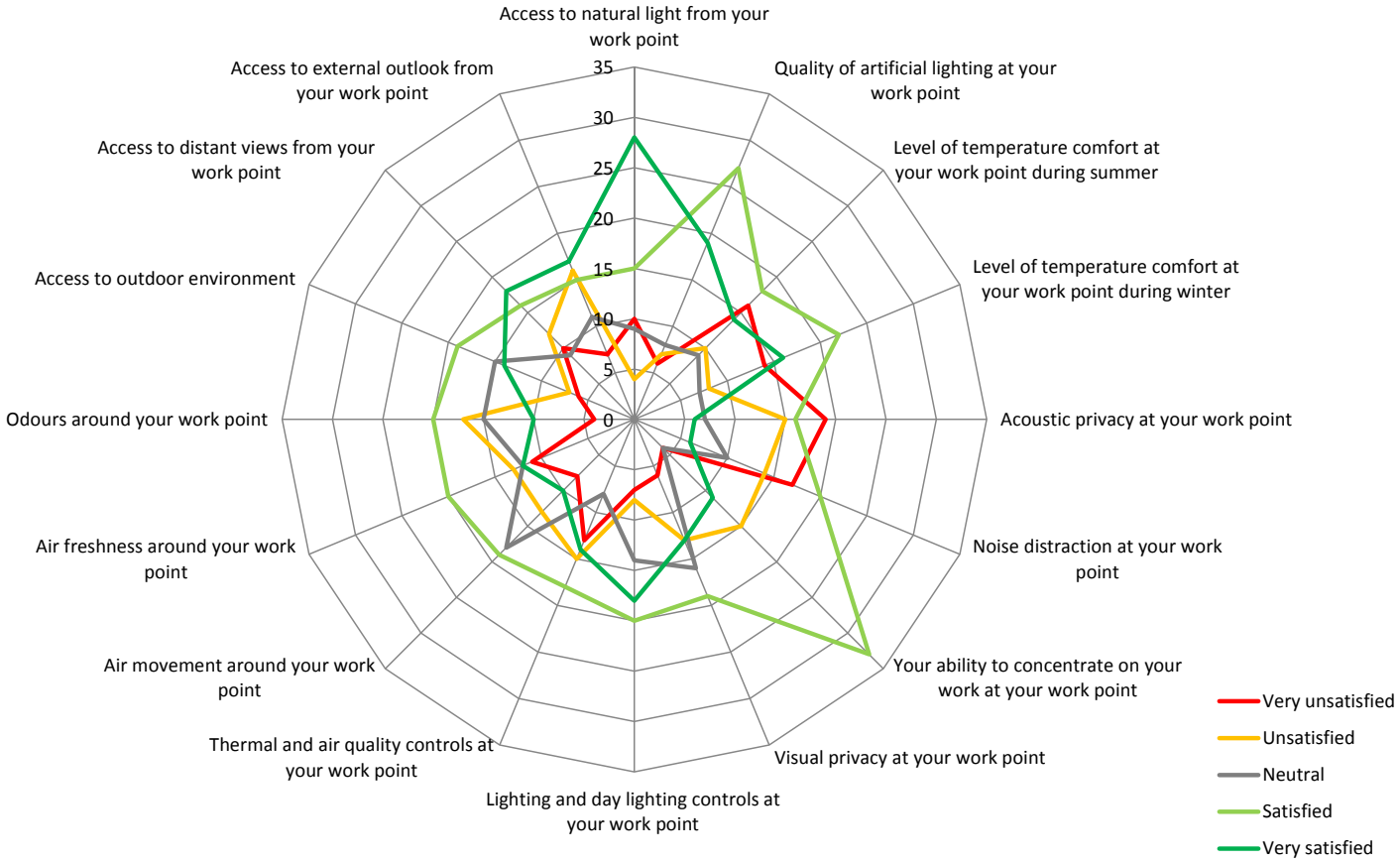


Figure 19, Summary of staff satisfaction with IEQ charactersistics at the old hospital

03.02

Findings
Staff General IEQ Satisfaction

The graph for the third survey period (new hospital, Figure 20) indicates a high rate of satisfaction for the majority of IEQ characteristics with the (green) lines extended towards the outer perimeter of the ring. The new hospital graph also indicates some dissatisfaction with IEQ characteristics, although significantly reduced when compared to Figure 19. This graph indicates that noise distraction and acoustic privacy are the most challenging aspects of the environment, however it is important to note that levels of dissatisfaction represents a minority of staff respondents.

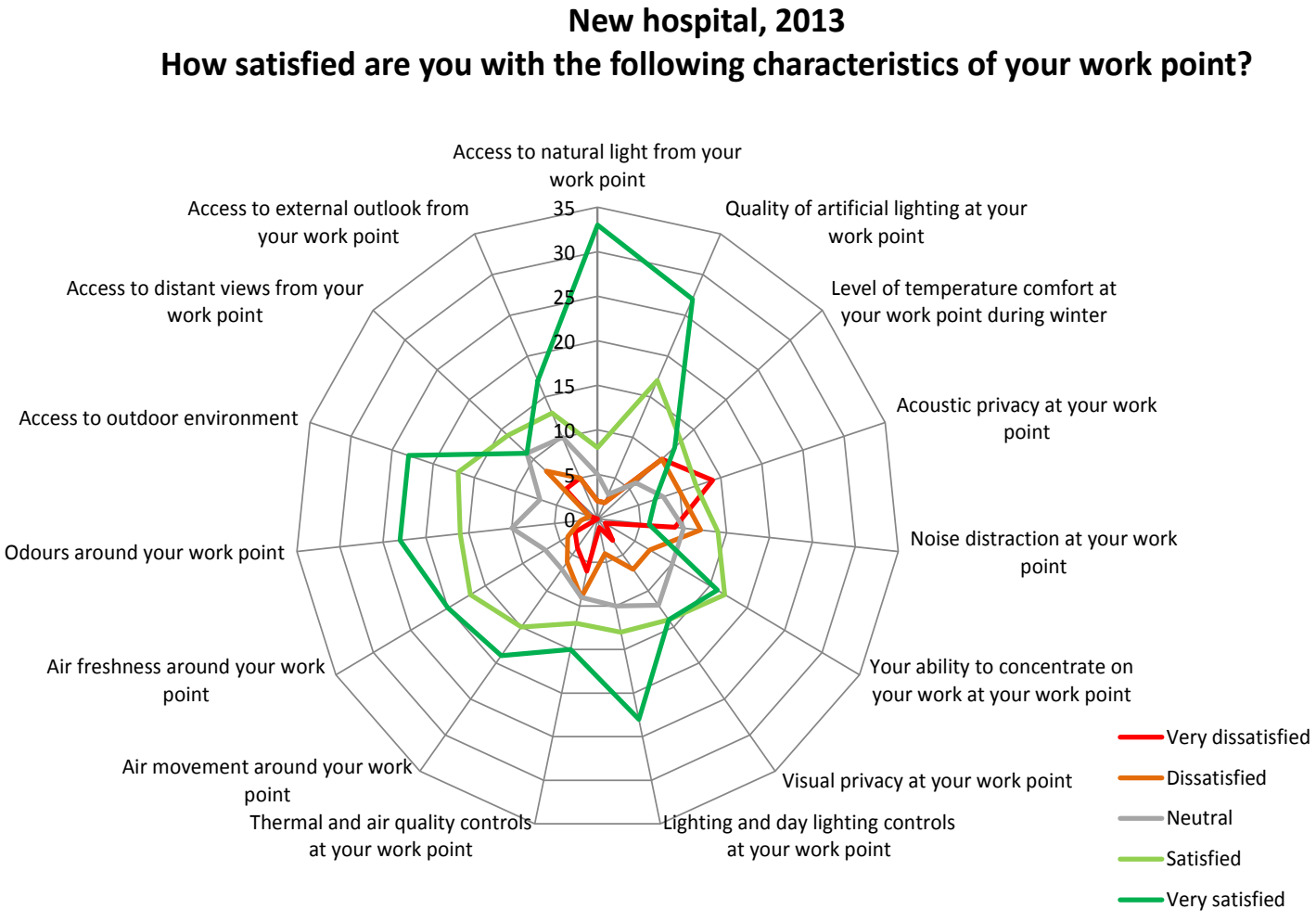


Figure 20, Summary of staff satisfaction with IEQ charactersistics at the new hospital, 2013


120
140
160
180
100
200
80
220
60
240
40
260
20
280
0
300

03.02

Findings
Staff General IEQ Satisfaction

A review of average responses for each survey period in the old and new hospitals indicates significant improvement in staff satisfaction in the new hospital compared to the old hospital. Staff indicated increased satisfaction against almost every IEQ characteristic. The only exceptions being:
a) levels of temperature comfort during winter (due to ongoing issues with the HVAC system, which will hopefully be resolved soon); and
b) acoustic privacy at their workpoint
c) noise distraction at their workpoint
In the second survey period staff indicated some dissatisfaction with access to distant views and access to external outlook when compared to the old hospital, however satisfaction for both of these characteristics has improved in the third survey period. This is most likely a reaction to settling into the new hospital and getting used to the reduced quality of distant views and different external outlooks. The outlook from the nurse's station continues to be represented with some dissatisfaction, however there is still a high degree of satisfaction from staff. Overall it can be concluded that the new hospital is perceived by staff to be a more satisfying work environment, especially when compared to the old hospital.

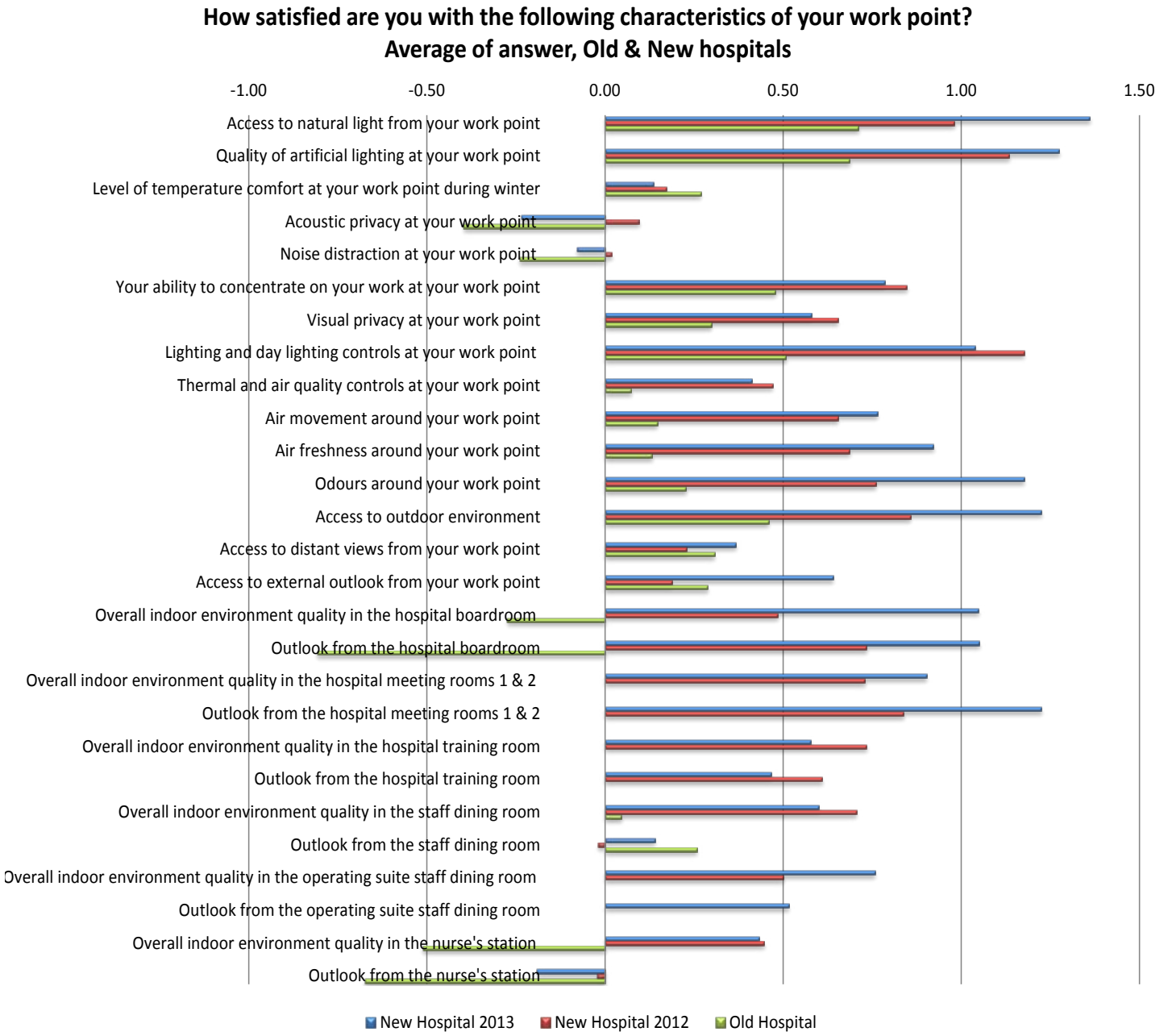


Figure 22, Summary of staff 'average of answers' for IEQ charactersistics at the old & new hospitals

03.03

Findings
Patient General IEQ Satisfaction

The following graphs compares **patient** satisfaction with IEQ characteristics of their patient care room between the old and new hospitals. As with the staff graphs, satisfaction is demonstrated by the light and dark green colours, dissatisfaction is demonstrated by the orange and red colours. The primary finding from this data is the high degree of satisfaction expressed by patients in the new hospital, coupled with a reduced degree of dissatisfaction.

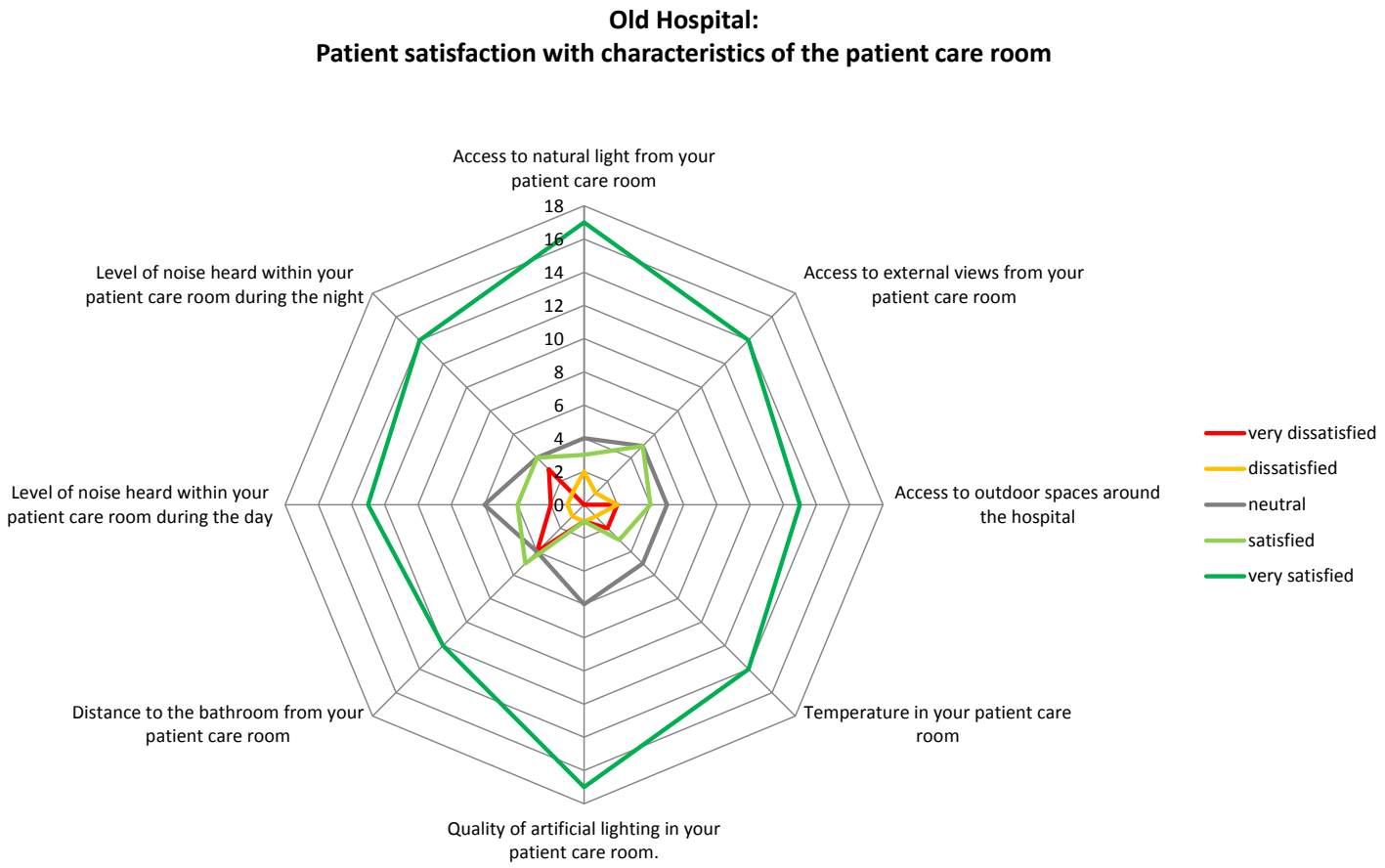


Figure 23, Summary of patient satisfaction with IEQ charactersistics at the new hospital, 2012

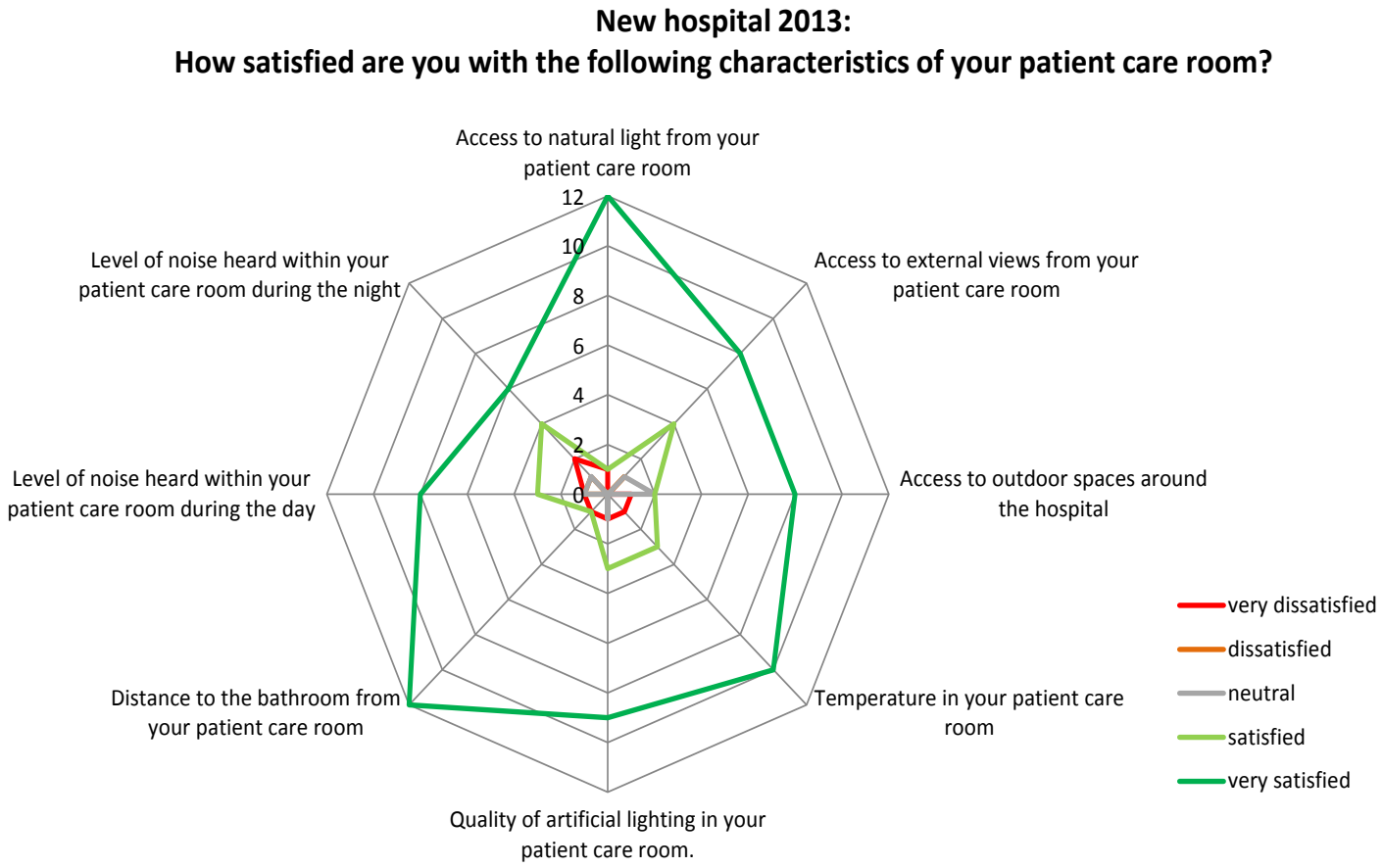


Figure 24, Summary of patient satisfaction with IEQ charactersistics at the new hospital, 2013

03.03

Findings
Patient General IEQ Satisfaction

When you review the average patient responses of the new hospital (2012 and 2013) there are generally high levels of satisfaction, although some reduced levels of satisfaction were recorded for:

– the quality of artificial light in the patient care room

– distance to the bathroom (even though the bathroom is in the patient care room)

– level of noise heard from the patient care room during the night

Compared to the old hospital, patient satisfaction increased in the new hospital in almost every category. The major exception was 'access to distant views from your patient care room'. This is not unexpected given the exceptional views that were experienced from the old hospital. However satisfaction of other outdoor elements such as 'access to natural light' and 'access to outdoor spaces' improved significantly in the new hospital.

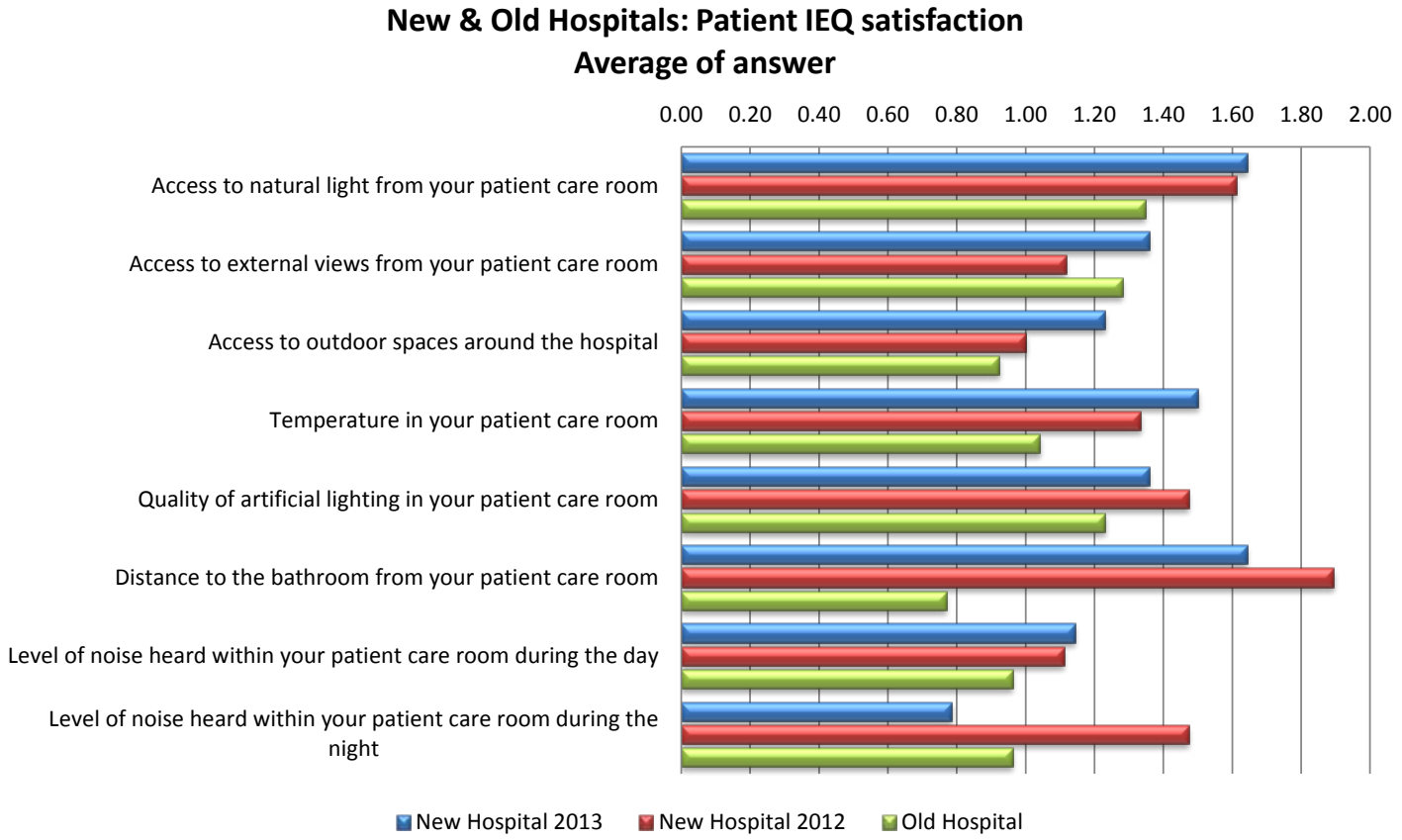


Figure 25, Comparison of patient 'average of answers' for IEQ charactersistics at the new hospital for 2012 & 2013

03.04 Findings
Thermal Comfort

Thermal comfort encapsulates air temperature, air flow and relative humidity. The American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) produced a publication known as ASHRAE 55, which identifies the recognised standards for human thermal comfort (ASHRAE, 2010). There is little evidence to demonstrate that thermal comfort alone leads to specific patient outcomes or staff productivity. However, discomfort as a result of temperatures and humidity outside of the ASHRAE 55 Standard, can impact upon staff and patient satisfaction with their environment, which in turn can lead to decreased productivity and slower recovery. The Umow Lai publication (2009) reports that

"staff satisfaction is achieved through the provision of comfortable working environments, which results in higher productivity levels and better quality of care. Patient satisfaction on the other hand could contribute to shorter hospital stays…" (p.23)

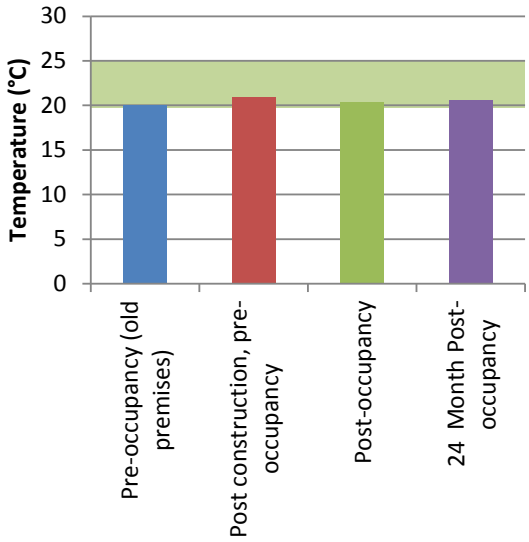
CETEC Measurements

CETEC measured temperature, relative humidity and airflow on four occasions:
1) in the old Hospital;
2) in the new hospital prior to occupancy;
3) in the new hospital 6 months after occupancy; and
4) in the new hospital 18 - 24 months after occupancy

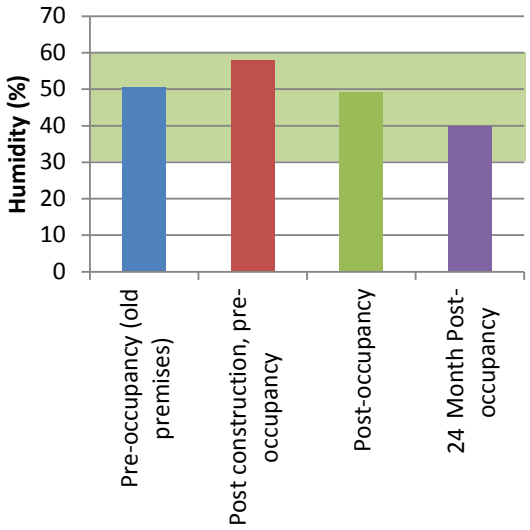
The following temperature graph (Figure 26) indicates that average measurements were at the low end of the acceptability range, although many of the morning temperature measurements taken in the new hospital building were well below the recommended range (refer Figure 27). The relative humidity graph indicates that humidity was within the acceptability range.

CETEC SUMMARY

- In most areas the morning temperature was below the guidelines. Outdoor temperatures were low (approximately 10°C minimum) before reaching 17.5°C mid-morning. Location A is the main entrance to the hospital and the slightly lower temperature measured in the morning would be influenced by the outdoor temperature due to the operation of the entrance doors.
- Afternoon measurements were all within the recommended guideline.
- Air movement within the building at the time the measurements were being taken was variable. Location D in the afternoon had an average airflow of 0 m/s. As most locations are serviced by individual air conditioning systems, once the temperature set point has been reached, the fans stop and airflow is solely influenced by central return registers.
- The relative humidity levels were all found to be within the recommended guidelines. It is typical for most Australian buildings to not directly control the relative humidity. Indoor relative humidity levels are influenced by the prevailing ambient level and the building's HVAC supply temperature.
- Thermal conditions are similar to previous levels as seen in Figure 26.



Graph 1: Temperature (°C)



Graph 2: Relative Humidity (%)

Figure 26, Excerpt of temperature & humidity measurements for new and old hospitals.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p14.

Morning Measurements

	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
Temperature (°C)	19.4	19.0	20.2	20.3	18.2	18.5	17.5	**20 - 25.5**	**22 - 23**

Figure 27, Excerpt of temperature measurements for new hospital indicating non-compliance with recommended guidelines.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p12.

CETEC LEGEND

A - RECEPTION
B - ANCILLARY SPACES (BACK OF HOUSE)
C - NURSE'S STATION
D - PATIENT ROOM (EAST)
E - PATIENT ROOM (SOUTH)
F - OPERATING THEATRE

03.04 Findings
Thermal Comfort

STAFF PERCEPTIONS

Prior to the first survey period in the new hospital building, the hospital acknowledged that there had been problems balancing the mechanical systems in the building. This appears to have been an ongoing issue throughout the second survey period as there was significant dissatisfaction regarding thermal comfort reported by staff (40%), and to a lesser degree by patients (7%).

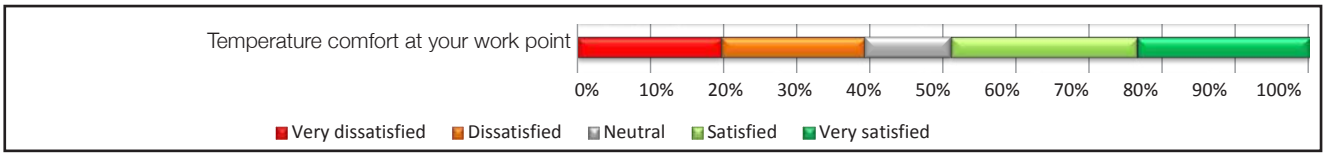


Figure 28, Staff thermal comfort in the new hospital

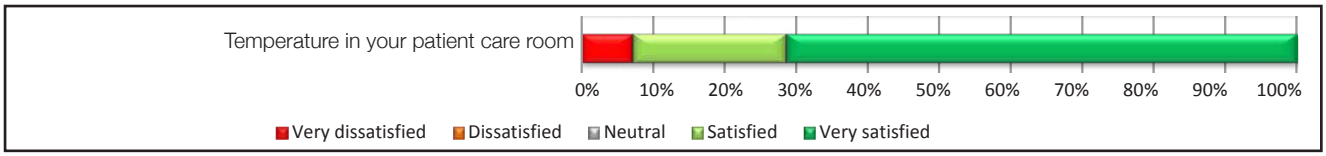


Figure 29, Patient thermal comfort in the new hospital

Furthermore, 26% of staff stated that poor thermal comfort negatively impacted their ability to undertake their work tasks.

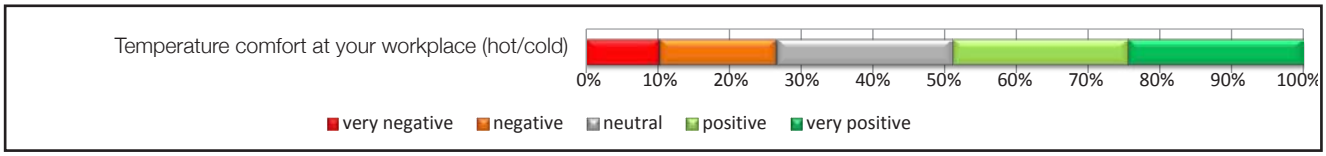


Figure 30, Staff impact of thermal discomfort on productivity in the new hospital

03.04

Findings
Thermal Comfort

Staff comments:
It is a much better place to work in than the old hospital eg bigger rooms ensuits colours pleasing to the eye ***the only problem is the heating and cooling***

Overall the working environment is OK, the airconditioner is not adequate, it gets hot and stuffy in rooms..

Thermostatic control throughout the building is terrible, some days the place is freezing in the winter wihtin the rooms and the passageways are like Siberia. Not good for patient or staff comfort.

Too cold throughout.

The corridors weren't mentioned but they are not comfortable as they are not heated or cooled.

SUMMARY

Improvements to the HVAC system in the new hospital building appear to be an ongoing problem and will require further work to establish a stable environment for thermal comfort. This is critical in light of the staff perceptions that thermal comfort has a major bearing on their ability to be productive.

03.05

Findings
Acoustic Comfort

The literature relating acoustics to the impact on people in various contexts is well documented, including hospital environments. Umow Lai (2009) reports on studies where noise-induced stress has resulted in physiological changes of patients such as increased heart rate and blood pressure and sleep disturbance which in turn can cause anxiety, increased pain and longer recovery times. This is supported by similar studies reported by Ampt et al (2008). Excess noise experienced by staff is linked to increased "stress levels, burnout and emotional exhaustion" (ibid. p.19). Noise-induced headaches account for lost productivity due to sick leave. Some studies indicate that excessive noise can lead to increased staff errors, a fundamental issue in patient safety. As Ampt et al (ibid) contend, "good communication is one of the foundations of error reduction in healthcare" indicating that acoustics "have serious implications for patient safety" (p.19). Umow Lai also state "it is very difficult to argue the case for not reducing the amount of noise generated in a hospital for the improvement of patient healing and staff wellbeing" (Umow Lai, 2009, p. 22).

Conversely Ampt et al (2008) reported upon several studies where the positive outcomes of an acoustically comfortable hospital environment were acknowledged. The positive outcomes included better sleep and less pain medication for patients, while staff benefitted from less stress and more effective communication, which was speculated to lead to reduced rate of errors. Furthermore, Umow Lai asserted that "a less noisy environment created the perception of a higher quality of care" (p.23)

Acoustic quality has been measured by CETEC in both the old and new hospital buildings and benchmarked against Australian Standards. Qualitative feedback from staff and patients has been collected to gain an understanding of the impact acoustics has on staff ability to undertake work tasks and patient sense of recovery.

CETEC Measurements

Ambient sound levels were measured in each of the six locations in the new hospital building. The graph below shows the average measured sound levels and the Australian Standard recommended sound levels, measured in dB. With the exception of the reception area (Area A), all other measurements indicated higher than recommended sound levels.

CETEC LEGEND

A - RECEPTION
B - ANCILLARY SPACES (BACK OF HOUSE)
C - NURSE'S STATION
D - PATIENT ROOM (EAST)
E - PATIENT ROOM (SOUTH)
F - OPERATING THEATRE

	A	B	C	D	E	F
Ambient Sound (dB)	41	42	43	42	44	51
Recommended Guidelines	**40-50**	**40-45**	**40-45**	**35-40**	**35-40**	**40-45**

Figure 31, Excerpt of acoustic measurements for the new hospital.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p25.

03.05 Findings
Acoustic Comfort

CETEC SUMMARY

Ambient sound levels in Locations A, B and C were all acceptable. Location D and E (patient rooms) were slightly elevated as the recommended sound level for wards (as per AS/NZS 2107:2000 Acoustics) is more stringent in these locations. The sound level of the split system air conditioning and return registers were the sources of noise. Location F (operating theatre) was also above the recommended sound level and was due to the constant noise from the separate HVAC system. Furthermore, sound has a higher tendency to travel in these areas in a hospital as polished surfaces required for cleaning purposes will allow more sounds to be reflected.

STAFF PERCEPTIONS

38% of staff expressed satisfaction with the level of acoustic privacy whilst 47% of staff expressed dissatisfaction with the level of acoustic privacy at their workpoint.

42% of staff expressed dissatisfaction with the level of noise distraction at their work point whereas 39% of staff were satisfied with the level of noise distraction at their work point.

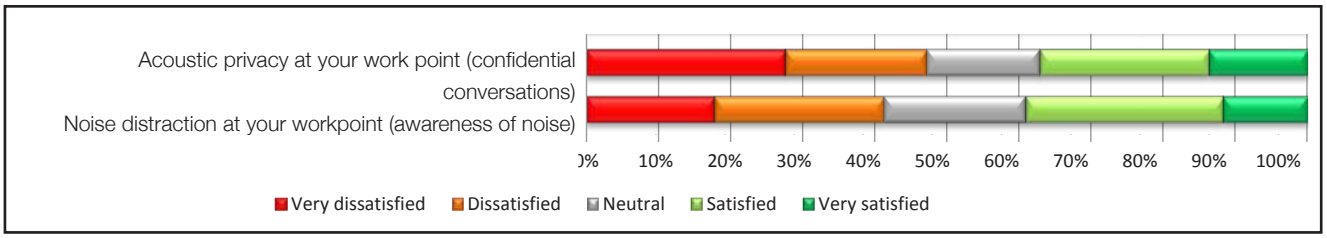


Figure 32, Staff acoustic comfort in the new hospital

Furthermore, 32% of staff conveyed that acoustics has had a negative impact on their ability to undertake work tasks. However, 52% of staff indicated that acoustic comfort has had a positive impact on their productivity

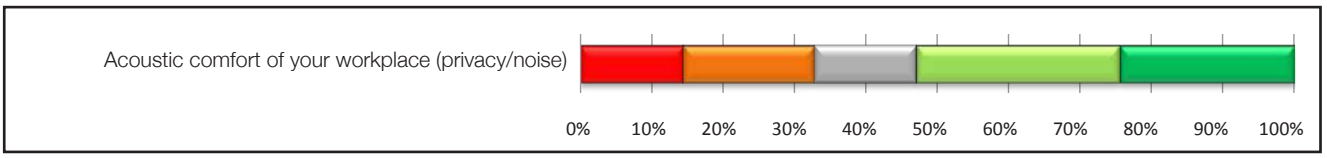


Figure 33, Impact of acoustic comfort on staff productivity in the new hospital

Staff comments:

Noise level in the staff dining room is disgraceful when more than 6 people in there, not relaxing or a refreshing break at all, people often return from breaks early due to the noise level

Noise levels from room to room during consultation is poor, staff and general public can hear conversations while walking in corridor.

Patient perceptions

Patients were surveyed about their perceptions of acoustics during the day and night (see below). The majority of patients reported a high degree of satisfaction with acoustics during both day and night, although there was a slight increase in dissatisfaction with level of noise heard at night time.

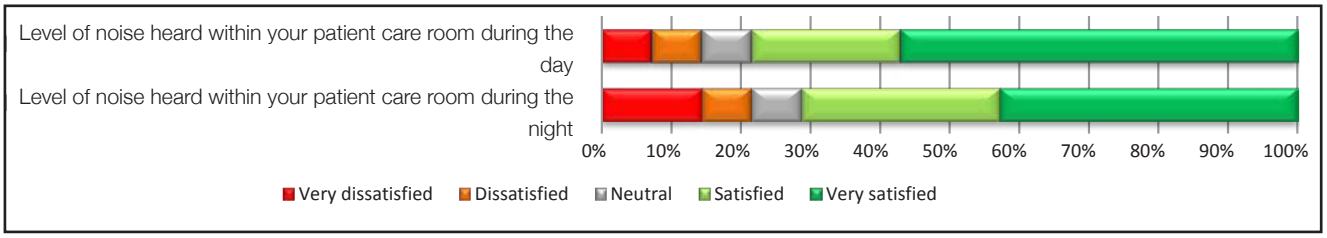


Figure 34, Patient acoustic comfort in the new hospital

Furthermore, 77% of patient respondents indicated that acoustics positively impacted on their recovery.

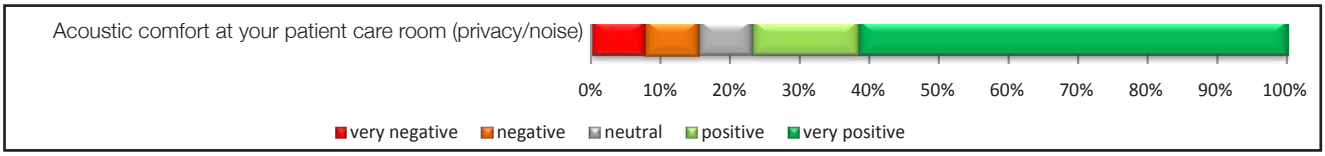


Figure 35, Impact of acoustic comfort on patient recovery in the new hospital

Patient comments:

The acoustics are a real problem. Voices seem to be amplified considerably and at night with changeover the voices are loud.

Deteriorated significantly. No acoustic consideration in building design or build.

The only noise I hear is some nurses having the odd laugh, which I think is good for patient moral.

SUMMARY

The majority of patients have indicated satsifaction with the acoustics in the new hospital and have indicated the positive impact this has on their recovery. There were lower levels of staff satisfaction recorded relating to acoustics, particularly regarding privacy at their workpoint. This may be improved by encouraging confidential conversations to take place in meeting rooms and other private spaces. Acoustic performance could also be improved by increasing soft furnishings and acoustic panelling if required.

03.06

Findings
Air Quality

A key indicator of poor air quality is increased rates of sickness as a result of air-borne germs and pollutants. Clearly in the context of a hospital this is critical as patients are already vulnerable. Staff too are subject to illness spread by air-borne particles, leading to a loss of productivity. Umow Lai reported on a particular study by Wargocki & Seppanen (2006), which found that increasing ventilation rates by 100% increased productivity (in Umow Lai, 2009, p. 23) although this study was undertaken in a workplace context and laboratory, not a hospital environment. Another study by Myhrvold et al (1996), also reported in Umow Lai's literature review, connected poor work place performance with higher rates of CO2, which equates to poor ventilation. Therefore, research into the impact of air quality on building occupants has concluded that higher ventilation rates equates to lower CO2 concentrations, which potentially results in reduced sick leave (ibid.).

CETEC MEASUREMENTS

CETEC measured three components of 'air quality':
1) presence of CO2 levels;
2) presence of chemical pollutants; and
3) presence of microbiological pollutants such as bacteria, fungi and viruses (CETEC, 2012).

Apart from the harmful effects of toxic pollutants on people, air quality is often reported by building occupants in terms of lack of ventilation, unpleasant odours and a general lack of air freshness. The measurements for components have been reported in the context of specific Standards and guidelines:
ASHRAE 62 (2001) for CO2 levels;
World Health Organisation (WHO);
NHMRC and related research for chemical pollutants (no specific standard exists)

Note: Microbiological pollutants are considered common in almost every environment and therefore the recommended acceptable measure is less than the outside conditions (CETEC, 2012).

The following graphs confirm that results of the air quality tests at both the new and old hospital buildings were within the acceptable range.

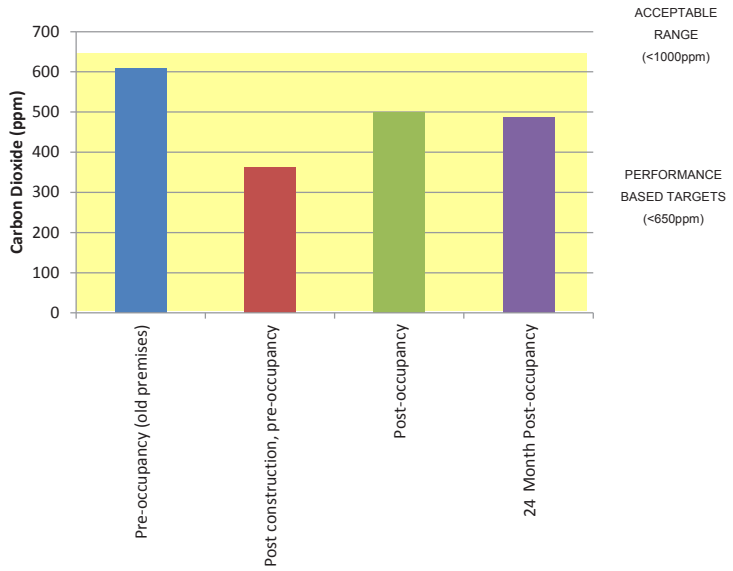
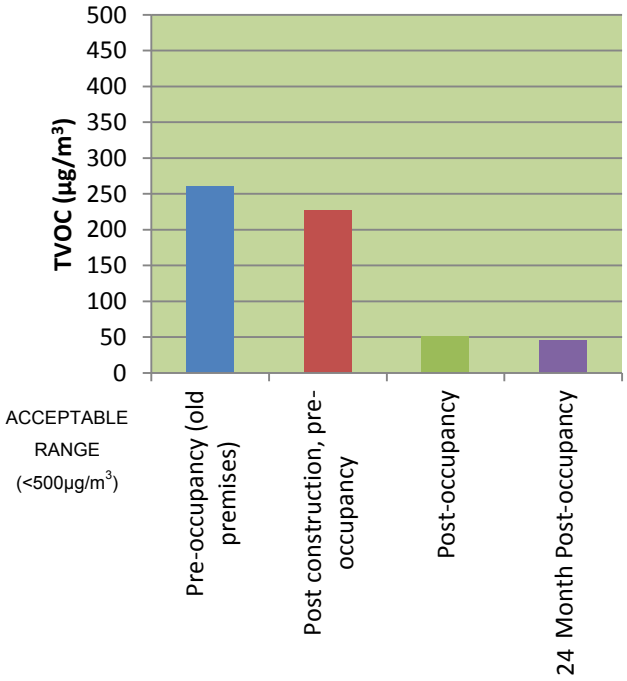
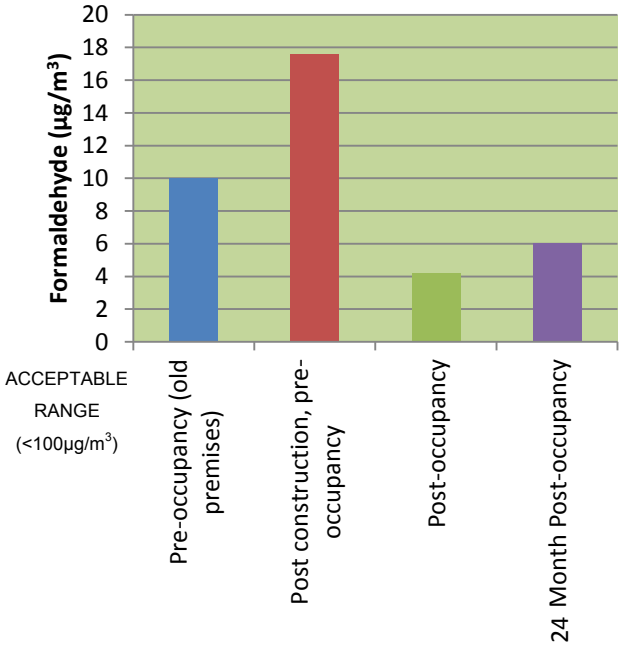


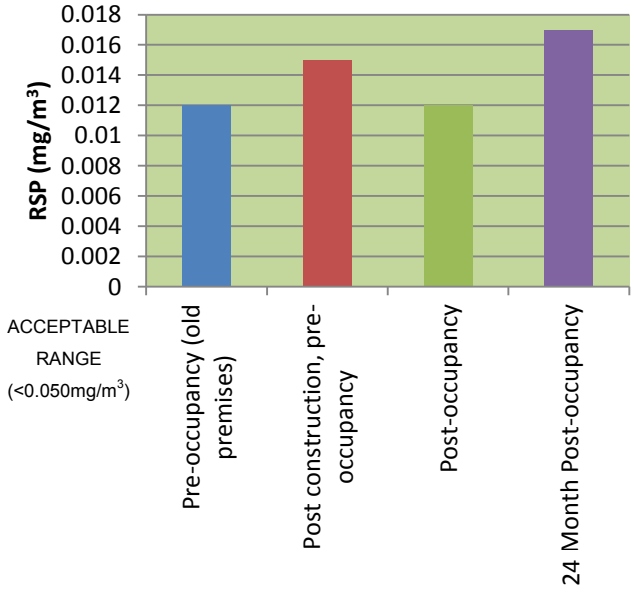
Figure 36, Comparison of average carbon dioxide concentration in the old and new hospitals.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p17.



Graph 1: TVOC



Graph 2: Formaldehyde



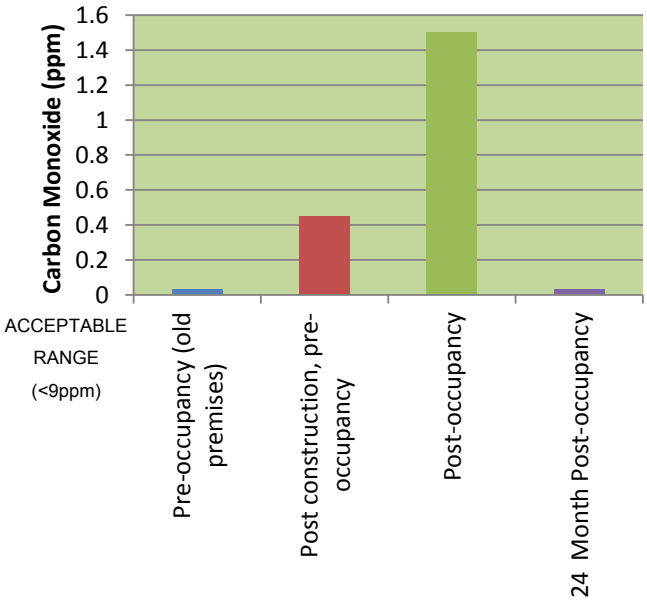


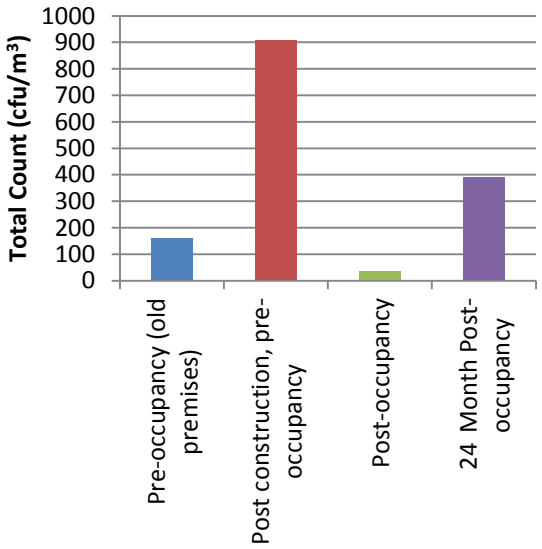
Figure 37, Comparison of Average Chemical Pollutants in the old and new hospitals.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p20.

CETEC SUMMARY

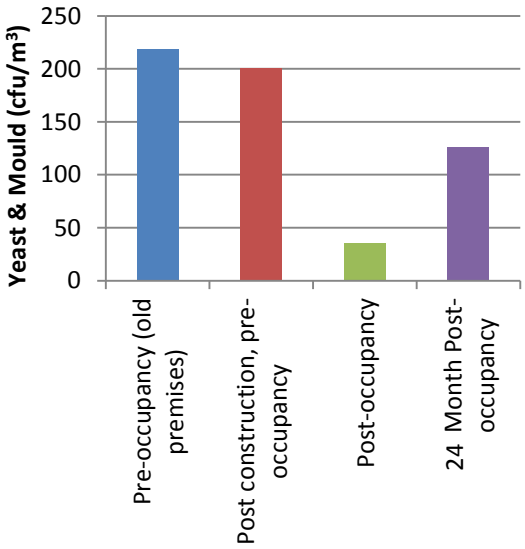
– Microbial pollutant results are variable with Location B showing slightly elevated yeast and mould levels, Locations C and E with slightly elevated total counts and Location F (operating theatre) with no colony forming units.

– Mould levels in B (office and maintenance) may be more influenced by outdoor conditions as these locations are close to entrance doors that are frequently used. The microbial plates were morphologically similar to ambient samples indicating that there was no additional source of mould growth.

– Location C and E showed slightly elevated total counts compared to outside. Further investigation is required to determine the source of the elevated levels. Measured ventilation rates and dust levels were acceptable on the day of testing, however as the HVAC system is not operated during periods of non-occupation, they should be monitored and regularly cleaned to reduce the existence of conditions that are conducive to microbial activity such as increased moisture and dust in these locations. General cleaning was carried out during the morning and may have included vacuuming that may have caused aerolisation of microbes and hence the elevated result. As noted previously, lawn mowing was occurring during the day though the outdoor reading was not elevated.



Graph 1: Total Count



Graph 2: Yeast and mould

Figure 38, Comparison of Average Microbiological Pollutants in the old and new hospitals.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p23.

STAFF PERCEPTIONS

Questions on the survey prompted staff to feedback on their perceptions of odours, air freshness and air movement around their work points.

Essentially staff indicated their satisfaction with each of these elements, with odours yielding a 76% satisfaction rating, air freshness attracting a 73% satisfaction rating and air movement yielding a 67% satisfaction rating. Dissatisfaction ratings were limited to a very small number of staff.

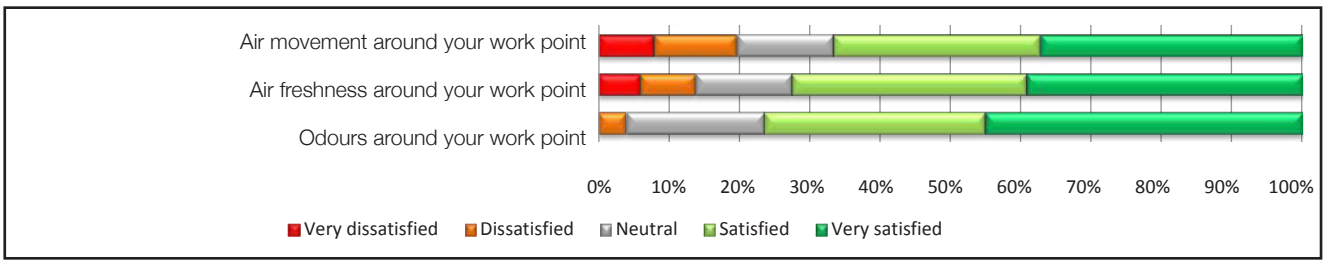


Figure 39, Staff air quality satisfaction in the new hospital

Importantly, 71% of staff confirmed their ability to undertake work tasks was positively influenced by the air quality.

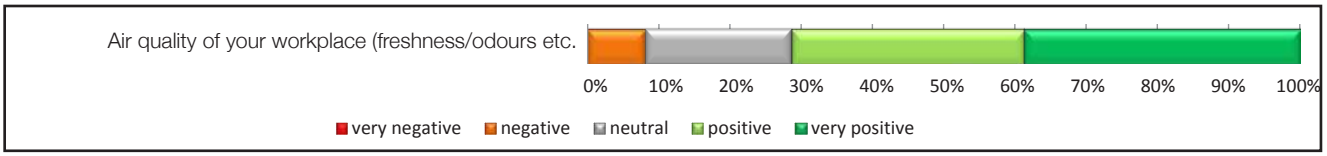


Figure 40, Impact of air quality on staff productivity in the new hospital

When compared to the old hospital building, 65% of staff respondents who worked in both hospitals stated that the air quality of the new hospital had improved.

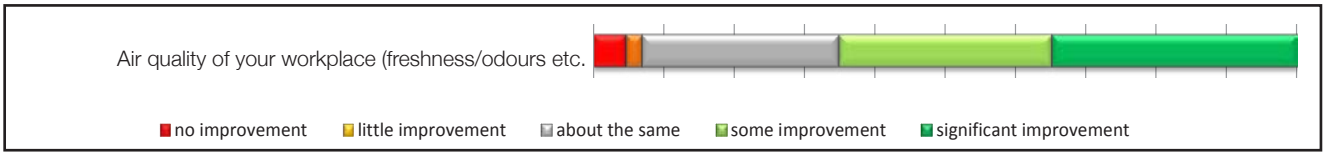


Figure 41, Staff comparison of air quality between the first and second POE in the new hospital

Staff comments

There were no specific staff comments relating to air quality.

PATIENT PERCEPTIONS

Patient perceptions of air quality in the new hospital were very high, with 89% of patients in the 2012 survey and 93% of patients in the 2013 survey responding that air quality has a positive or very positive impact on recovery.

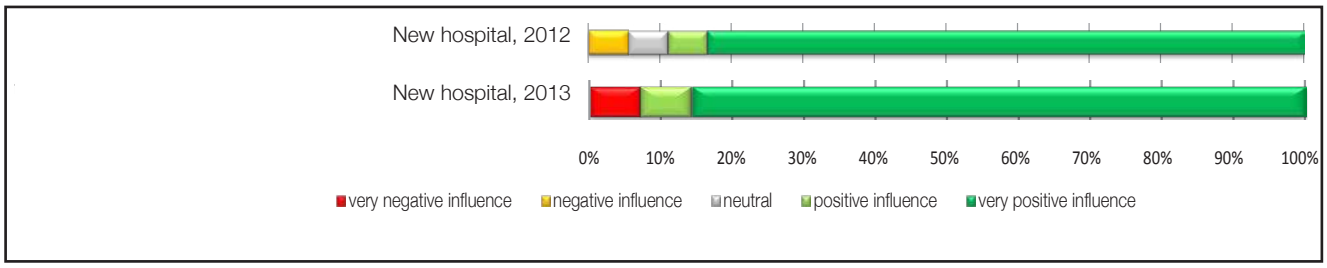


Figure 42, Impact of air quality on patient recovery in the old and new hospital

Critically, 80% of patients in the 2013 survey stated that air quality had improved or significantly improved compared to the old hospital.

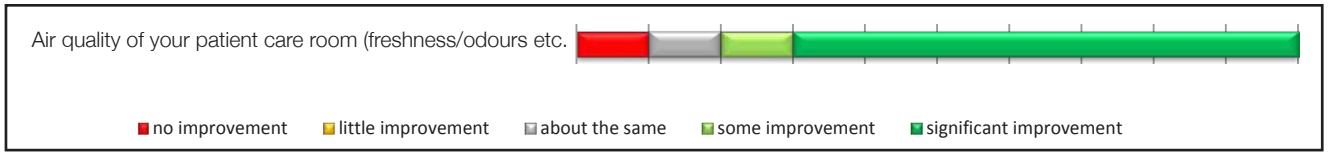


Figure 43, Patient perception of improved air quality in the new hospital

SUMMARY

Continue to monitor air quality in the new hospital through regular measurements of CO2, chemical pollutants and microbiological pollutants.

03.07

Findings
Light Quality

Lighting, and in particular daylighting, is one of the most critical aspects of IEQ that can fundamentally impact staff productivity and patient outcomes. Ampt et al (2008) reported on several studies that have strong conclusions linking good quality light to better patient outcomes. Some key findings include:

– People generally prefer daylight to artificial light (Devlin and Arneill 2003)
– Bright light – and in particular morning light - can elevate the mood of patients suffering depression (Lorenz, 2007; Ulrich & Quan, 2005).
– Exposure to morning light has been linked to reduced length of stay (Lorenz, 2007).
– Patients who are located in the brightest (sunlit) rooms have been shown in some studies to require less pain medication (Dijkstra, Pieterse et al. 2006).

Similarly nursing staff have been shown to experience less stress and greater job satisfaction through exposure to daylight for at least 3 hours per day (Joseph & Hamilton, 2008). Other qualitative studies have demonstrated staff optimism for increased natural light and have been documented as significantly valuing natural light (Mroczek, Mikitarian et al. 2005).

While the research regarding natural light, better patient outcomes and greater staff satisfaction is compelling, the study of the Alexandra District Hospital did not seek to measure natural light. It was noted that the majority of patient rooms have a northerly or easterly aspect – which can take advantage of the morning sun. CETEC measured horizontal and vertical lux levels of artificial lights at each of the designated measurement points.

CETEC MEASUREMENTS

CETEC's evaluation of lighting levels was informed by Australian Standard 'AS1680.2.2 2008: Interior Lighting and Workplace Lighting', the 'American Nation Standard Practice for Office Lighting 2004" and Newsham et al. (2005). The following graphs show that the average horizontal lux at the new hospital building was measured at the lower end of the recommended range and average vertical lux was measured within the recommended range. Most notably, lower than recommended lux levels were reported at the Nurse's station.

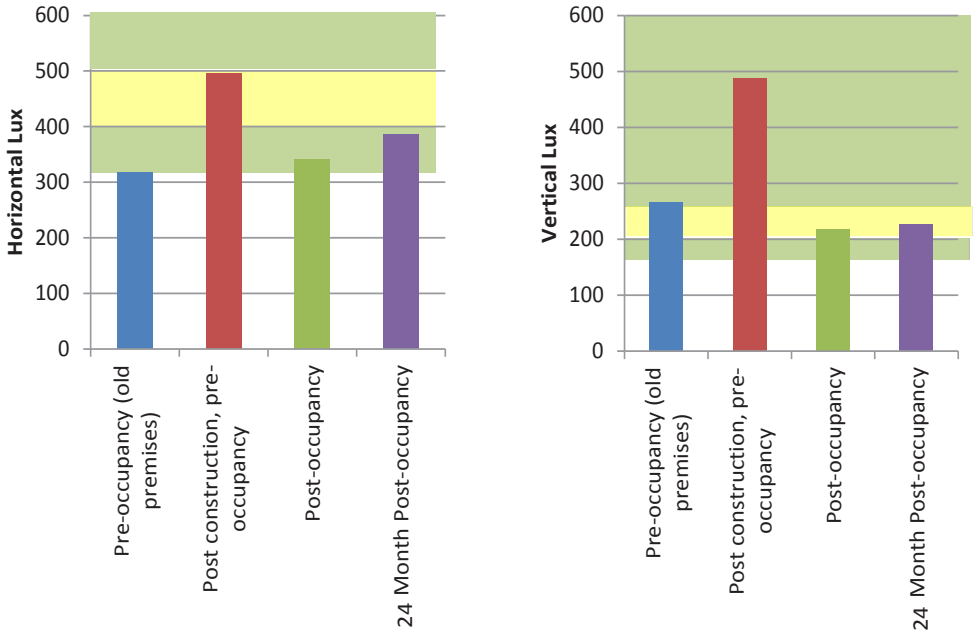


Figure 44, Comparison of Average Light Levels in the old and new hospitals.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 4 Month Post-Occupancy Evaluation dated November 2013, V3.0, p28.

03.07

Findings
Light Quality

CETEC SUMMARY

– Lighting measurements varied greatly across the areas measured, with some measurements being below the recommended guidelines while others were ideal.

– Location A (reception) should increase vertical luminance to increase lighting to tasks such as reading computer screens. Location C (nurses' station) should increase overall lighting to improve visual task comfort.

CETEC LEGEND

A - RECEPTION
B - ANCILLARY SPACES (BACK OF HOUSE)
C - NURSE'S STATION
D - PATIENT ROOM (EAST)
E - PATIENT ROOM (SOUTH)
F - OPERATING THEATRE

	A	B	C	D	E	F	Recommended Guidelines	Performance Based Targets
Horizontal (lux)	444	513	264	450	307	510	**320 min**	**400-500**
Vertical (lux)	140	324	140	207	390	308	**160 min**	**200-250**
Uniformity	3.2	1.6	1.9	2.2	0.8	1.7	**3 max**	**NA**

Figure 45, Lighting Results Summary in the new hospital.
Source: CETEC Report titled Alexandra Hospital Indoor Environment Quality: 24 Month Post-Occupancy Evaluation dated November 2013, V3.0, p26.

03.07 Findings
Light Quality

STAFF PERCEPTIONS

While the CETEC measurements indicated there were some areas with less than recommended lighting levels, there was very little dissatisfaction expressed by staff on this matter. Generally there was an overwhelming sense of positivity reported by staff towards the quality of light and access to natural light.

80% of staff were satisfied with the quality of light at their work point.
82% of staff were satisfied with access to natural light from their work point.

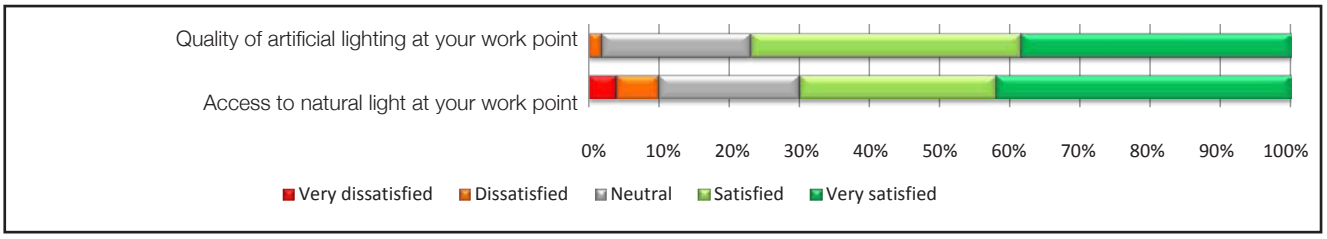


Figure 46, Staff satisfaction with lighting in the new hospital

82% of staff respondents stated that the quality of light was a positive or very positive influence in their ability to undertake work tasks.

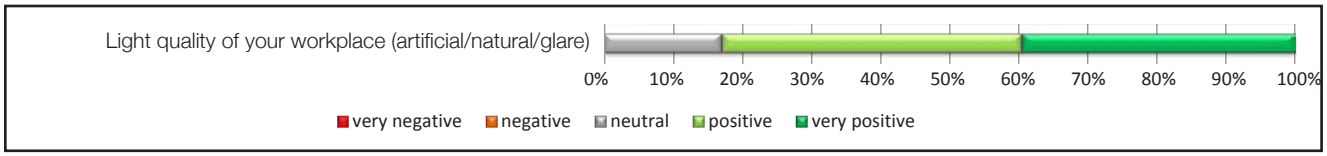


Figure 47, Impact of quality of light on staff work tasks in the new hospital

77% of staff respondents also believe the quality of light has improved their ability to undertake work tasks in the new building when compared to the old building.

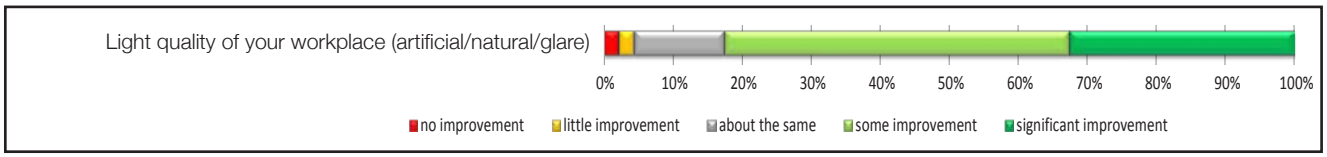


Figure 48, Staff perception of improvement of light quality between the new & old hospitals

03.07 Findings
Light Quality

PATIENT PERCEPTIONS

86% of patient respondents were satisfied or very satisfied with the quality of artificial light in the patient care room.
93% of patient respondents were satisfied or very satisfied with the access to natural light in their patient care room.

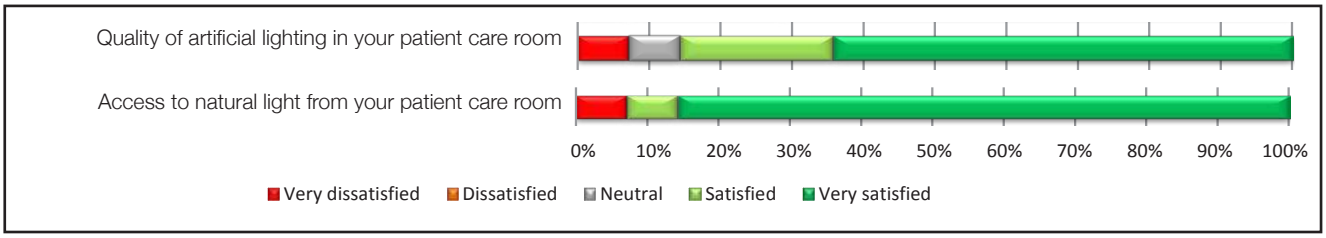


Figure 49, Patient satisfaction with lighting in the new hospital

When asked what impact the quality of lighting influenced their recovery, 93% of patient respondents stated it was a positive or very positive influence.

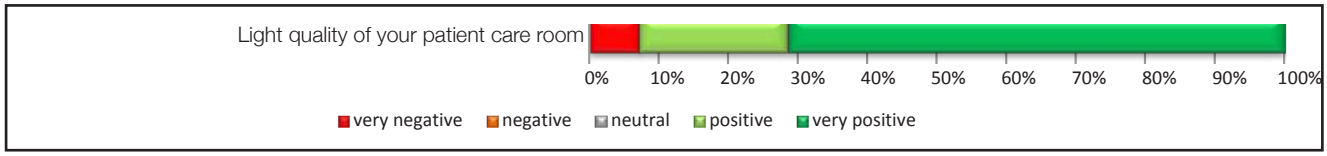


Figure 50, Impact of quality of light on patient recovery in the new hospital

When compared to the old hospital building, 80% of patients believed that the quality of light in their patient care room in the new hospital building was an improvement on the lighting in patient care rooms in the old hospital building.

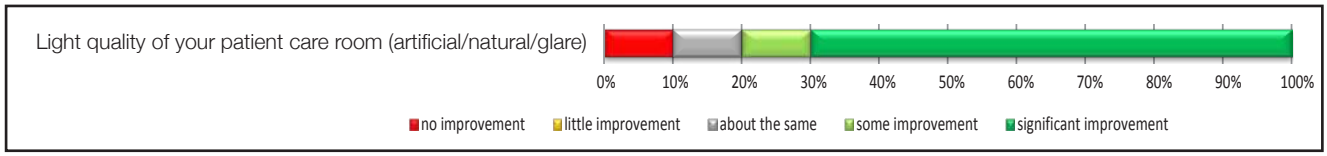


Figure 51, Patient perception of improvement of light quality between the new & old hospitals

SUMMARY

Existing lux levels should periodically be measured to evaluate against recommended lux levels.
Artificial lighting at reception and the nurse's station should be reviewed to increase light levels in line with recommended guidelines.

03.08 Findings
Planning and Design

A growing body of evidence contends that the planning and design of hospitals is a critical factor in patient well-being and staff satisfaction. The overriding objective in designing a healthcare building is to reduce stress of patients, resulting in reduced lengths of stay and better patient outcomes. A well designed healthcare building can also provide a satisfying work environment for staff, leading to less medication errors, reduced sick leave and greater productivity. IEQ factors have already been discussed in this paper, including quality of acoustics, artificial light and natural light. However it must be acknowledged that the planning of healthcare facilities will often determine the quality of the indoor environment. Stress in patients may be induced through lack of sleep, lack of outlook, disorientation etc. Stress in staff may be induced through too much noise, too many distractions and interruptions. Therefore, reduced stress in patients and staff can be linked to good planning and design including a) strategic positioning of windows; and b) layout of wards to mitigate disorientation and excessive walking distances.

WINDOWS

While access to natural light, and particularly morning sunlight, has been documented as a contributor to shorter hospital stays and reduced pain medication (Dijkstra et al. 2006; Lorenz, 2007) this can only occur through the considered orientation of the building and location of windows proximal to beds, to optimise patient access to natural light. Not only do windows afford access to natural light, they also present the opportunity for patients to access pleasant views and outlooks - a factor referred to by Ulrich et al as “positive distraction” (Ulrich et al, 2005, p21.). Several studies support this notion (Ulrich, 1984; Dalke et al. 2006). Evidence to assert the positive patient outcomes of enabling access to views of the natural environment is relatively scant, and often contextualised in very specific patient groups (eg. patients recovering from heart surgery, depression or gynecology patients). However, the literature does nonetheless provide compelling evidence to support the benefits of windows for patients to access natural light and pleasant outlooks (Ulrich, 1984; Ampt et al, 2008; The Institute for Innovation in Large Organizations, 2008).

At the Alexandra District Hospital every patient bed is located in close proximity to a window so patients can look out the window into a garden or courtyard. Furthermore the building has been deliberately oriented so the majority of rooms have north or east facing windows, to maximise morning sunlight. Unfortunately the garden beds had not been developed at the time of the survey period, which diminished the pleasantness of the outlook. This was further exacerbated when compared to the old hospital building located at the top of a hill, which afforded many patients highly valued distant views. There was a sense that the outlook from the new hospital was inferior to the old hospital, although this perception would have been reduced had the garden beds been developed as per the Architect’s scheme. The hospital intends to develop the gardens in the near future.

Staff perceptions

51% of staff expressed satisfaction regarding the access to distant views from their workpoint, and 60% expressed satisfaction regarding access to an external outlook from their workpoint.

Although the new hospital does not have distant views of the same scale as the old hospital, it does nonetheless offer pleasant tree views from many parts of the hospital.

Landscaping around the new hospital has commenced and whilst this will take some time to develop mature plants, has already provided significant improvements in the outlook into external spaces around the hospital.

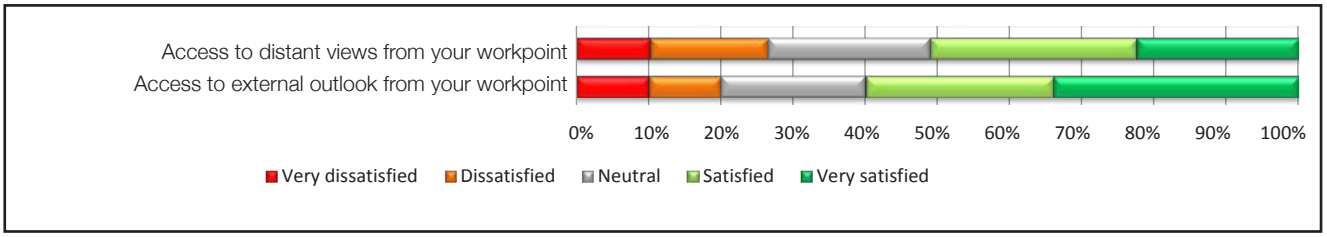


Figure 52, Staff satisfaction with outlook and views in the new hospital

Staff comments

Cannot see outside unless move to window/door in hallway.

Better workplace making working here more enjoyable and productive.

03.08 Findings
Planning and Design

Patient perceptions

There was a high degree of satisfaction with external views from the patient care rooms in the new hospital building, with 86% patient satisfaction.

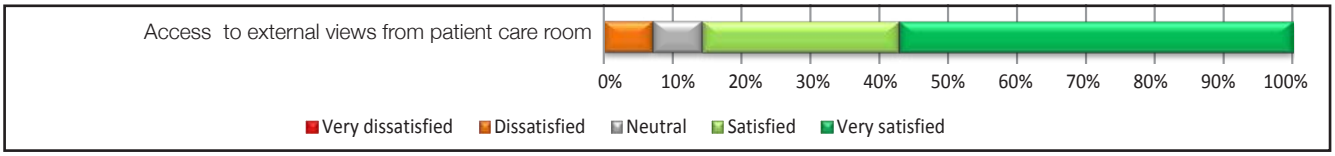


Figure 54, Patient satisfaction with outlook from the new hospital

Patient comments

Gardens in progress. Will be good when done.

Great hospital. Great staff.

SUMMARY

Continue to develop the landscaping as pleasant outlooks to be enjoyed by both staff and patients.

LAYOUT OF THE BUILDING

Loftness et al (2006) describe the characteristics of a healthy building as having

"many of the characteristics of sustainable, healthy humans - they are physically fit rather than obese (thin floor plans, finger plans and courtyard buildings); they have circulatory systems that take the heat from the core out to the surface (eg air flow windows), they absorb sunlight and breathe fresh air" (p.6).

The layout of the Alexandra District Hospital fits with this idea, having a finger plan that keeps the building envelope thin, while enabling good quality IEQ and access to abundant natural light. Ulrich et al (2004) speculate that a radiating plan, such as is the case at ADH, is preferable to a rectangular plan as a radiating plan serves to reduce walking distances for staff. Such a planning convention also reduces the negative impact of long corridors which contribute to excessive noise, disorientation and tiredness (Ampt et al, 2008).

The location of the nurse's station is located at a central point convenient to two wards which are located in two 'fingers' of the building. While this is the most central and convenient location for the nurse's station, its location appears to have resulted in increased walking distances for nursing staff during a typical shift. This perception must also be factored in with the high density layout of the old building, where patients were often in 4-bed rooms with access to centralised shared bathrooms, which is no longer considered an appropriate design layout for a hospital ward.

03.08 Findings
Planning and Design

Staff perceptions

Nursing staff have noted that walking distances have increased at the new hospital, although this is not always perceived as a negative response.
69% of staff respondents expressed that how far they have to walk during their work shift has a positive or very positive influence on their ability perform work tasks.

Space planning and wayfinding was viewed by staff as having a very positive impact on their ability to undertake work tasks in the new hospital, with 88% of staff responding positively.

Staff comments

There were no specific comments relating to walking distances, space planning or wayfinding in the 2013 survey responses.

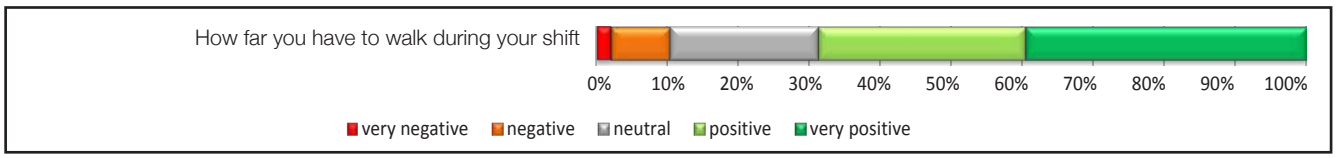


Figure 56, Staff impact of walking distances on ability to undertake work tasks in the new hospital

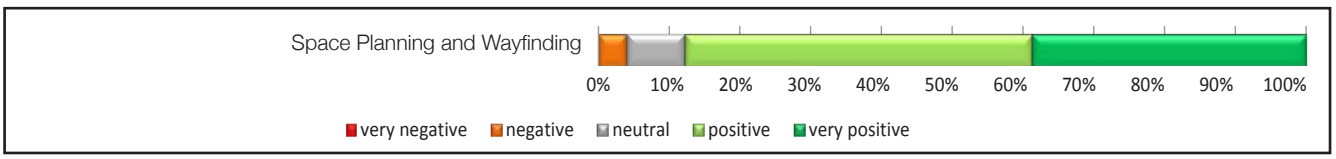


Figure 58, Staff impact of space planning and wayfinding on ability to undertake work tasks in the new hospital

03.08 Findings
Planning and Design

Patient perceptions

In relation to planning and design, patients were asked to comment on their degree of satisfaction towards the location of the bathrooms. The new hospital incorporate ensuites to every single bed and twin bed room.

93% of respondents in the new hospital expressed their satisfaction with the distance to the bathroom from their patient care room. As expected the location of ensuites in to the patient care rooms has been a highly valued improvement in the new hospital.

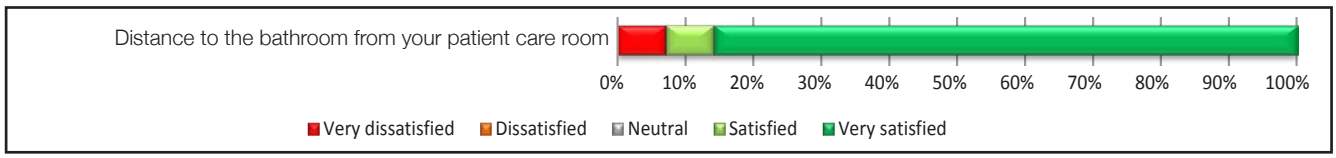


Figure 60, Patient satisfaction with distance to the bathroom in the new hospital

Patient comments

I have always found the staff to be exceptional. What I do miss is the elevated views to the surrounding hills that were afforded from the old hospital and not so much glare as now comes from the present entrance etc. BUT I expect that as the gardens mature this will be rectified.

The care, staff at the old and new hospital has always been tops in my opinion.

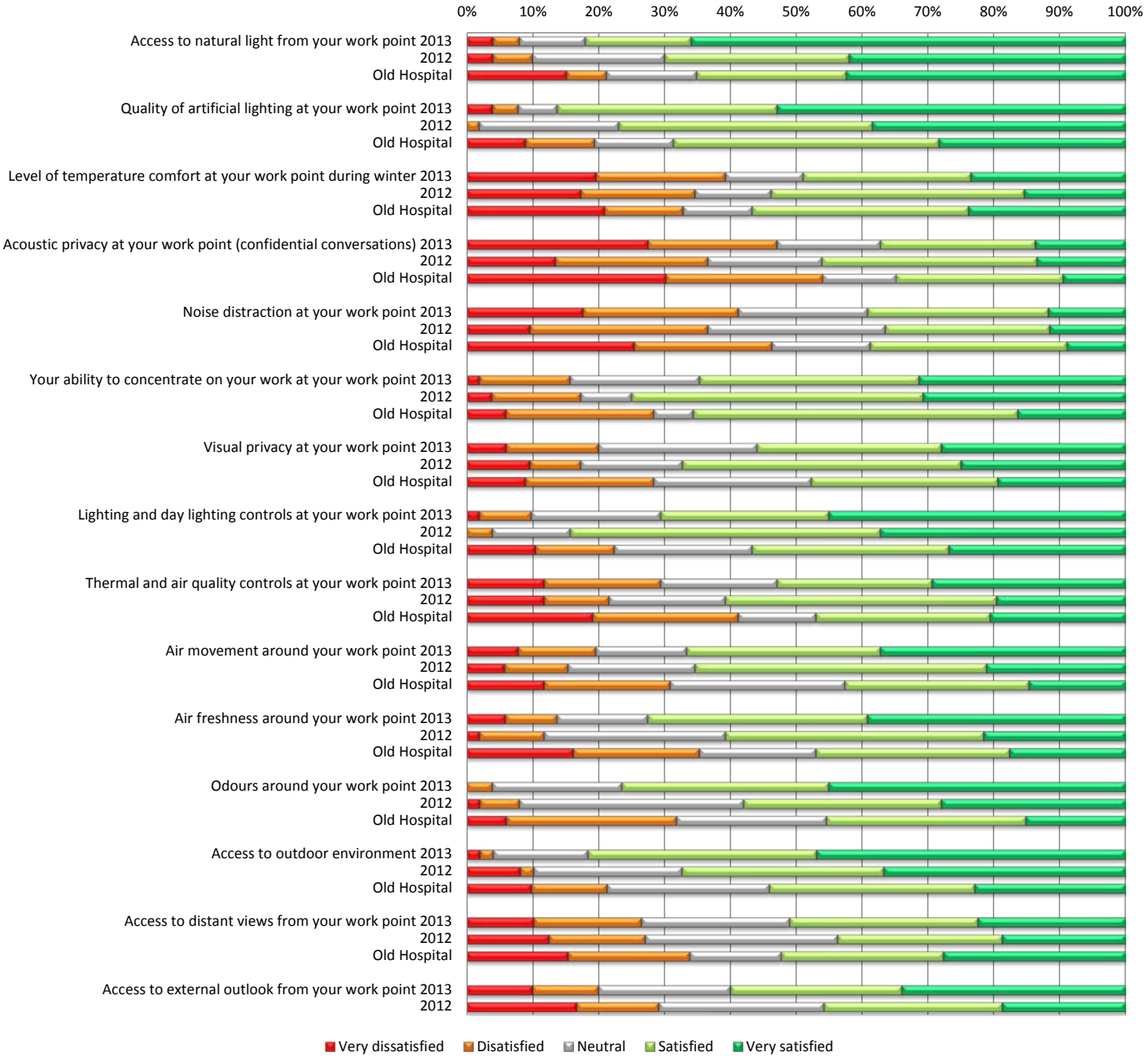
SUMMARY

The high levels of satisfaction relating to space planning and design attributes in the new hospital do not indicate a requirement to recommend any specific actions. While walking distances for staff may have increased in the new building, it is expected that staff will adjust to the new environment and this will eventually cease to be an issue.

03.09

Summary Findings
Comparative Analysis: Staff

How satisfied are you with the following characteristics of your work point?



There are significant levels of satisfaction relating to all work point characteristics in both hospitals, however satisfaction in the new hospital is even higher. Furthermore, in the new hospital levels of dissatisfaction have reduced for every characteristic.
The highest levels of satisfaction in the new hospital relate to:

– access to natural light
– quality of artificial light
– the ability to concentrate on work at their work point
– air freshness and odours
– access to the outdoor environment

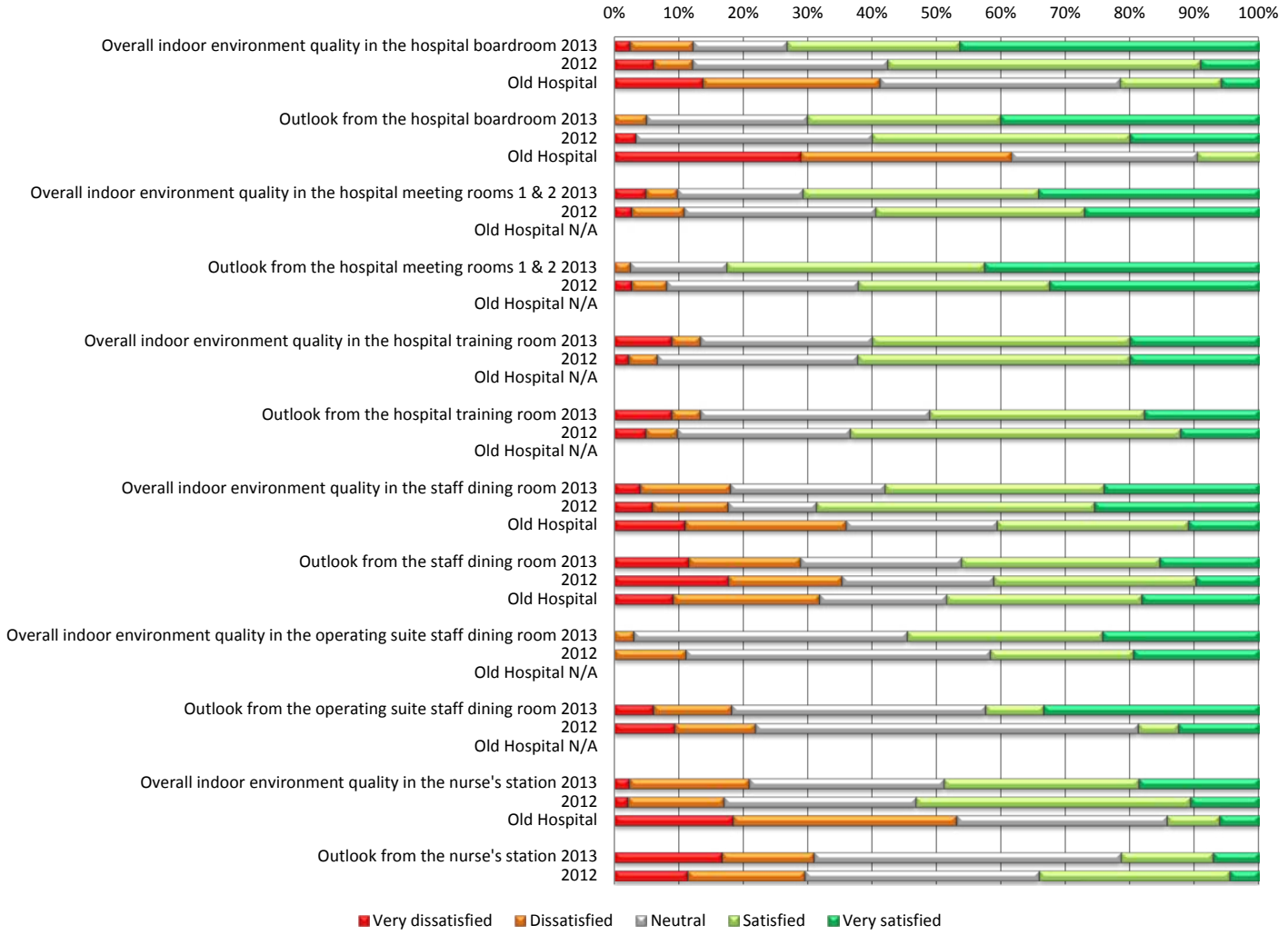
The highest levels of dissatisfaction in the new hospital relate to:

– levels of temperature comfort
– acoustic privacy at their work point
– noise distraction at their work point

03.09

Summary Findings
Comparative Analysis: Staff

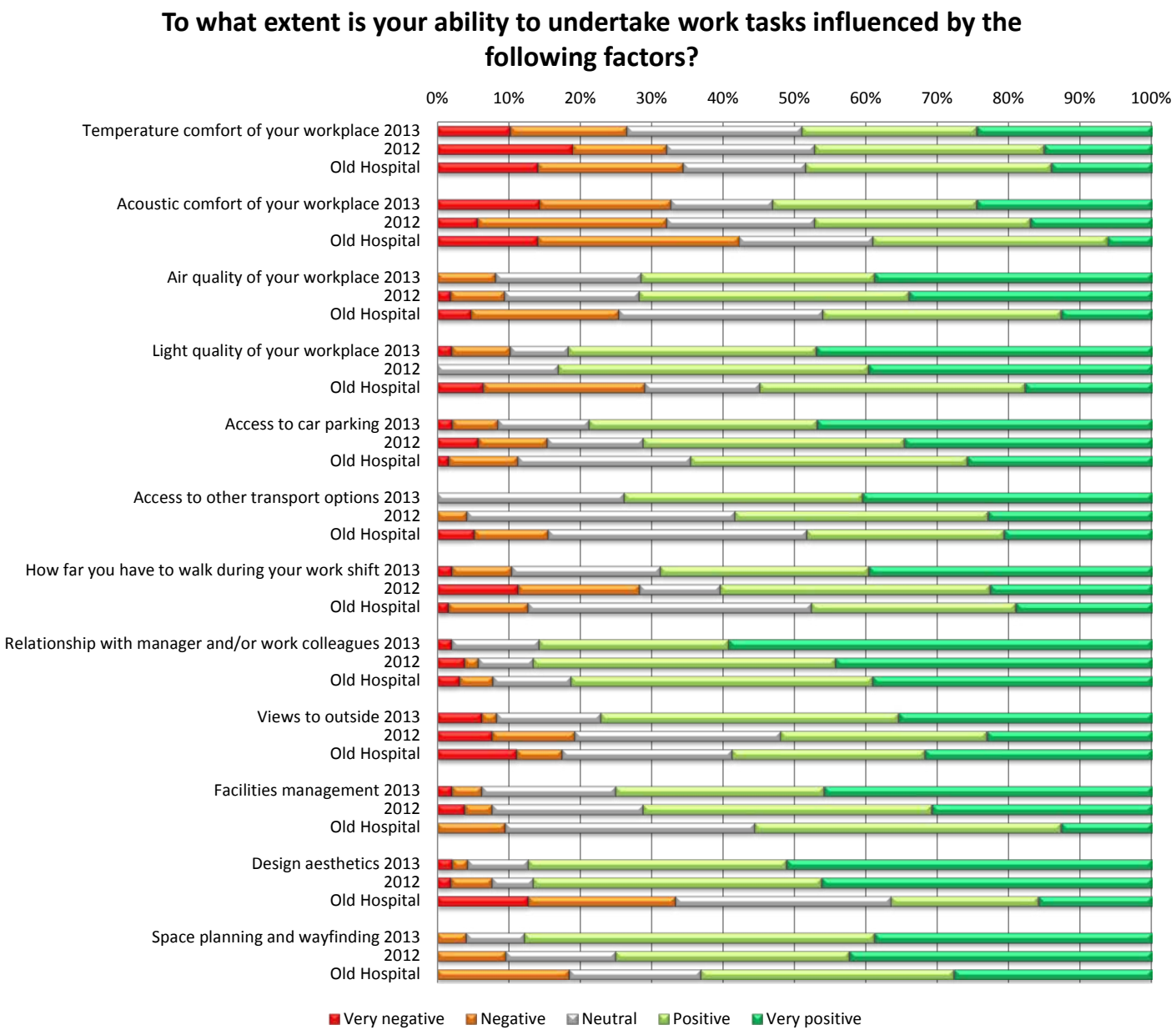
How satisfied are you with the following characteristics of other work facilities you regularly use?



There are significant levels of satisfaction relating to work facilities within both hospitals, however satisfaction in the new hospital is even higher. Furthermore, in the new hospital levels of dissatisfaction have reduced for every facility.
The highest levels of satisfaction in the new hospital relate to:
– IEQ and outlook from the hospital boardroom
– IEQ and outlook from the hospital meeting rooms 1 & 2
– IEQ of the staff dining room
The highest levels of dissatisfaction in the new hospital relate to:
– outlook from the staff dining room
– IEQ and outlook from the nurse's station

03.09

Summary Findings
Comparative Analysis: Staff



Staff expressed that the highlighted environmental factors have had a very positive or positive influence on their ability to undertake work tasks, and in most cases data for environmental factors in the new hospital had a higher positivity rating than in the old hospital. Conversely, negativity relating to some environmental factors decreased in the new hospital.

The highest levels of positivity in the new hospital relate to:

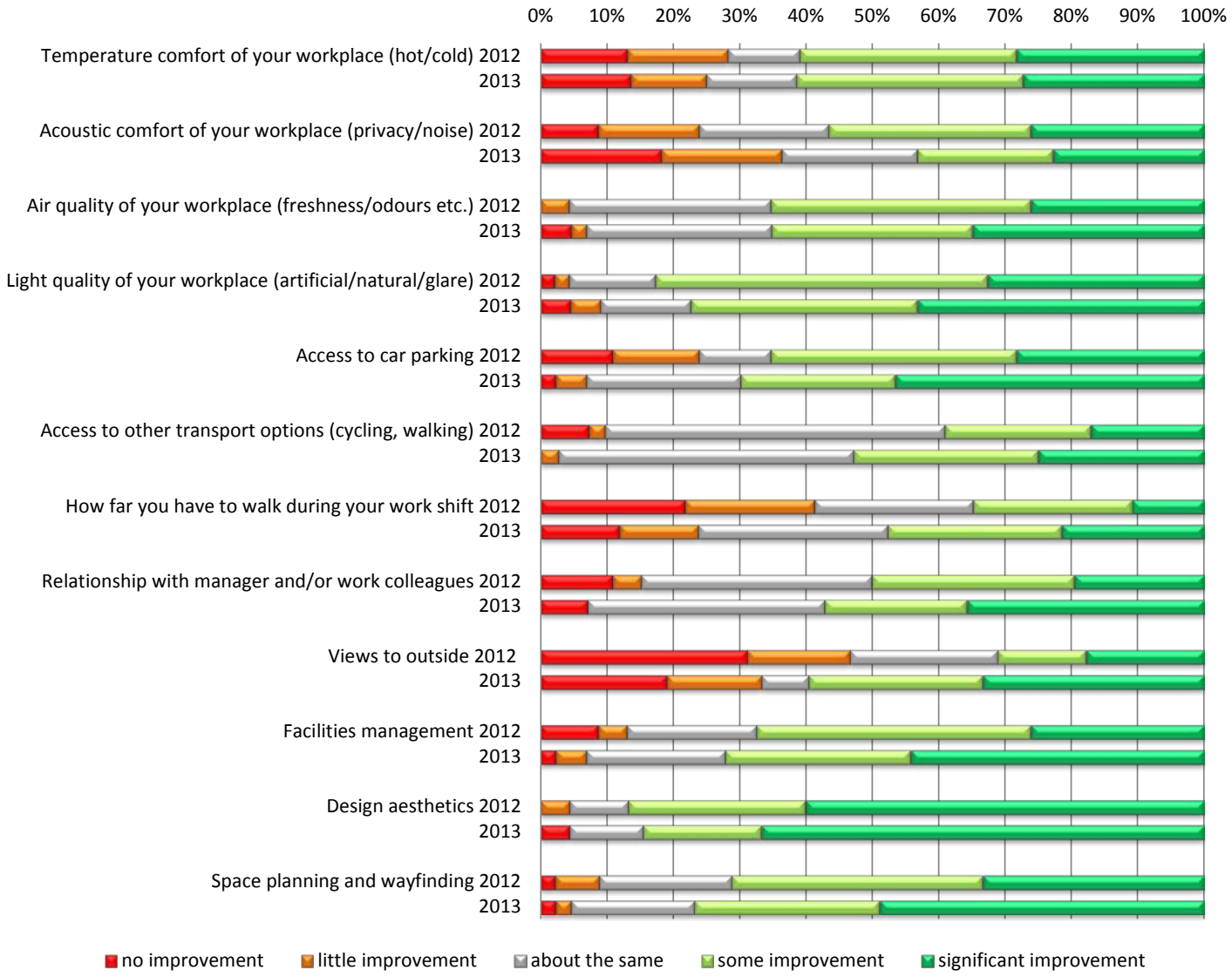
– space planning and wayfinding
– design aesthetics
– relationship with manager and /or work colleagues
– light quality of the workplace

The highest levels of negativity in the new hospital relate to:

– temperature comfort (due to the ongoing issue with balancing the HVAC system, which will hopefully be resolved in time)
– acoustic comfort

It is also interesting to note that when staff first moved to the new hospital many found they had to walk further as part of their work activities. This was expressed as some degree of negativity during the 2012 survey, however as staff have become used to the extra distance, this issue seems to have attracted less negativity.

To what degree have the following factors improved your ability to undertake work tasks in the new hospital building?



Staff who had worked in both the old and new hospitals were asked to indicate the level of improvement on certain environmental factors between the old and new hospital buildings. Very high levels of improvement were recorded against almost every category.

The highest levels of improvement in the new hospital related to:

– design aesthetics
– space planning and wayfinding
– light quality of the workplace

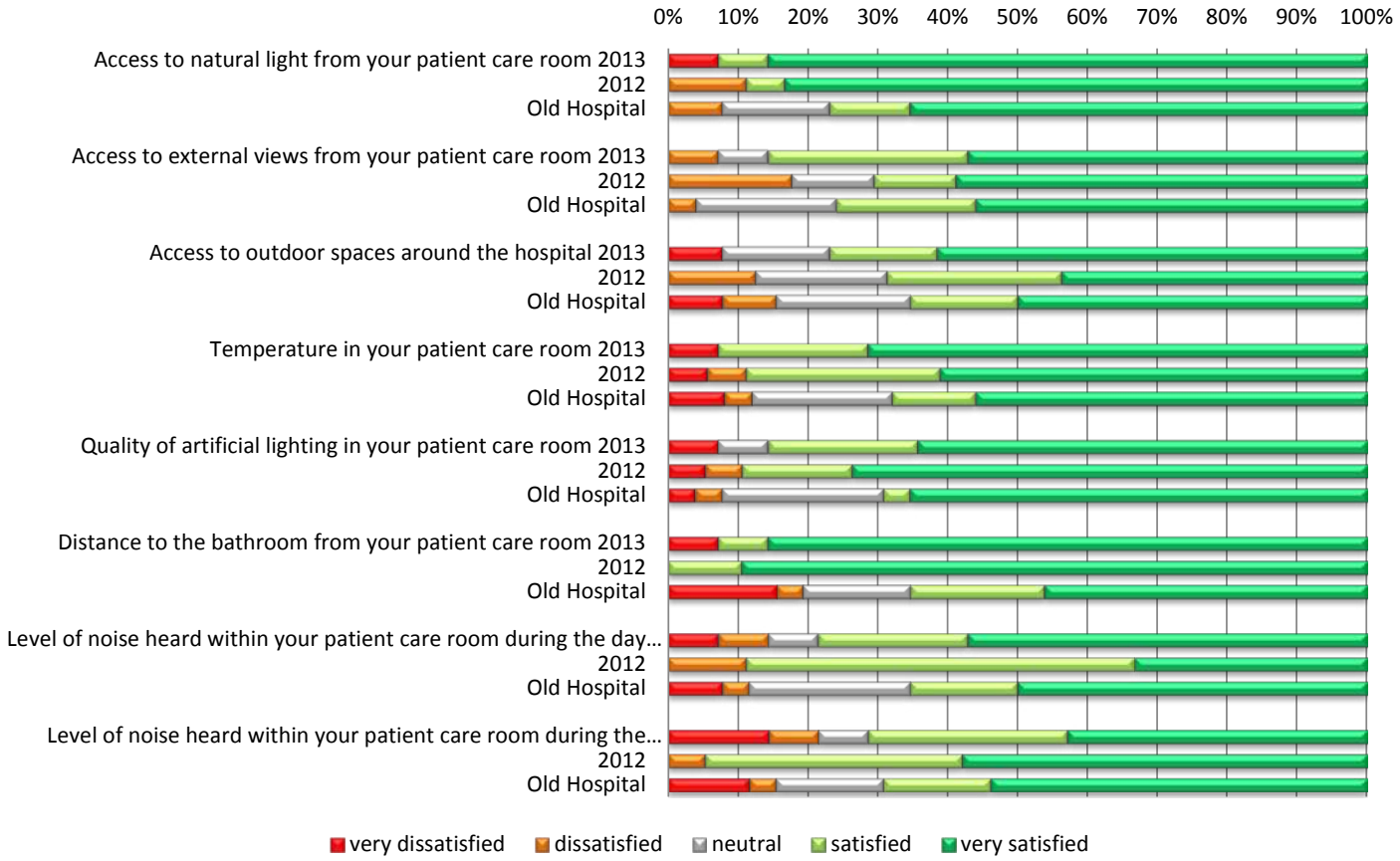
The lowest levels of improvement in the new hospital related to:

– views to outside (not surprising when you consider the amazing distant views from the old hospital, located on top of a hill)
– how far you have to walk during a work shift (recognition that the hospital is larger and some staff do have to walk longer distances)
– acoustic comfort
– temperature comfort

03.09

Summary Findings
Comparative Analysis: Patients

How satisfied are you with the following characteristics of your patient care room?
Comparison between old (2011) & new hospitals (2012 & 2013)



There are significant levels of satisfaction relating to all patient care room characteristics in both hospitals, however satisfaction in the new hospital is even higher. The highest levels of satisfaction relating to patient care rooms in the new hospital relate to:

– access to natural light
– distance to the bathroom
– temperature
– quality of artificial light

The highest levels of dissatisfaction in the new hospital relate to:

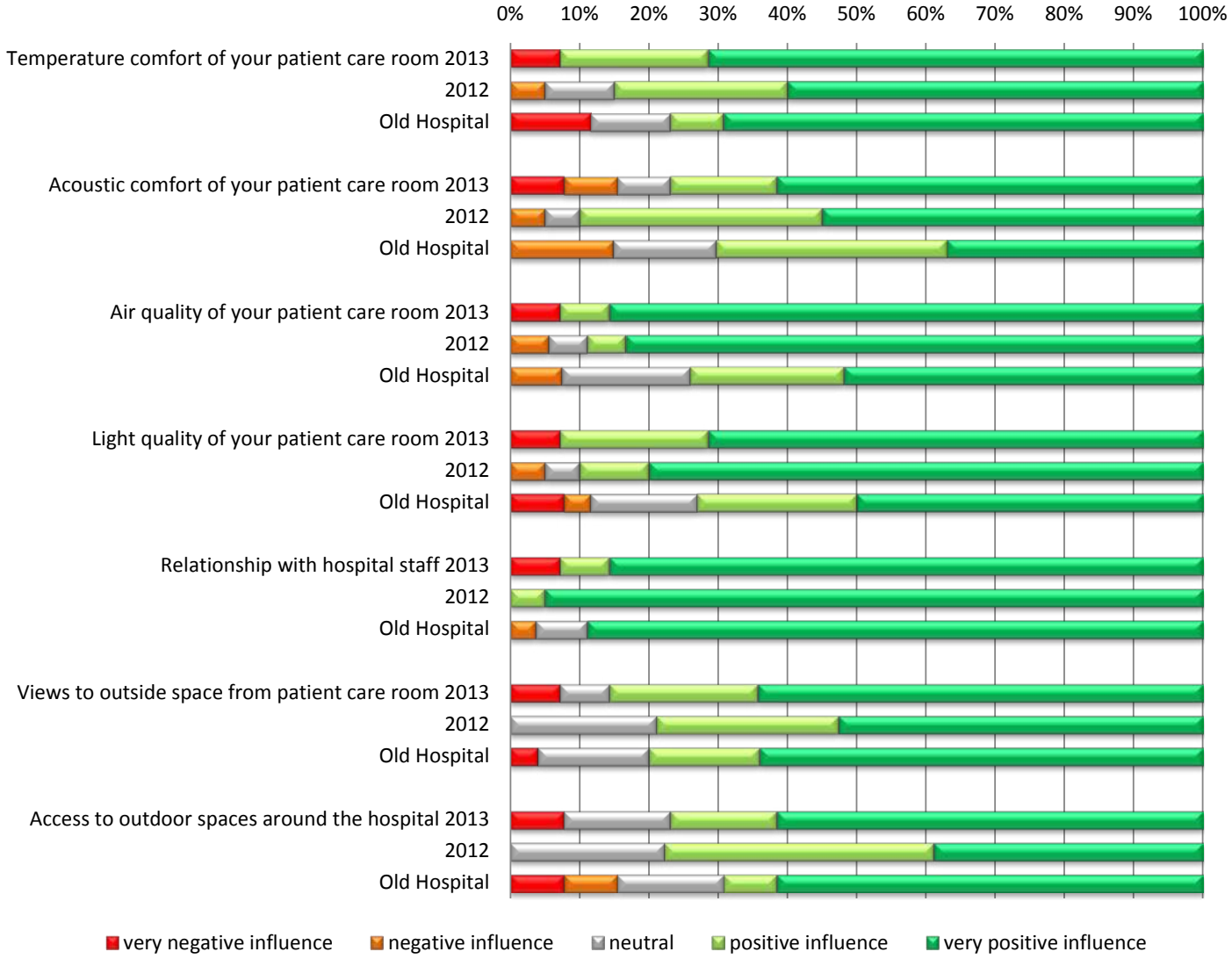
– access to external views (less dissatisfaction in the 2013 survey, but acknowledging that the old hospital views were extraordinary)
– level of noise heard within the patient care room during the night
– level of noise heard within the patient care room during the day

It is important to note that dissatisfaction ratings represented a small minority of patient respondents.

03.09

Summary Findings
Comparative Analysis: Patients

To what extent, if any, do you believe your recovery has been influenced by the following factors?



A high percentage of patients expressed that the highlighted environmental factors have had a very positive or positive influence on their recovery, and in every case data for environmental factors in the new hospital had a higher positivity rating than in the old hospital.

The highest levels of positivity in the new hospital relate to:

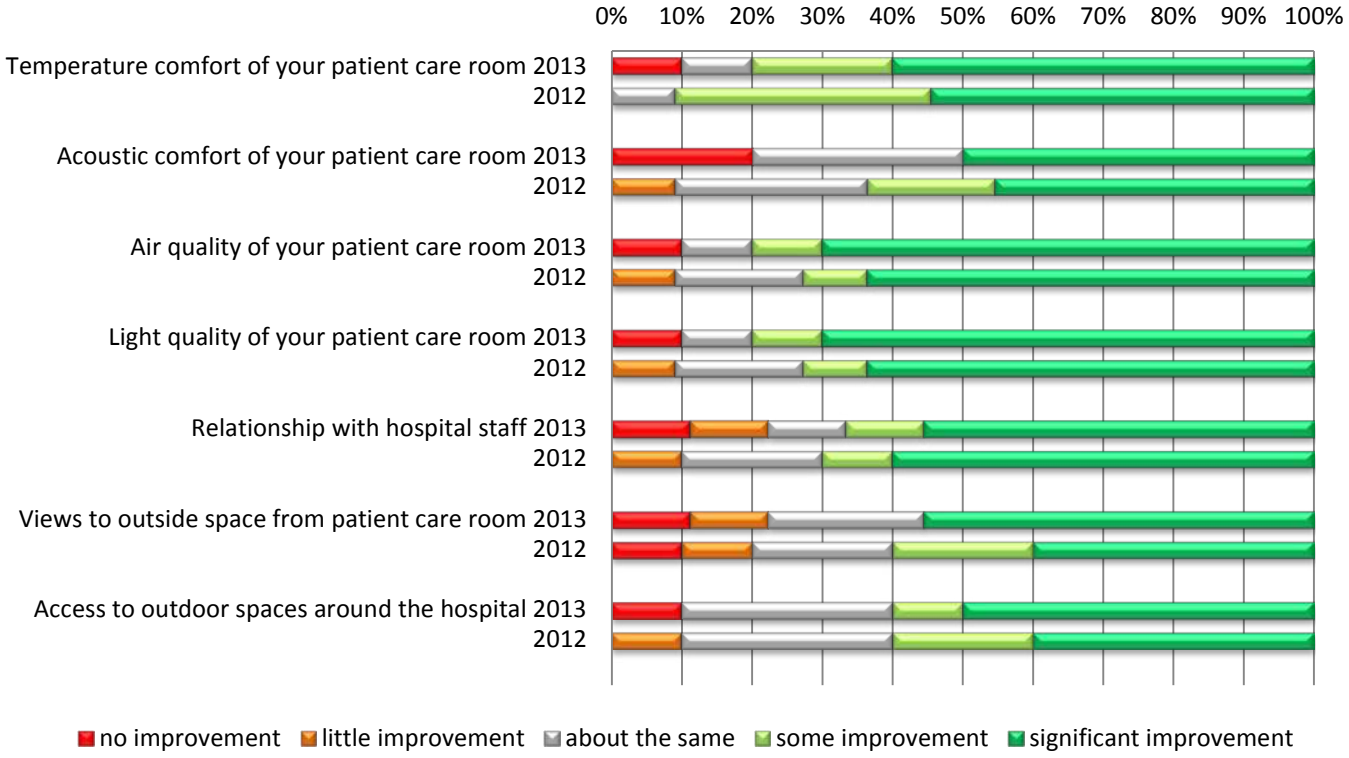
– relationship with hospital staff
– temperature comfort
– air quality
– light quality
– light quality of the workplace

The highest levels of negativity in the new hospital relate to:

– temperature comfort
– acoustic comfort

It is important to note that negative ratings represented a small minority of patient respondents.

Compared to the old Alexandra District Hospital, to what degree have the following indoor environment qualities improved in the new Alexandra District Hospital?



Patients who had been admitted to both the old and new hospitals in the last three years were asked to indicate the level of improvement on certain environmental factors between the old and new hospital buildings. Although there were a small number of respondents in this category, the findings indicate improvement to most categories.

The highest levels of improvement in the new hospital related to:

– temperature comfort of the patient care room
– air quality
– light quality

The lowest levels of improvement in the new hospital related to:

– views to outside (not surprising when you consider the amazing distant views from the old hospital, located on top of a hill)
– acoustic comfort
– access to outdoor spaces

Little or no improvement was expressed by a small minority of patients

03.10

Findings
Staff Productivity

It was established at the commencement of the Study that a measure of staff productivity would be data associated with sick leave and annual leave. High rates of sick leave may be due to work dissatisfaction, but may also be related to poor air quality. Therefore, reduced sick leave hours per staff member would support the contention that a healthy building leads to greater staff satisfaction and therefore, productivity. Another hypothesis related to staff annual leave, in particular short durations of annual leave, which could indicate days off due to dissatisfaction with work. The latter data set was difficult to track as sick leave data was issued in a de-identified format, with no record of patterns of sick leave taken.

While it was an interesting line of inquirity to explore in relation to the whole project, the findings do not yield any convincing conclusions. This type of data may reveal more sustained conclusions following a longitudinal investigation of sick leave and annual leave.

SUMMARY

Continue to regularly review sick leave and annual leave data for the next 2 - 3 years to determine whether there is a long term trend of reduced absenteeism.

03.10

Findings
Patient Outcomes

It was established at the commencement of the Study that a measure of 'better patient outcomes' would be data associated with reduced patient falls, and that a measure of 'improved staff productivity' would be reduced medication errors and patient infections.

The following graphs combine staff and patient statistics for the old and new hospitals. They indicate that patient falls were higher in the first year of occupancy of the new hospital (when compared to data from the old hospital) but were lower in the second year of occupancy. While this does not represent a distinct trend, it is promising data, especially when there appears to be a larger number of patients in 2013 than 2012.

There were no patient infections recorded throughout 2011, 2012 and 2013, therefore this element is not conclusive.

Medication errors were higher in 2013 than in previous years of this Study, which is a concerning trend. Medication errors may be an indication of poor IEQ, resulting in staff experiencing reduced performance. However, there are other reasons to explain medication errors, such as staff wellbeing and issues with training. Staff feeling unwell, unsatisfied at work or not trained adequately may also lead to lapses in concentration, potentially resulting in medication errors. While the data for 2013 is concerning it is inconclusive on the basis of one year of poor results.

SUMMARY

Continue to regularly review patient falls, patient infection and medication errors. Where higher than expected results occur, further investigation should be conducted to explore reasons for errors and incidents. The data should also be benchmarked against other similar sized hospitals to ascertain if the results for ADH are within 'normal' rates.

03.10

Findings
Patient Outcomes

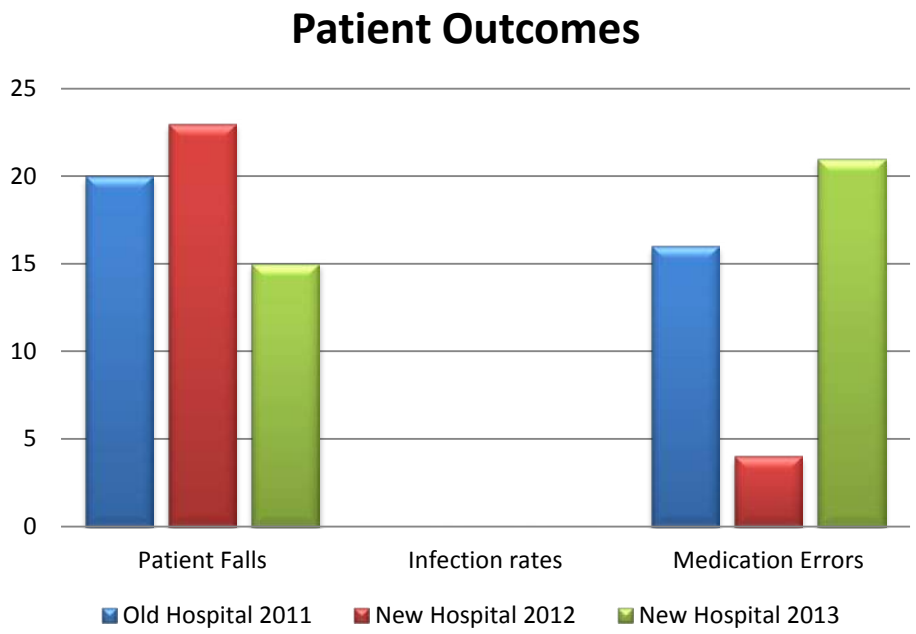


Figure 62, Comparison in patient outcomes between the new & old hospitals

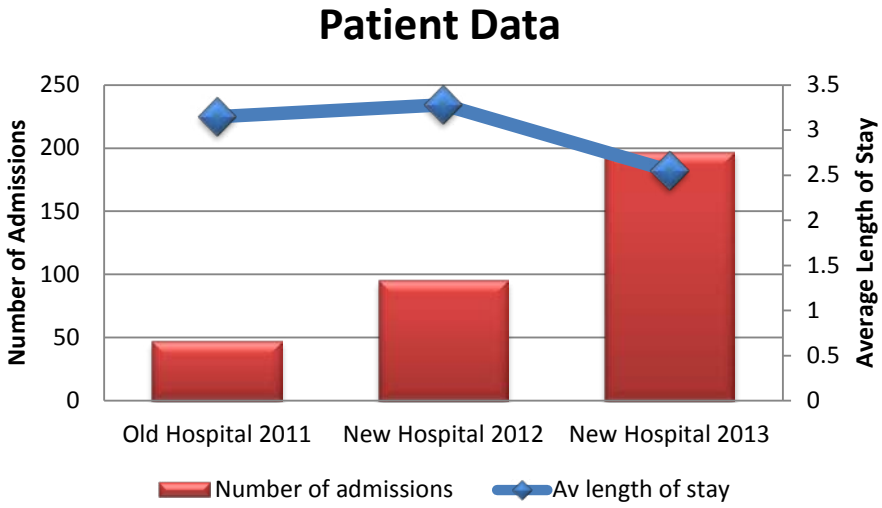


Figure 63, Comparison in patient data between the new & old hospitals

04.01 Conclusion

This longitudinal comparison between the old and new Alexandra District Hospitals set out to support the contention that a healthy hosptial building leads to better patient outcomes and greater staff productivity. While the collective body of data for this project does appear to support this contention, one study on its own does not prove this contention beyond doubt. That being said, this Study together with other related research studies, does add weight to the contention that healthy hospital buildings lead to better patient outcomes and improved staff productivity.

This Study has reviewed the findings in the context of relevant research undertaken in the context of health settings. In some cases this was quite difficult as there was not one singular study that exactly mirrored the methodology, context and objectives of the present Study. Therefore, the researchers have drawn upon various literature for a range of specific issues relevant to circumstances at the Alexandra District Hospital.

A large part of this Study sought patient and staff satisfaction of various environmental conditions in both the old and new hospital, on the basis that satisfaction leads to better patient outcomes and increased staff productivity. Although the patient and staff respondents at both hospitals varied, there were reasonable numbers of participants who were able to complete the surveys having experienced both the old and new hospitals.

Staff productivity was explored through de-identified data relating to staff sick leave and annual leave. While the findings begin to indicate increased staff productivity, it may be too soon to make a complete value judgement. The pattern of productivity is however, heading in the right direction.

While patient satisfaction was quite high for the old hospital, there was a noticeable reduction in dissatisfaction of aspects of the new hospital, combined with very high satisfaction ratings for the new hospital.

It is too early to say if patient length of stay has decreased since the new hospital has opened, but this data may be tracked over a longer period of time to establish a significant pattern of shorter hospital stays for patients.

In general the findings from this Study contribute to a larger collection of related research studies supporting the contention that a healthy hospital building leads to better patient outcomes and increased staff productivity. These findings should be harnessed to influence the future direction of new hospital buildings, where ESD targets present benefits well beyond energy savings. The findings from this Study and others, are sufficiently convincing that investing in good IEQ in hospital buildings should be considered of great value to both patients and staff. Furthermore, hospitals designed and built to purposeful project briefs, that explicitly outline the intended benefits to patients and staff, will provide useful benchmarking to enable continual improvements in future hospital developments.

05.01 Standards and Guidelines

The standards and guidelines referenced by CETEC as part of its Indoor Environment Quality studies are:

ASHRAE 55
- American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) guidelines
- Thermal comforts of an environment i.e. temperature (20-26ºC at winter and 23-28ºC at summer), relative humidity (30-60%) and air velocity (<0.2m/sec)

WHO
- World Health Organisation: Air Quality Standard
- Chemical (VOC < 0.5mg/m3, CO <10ppm, HCHO <0.1mg/m3), biological (<detected at ambient) and particulate indoor pollutants (<0.05mg/m3)

ASHRAE 62
- American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) guidelines
- Carbon dioxide (<1000ppm)

AS1680:1998
- "Interior Lighting" provides guidance for the general principles and recommendations for the lighting of interiors of buildings.
- In the horizontal plane 320 lux minimum for common office tasks
- In the vertical plane recommends 160 lux as a minimum

AS2107:2000
- "Acoustics – Recommended design sound levels and reverberation times for building interiors"
- 45db for general offices

IESNA
- Illuminating Engineering Society of North America (IESNA). (2000). Lighting handbook: Reference and application (9th ed.). New York: Illuminating Engineering Society of North America
- uniformity ratio establishes the difference in light levels that are allowed throughout a space
- recommended target is 3

Equipments used for measurement:
- Sound meter – for acoustic
- Lux meter – for illuminance of light
- Formaldehyde meter – for formaldehyde (HCHO)
- ppbRae PID – for VOC
- Q-trak – for CO2, CO, temperature, relative humidity
- Dust Trak – for particulate matter
- Testo 425 – for flow rate
- Quick Take – for airborne monitor

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Woods Bagot

Alexandra Hospital Indoor Environment Quality:

24 Month Post-Occupancy Evaluation

Cnr. Cooper and Myrtle Streets, Alexandra, Victoria 3714

Project Reference: CV131109

November 2013

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PROJECT OVERVIEW

CETEC were engaged by Woods Bagot to conduct an Indoor Environment Quality (IEQ) Study of the new Hospital in Alexandra.

Woods Bagot has a strong interest in undertaking this study to satisfy the following objectives:

- To measure and quantify the IEQ in the new hospital;
- To determine where improvement to IEQ are achievable and cost effective;
- To validate the success in relation to IEQ of moving to a superior building.

As per the scope of works described in the proposal CQV100408, CETEC has now delivered reports at the completion of each stage of the project as follows:

1. Pre-occupancy Indoor Environment Quality Report (testing conducted in March 2011. Refer CETEC report CV100920 Alexandra Hospital Pre Occupancy Study v1.7)
2. Post-construction, pre-occupancy Indoor Environment Quality Report (testing conducted in November 2011. Refer CETEC report CV111119 WB ADH Post Construction Pre occupancy IEQ)
3. Post-occupancy Indoor Environment Quality Report (testing conducted in May 2012. Refer CETEC report CV111119 WB ADH Post Occupancy IEQ v2.7)
4. 24 Month Post-occupancy Indoor Environment Quality Report (testing conducted November 2013.)

DISCLAIMER

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EXECUTIVE SUMMARY

CETEC has conducted the 24 month post-occupancy indoor environment quality (IEQ) assessment at the Alexandra District Hospital for Woods Bagot. The measurements were taken on Monday 11th November 2013.

The key performance areas are summarised below:

1. Thermal comfort has remained acceptable
2. Ventilation has been optimal and CO_2 levels are lowest at the new hospital
3. Chemical pollutants have remained low with TVOC and formaldehyde at the lowest concentration in the new hospital

CETEC recommend the following additional IEQ improvements at the post-occupancy site:

1. Further task lighting may be required in low light areas to avoid eye strain. Arranging of workstations to take advantage of natural light sources can improve occupant satisfaction.

2. Overall, ambient noise levels were elevated above the recommended guideline range. HVAC noise levels in patient areas should be reduced to improve acoustic comfort. Compared to the old premises, ambient sound levels have improved.

3. Elevated microbial results suggest some underlying issues. Further investigation is required to determine the source of the issue.

CETEC also conducted a review of the Energy Consumption at the hospital for the previous 12 months and found that energy consumption is equivalent to 0.81 GJ per square metre compared to an average of 1.49 GJ per square meter for previous 6 years of data which is a 45% reduction in usage per square meter.

1 INDOOR ENVIRONMENT QUALITY ASSESSMENT

1.1 Introduction

IEQ Assessments and Productivity Studies are increasingly used to predict and quantify the economic benefit of improving IEQ in a working environment. Research evidence has increasingly confirmed strong links between the indoor environment, occupant wellbeing, comfort and productivity and significant economic savings and productivity gains in worker performance are estimated even with a small improvement in indoor environmental quality *(Fisk 2000)*.

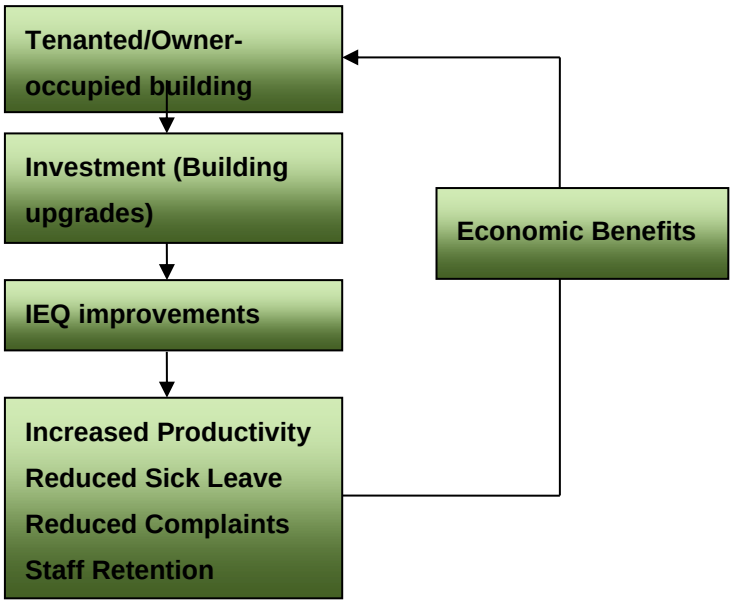


Figure 1: *Schematic illustration of how the building owner as an employer benefits from the improved indoor environment (based on Wargocki et al 2006)*

The established protocol for quantifying the benefit of improved IEQ in a work place is as follows:

1) Take quantitative measurements of IEQ prior to implementing building upgrades or re-location. This stage primarily measures current IEQ performance so areas where improvements are possible can be identified and potential productivity benefits arising from improvements can be predicted. This is referred to as the 'Pre-occupancy Study'. In this case the pre-occupancy study was conducted at the old Alexandra District Hospital located at the Corner of Cooper Street and Myrtle Street, Alexandra in March 2011.

2) Take quantitative measurements of IEQ after implementing building upgrades or re-

location, but prior to occupation of the new premises. This is referred to as the 'Post-construction, Pre-occupancy Study'.

3) Take quantitative measurements of IEQ after implementing building upgrades or re-location. This stage is primarily used to validate that implemented changes yielded improved IEQ and hence potential productivity benefits. This is referred to as the 'Post-occupancy Study'.

This report contains the findings of the Post-occupancy Study for the Alexandra District Hospital of located at the Corner of Cooper Street and Myrtle Street, Alexandra, and from here on will be referred to as the 'post-occupancy site'. It is noted that on the day of the assessment that the patient beds (Location E) E were not occupied due to a lack of demand for their use and that the Operating theatre (Location F) was also not being used on this day. During times of non-occupation of the patient areas the locations are isolated from the rest of the hospital and the HVAC systems shut down.

1.2 Post-occupancy Site Details

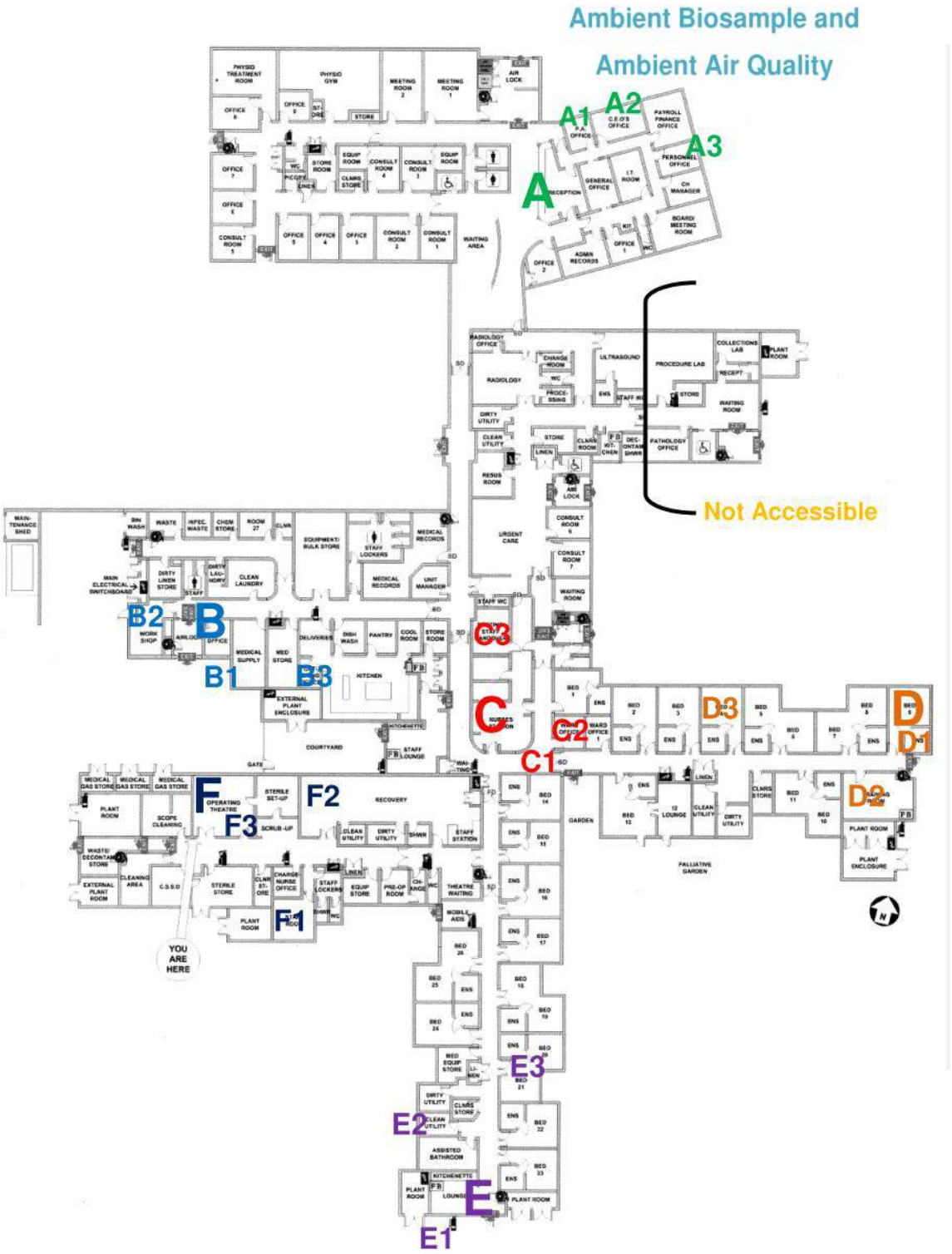
Address:	Corner of Cooper Street and Myrtle Street, Alexandra VIC 3714
Building Owner	Victorian Department of Health
Tenant	Alexandra District Hospital
General Layout:	• Offices and reception area • Specialty consolation rooms • Utilities and kitchen • Operating suite • Central nurse's station • Two sections with patient beds

1.3 Study Design and Methodology

IEQ measurements for this study were generally conducted in accordance with the *NABERS Indoor Environment for Offices Validation Protocol for Accredited Ratings.* The NABERS IE Protocol forms part of an Australian Government recognised building rating scheme and its use is well established in Australia.

Using this standardised approach in both the pre and post occupancy stages allows for quantitative comparisons to be made between the two buildings which are the subject of this study.

1.4 SITE LAYOUT AND SAMPLE LOCATIONS



Location A: Reception and Admin

Location B: Maintenance and offices

Location C: Nurses Station

Location D: East wing rooms

Location E: South wing rooms

Location F: Theatre

2 INDOOR ENVIRONMENT QUALITY

2.1 Thermal Comfort

Thermal comfort is a key component of IEQ and has been assessed in this study by measuring airflow, air temperature and relative humidity. Other factors such as local climate, thermal radiation and personal factors such as; clothing, an individual's level of physical activity and acclimatisation to a particular climate, can affect an individual's thermal comfort.

Guideline thermal comfort ranges have been developed by the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) which has established general temperature and humidity recommendations that create thermal comfort. Figure 3 provides acceptable operating temperatures as specified by *ASHRAE 55 "Thermal environmental conditions for human occupancy"*.

ACCEPTABLE OPERATIVE TEMPERATURES		
	Conditions	**Acceptable Operative Temperatures**[a,b]
Summer	Relative Humidity 30%	24.5 - 28°C (76-82°F)
	Relative Humidity 60%	23-25.5°C (74-78°F)
Winter	Relative Humidity 30%	20.5-25.5°C (69-78°F)
	Relative Humidity 60%	20-24°C (68-75°F)
a: Assumes sedentary office activities and air velocity less than 0.2 m/s (40 fpm). b: Operative temperature is a combination of air temperature and radiant temperature. For relatively uniform environments, radiant temperature is equal to air temperature. Based on : ASHRAE (2004).		

Figure 3: *Acceptable operating temperatures as specified by ASHRAE 55.*

Further to the thermal comfort ranges specified by *ASHRAE 55* which give a general range which will be acceptable to 80% of occupants, studies conducted by *Seppänen et al 2006* have shown that performance increases with temperature up to 21-22^{0}C, and decreases with temperature above 23-24^{0}C (Figure 4). Therefore, a performance based target of 22-23^{0}C is recommended for increased productivity in office/administration areas of the hospital.

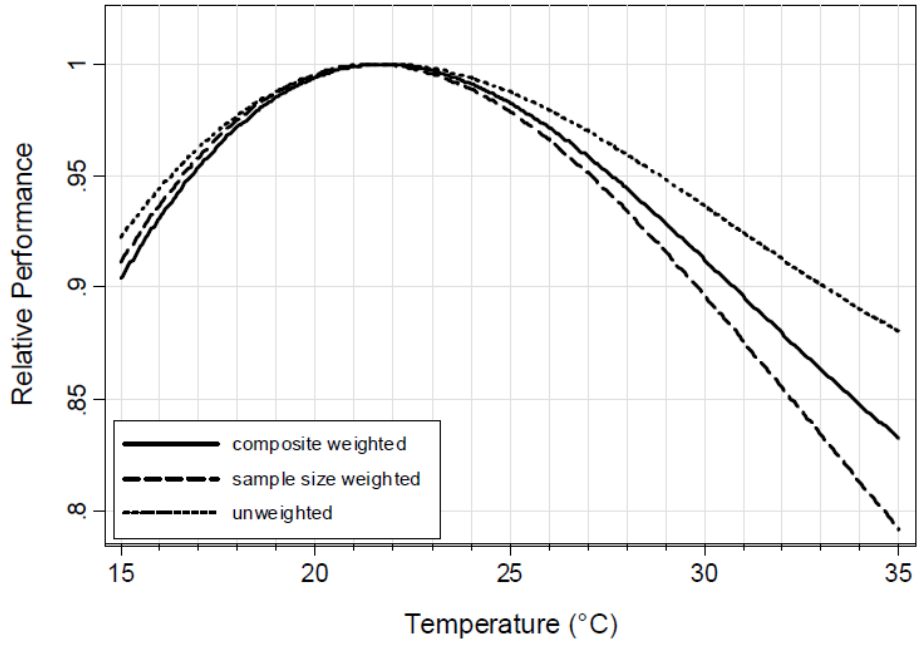


Figure 4: *Normalized performance vs. temperature (Seppänen et al 2006)*

ASHRAE also gives general guidance on preferred relative humidity ranges. Figure 5 shows preferred humidity bands for a range of contaminants. The optimum range appears to be 40 to 60%.

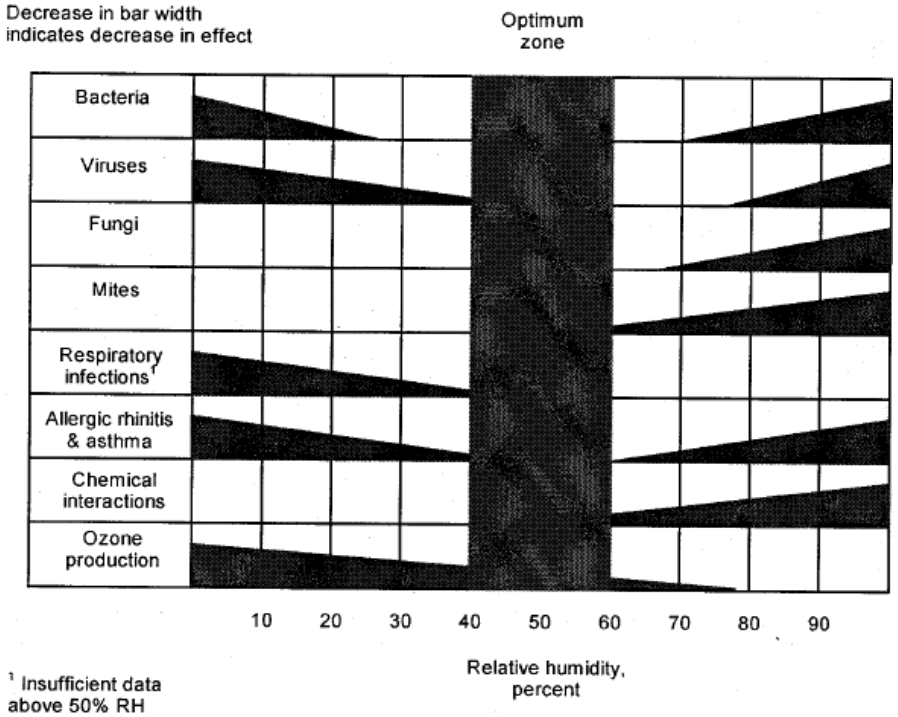


Figure 5: *Optimum humidity range for contaminant minimisation as per ASHRAE Systems Handbook.*

Design guidelines for hospital and day procedures centre (DHS 2004) prescribe a range of 30%-60% in most areas within the facility except for specialised areas such as burns (30%-95%) and trauma rooms (45%-60%).

As healthcare facilities are complex environments with a variation in occupancy levels and types, different functional spaces, and sometimes the requirement for specific temperature and humidity conditions, it is difficult to obtain a single performance target. For example, a study at a Taiwanese hospital found that the nurses were comfortable most of the time; however patients and visitors were dissatisfied especially during the night (Azizpour et al, 2012). In some areas of the healthcare facilities, such as operating theatres, there has been little research into the effect of thermal comfort on staff and productivity, as the main priority is the provision of appropriate indoor air quality and to guard against infection (Melhado et al, 2006). Nonetheless, the research undertaken in relation to thermal comfort and staff in other environments, such as office space highlights the need to provide a high level of thermal comfort in order to maximize the satisfaction and productivity outcomes from staff.

2.1.1 Thermal Comfort Results Alexandra District Hospital

Tables 2a and 2b below give a detailed summary of the post occupancy site measurements.

Table 2a: *Thermal Comfort Results Summary – Alexandra District Hospital*

Morning Measurements

	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
Temperature (°C)	19.4	19.0	20.2	20.3	18.2	18.5	17.5	**20 - 25.5**	**22 - 23**
Relative Humidity (%)	44.7	44.8	41.6	40.5	42.9	39.8	42.0	**30-60**	**40-60**
Average Airflow (m/s) – At occupant desk	0.03	0.05	0.03	0.04	0.04	0.03	-	**<0.2**	**NA**

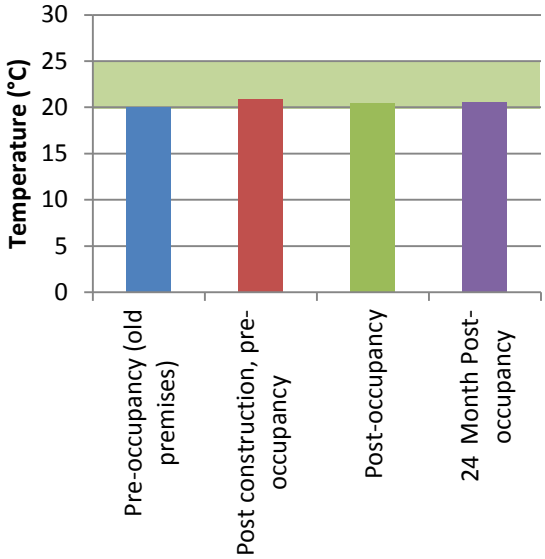
Table 2b: *Thermal Comfort Results Summary – Alexandra District Hospital*

Afternoon Measurements

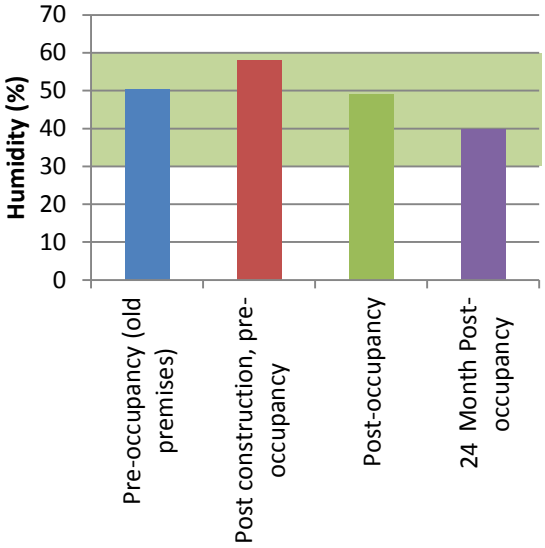
	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
Temperature (^{o}C)	21.4	22.0	21.7	21.9	23.0	21.1	19.4	**20 - 25.5**	**22 - 23**
Relative Humidity (%)	39.8	39.3	37.3	36.6	34.4	35.4	38.6	**30-60**	**40-60**
Airflow (m/s) – At occupant desk	0.03	0.02	0.03	0.00	0.04	0.05	-	**<0.2**	**NA**

Results indicate the following:

- In most areas the morning temperature was below the guidelines. Outdoor temperatures were low (approximately 10°C minimum) before reaching 17.5°C mid-morning. Location A is the main entrance to the hospital and the slightly lower temperature measured in the morning would be influenced by the outdoor temperature due to the operation of the entrance doors.
- Afternoon measurements were all within the recommended guideline.
- Air movement within the building at the time the measurements were being taken was variable. Location D in the afternoon had an average airflow of 0 m/s. As most locations are serviced by individual air conditioning systems, once the temperature set point has been reached, the fans stop and airflow is solely influenced by central return registers.
- The relative humidity levels were all found to be within the recommended guidelines. It is typical for most Australian buildings to not directly control the relative humidity. Indoor relative humidity levels are influenced by the prevailing ambient level and the building's HVAC supply temperature.
- Thermal conditions are similar to previous levels as seen in Figure 6.



Graph 1: Temperature (°C)



Graph 2: Relative Humidity (%)

Figure 6: *Comparison of Average Thermal Comfort Parameters Pre-occupancy, Post-construction and Post-occupancy*

2.2 Ventilation and Air Quality

People generally spend as much as 90 percent of their time indoors and therefore, the condition of indoor air has a vital impact in human health. Today, buildings are designed to be airtight to save energy, resulting in less fresh air intake and a general build-up of pollutants in the indoor environment.

Several studies have shown that indoor environmental quality affects the performance of workers and the degrade of performance was caused through physiological response as dissatisfaction and fatigue. Relationships between indoor air quality, health and comfort of occupants are complex; many indoor stressors (e.g. ventilation, biological, chemical compounds and particulates) can cause their effects additively or through complex interactions *(Bluyssen 2011)*.

2.2.1 Ventilation

Ventilation rates do not directly affect occupant health or perception outcomes, they affect indoor environmental conditions including air pollutant concentrations that may modify the occupants' health or perceptions. Research has shown that exposure to an increased ventilation rate can lead to occupants reporting having a clearer head, perceived fresher air and exerting less effort to complete tasks. *(Wang et al 2011)*.

Carbon dioxide (CO_2) measurements can be used to determine if the HVAC system is balanced and providing adequate ventilation to the building occupants. Hence carbon dioxide should not be considered as an indoor air pollutant but instead as a measure of ventilation effectiveness. As a guideline, a maximum 1000ppm for CO_2 is generally accepted for indoor environments *(ASHRAE 62, 2001)* however, studies have shown that a higher risk of dissatisfaction with ventilation is associated with levels greater than 650ppm *(Newsham 2008).*

In terms of productivity, research indicates that doubling the outdoor air supply rate can reduce illness and sick leave prevalence by roughly 10% and increase office work by roughly 1.5% *(Wargocki et al 2006)*.

Although we have not directly measured outside air supply rate there is an approximate relationship with CO_2 levels as follows:

Indoor Carbon Dioxide (ppm)	Outside Air Ventilation (l/s Per Person)	CO2 Differential (Inside - Outside)
800 ppm suggests about	9.5 l/s (or less)	500 ppm
1,000 ppm suggests about	7.0 l/s (or less)	650 ppm
1,400 ppm suggests about	5.0 l/s (or less)	1,050 ppm
2,400 ppm suggests about	2.5 l/s (or less)	2,050 ppm

l/s = litres per second

Note: The values in this table are approximate, and are based on a constant number of occupants (sedentary adults), a constant ventilation rate, an outdoor air CO_2 concentration of about 350 ppm, and good mixing of the indoor air.

Figure 7: *Relationship between ventilation rate and CO_2 concentration in indoor air*

2.2.2 Ventilation Results Post-Occupancy at Alexandra District Hospital

Tables 3a and 3b below give a detailed summary of the post occupancy site measurements.

Table 3a: *Carbon Dioxide Results – Alexandra District Hospital*

Morning Measurements

	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
CO_2 (ppm)	714	609	441	441	427	380	344	**1000 max**	**<650**

Table 3b: *Carbon Dioxide Results – Alexandra District Hospital*

Afternoon Measurements

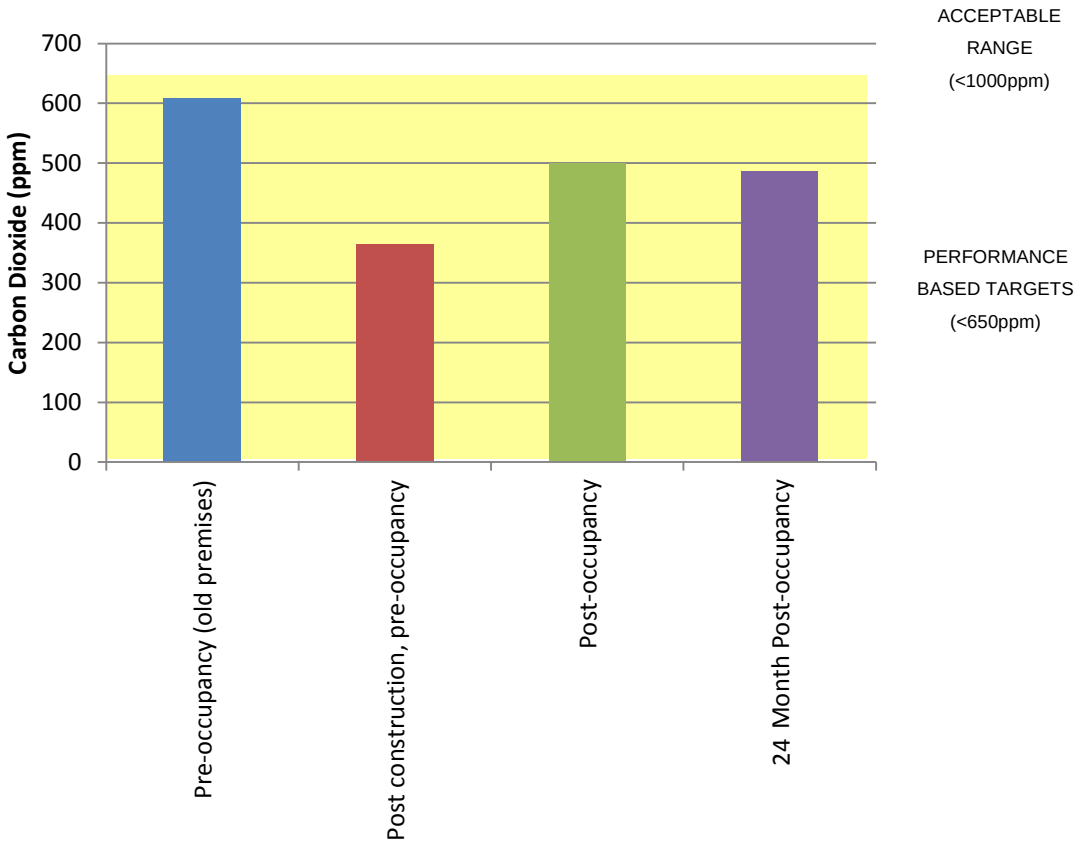
	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
CO_2 (ppm)	713	487	451	398	412	365	352	**1000 max**	**<650**

Carbon dioxide levels were within the performance based target (i.e. below 650ppm) at most locations and were found to be between 365 to 714 throughout the day, with the lowest reading found to be in the operating theatres. These areas are designed to have higher ventilation rates (DHS2004).

Location A (main reception, waiting and aministration area) showed a slightly elevated level of carbon dioxide which is likely due to the higher number of occupants in the area. It should be noted that locations D, E and F were patient areas and not occupied at the time of testing. It is expected that carbon dioxide levels will differ during times of higher occupancy.

Average carbon dioxide levels have improved since moving to the new hospital as seen in Figure 8.

Figure 8: *Comparison of average carbon dioxide concentration Pre-occupancy, Post-construction and Post-occupancy*



2.2.3 Chemical Pollutants

Volatile Organic Compounds (VOC) plays an important role because of their potential health relevance. The health effects of exposure to VOCs in the non-industrial indoor environment range from sensory irritation at low/medium levels of exposure to toxic effects at high exposure levels. As VOCs belong to different chemical classes the severity of these effects at the same concentration level may differ by orders of magnitude. When many pollutants are present at low concentrations, their possible combined human health effects are hardly predictable based on present toxicological knowledge.

VOC is a large group of chemicals and often exist as a complex mixture in indoor environments. As a result it is more practical to test Total VOC (TVOC) in the indoor environment rather than testing for specific chemicals. No guideline limit currently exists for TVOC in indoor air however past recommendations from the NHMRC and the consensus of many researchers is that a recommended limit of 0.5 milligrams per cubic metre (mg/m^3) TVOC and less than $0.25mg/m^3$ of any one VOC is appropriate in office environments.

Formaldehyde is a chemical used widely by industry to manufacture building and fitout materials, fabrics, cleaning fluids and numerous other office products. Formaldehyde can also be a by-product of combustion and certain natural processes.

Exposure to formaldehyde produces irritation of eyes, nose and throat, headaches and dizziness. Since 2004 formaldehyde has been classed as a human carcinogen. The recommended limit is given by *WHO Guidelines for Indoor Air Quality: Selected Pollutants 2010* as 0.1 milligrams per metre cubed ($0.1mg/m^3$) as a 30-minute average.

Respirable Suspended Particles (RSP) are particulates or particulate matter, either solid or liquid matter with aerodynamic diameters ranging from 0.005 to 100 micrometres. Respirable suspended particulate is the term used for suspended airborne particles with a nominal aerodynamic diameter of 10 micrometres or less. Air quality standards for particulate matter are continuing to be reviewed. *NEPM: Ambient Air Quality 2003* recommended exposure limit for PM_{10} (particulate less than 10 micrometers) 0.05 mg/m^3 mean for 24 hours.

Carbon Monoxide (CO) is a highly toxic, colourless and odourless air contaminant that is produced when fossil fuels such as petrol are burned. The vehicular activities in the immediate vicinity of the building may lead to the ingress of exhaust into the building. The recommended limit for carbon monoxide is given by *WHO Guidelines for Indoor Air Quality: Selected Pollutants 2010* as 10 mg/m^3 (or 9ppm) for an eight hour time weighted average.

2.2.4 Chemical Pollutant Results at Alexandra District Hospital

Tables 4a and 4b below give a summary of the post occupancy site measurements.

Table 4a: *Chemical Pollutants - Alexandra District Hospital*

Morning Measurements

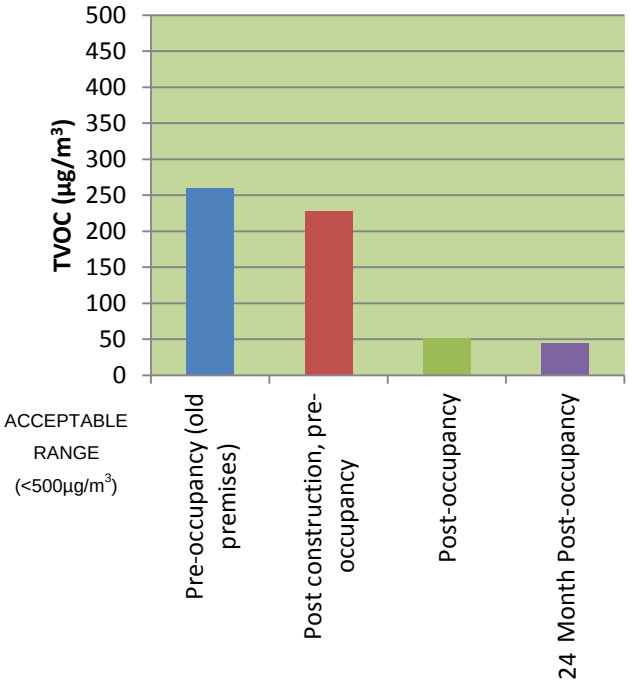
	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
TVOC ($\mu g/m^3$)	80	30	11	<10	59	<7	-	**500**	**NA***
Formaldehyde ($\mu g/m^3$)	<11	7	4	<6	<4	<5	-	**100**	**NA***
RSP (mg/m^3)	0.009	0.005	0.040	0.001	0.030	0.001	-	**0.050**	**NA***
CO (ppm)	0	0	0	0	0	0	0	**9**	**NA***

** Indoor pollutants are generally undesirable hence for improved performance the desired levels would be as low as possible*

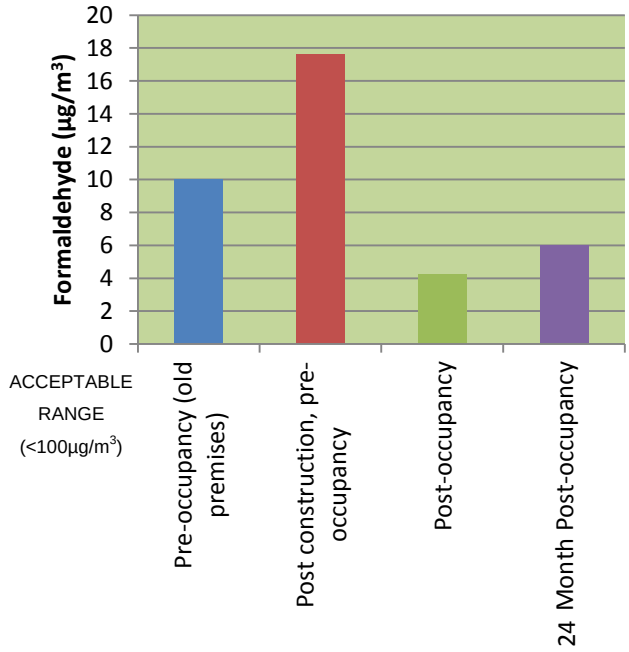
Table 4b: *Chemical Pollutants - Alexandra District Hospital*

Afternoon Measurements

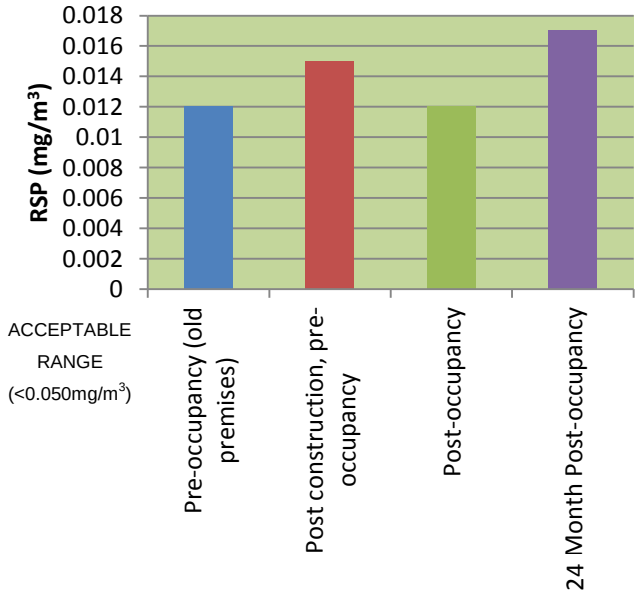
	A	B	C	D	E	F	Outside	Recommended Guidelines	Performance Based Targets
RSP (mg/m^3)	0.060	0.007	0.010	0.010	0.030	0.000	-	**0.050**	**NA***
CO (ppm)	0	0	0	0	0	0	0	**9**	**NA***



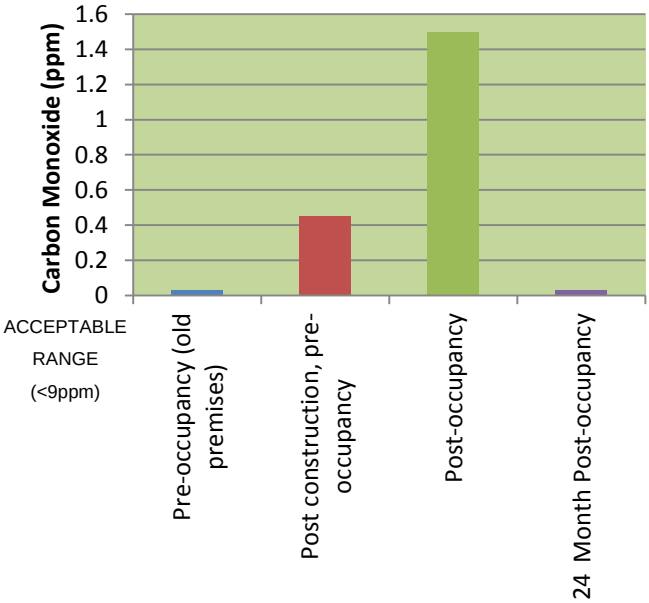
Graph 1: TVOC



Graph 2: Formaldehyde



Graph 3: RSP



Graph 4: Carbon monoxide

Figure 9: *Comparison of Average Chemical Pollutants Pre-occupancy, Post-Construction and Post-occupancy*

Results showed that:

- RSP was acceptable but slightly higher on the day of testing than in the previous premises and during other times of testing. CETEC noted that lawn mowing was being conducted around the site on the day of testing
- Carbon monoxide was acceptable
- TVOC and formaldehyde was acceptable at all locations

2.2.5 Microbiological Pollutants

The three common types of microbiological contaminants found in buildings are bacteria, fungi (moulds and yeasts) and viruses. Micro-organisms are present in every environment found on the surface of the earth. In buildings, microorganisms are generally found on surfaces (such as carpet, ceiling, tiles, etc.) within the building water systems, as well as floating within the airspace on dust and aerosol particles. The building characteristics could change the number of aerosols containing virus or bacteria that are inhaled, increase or diminish the viability of the inhaled virus or bacteria, or modify the susceptibility of occupants to infection. The obvious costs of respiratory illness include health care expenses and the costs of absence from work. Additionally, respiratory illness may cause a performance decrement at work. Previous studies have shown that viral respiratory illnesses can adversely affect performance on several computerized and paper-based tests that simulate work activities *(Fisk 2000)*.

From an infection control perspective in health care facilities, it is important that the level of microbial activity is maintained as low as possible. As there is no regulated level of microbial activity, accepted practice for the assessment of microbial activity is to compare the ambient airborne concentration with the indoor concentration. Consideration should also be given to the fact that the air samples for these studies are taken at a single point in time and are affected by a number of factors including indoor traffic, visitors, time of day and year, relative humidity, HVAC performance and as such should also be compared temporally (LMRICRC, 2005). The result is deemed acceptable if the indoor concentration is not greater than the outside level by an order of magnitude.

2.2.6 Microbiological Pollutant Results at Alexandra District Hospital

Table 5 below gives a detailed summary of the post occupancy site measurements.

Table 5: *Microbiological Pollutants - Alexandra District Hospital*

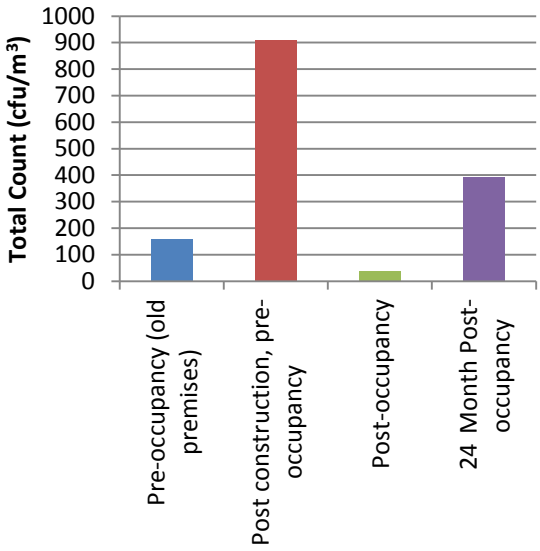
	A	B	C	D	E	F	Outside	Recommended	Performance Based Targets
Total Count (cfu/m^3)	337	212	465	396	>943	0	342	**<Outside**	**NA***
Yeast & Mould (cfu/m^3)	184	382	49	35	106	0	170	**<Outside**	**NA***

** Indoor pollutants are generally undesirable hence for improved performance the desired levels would be as low as possible*

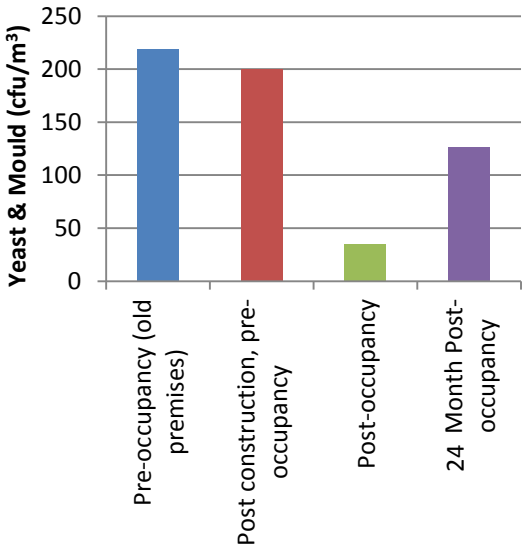
Microbial pollutant results are variable with Location B showing slightly elevated yeast and mould levels, Locations C and E with slightly elevated total counts and Location F (operating theatre) with no colony forming units.

Mould levels in B (office and maintenance) may be more influenced by outdoor conditions as these locations are close to entrance doors that are frequently used. The microbial plates were morphologically similar to ambient samples indicating that there was no additional source of mould growth.

Location C and E showed slightly elevated total counts compared to outside. Further investigation is required to determine the source of the elevated levels. Measured ventilation rates and dust levels were acceptable on the day of testing, however as the HVAC system are not operated during periods of non-occupation, they should be monitored and regularly cleaned to reduce the existence of conditions that are conducive to microbial activity such as increased moisture and dust in these locations. General cleaning was carried out during the morning and may have included vacuuming that may have caused aerolisation of microbes and hence the elevated result. As noted previously, lawn mowing was occurring during the day though the outdoor reading was not elevated.



Graph 1: Total Count



Graph 2: Yeast and mould

Figure 10: *Comparison of Average Microbiological Pollutants Pre-occupancy, Post-Construction and Post-occupancy*

The levels measured during this study are slightly higher than the post occupancy study (March 2012) and at the previous premises (March 2011), but lower than in the post construction , pre-occupancy study (November 2011).

2.3 Acoustic Quality

Acoustic comfort is the preferred term for noise as this potentially complex subject is more than just the loudness of noise. Auditory information can be a stimulus or a distraction.

Acoustic satisfaction for occupants requires speech privacy and comfortable sound levels. With acceptable speech privacy a person cannot understand conversations overheard from other cubicles. If there were no ambient sound, overheard speech would be perfectly intelligible and very annoying because of its information content, unpredictability, and uncontrollability.

Distracting noise has a detrimental effect on complex task performance. Memory and problem solving decline with realistic office noise. Noise level is not the principal problem: these effects are seen with unpredictable, intermittent noises.

Controlling ambient sound is only one part of creating satisfactory acoustic conditions and speech privacy. Annoying noises, like speech, printer noise, typing, and telephone rings, also require control. Noise sources can be isolated and reduced, and travelling sound can be

absorbed and blocked with good office design and layout so that noises, such as speech, do not transmit from one workstation to another. The best way to control noise sources is through office design. The acoustic properties of the office can significantly reduce sound travel by blocking sound transmission and by absorbing reflected sound.

Research suggests that acceptable acoustic conditions in open plan offices would have average noise levels in the range 45-50dB *(Navai et al 2003)*. Australian Standard *AS2107:2000* recommends design sound levels in general office areas of 40-45dB however this refers to measurements taken in an unoccupied space and hence are not applicable to an occupied office. Acoustic conditions for healthcare facilities should vary and the standards will differ for different functional spaces. For example, wards would be expected to be quieter than nurse's stations.

High noise levels in the health care environment have been shown to have negative impacts on staff health and well-being and may slow the healing process among patients. Also, speech privacy is important in these environments and poor acoustics can impede communication between staff which has implications for patient safety (Joseph, Ulrich, 2007). In a recent limited study on the disruptive effect of hospital noises on sleep, it has been shown that these noises disrupt sleep as they influence both cortical and cardiovascular function (Buxton et al, 2012)

The World Health Organisation (WHO) guidelines for continuous background noise in hospital patient rooms are 35 dB(A) during the day and 30 dB(A) at night with peaks at night no greater than 40 dB(A). Busch-Vishniac and colleagues (2005) did not find a compliant facility in thirty five published studies over the last forty five years.

AS/NZS 2107:2000 Acoustics – Recommended design sound levels and reverberation times for building interiors suggests a design level of:

- 40-50db for waiting rooms and reception areas – Area A
- 40-45db for office areas – Area B
- 40-45db for nurses' stations – Area C
- 35-40db for wards – Areas D and E
- 40-45db for operating theatres – Area F

2.3.1 Acoustic Quality Results at Alexandra District Hospital

Table 6 below gives a detailed summary of average acoustic levels per level post occupancy site measurements.

Table 6: *Average acoustic Comfort Results - Alexandra District Hospital*

	A	B	C	D	E	F
Ambient Sound (dB)	41	42	43	42	44	51
Recommended Guidelines	**40-50**	**40-45**	**40-45**	**35-40**	**35-40**	**40-45**

Ambient sound levels in Locations A, B and C were all acceptable. Location D and E (patient rooms) were slightly elevated as the recommended sound level for wards (as per AS/NZS 2107:2000 Acoustics) is more stringent in these locations. The sound level of the split system air conditioning and return registers were the sources of noise. Location F (operating theatre) was also above the recommended sound level and was due to the constant noise from the separate HVAC system. Furthermore, sound has a higher tendency to travel in these areas in a hospital as polished surfaces required for cleaning purposes will allow more sounds to be reflected.

Ambient sound levels have improved compared to the previous premises as can be seen in Figure 11.

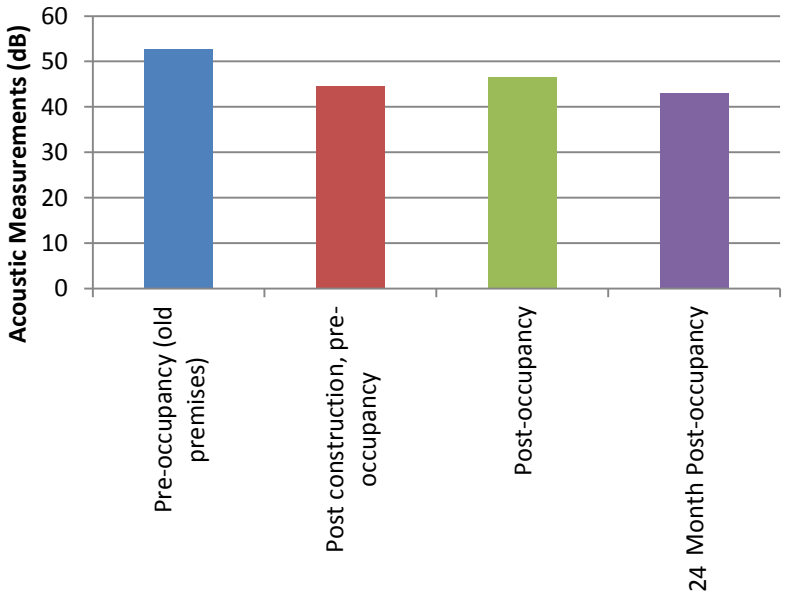


Figure 11: *Comparison of Average Sound Levels Pre-occupancy, Post-construction and Post-occupancy*

2.4 Lighting Quality

Design of the work environment has long been known to play a role in influencing employee satisfaction and productivity, and quality lighting is a major element contributing to optimal workplace design. In addition to reducing energy consumption and costs and benefiting the environment, optimal lighting can play a role in boosting workplace ambiance and efficiency. As a result, the need to use illumination within the work environment to improve productivity, to reduce stress, and to accommodate individual preferences has emerged *(Miki 2007)*.

In a health care environment, adequate lighting is essential to staff who are required to perform visual tasks as it is required to minimise the error rate. There is also strong evidence to suggest that patient exposure to daylight assists the healing process through alleviation of pain, reducing depression and improving circadian rhythms and sleep (Joseph,2006) .

AS1680.2.2 2008: Interior Lighting and Workplace Lighting provides guidance for the general principles and recommendations for the lighting of interiors of buildings. As many activities in an office involve both reading and writing tasks, as well as screen based or computer tasks, then light levels should be determined as:

- In the horizontal plane to characterise the visual task of reading and writing. *AS1680.2.2 2008* recommends 320 lux minimum for these common office tasks; and

- In the vertical plane to characterise screen based tasks. The light reading is taken against the computer monitor. *AS1680.2.2 2008* recommends 160 lux minimum.

Uniformity is based upon the minimum lux in the horizontal plane divided by the minimum lux in the vertical plane. The uniformity ratio establishes the difference in light levels that are allowed throughout a space. Very high non-uniformity requires frequent eye adaptation and can increase fatigue and discomfort. Extreme uniformity creates a perceptually flat, uninteresting scene, which is also displeasing. The value of 3 to 1 is a recommended target by the *American Nation Standard Practice for Office Lighting 2004.*

For improved performance it has been recommended *(Newsham et al. 2005)* that ambient lighting on the desktop of 400-500 lux is appropriate based on average occupant preferences and for illuminance on vertical surfaces such as partitions 200-250 lux is appropriate.

AS1680.2.5 1997: Interior Lighting – Hospital and Medical Tasks provides guidance on lighting requirements for a variety of tasks that are carried out in hospitals. Typical lighting

values in medical areas should be 160 lux in patient transit areas, 160-400 lux in high dependency areas, 320 lux (day) / 240 lux (night) at nurses stations, 240-400 lux in operating suites.

Task based lighting should be considered for relevant staff working outside of office areas as it has been shown in a study that error rates for pharmacists dispensing medications reduced when work surface lighting increased. Error rates were 2.6% lower at illumination levels of 1500 lux compared to 3.8% at 450 lux (Buchanan et al., 1991).

2.4.1 Lighting Quality Results at Alexandra District Hospital

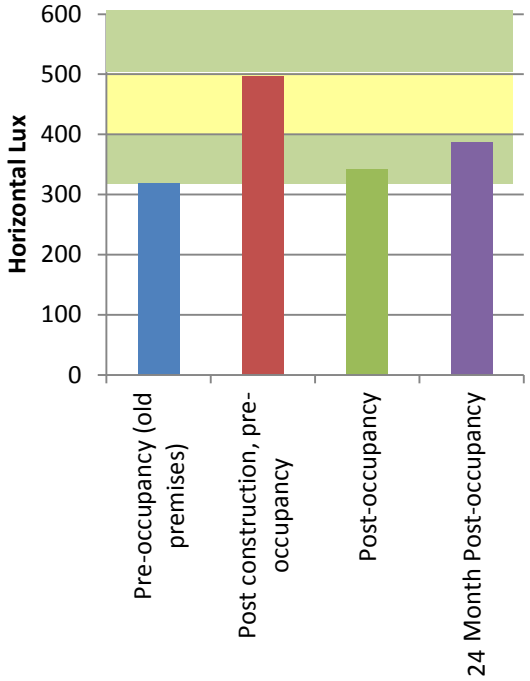
Table 7 below gives a detailed summary of the post occupancy site measurements.

Table 7: *Lighting Results Summary – Alexandra District Hospital*

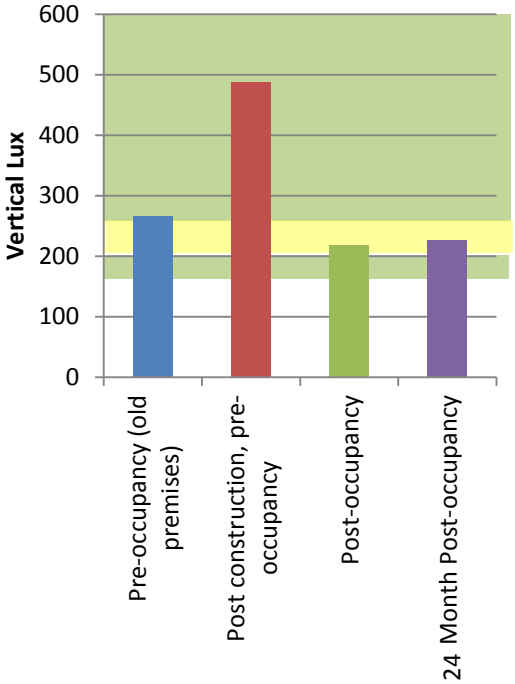
	A	B	C	D	E	F	Recommended Guidelines	Performance Based Targets
Horizontal (lux)	444	513	264	450	307	510	**320 min**	**400-500**
Vertical (lux)	140	324	140	207	390	308	**160 min**	**200-250**
Uniformity	3.2	1.6	1.9	2.2	0.8	1.7	**3 max**	**NA**

Lighting measurements varied greatly across the areas measured, with some measurements being below the recommended guidelines while others were ideal.

Location A (reception) should increase vertical luminance to increase lighting to tasks such as reading computer screens. Location C (nurses' station) should increase overall lighting to improve visual task comfort.



Graph 1: Horizontal Lux



Graph 2: Vertical Lux

Figure 12: *Comparison of Average Light Levels Pre-occupancy, Post-construction and Post-occupancy*

3 DISCUSSION

3.1 Comparison of Pre-Occupancy and Post-Occupancy Sites

3.1.1 Comparison of IEQ Measurements

Comparison of IEQ measurement results between the pre and post occupancy sites are shown in Table 8. A summary of results from the 24-month post-occupancy testing is shown in Table 9.

Table 8: *Comparison of pre-occupancy and post-occupancy site measurement results*

Core Categories	Pre-Occupancy (old premises)	Post-Construction, pre-occupancy	Post-occupancy	24 – Month Post-occupancy
Temperature	Acceptable	Acceptable	Improvement Needed	Acceptable
Relative Humidity	Optimal	Optimal	Optimal	Acceptable
Ventilation (CO_2)	Optimal	Optimal	Optimal	Optimal
TVOC	Acceptable	Acceptable	Acceptable	Acceptable
Formaldehyde	Acceptable	Acceptable	Acceptable	Acceptable
RSP	Acceptable	Acceptable	Acceptable	Acceptable
CO	Acceptable	Acceptable	Acceptable	Acceptable
Microbiological	Acceptable	Acceptable	Acceptable	Improvement Needed
Acoustics	Improvement needed	Acceptable	Improvement Needed	Improvement Needed
Lighting	Acceptable	Acceptable	Improvement Needed	Improvement Needed

Table 9: *Summary of 24-month post occupancy testing*

Core Categories	24 – Month Post-occupancy	Comment
Temperature	Acceptable	Morning temperature slightly low but acceptable on average throughout the day
Relative Humidity	Acceptable	Acceptable or optimal throughout the day
Ventilation (CO_2)	Optimal	Mostly optimal. Acceptable at Location A
TVOC	Acceptable	Acceptable at all locations tested
Formaldehyde	Acceptable	Acceptable at all locations tested
RSP	Acceptable	Acceptable at all locations tested
CO	Acceptable	Acceptable at all locations tested
Microbiological	Improvement Needed	Elevated results at 5 of 6 locations
Acoustics	Improvement Needed	Elevated results at 3 of 6 locations
Lighting	Improvement Needed	Lighting improvement needed at locations where office based tasks are performed

3.2 Recommendations for IEQ Improvement at the Post-Occupancy Site

Based on measurement data obtained at the post-occupancy site the following are recommended for improved satisfaction and IEQ :

1. To address the wide range in lighting results near functional work spaces, the following is recommended;

    a. In areas of low light task lighting should be considered to avoid straining of eyes

    b. In office areas affected the position of the sun or installed lighting – re-arranging computer monitors and workstations to take advantage of natural light sources or reduce glare.

2. Sound levels were on average higher than recommended levels. It was observed that HVAC systems in these areas were accountable for emitting the best part of the detected noise. Furthermore, the elimination or reduction of intermittent, unexpected sounds will improve occupant satisfaction.

3. Elevated microbial results suggest some underlying issues. Further investigation is required to determine the source of the issue.

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5 APPENDIX 1 – ENERGY CONSUMPTION REVIEW

OHS & Environmental Care
Sustainability
Advanced Laboratory/Analytical Services

CETEC
Professional Scient

23 January 2014
CETEC Ref: CV131109

Jo Dane
Senior Consultant
Woods Bagot
Podium Level 1
3 Southgate Avenue, Southbank, VIC 3006
Via email: jo.dane@woodsbagot.com

Dear Jo,

RE: Review of energy consumption data for the New Alexandra District Hospital (CV131109)

Based on data CETEC has been provided by Alexandra District Hospital, the total energy consumption for the last 12 months (July 2012 to June 2013) was 3,147 GJ. Considering the floor area of 3,863 m^2, the energy consumption is equivalent to 0.81 GJ per square metre.

Energy consumption has been similar in previous years but considering the increase in floor area, energy consumption has greatly decreased as seen in Table 1 and Figure 1. The value of 0.81 compared to an average of 1.49 GJ per square meter for previous 6 years of data shows a 45% reduction in energy usage per square metre.

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Table 1: Total energy consumption at Alexandra District Hospital over the last eight years.

Year	Total Energy (GJ)	Agency Floor Area	GJ/m^2
July 12- Jun 13	3147	3863	0.84
Mar10 – Feb11	3251.65	2275	1.43
2009/2010	N/A	N/A	N/A
2008/2009	3435.14	2275	1.51
2007/2008	3670.70	2275	1.61
2006/2007	3514.17	2275	1.54
2005/2006	3310.94	2275	1.46
2004/2005	3213.08	2275	1.41
2003/2004	4214.37	2075	2.03

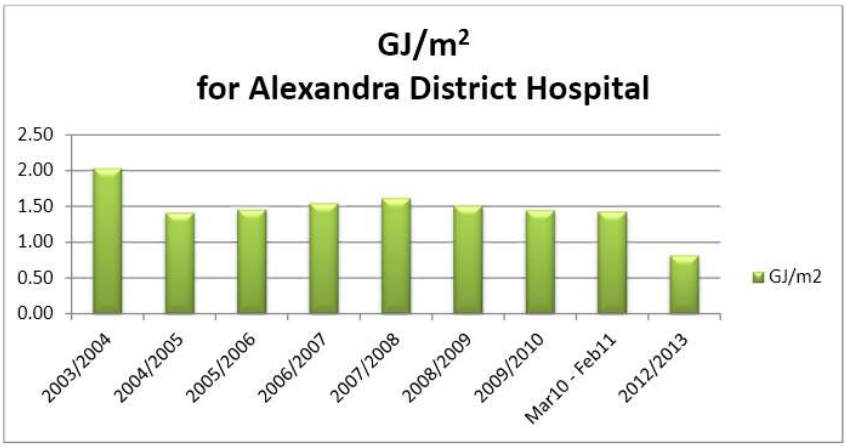

Figure 1: Total energy consumption at Alexandra District Hospital over the last eight years following consideration of floor area.

Electricity consumption has doubled at the New Alexandra Hospital compared to the old hospital (Figure 2) while LPG consumption has reduced to 1/6th of previous levels (Figure 3). The shift to a more efficient building with less reliance on LPG has greatly improved total energy consumption per square metre.

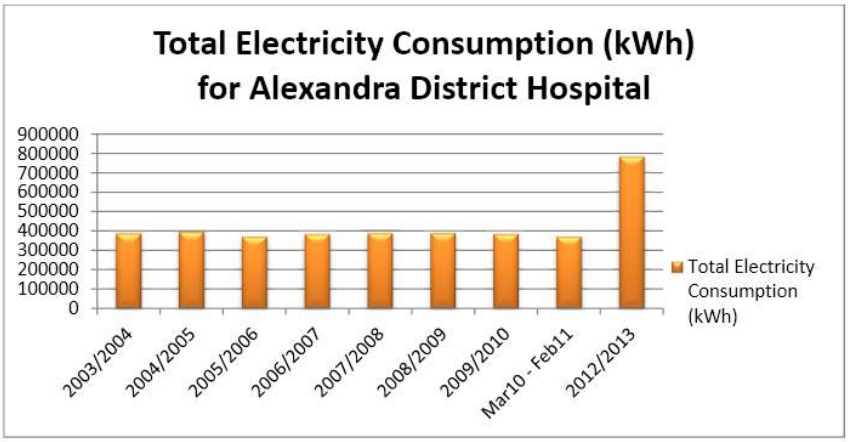

Figure 2: Total electricity consumption for Alexandra District Hospital over the last eight years.

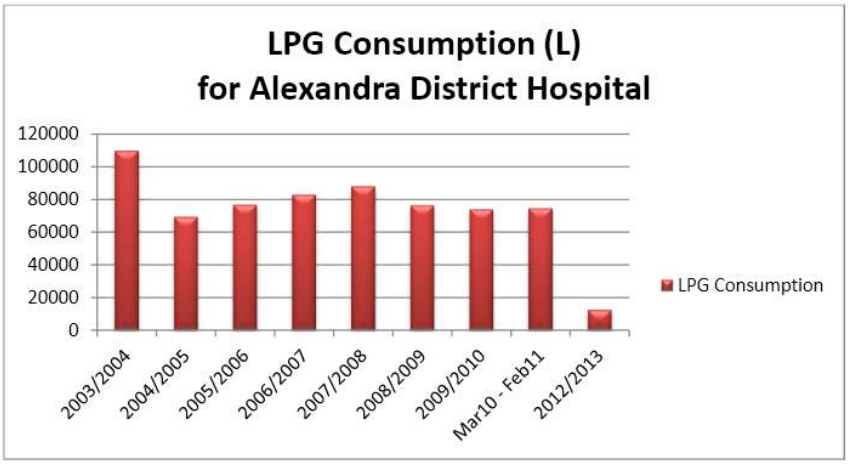

Figure 3: Total LPG consumption for Alexandra District Hospital over the last eight years.

Please do not hesitate to contact us should you have any questions or comments.

Regards,

Dr. Vyt Garnys
PhD, BSc(Hons) AIMM, ARACI, ISIAQ, ACA, AIRAH, FMA
Managing Director and Principal Consultant

Jack Noonan
MBus(S&T), BSc, BA
Consultant


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