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**Occupants' satisfaction and perceived productivity in open-plan offices designed to support Activity-Based Working: findings from different industry sectors**

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# Occupants' satisfaction and perceived productivity in open-plan offices designed to support Activity-Based Working: findings from different industry sectors

## Abstract

**Purpose** – In the rise of offices designed to support Activity-Based Working (ABW) parts of industry have fully transitioned to open-plan environments and then later to unassigned seating, while other parts, such as tertiary education are still in the process of moving away from individual offices. There are a few relevant studies to understand how occupants from industry sectors with different levels of adoption of ABW perceived environments designed to support this way of working. This paper contributes to the knowledge gap by providing insight into workers' satisfaction and dissatisfaction from open-plan offices designed to support ABW along with the key predictors of perceived productivity.

**Design/ Methodology/ Approach** – A dataset of 2,090 Post-Occupancy Evaluation surveys conducted in five sectors – tertiary education, finance, construction, property/asset management and design/engineering was analyzed. ANOVA and confirmatory factor analysis (CFA) were conducted for the survey questionnaires. First, ANOVA tests were conducted for the whole sample with perceived productivity as the dependent variable. A seven-point Likert scale with 5 theoretical factors was generated with all survey questionnaires. Confirmatory factor analysis (CFA) was performed to show the factor loadings. In addition, regression analyses were carried out for each of factor item taken as the independent variable, where perceived productivity was the dependent variable. Key sources of satisfaction and dissatisfaction per sector were analyzed and differences between occupants reporting a negative or positive impact on their productivity were also investigated. Finally, open-ended comments were analyzed to show the key sources of dissatisfaction based on open-ended comments.

**Findings** – Workers from construction were the most satisfied, followed by finance and tertiary education. Occupants from all industry sectors consistently rated their workspaces highly on biophilic and interior design. Distraction and privacy received the lowest scores from all sectors. Open-ended comments showed mismatches between spatial and behavioral dimensions of ABW both for satisfaction and perceived productivity. Interior design was the strongest predictor for perceived productivity for all sectors. Findings dispel the notion that ABW implementation may not be suitable for certain industries, as long as the three key pillars of ABW are fully implemented, including design, behavior and technology.

**Originality/ Value** – This paper provides insight into workers' satisfaction and dissatisfaction from open-plan offices designed to support ABW in different industry sectors along with the key predictors of perceived productivity.

**Keywords:** Activity-Based Working, open-plan office, Post-Occupancy Evaluation, perceived productivity, Indoor Environmental Quality, workspace design.

## 46 1. Introduction

47 Activity-Based Working (ABW) recognizes that people perform different work tasks during the day. As such,  
48 in order to be properly support workers, the workplace must offer people a range of physical and virtual  
49 settings along with the appropriate technology and behavior etiquettes. ABW has broadened its original  
50 motivation of reducing overcapacity, space requirement and overall real estate costs to becoming a key enabler  
51 of workplace flexibility and sense of community expected by the millennial workforce (AECOM, 2017).

52 Despite the rapid growth in implementation and subsequent documentation of strengths and weakness of  
53 ABW, its uptake has not been the same in all parts of industry. While the finance sector has been aggressively  
54 experimenting with ABW and subsequently the way spaces are designed and used, other sectors such as  
55 tertiary education (post-school education including college and university), have not been so quick to change.  
56 In Australia, the pioneers are from the finance sector - Macquarie Bank was the first major bank to transition  
57 the whole building fit-out to ABW in 2008 (Veldhoen, 2018), with others following suit in about ten  
58 consecutive years. During the same time, other parts of industry have also been changing their ways of  
59 working, although at different paces. The property and construction sector has followed the lead after banks  
60 and the uptake in the design and engineering sector happened more recently. Over the last five years, ABW  
61 has started to emerge in the government and tertiary education sectors as well.

62 A considerable amount of literature has been published on effects of ABW environments on the occupants.  
63 Their analysis might be conducted on a sample from one industry sector such as finance (Ekstrand and  
64 Damman, 2016), health (de Kok et al., 2016), government (Babapour, 2019), research (Sugino et al., 2019)  
65 and consultancy (Wadu and Chiang, 2019); or they might have investigated several industry sectors as one  
66 sample (Budie et al., 2019; Wohlers et al., 2017). Either of these study groups have not focused on the  
67 industry sector as their mainstream, nor have they looked at satisfaction/dissatisfaction that might raise from  
68 the type of industry or a comparison between different industry sectors.

69 Findings reported from these studies might be similar-although looking at different industry sectors in some  
70 cases: Wohlers et al. (2017) conducted a study in an engineering company with 136 staff. They concluded that  
71 the design was beneficial for collaboration across teams while it slows down the teamwork. They suggested  
72 organizational support to maintain the functioning of teams in such a way that information sharing and  
73 cohesion within teams are ensured. Same findings were reported by Rolfö et al. (2018), in a study conducted  
74 in a large insurance company. The employees were significantly less satisfied about getting hold of co-  
75 workers after relocation to an ABW environment. In some other studies, the findings are contradictory for  
76 different industry sectors. For example, Gerdenitsch et al. (2018) reported positive effects on distraction in a  
77 pre-post study conducted in a consultancy company. In contrast, de Been et al. (2015) showed negative  
78 outcomes related to distraction and privacy for government office workers when working in an office designed  
79 to support ABW. It is also interesting to note that some studies published on ABW environments and their  
80 effects on satisfaction, productivity and health of the occupants have not mentioned the industry sector(s) for  
81 their sample. This makes it hard to draw trustable and consolidates conclusion based on industry sector from  
82 the available literature. Furthermore, limited explanation and details are available for the case studies in each  
83 research. This makes it even more difficult to conclude that the industry sector plays or does not play a  
84 significant role in the differences reported in each study.

85 Although, to the best of our knowledge, there is no research with industry sectors as the key focus, effects of  
86 ABW environments on occupants' satisfaction and productivity have been discussed. Research on overall  
87 satisfaction with ABW environments (Lusa et al., 2019; Rolfo, 2018; Arundell et al., 2018), productivity  
88 (Hoendervanger et al., 2016; Wadu and Chian, 2019; De Been and Beijer, 2015; Haapakangas et al., 2018),  
89 indoor environmental quality (Candido et al., 2019b; Roflo, 2018), biophilic design (Candido et al., 2019a),  
90 collaboration and communication (Budie et al., 2019; Haapakangas et al., 2018), and distraction and privacy  
91 (De Been et al., 2015) have reported outcomes regarding the effects of ABW environments on the occupants.

92 Overall, although there is some discussion that spaces designed to support ABW and the way of working itself  
93 may not be suitable for different industry sectors, the evidence is yet to be produced. The probable  
94 unsuitability of the ABW concept for some industries might be related to various factors: from the nature of  
95 the work carried out in each industry to managerial reasons or even the physical space. The collaborative  
96 nature of some industries like design and engineering might be in favor of concepts like ABW that ease  
97 communication and collaboration. In contrast, tertiary education industry might not receive ABW concept  
98 very well as the individuals are mainly working independently. In addition, there is also little evidence  
99 gathered about differences, if any, in terms of sources of satisfaction/dissatisfaction as reported by workers  
100 from different industries. This constitutes an interesting knowledge gap, considering that the very idea of  
101 working from an open-plan environment is somewhat unthinkable to some knowledge workers, let alone the  
102 removal of desk ownership altogether. At the same time, workers from other sectors have come to expect to be

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3 103 working from an open environment where desk ownership may or may not be available to them. While these  
4 104 questions have been from time to time under the spotlight in industry, they have been less investigated in  
5 105 academia.

6 106 This paper aims to identify key differences in occupants' satisfaction with offices designed to support ABW  
7 107 from five different industries – tertiary education, finance, property/asset management, construction,  
8 108 design/engineering. By examining a dataset of 2,090 Post-Occupancy Evaluation surveys, this paper identifies  
9 109 key shared sources of satisfaction and dissatisfaction with the indoor environments designed to support ABW  
10 110 along with key drivers behind perceived productivity and satisfaction per industry sector.

## 111 2. Methodology

### 112 2.1 BOSSA Time-Lapse survey

113 This paper interrogates a dataset of 2,090 Post-Occupancy Evaluation surveys from 14 offices conducted using  
114 the BOSSA (Building Occupant Survey System Australia) Time-Lapse online questionnaire. The BOSSA  
115 time-lapse online questionnaire features 29 core items, asking occupants to rate their satisfaction on spatial  
116 comfort, individual space, indoor air quality, thermal comfort, noise distraction and privacy, visual comfort,  
117 personal control, and building image on a seven-point scale. In addition, occupants were also asked to rate  
118 their overall satisfaction with their work area, perceived productivity, perceived health and overall satisfaction  
119 with the building on a seven-point Likert scale. The questionnaire has a branch structure to allow further  
120 investigations about sources/reasons for dissatisfaction (refer to Appendix). The questionnaire also invites  
121 occupants to leave their comments at an open-ended question at the end of the survey. Further, the  
122 questionnaire also asks basic information about occupants' descriptive characteristics such as age and gender,  
123 along with basic information about their workplace (office layout, way of working and seat arrangement,  
124 window proximity) and work profile and arrangements (type of work, time spent at work/building, hours spent  
125 at work area) is also included. Candido et al. (2016b) provide a comprehensive description of the BOSSA  
126 Time-Lapse questionnaire. Most surveys were conducted for the purposes of certification from the Green  
127 Building Council of Australia and were deployed between 2017 and 2018.

### 128 2.2 Workspaces and organizations

129 As depicted in Table I, out of the 14 offices investigated here, five are from the finance (36%), three from  
130 property/asset management (21%), three from design/engineering (21%), two from construction (15%) and  
131 tertiary education/research (7%) sectors. Combined, these 14 offices were responsible for a total of 1,959  
132 surveys in the database. The other surveys (n=131) were conducted in other sectors (government, non-profit,  
133 consulting, transportation, HR, etc). However, the sample sizes were too small to be grouped per sector for  
134 analytical purposes at the sector level however they were included on database level analysis. Organizations  
135 volunteered to participate in this study by reaching out to researchers to use the survey tool. Occupants'  
136 participation was on opt in and anonymous basis.

137 Offices are distributed in building located across three Australian capital cities in Australia (Sydney,  
138 Melbourne and Brisbane) and are all located within the CBD region. All buildings' hosting organizations were  
139 rated by the National Australian Built Environment Rating System (NABERS) Energy scheme, with five  
140 having NABERS Water rating. Some of the tenant organizations also received certification from the NABERS  
141 Indoor Environment rating (1 out of 14), Green Building Council of Australia (GBCA)(8 out of 14) and  
142 WELL Building Standard (1 out of 14). Combined, the sample of office buildings investigated here are  
143 representative of the top-end of the market in Australia. In terms of layout, all offices adopt an open-plan  
144 configuration and nine out of 14 have low partitions in place as well.

145 All offices were designed with unassigned seating in order to support Activity-Based Working (12 out of 14)  
146 or Agile as way of working implemented by the organization. The space is designed to support several work-  
147 related activities varying from focused to collaborative tasks. Workspace design also implemented breakout  
148 spaces of different sizes. All workplaces operated with an open-plan configuration before the time this study  
149 was conducted, all organizations had already either embraced ABW before moving into the new space or been  
150 operating with ABW for at least six months after the study was conducted.

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**Table I.** Basic information about surveyed offices.

Industry Sector	Office No.	Sample size/ response rate	Year construction /renovation	Office fit-out	Way of working	Rating/ Certification
Finance (n=613)	1	167/30%	2015	Open-plan without partitions	ABW	NABERS Energy/ GBCA Interiors
	2	78/37%	-	Open-plan with low partitions/ without partitions	ABW	NABERS Energy, Water, Indoor Environment/ GBCA Interiors
	3	79/22%	2004	Open-plan with low partitions/ without partitions	ABW	NABERS Energy
	4	251/14%	-	Open-plan without partitions	ABW	NABERS Energy, Water/GBCA Performance
	5	38/21%	-	Open-plan with low partitions/ without partitions	ABW	GBCA Office Interiors
Property/ asset management (n=733)	6	651/30%	2016	Open-plan with low partitions/ without partitions	ABW	NABERS
	7	54/59%	2013	Open-plan with low partitions/ without partitions	Agile	NABERS
	8	28/62%	2018	Open-plan with low partitions/ without partitions	ABW	NABERS
Design/Engineering (n=324)	9	89/31%	-	Open-plan without partitions	ABW	NABERS Energy and Water
	10	157/24%	2012	Open-plan with low partitions/ without partitions	ABW	NABERS Energy, Water/GBCA Office Interiors
	11	118/27%	2016	Open-plan without partitions	ABW	NABERS/ GBCA Office Interiors
Construction (n=188)	12	50/48%	-	Open-plan without partitions	ABW	NABERS Energy, Water/ GBCA Office Interiors
	13	138/20%	-	Open-plan without partitions	Agile	NABERS Energy, Water/WELL/GBCA Office as built and Design
Tertiary Education (research) (n = 61)	14	61/55%	-	Open-plan with low partitions/ without partitions	ABW	-

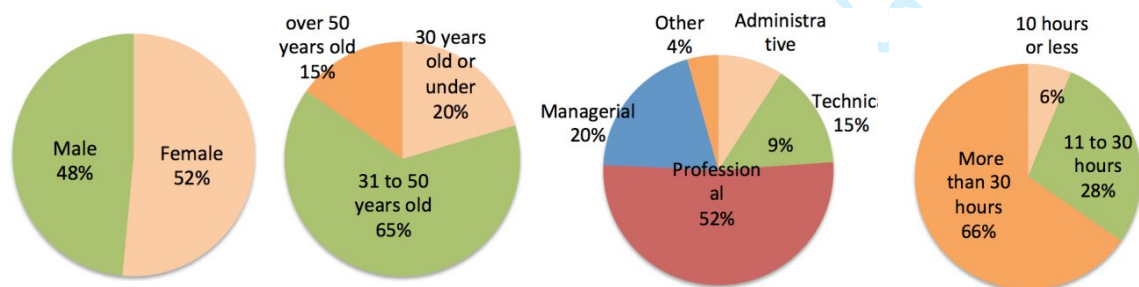
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### 2.3 Occupants

159 Out of the whole sample of those volunteers, there was an even split between male and female workers, 48 and  
 160 52% respectively. The majority of workers are between 31 and 50 years of age (65%) followed by the younger  
 161 group (30 years old or less) (20%) and older group (over 50 years old) (15%). More than half of occupants  
 162 (52%) are professionals and working more than 30h a week (66%). Basic information about office workers'  
 163 profile is depicted in Figure 1.

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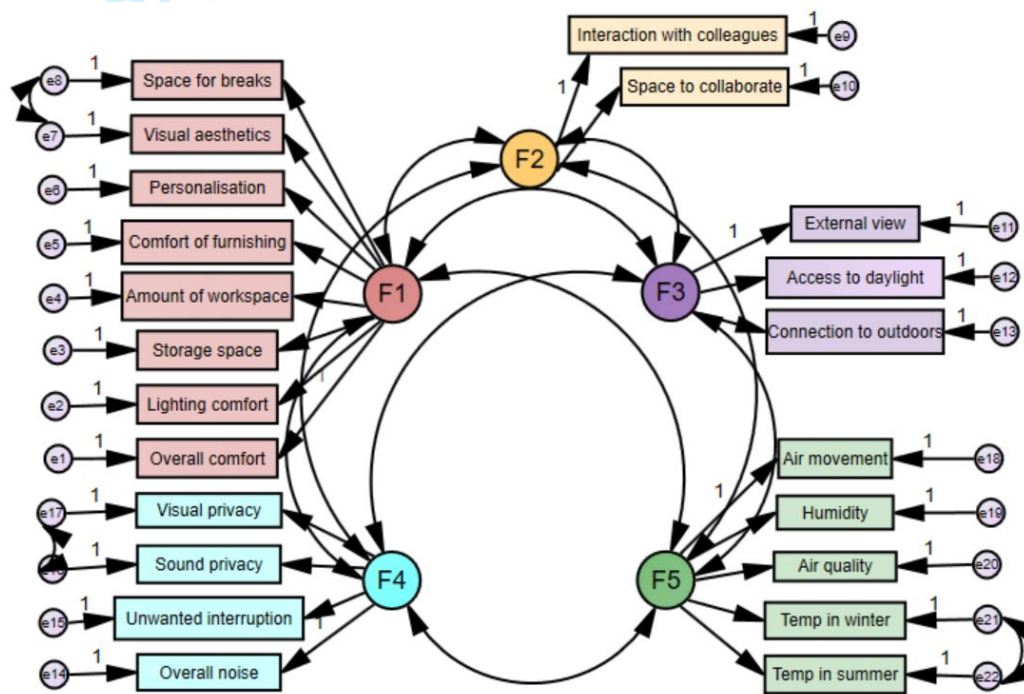
**Figure 1.** Office workers' overall demographics.165 

### 2.4 Statistical and text analysis method

166 First, several one-way ANOVA tests were conducted for the whole sample to determine if the perceived  
 167 productivity scores were different when having industry sector, age, gender, type of work, and time spent at

work as the independent variables. A seven-point Likert scale with 22 items and, initially, 5 theoretical factors was generated with all survey questionnaires (Figure 2). Confirmatory factor analysis (CFA) was performed in the AMOS v.24, a software tool distributed by SPSS Inc. Factor scores can be assigned to a surveyed office based on the five factors found during the CFA. Factor scores were computed by averaging the individual questionnaire item scores comprising each factor. The mean score of the dataset is an average of the all-office scores, giving equal weight to every office included in the dataset.

Several linear regression analyses were carried out for each of factor item taken as the independent variable, where perceived productivity was the dependent variable. Differences between occupants reporting a negative or positive impact on their productivity were also investigated. Further, effect sizes are also reported. Apart from the 22 questionnaire items used in the CFA, the BOSSA time-lapse survey also has the question for perceived productivity. Finally, open-ended comments were analyzed with Nvivo 12 software. comments are separated in three main themes: IAQ/thermal comfort, distraction and privacy and then interior design aspects. Word clouds are created to show the key sources of dissatisfaction based on the frequency of each word in open-ended comments.



**Figure 2.** Path diagram of confirmatory factor analysis and grouping of physical environment parameters.

The Figure 2 shows the five factors of the IEQ (represented by the circles). Each rectangle represents one item of the questionnaire, linked to its parent factor by a single-headed arrow. The double-headed arrows connected to items Space for breaks and Visual aesthetics, Visual privacy and Sound privacy, and Temperature in winter and Temperature in summer represent covariance between two latent variables. goodness-of-fit index (GFI) and adjusted goodness-of-fit index (AGFI) were 0.932 and 0.912 respectively, indicating good fit. Comparative fit index (CFI) was 0.955 and Tucker Lewis index (TLI), 0.946. The root mean square error of approximation (RMSEA) was 0.059 ( $< 0.080$ ). The values of indices obtained from the CFA analyses were suggesting a well-fitting model and satisfactory (Figure 2). **The Cronbach's alpha values obtained for the total scale (0.88) and each of the five factors were high, suggesting high internal consistency.**

### 3. Results

#### 3.1 Whole sample analysis, perceived productivity

Separate one-way ANOVA tests were conducted with perceived productivity as the dependent variable and industry sector, age, gender, type of work, and time spent at work as the independent variables. All ANOVA tests returned statistically significant differences as depicted in Table II. This means that at least two groups for each independent variable is statistically different in perceived productivity with the exception of gender since only two groups (female and male) are defined for this variable.

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**Table II.** p values for ANOVA tests for the differences in perceived productivity

Independent variable	Groups	Mean	Sig.
Age	30 years old or under	4.82	.013
	31 to 50 years old	4.67	
	over 50 years old	4.62	
Gender	Female	4.81	.000
	Male	4.56	
Office layout	open plan with partitions	4.46	.000
	open plan without partitions	4.78	
	other (private, private shared with others, other)	4.88	
Type of work	Administrative	5.03	.000
	Technical	4.58	
	Professional	4.59	
	Managerial	4.65	
Time at work	10 hours or less	5.14	.001
	11 to 30 hours	4.74	
	More than 30 hours	4.60	
Industry sector	Tertiary Education	5.02	0.000
	Finance	4.92	
	Property/asset management	4.34	
	Design/Engineering	4.38	
	Construction	5.57	

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Following up with the one-way ANOVA test for the whole sample with industry sector as independent and perceived productivity as dependent variable, Tukey HSD post hoc analysis was conducted to compare the industry sectors in groups of two. **Table III** shows the results of this test, and Figure 3(b) represents the productivity scores per sector. Workers in the construction industry reported the highest perceived productivity levels (mean=5.5). In addition, the difference between perceived productivity for employees working in construction industry is statistically significant compared to finance ( $p < 0.0005$ ), property ( $p < 0.0005$ ), and design/engineering ( $p < 0.0005$ ) sector, while not statistically significant compared to tertiary education. Statistically significant differences regarding perceived productivity can also be seen between design/engineering and tertiary education ( $p < 0.036$ , mean difference= 0.63), design/engineering and finance ( $p < 0.0005$ , mean difference= 0.545), property/asset management and tertiary education ( $p < 0.011$ , mean difference=0.67) and finally property/asset management and finance ( $p < 0.0005$ , mean difference=0.57).

**Table III.** p values for ANOVA test for the differences in perceived productivity between industry sectors

	Tertiary Education		Finance		Property/asset management		Design/Engineering		Construction	
	P value	Mean difference	P value	Mean difference	P value	Mean difference	P value	Mean difference	P value	Mean difference
Tertiary Education			Not significant	-	0.011	0.672	.036	0.639	Not significant	-
Finance					.000	0.579	.000	0.545	.000	0.643
Property/asset management							Not significant	-	.000	1.222
Design/Engineering									.000	1.189
Construction										

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To investigate the differences between perceived productivity in different industry sectors for sociodemographic variables such as age, gender, office type, type of work and time spent at work, t-test and Variance analyses tests were conducted. The results of the test were non-conclusive as it just showed significant differences for one variable. Two age groups ( $\leq 30$  years old and  $> 31$  years old) showed statistically significant results for biophilia.

**Table IV** shows the ANOVA for each factor items and sectors. Tertiary Education sector had a higher satisfaction rate on Distraction & Privacy than the Finance, Property and Design/Engineering sectors. The office workers in Construction sectors reported more satisfaction levels for Biophilic Design, IAQ & Thermal comfort, and there was a statistically significant difference between the sectors Construction and the others such as Finance, Property and Design/Engineering. In Collaboration factor item, Tertiary Education and Finance sector workers were more satisfied than Property and Design/Engineering sector workers.

**Table IV.** ANOVA results

Variable			Mean Difference	Std. Error	Sig.	Partial Eta Squared
			(I-J)			
Distraction & privacy	Tertiary education	Finance	0.49099	0.143	0.005	0.089
		Property	1.17753	0.141	0.001	
		Design/Engineering	0.93124	0.156	0.001	
	Finance	Property	0.68653	0.065	0.001	
		Design/Engineering	0.44025	0.095	0.001	
	Construction	Finance	0.34895	0.102	0.006	
		Property	1.03548	0.099	0.001	
	Design/Engineering	Property	0.78919	0.121	0.001	
		Property	0.24629	0.079	0.02	
	Biophilic design	Construction	Finance	0.42163	0.114	
Property			0.52488	0.111	0.001	
Design/Engineering			0.59375	0.135	0.001	
Collaboration	Tertiary education	Property	0.67201	0.117	0.001	0.112
		Design/Engineering	0.58425	0.13	0.001	
	Finance	Property	0.63654	0.054	0.001	
		Design/Engineering	0.54879	0.079	0.001	
	Construction	Tertiary education	0.42337	0.134	0.014	
		Finance	0.45884	0.085	0.001	
		Property	1.09539	0.083	0.001	
		Design/Engineering	1.00763	0.1	0.001	
Interior design	Tertiary education	Property	0.62348	0.126	0.001	0.103
		Design/Engineering	0.62031	0.14	0.001	
	Finance	Property	0.59494	0.059	0.001	
		Design/Engineering	0.59176	0.085	0.001	
	Construction	Tertiary education	0.54328	0.144	0.002	
		Finance	0.57182	0.091	0.001	
		Property	1.16676	0.089	0.001	
		Design/Engineering	1.16358	0.108	0.001	
IAQ & Thermal Comfort	Finance	Design/Engineering	0.34526	0.102	0.007	0.042
		Tertiary education	0.69856	0.174	0.001	
	Construction	Finance	0.79808	0.11	0.001	
		Property	0.93697	0.107	0.001	
		Property	1.14334	0.13	0.001	
		Design/Engineering	1.14334	0.13	0.001	

The mean difference is significant at the 0.05 level.

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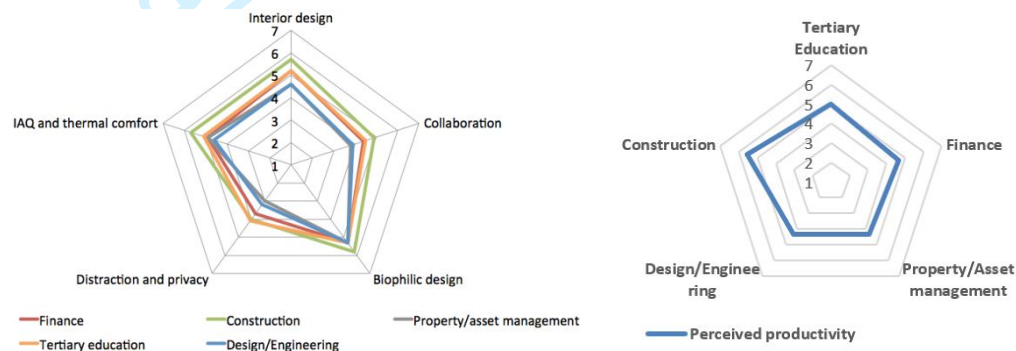
### 234 3.2 Key sources of satisfaction and dissatisfaction per sector

235 Overall, satisfaction scores from all sectors showed a similar trend with occupants consistently rating their  
 236 workspaces highly on biophilic, interior design and IAQ/thermal comfort (5.3, 5.1 and 5.1 out of 7,  
 237 respectively) (Figure 3(a)). The difference between the highest performer (construction, 5.7) and lowest  
 238 (design and engineering, 4.6) was 1.1 point score on interior design (statistically significant). For biophilic  
 239 design, this difference was the lowest out of all five factors, just 0.5 score difference, with construction  
 240 workers rating their premises the highest (5.8) and design and engineering receiving the lowest score of 3.

241 Thermal comfort and Indoor Air Quality were rated the third highest scores for all sectors. Considering these  
 242 are all open-plan offices, it is not surprising that out of all factors investigated here, distraction and privacy  
 243 received the lowest scores from knowledge workers from all sectors although the spaces were designed to  
 244 facilitate a range of activity from focused work to collaboration. That said there is a difference between lowest  
 245 and highest score for distraction and privacy of over one point (1.1). Offices from the property and asset  
 246 management sector received the lowest score – just 3 – followed by designing and engineering (3.2).

247 For IAQ and thermal comfort, scores hovered around the five-point mark for all sectors, with occupants from  
 248 construction sector being the most satisfied (mean=6.0) and design/engineering (mean= 4.9) the least Mean  
 249 scores for tertiary education, finance and property/asset management are 5.2, 5.1 and 5.0, respectively. The  
 250 weakest performance out of all questions from this factor was observed for air movement and temperature  
 251 conditions during summer and winter. When asked about the main reason why they were dissatisfied with air  
 252 movement/temperature conditions, the majority of occupants indicated coldness (40%), not enough air  
 253 movement (16%) and local discomfort with their hand, ankle of neck being too hot or cold (11%).

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255 **Figure 3.** (a) Mean satisfaction scores from each sector on Interior design, collaboration, biophilic design,  
 256 distraction & privacy, IAQ & thermal comfort. (b) Mean perceived productivity scores from each  
 257 industry sector 7 is the highest possible score on the survey scale score and 1 is the lowest.

255 Out of 2,090 respondents, 23.5% (n=476) provided a comment related to indoor environment of their work  
 256 area. The analysis of these open-ended questions revealed three recurring sources of dissatisfaction: interior  
 257 design, IAQ/thermal comfort and distraction and privacy. Word clouds are generated from the open-ended  
 258 comments using Nvivo 12 where frequently occurring words are in larger fonts. Regarding IAQ/thermal  
 259 comfort and distraction and privacy, two questions in the BOSSA questionnaire asked the occupants to  
 260 provide the dissatisfaction reason (**Refer to Appendix for the two questions**). Figure 4(a) and Figure 6(a)  
 261 show the percentage frequency of these reasons. However, for interior design dissatisfaction, there is no such a  
 262 question which asks about dissatisfaction reason in the BOSSA questionnaire.

263 Open-ended comments from dissatisfied occupants (Figure 4(b)) point out temperature control/preference  
 264 issues as air-conditioning is deemed too cold by most along with great annoyance from the constant need to  
 265 wear warm clothes while working in the office. Occupants have also mentioned dissatisfaction with how  
 266 complaints were managed by facilities. Occupants' responses to the survey question which asked about  
 267 dissatisfaction reasons regarding thermal comfort (Figure 4(a)) also indicate that low temperature is the  
 268 biggest issue mentioned by 40% of the respondents. Combined, these results are consistent with common  
 269 thermal comfort issues found in open-plan offices. That said, the result found here was high being above the  
 270 scale mid point for all sectors (above four on seven-point satisfaction scale) which is high.

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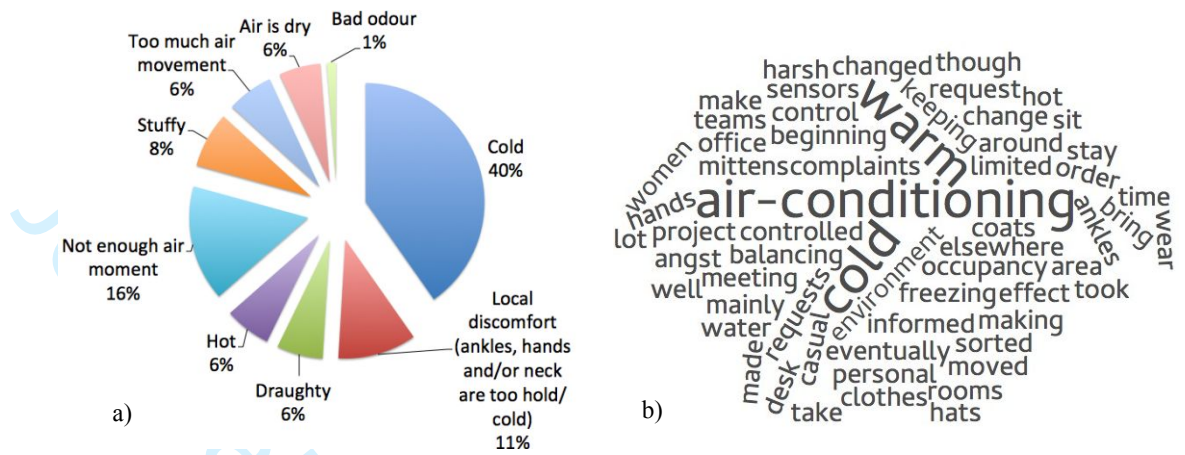


Figure 4. (a) Key sources of dissatisfaction reported by occupants on IAQ and thermal comfort and (b) word cloud generated from open-ended comments left by occupants reporting dissatisfaction with IAQ and thermal comfort.

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Figure 5. Word cloud from open-ended comments left by occupants reporting dissatisfaction with interior design.

Table V. Summary of number of open-ended comments for each industry sector and each category

	Whole sample	IAQ and thermal comfort	Interior design	Distraction and privacy
Tertiary education	36	12	6	14
Finance	140	36	34	66
Property/asset management	258	55	40	165
Design/Engineering	10	4	3	5
Construction	32	6	11	19
Total	476	113	94	269

274 For interior design-related questions, the biggest differences in terms of scores were observed for satisfaction  
 275 with space for breaks, work area aesthetics, personalization, and storage. These results were consistent for all  
 276 sectors. Space from breaks, personalization for work area and storage results were the only ones, which dipped  
 277 below 4/7 for property/asset management and design/engineering sectors. Amount of space was rated the  
 278 highest by occupants with lighting and overall comfort of work area following. Open-ended comments from  
 279 dissatisfied occupants (Figure 5) pointed out that desk sharing policy declines efficiency by wasting time to  
 280 unpack/set up every day and pack up at the end of the day. In addition, dissatisfaction with the overall  
 281 ergonomics of the work area, low number of sit-stand desks and lockers/storage spaces are raised as major



319 collaborative work, along with low-to-high energy levels zones, which includes breakout spaces, relaxation  
 320 and community engagement. The layout and spatial design has also placed emphasis on integrating flexibility  
 321 to support mobility with the use of high information and communication technologies, implementing greenery,  
 322 and using plants and ecofriendly, smart and advanced materials to make spaces more creative. There is strong  
 323 evidence of newly designed open plan offices putting into practice the innovative design strategies hold  
 324 promise to increase job satisfaction, health and productivity (Chafi, 2020; Kämpf-Dern & Konkol, 2017; van  
 325 der Voordt, 2004). Previous research conducted in Australian premium open-plan offices suggest that  
 326 satisfaction with work area aesthetics ranks extremely highly when it comes to knowledge workers' overall  
 327 satisfaction, perceived productivity and health (Candido et al, 2019a). Our findings overlap with the outcomes  
 328 of these studies.

329 Collaboration including interaction with colleagues and space to collaborate items yielded the second strongest  
 330 association with respect to perceived productivity. This finding becomes crucial when the intention of ABW,  
 331 increasing collaboration among occupants by removing barriers (walls, doors and hallways) (Barnes et al.,  
 332 2020), has been considered. Open, transparent and spacious office design increases accessibility of colleagues  
 333 and encourages communication and collaboration. Spaces for socialization such as big kitchen table serves as  
 334 a place for meetings, having coffee or eating lunch together and having plush sofas and small tables with a few  
 335 chairs invite people to meet each other increases creativity among the employees (De Paoli & Ropo, 2017).  
 336 The idea of open plan office is to increase the "chance" of impromptu meetings and conversations, which can  
 337 lead to unplanned collaborations (Walsh, 2018). On the other hand, Davis et al. (2011) took attention to the  
 338 risk of open plan offices negatively affecting cognitive processes and task performance and/or contributing to  
 339 stress due to the increased communicative spontaneity and over-stimulation.

340 Distraction and Privacy consisting of unwanted interruption, visual and sound privacy, and overall noise was  
 341 the third strongest predictor for each sector for perceived productivity. Although it is the most unsatisfactory  
 342 IEQ factor among the other factors (Figure 2), it came as the third strongest predictor for productivity. This is  
 343 a surprising result considering the distraction and privacy is deemed as the 'Achilles heel' of open-plan  
 344 offices. That said, dissatisfaction results discussed earlier show that workers reported several issues regarding  
 345 the amount of noise from other people and the difficulty in performing phone calls, which suggest a  
 346 spatial/behavioral, related issue.

347 **Table VI.** Results of linear regression data analyses for each factor with respect to perceived productivity for  
 348 each sector

Sectors	Interior design		Collaboration		Biophilic design		Distraction & privacy		IAQ & Thermal comfort	
	R <sup>2</sup>	β	R <sup>2</sup>	β	R <sup>2</sup>	β	R <sup>2</sup>	β	R <sup>2</sup>	β
Tertiary Education	0.69	1.05	0.64	1.14	0.35	0.66	0.49	0.76	0.53	0.79
Finance	0.47	0.89	0.47	0.95	0.17	0.49	0.41	0.71	0.21	0.47
Property	0.50	0.99	0.51	1.06	0.15	0.42	0.41	0.87	0.18	0.51
Design/Engineering	0.44	0.89	0.41	0.93	0.15	0.36	0.30	0.64	0.21	0.47
Construction	0.52	1.04	0.49	1.10	0.21	0.42	0.40	0.68	0.33	0.72

349 Note: p-values for all factor items are statistically significant ( $p < 0.001$ ).

350

### 351 3.4 Reported positive and negatives impacts of work area on perceived productivity per sector

352 When asked about how the work area affects their productivity, most occupants reported a positive impact  
 353 (Figure 7). The most positive results were from the construction sector (82%), followed by tertiary education  
 354 (70%) and then finance (62%). Property/asset management and design/engineering reported the most negative  
 355 impact of the work area on perceived productivity (30 and 23%, respectively). This question was asked on a 7-  
 356 point Likert scale (1-7). The respondents were separated in two groups: people who negatively rated their  
 357 productivity (1-3), and people who positively rated their productivity (4-7). Significant differences were found  
 358 per sector between occupants reporting a negative or positive impact of the work area on their productivity.  
 359 Medium to large effects sizes were found (0.5-0.8).

360

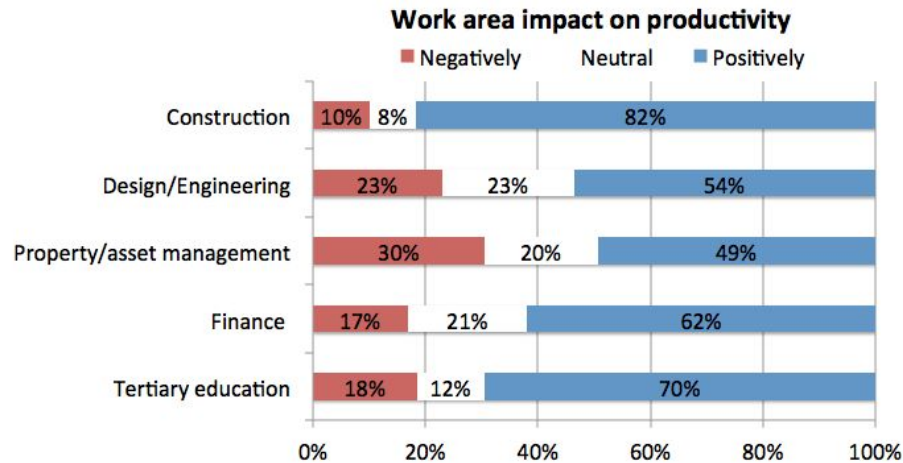


Figure 7. The impact of the work area on perceived productivity.

361

362 When drilling down into open-ended comments left by those occupants reporting a negative impact of the  
 363 work area on their productivity, it was revealed that most of the reported issues were related to the interior  
 364 design of the space. In addition, users also reported significant impact of the way of working on their  
 365 emotional being. For those reporting complaints about the design of the space, there were five key topics:  
 366 meeting rooms, desks, rooms/locations for focused work, acoustics and overall ergonomics. Occupants  
 367 extensively reported their frustrations with the ability to book meeting rooms as well as the insufficient  
 368 number of meeting rooms of all sizes available to them. In addition, they have also reported similar issues  
 369 around the location of zones dedicated to focused work, which were often located next to noisy environments  
 370 such as kitchen and large break-out spaces. In addition, occupants also reported several issues about the  
 371 focused workrooms being too cold and/or visually unattractive. Occupants were also particularly frustrated by  
 372 the difficulty in finding desks (and colleagues), which suggest issues related to way finding and the number of  
 373 workstations. Not being able to find colleagues was very pronounced in environments where neighborhoods  
 374 were not implemented (finance sector and agile working). Acoustics-related complaints are consistent with  
 375 issues reported before in this paper including the lack of space to have a private conversation, the amount of  
 376 noise from other people and inability to concentrate. Overall furniture ergonomics, especially the inability to  
 377 adjust desk/chair were also frequently mentioned by occupants. Despite perceptions that occupants in ABWs  
 378 have the opportunity to choose their desk that supports their task and/or personal related needs, desk sharing  
 379 may have a negative influence on the occupants' sense of belonging since the lack of individuality and  
 380 personalization to define their territory (Candido et al., 2019).

381 Findings also indicate that is possible to achieve high levels of occupants' satisfaction, health and productivity  
 382 if interior design properly caters for workers' needs, even if desk-ownership is removed (van der Voordt,  
 383 2004). This is also aligned with prior research led by authors in other ABW supportive environments in  
 384 Australia, which also highlighted the crucial role interior design plays in high-performance workplaces  
 385 (Candido et al., 2019; Candido et al., 2020). The ability to choose the workstation has been linked to higher  
 386 levels of job-satisfaction (Bodin-Danielsson and Bodin, 2008). Non-assigned seating has also been found as  
 387 facilitator for spontaneous interactions (which in turn contributes to productivity levels), (Brill and Weideman,  
 388 2001). Studies have also pointed to the need of properly providing on-demand/reservable spaces for  
 389 collaboration, concentration and breaks (Gensler, 2020). In fact, interior design is front and center when it  
 390 comes to successfully implementing the infrastructure needed to support ABW (Candido et al., 2016a, De  
 391 Been and Beijer, 2014, Hua et al., 2011., Medik & Stettina, 2014). Beyond interior design, previous research  
 392 (Hoendervanger et al., 2016) has also found that respondents who switched several times a day showed higher  
 393 satisfaction rates in ABW environments.

394 Finally, those indicating a negative impact of the work area on their productivity also mentioned concerns  
 395 around the sense of belonging (or the lack thereof) in ABW environments. Occupants reported feeling of  
 396 missing their own desk and the ability to keep their belongings at the same location. They have also  
 397 commented on the negative impact of ABW on teamwork and the overall inability to find their teammates.  
 398 This was particularly pronounced on the finance sector and the two offices that support agile working where  
 399 neighborhoods were not implemented thereby limiting the ability of teams working from the same location.  
 400 Similar issues around emotional attachment-related issues in ABW offices have been reported by previous

research and our findings are in alignment with them (Göçer et al., 2018; Gensler, 2020; Haapakangas, 2019). Appel-Meulenbroek et al. (2011) also highlighted the possible loss of productivity, illness and dissatisfaction when ABW concept is not used as intended.

#### 4. Conclusions

This paper analysed key differences in occupants' satisfaction along with predictors of perceived productivity in offices designed to support ABW from five different industries – tertiary education, finance, property/asset management, construction, design/engineering. In terms of occupants' satisfaction, workers from construction were the most satisfied, followed by finance and tertiary education. Design/engineering and property asset management were the least satisfied out of the five industry sectors investigated here. In fact, Tertiary education sector had a higher satisfaction rate on distraction and privacy, which is one of the key issues faced by occupants in open-plan environments.

In terms of key drivers for perceived productivity per sector, interior design was the strongest predictor ( $R^2$  ranked between 0.69-0.44) for entire data set and all sectors, except Property. While the strongest predictor was collaboration ( $R^2=0.51$ ,  $\beta=1.06$ ,  $p<0.001$ ) for this sector, it was the second strongest predictor for the others. The weakest predictor of the analysed questionnaire items/factors was biophilic design for the entire data set and all sectors. For the Property sector, the difference between the first (interior design) and second predictor (collaboration) is not very high, so it can be assumed the predictors are same for perceived productivity.

Open-ended comments showed mismatches between spatial and behavioral dimensions in the non-assigned seating environments investigated here both for satisfaction and perceived productivity. Key issues reported were the number/availability of bookable/on demand meeting rooms, number/findings desks, and inadequacy of location of focused-work rooms, overall acoustics and office ergonomics. In addition, occupants also reported the impact of ABW on their emotional being due to desk ownership removal and losses on the sense of belonging (team and broader work community). These were particularly pronounced on offices from the finance sector and those where agile working was implemented.

Combined, this research highlights the crucial role interior design plays in open-plan environments. The consistency of results across sectors is somewhat surprising considering that ABW is the norm for the finance sector but an exception for tertiary education. That being said, one can argue that the type of tasks knowledge workers perform is similar and as such, the spatial-related needs would be equivalent regardless of the sector they are coming from. Nevertheless, findings dispel the notion that ABW implementation may not be suitable for certain industries, as long as the three key pillars of ABW are fully implemented, including design, behavior and technology. That said, results from this paper are limited to design and behavioural aspects and technology needs to be further explored in future research.

Authors acknowledge there is some information missing within existent data and questions about sectors. The ratio of industry sectors in regard to the whole sample size were also different. This may also affect findings of this study. We also acknowledge that occupants are knowledge workers but we were unable to provide detail the exact type of activities these workers were doing at their workspace.

Clearly, this research was conducted prior to the onset of COVID-19. The pandemic has cast doubt over the future of continuation/adoption of Activity-Based Working-supportive environments **post-COVID-19**, due to concerns around desk and equipment sharing but also increased occupants' movement. The ABW approach recognizes that people will perform different tasks during their workday and as such they a variety of work settings. The pandemic is in fact fast-tracking the same approach at a scale never seen before with many realizing that offices play a central role as social, collaborative and learning environments. Whatever shape workplaces will take **post-COVID-19**, clearly offices need of a rethink and the pandemic has placed the purpose of offices under the spotlight alongside with the new possibilities afforded by the large-scale uptake of remote working and/or the addition to a network of workplaces to the traditional HQ. Where ABW will land, is yet to be seen, but it was never about the place, it is about *where and how* people and organizations want to work and for that, flexibility and trust are key.

The result of this research could be practically implemented as evidence to strengthen the arguments around the crucial role of interior design and physical configuration of the workspace on occupants' satisfaction and productivity. If designed and implemented well, ABW seems to be working for many organizations in different industry sector.

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## Appendix

## BOSSA Time-Lapse survey- full questionnaire set

Dimension		Label	Question	Answers
Occupants profile & work area	1	Gender	Are you a female or a male occupant?	1=Female 2=Male 3=Prefer not to respond
	2	Age	How old are you?	1=30 years old or under 2=31 to 50 years old 3=over 50 years old
	3	Type of work	Which one of the following best describes the type of work you do?	1=Administrative 2=Technical 3=Professional 4=Managerial 5=Other
	4	Time spent in building	How long have you been working in this building?	1= Less than 6 months 2= 7 to 12 months 3= 1 to 2 years 4= 2 to 5 years 5= More than 5 years
	5	Hours per week in work area	In a typical week, how many hours do you spend in your normal work area?	1= 10 hours or less 2= 11 to 30 hours 3= More than 30 hours
	6	Floor	On which floor is your normal work area located?	
	7	Office layout	Which one of the following best describes your normal work area?	1= Private office 2= Private office shared with other occupants 3= Open plan office with high partitions (higher than 1.5m) 4= Open plan office with low partitions (lower than 1.5m) 5= Open plan office without partitions 6= Other
	8	Workspace arrangement	Which of these two options best describe your current workspace arrangement?"	1= Fixed location (includes exclusive and shared use of the same workstation) 2= No fixed location (varies e.g. activity based workspace, flexi-desk)
	8-1	Seat selection	The overall indoor environmental quality of my work area influences my seat/location selection.	1= disagree ~ 7= agree
	9	Time spent at work area	How long have you been working at your normal work area?	1= Less than 6 months 2= 6 to 12 months 3= 1 to 2 years 4= 2 to 5 years 5= More than 5 years
	10	External window	Is your normal work area near an external window (3m or less)?	1=Yes 2= No
11	Boundaries	Is your normal work area close to any of the following (you may select more than one, if applicable)?	Not applicable, Atrium, Courtyard, Garden, Balcony, Glass wall, Other	
Spatial comfort	12	Space for breaks	This building provides pleasant spaces (e.g. indoor or outdoor green space, break-out areas) for breaks and relaxation.	1= Disagree ~ 7= Agree*
	13	Work area aesthetics	Please rate your satisfaction with the visual aesthetics of your normal work area.	1= Dissatisfied ~ 7= Satisfied*

	14	Interaction with colleagues	How do you rate your normal work area's layout in terms of allowing you to interact with your colleagues?	1= Dissatisfied ~ 7= Satisfied*
	15	Personalisation of work area	My normal work area can be adjusted (or personalised) to meet my preferences.	1= Disagree ~ 7= Agree*
	16	Space collaborate to	The building provides adequate formal and informal spaces to collaborate with others.	1= Disagree ~ 7= Agree *
	17	Comfort furnishing of	Please rate how comfortable your work area's furnishings are (including chairs, desk, equipment, etc).	1= Uncomfortable ~ 7= Comfortable*
Individual space	18	Amount workspace of	Please rate your satisfaction with the amount of space available to you at your normal work area.	1= Dissatisfied ~ 7= Satisfied
	19	Storage space	Please rate your satisfaction with the amount of personal storage space available to you.	1= Dissatisfied ~ 7= Satisfied*
Indoor air quality	20	Air movement	Please rate your satisfaction with the air movement available to you in your normal work area?	1= Dissatisfied ~ 7= Satisfied*
	21	Humidity	Please rate your satisfaction with the overall humidity in your normal work area?	1= Dissatisfied ~ 7= Satisfied*
	22	Air quality	Please rate your satisfaction with the overall air quality in your work area.	1= Dissatisfied ~ 7= Satisfied*
	22-1	Air quality reason	Please indicate why you are dissatisfied with the overall air quality in your normal work area (you may select more than one, if applicable).	Too much air movement, Stuffy, Not enough air movement, Bad odour, Air too humid, Air too dry, Other
Thermal comfort	23	Temperature in winter	Please rate the temperature conditions of your normal work area in winter.	1= Uncomfortable ~ 7= Comfortable*
	23-1	Temperature reason winter	Please identify the reason why your normal work is uncomfortable in winter.	Too hot, Too cold, Draughty, Incoming sun, hot or cold surrounding surfaces, local discomfort (neck, hands or ankles are too hot/cold), Other
	24	Temperature in summer	Please rate the temperature conditions of your normal work area in summer.	1= Uncomfortable ~ 7= Comfortable*
	24-1	Temperature reason summer	Please identify the reason why your normal work is uncomfortable in summer.	Too hot, Too cold, Draughty, Incoming sun, hot or cold surrounding surfaces, local discomfort (neck, hands or ankles are too hot/cold), Other
Noise distraction & privacy	25	Unwanted interruption	The work area's layout enables me to work without distraction or unwanted interruptions.	1= Disagree ~ 7= Agree*
	26	Visual privacy	My normal work area provides adequate visual privacy (not being seen by others).	1= Disagree ~ 7= Agree*
	27	Sound privacy	My normal work area provides adequate sound privacy (not being overheard by others).	1= Disagree ~ 7= Agree*
	28	Noise	Please rate your satisfaction with the overall noise in your normal work area.	1= Dissatisfied ~ 7= Satisfied*
	28-1	Noise reason	Please identify the reason why you are dissatisfied with the overall noise in your normal work area (you may select more than one, if applicable).	Noise from people, HVAC noise, Office equipment, Phones ringing, Radio/music/TV, Other indoor noise, Outdoor traffic, Other outdoor noise
Visual comfort	29	Lighting	Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of light, glare, reflections, contrast)?	1= Dissatisfied ~ 7= Satisfied*

	29-1	Lighting reason	Please identify the reason why you are dissatisfied with the overall lighting comfort in your normal work area (you may select more than one, if applicable).	Too bright, Too dim, Glare from lights, Glare from sun and sky, Reflection on screen, Flickering lights, Contrast, Other
	30	Shading	Please rate your satisfaction with shading devices (blinds, curtains, etc) in terms of controlling unwanted glare?	1= Dissatisfied ~ 7= Satisfied*
Personal control	31	Personal control heating/cooling	How do you rate the level of personal control over heating or cooling of your normal work area?	1= No control ~ 7= Full control*
	32	Personal control air movement	How do you rate the level of personal control over air movement of your normal work area?	1= No control ~ 7= Full control*
	33	Personal control lighting	How do you rate the level of personal control over the artificial lighting at your normal work area?	1= No control ~ 7= Full control*
	34	Degree of freedom to adapt	All things considered, how satisfied are you with the degree of freedom to adapt your normal work area (air-conditioning, opening the window, lighting, etc.) to meet your own preferences?	1= Dissatisfied ~ 7= Satisfied*
Connection to outdoor environment	35	External view	Please rate your satisfaction with the external view from you normal work area.	1= Dissatisfied ~ 7= Satisfied*
	36	Access to daylight	Please rate your satisfaction with the access to daylight from your normal work area.	1= Dissatisfied ~ 7= Satisfied*
	37	Connection to outdoors	This building provides a sense of connection between my normal work area and the outdoor environment.	1= Disagree ~ 7= Agree*
Building image & maintenance	38	Cleanliness	Please rate your satisfaction with the general cleanliness of your normal work area?	1= Dissatisfied ~ 7= Satisfied*
	39	Maintenance	Please rate your satisfaction with the general maintenance of this building?	1= Dissatisfied ~ 7= Satisfied*
	40	Building aesthetics	Please rate the overall visual aesthetics of this building.	1= Dissatisfied ~ 7= Satisfied*
General	41	Overall comfort workarea	All things considered, how satisfied are you with the overall comfort of your normal work area?	1= Dissatisfied ~ 7= Satisfied*
	42	Overall building	How satisfied are you with this building overall?	1= Dissatisfied ~ 7= Satisfied*
	43	Productivity	Productivity How does your work area influence your productivity?	1= Negatively ~ 7= Positively*
	44	Productivity estimate	Please estimate how much your work area influences your productivity.	1= Decreases by 30% 2= Decreases by 20% 3= Decreases by 10% 4= Neutral 5= Increases by 10% 6= Increases by 20% 7= Increases by 30%
	45	Health	How does your work area influence your health?	1= Negatively ~ 7= Positively*
	46	Request for change	Have you ever made requests for changes to the heating, lighting, ventilation or air-conditioning/cooling?	1= Yes 2= No
	46-1	Request reason	Please choose which of the following best describes the nature of your request (you may select more than one, if applicable).	Temperature (want cooler), Temperature (want warmer), Air movement (want more), Air movement (want less), Lighting, Other
	46-2	Response to request	How satisfied were you with the speed and effectiveness of the response to your request?	1= Dissatisfied ~ 7= Satisfied*
	47	Comments	Would you like to add any additional comments?	1= Yes 2= No

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	47-1	Type comments	Please type your comments here [text box]	
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\*All the scale questions are on a 7-point Likert scale.

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