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Facility Management Role in Thermal Adaptability Enhancement in Thai Universities

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Abstract

This study examined the role of strategic and operational facility management in thermal adaptability enhancement in educational estates. Individual and organisational ability to adapt to non-air-conditioned environments were assessed using a questionnaire survey of university students and from interviews with facility managers. The aim of the study is to address the risks and opportunities in relation to thermal adaptability enhancement through facility management practice in non-residential buildings. In this study, adaptive thermal comfort theory and mixed-mode operational strategies were adopted in proposing a thermal adaptability assessment tool. The results show that an attempt to satisfy users by overprovision of air-conditioning and some minor building adaptations, e.g. space pre-cooling and removing fans, are the main barriers to enhancing thermal adaptability. The findings suggest that providing a greater diversity of thermal environments rather than fully air-conditioned surroundings would be more beneficial to thermal adaptability enhancement.

Key words

Thermal adaptation, facility management, mixed-mode, higher education sector, hot-humid climates

1. Introduction

This study is prompted by the rising temperatures in hot-humid countries that increase the demand for air-conditioned (AC) buildings in those countries, thus resulting in carbon emission intensification which in return contributes to global warming. The role of facility management (FM) in reducing AC demand in the higher education (HE) sector is of interest in this study.

While signs of AC addiction[1] has been found in many empirical studies about thermal comfort in hot and hot-humid climates (e.g. Brager & de Dear, 1998; Matias, Almeida, Pina Santos, Rebelo, & Correia Guedes, 2009), adaptive thermal comfort and mixed-mode (MM) strategies is gaining a lot of attention as another alternative thermal design for more energy-efficient buildings. However, for non-residential buildings to apply the concept and strategies to existing AC users is not straightforward. From the demand side, reducing AC use in buildings where it is available and accessible is against most users' expectations and habits. From the supply side, AC is inextricably intertwined with user productivity, health, and satisfaction (Clements-Croome, 2006; Rashid & Zimring, 2008; Vischer, 2007). In tropical climates, where outdoor temperatures always exceed the upper limit of the static comfort boundary, AC is viewed as the only reliable cooling method. Therefore, building designers and facility managers are reluctant to trust in other low-energy cooling strategies, resulting in limited opportunities for users to practice their thermal adaptive skills.

In the early 21st century, when energy is becoming a higher priority than personal comfort, the future of thermal comfort standards has been intensely debated worldwide (e.g. Chappells & Shove, 2005; de Dear, 2011; Kwok & Rajkovich, 2010; Nicol & Humphreys, 2009; Stephen Turner, 2008; Tuohy, 2008). Both the adaptive comfort theory and MM strategies maximise the benefits from outdoor climates to reduce heating/cooling loads, and require active users to adapt themselves and/or their environments to maintain their comfort. A number of research studies in MM buildings have shown that occupants in this building type are more satisfied and could

[1] The strong relationship between air-conditioning and user comfort expectations was originally stated by Kempton (1992), using the term 'air-conditioning addiction' (Brager & de Dear, 2003). In this case, it refers to people in air-conditioned buildings who tend to prefer cooler-than-neutral temperatures and demand quick cool air.

tolerate a wider range of indoor temperatures than those in fully AC buildings – as far as user controls are available and accessible (Brager & Baker, 2009; Deuble & de Dear, 2010; Leaman, 2003). At this point, the thermal adaptability of both design and users is considered a key to the future thermal comfort concept. However, thermal adaptations, their extent and practicality, considered from a managerial aspect, have not yet been widely studied.

In order to investigate thermal adaptability in non-residential buildings, this study applied the concept of adaptive thermal comfort and MM strategies for assessing thermal adaptability at both individual and organisational levels. HE buildings in Thailand were chosen as a case study. The main objective of this study is to address the risks and opportunities in relation to thermal adaptability enhancement through FM practice in non-residential buildings.

2. Methods

The methodology is divided into two parts; a questionnaire survey and a FM interview for individuals and organisational thermal adaptability assessments.

2.1 Thermal Adaptive Opportunity Survey

A questionnaire survey is designed for assessing the thermal adaptive opportunity in existing MM classrooms through users' perceptions. Please note that all the users are more familiar with full AC than other cooling strategies. In order to quantify the thermal adaptive opportunity in this context, a set of thermal adaptive behaviours to relieve the heat discomfort were provided. Generally, adaptive behaviours differ from context to context with regard to empirical studies in different building types (for example, Bernardi & Kowaltowski, 2006; Indraganti, 2010; Rijal, Ooka, Minami, Sakoi, & Tsuzuki, 2010). For this study, ten possible thermal adaptive behaviours in classrooms were selected (Table). Five of them are environmental adaptations and the other five are self-adaptations. Students were asked to rate the 'effectiveness' and 'probability' of the given adaptive actions based on a 5-point rating scale (1-very low to 5-very high). These two dimensions of adaptive behaviours were derived from a study by Hwang et al. (2009).

Table 1 Thermal adaptive behaviours in classrooms included in the Thermal Adaptive Opportunity questionnaire survey

Environmental adaptations	**Self-adaptations**
Opening door(s)	Changing clothes
Opening window(s)	Drinking cold water
Adjusting internal shading device(s)	Washing face
Adjusting external shading device(s)	Fanning yourself
Turning-on electric fan(s)	Moving your seat

Then, by borrowing the risk assessment method (appeared in Shah, 2007) (Figure 1), the opportunity of thermal adaptations in classrooms can be calculated using the 'effectiveness' and 'probability' ratings. The opportunity scores range from 1 to 25, classified as low (1-9), medium (10-16), and high (20-25) opportunity. Notably, this method was purposively used for a primary measure of thermal adaptive opportunity. To some extent, it is anticipated that it will reveal the tendency of adaptive behaviours in a real context.

5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Occurrence / Severity	1	2	3	4	5

a) Quantitative risk assessment methodology (Shah, 2007)

5	5	10	15	20	25	High
4	4	8	12	16	20	
3	3	6	9	12	15	Medium
2	2	4	6	8	10	
1	1	2	3	4	5	Low
Effectiveness / Probability	1	2	3	4	5	

b) Proposed thermal adaptive opportunity quantification

Figure 1 Risk assessment methodology and proposed thermal adaptive opportunity quantification

Apart from thermal adaptive opportunity quantification, this survey also aims to test its relationship with users' acceptance to use natural ventilation (NV) in the classrooms. The NV environment is used as a scenario since it is the situation to which students need to adapt the most in order to maintain thermal comfort in hot-humid climates. Hypothetically, levels of thermal adaptive opportunity and perceptions of the potential for NV to facilitate thermal comfort should be positively correlated. Therefore, students were also asked to rate how they would agree to the potential of NV assisted with fans in their classroom to maintain thermal comfort in cool and hot seasons, using a 3-point scale (1-disagree, 2-uncertain, and 3-agree). Some contextual and personal variables were also collected. For example, participant's daily thermal experience and monthly allowance were included as they could probably indicate the level of psychological (expectation) and physiological (acclimatisation) adaptability of the users.

2.2 Facility Management Interview

The second part of the study focuses on the FM role in thermal adaptability enhancement in the HE sector. A facility manager is in the forefront of the thermal adaptability enhancement process at both strategic and operational levels. Aimed at the estimation of the organisational thermal adaptability in the HE institutes, an interview with facility managers was arranged in selected Thai universities. The content of the interview centred on how buildings are thermally operated and the possibility of implementing MM strategies in existing HE buildings. Three strategies were proposed (in italic), corresponding to the MM approach (quoted from Center for the Built Environment, 2005);

1) Concurrent (same space, same time): the AC system and operable windows operate within the same space and at the same time
   Strategy 1: to use fans to assist air-conditioners and set AC temperature 1-2℃ higher to reduce energy consumption (from 25℃ to 26-27℃)
2) Change-over (same space, different times): the building "changes-over" between NV and AC on a seasonal or even daily basis
   Strategy 2: to use NV for the morning/evening classes and in the cool season
3) Zoned (different spaces, same time): different zones within the building have different conditioning strategies
   Strategy 3: to preserve existing non-AC spaces or increase non-AC spaces in the future

3. Results

3.1 Potential Adaptive Behaviours in Mixed-Mode Classrooms and Factors:

The surveys were administered in 25 classes from 10 different faculties in the Central region of Thailand. In total, 878 students participated in the survey. The number of female respondents was nearly triple that of the male respondents (651: 227). The average age was 20. The average value of clothing insulation was 0.39 (fairly low and considered normal for hot-humid countries). Approximately half of the participants had low-medium allowance (2,501-5,000 baht/month). Almost 70% of respondents reported they had a MM thermal experience daily.

Effectiveness and probability of thermal adaptive behaviours in classrooms

First of all, the 'effectiveness' and the 'probability' scores for the ten individual thermal adaptive behaviours in each observed classroom were averaged.

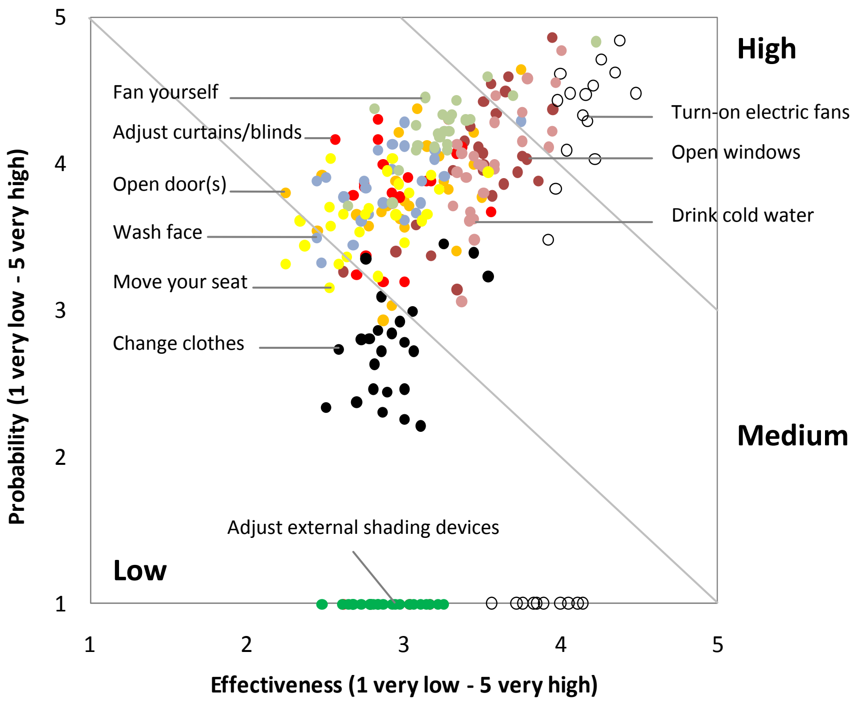

Figure 2 Scatter plot of mean scores on the 'effectiveness' against the 'probability' of given thermal adaptations of 25 individual cases

Error! Reference source not found. shows a scatter plot of mean scores on the 'effectiveness' (1-5) against the 'probability' (1-5) of given thermal adaptations of 25 individual cases. From the graph, the effectiveness scores of all adaptive behaviours were above 2 (moderately low). The probability scores of those behaviours were divided into two groups; 1 (extremely low) and above 2 (moderately low). The first group was principally the adaptive behaviours that related to the availability and adjustability of relevant design features, such as fans and internal and external shading devices. Since these facilities were not available in some classrooms, the corresponding probability scores were low. In most cases, the probability scores were slightly higher than the effectiveness scores, except for turning-on fans, changing clothes, and adjusting external shading devices.

The all-case average scores (1 low – 5 high) of the effectiveness and the probability of ten adaptive behaviours are shown in Table . Turning-on electric fans (4.06) was voted the most effective thermal adaptation in lecture rooms in all cases, followed by drinking cold water (3.55) and opening windows (3.49) with almost equal scores. Compared to the effectiveness score, the probability scores varied more widely. The probability of fanning yourself scored the highest (4.25). Opening windows (4.08) came second, followed by drinking cold water (3.94) with a slightly lower score. The probability of turning-on electric fan (3.17) was the third from last due to the absence of electric fans in some rooms.

Table 2 Average scores (all 25 cases) on the 'effectiveness' and the 'probability' of given thermal adaptations

Thermal adaptations	**Average 'effectiveness' score (rank)**	**Average 'probability' score (rank)**
Opening door(s) (OPPdoor)	3.01 (5)	3.84 (4)
Opening windows (OPPwindow)	3.49 (3)	4.08 (2)
Adjusting internal shading devices (OPPint)	2.95 (6)	3.18 (7)
Adjusting external shading devices (OPPext)	2.87 (9)	1.00 (10)
Turning-on electric fans (OPPfan)	4.06 (1)	3.17 (8)
Changing clothes (OPPclo)	2.92 (7)	2.72 (9)
Washing face (OPPface)	2.90 (8)	3.84 (4)
Drinking cold water (OPPdrink)	3.55 (2)	3.94 (3)
Fanning yourself (OPPself-fan)	3.23 (4)	4.25 (1)
Moving your seat (OPPseat)	2.77 (10)	3.63 (6)

The relationships between thermal adaptive opportunity and perceived potential of natural ventilation

The correlations between the thermal adaptive opportunity level of the ten adaptive behaviours and the perceived potential of NV of the 878 individual students were examined using the chi-square correlation test. Prior to the test, thermal adaptive opportunity scores were calculated by multiplying the 'effectiveness' and 'probability' ratings and transformed into a three-level ordinal scale (1-low, 2-medium, and 3-high opportunity), as stated in the methodology section.

Overall, the correlations were weak (Cramer's V[2] value is lower than 0.30). Among these, the opportunity of fan operation (OPPfan), window operation (OPPwindow), and door operation (OPPdoor) were significantly correlated with the perceived potential of NV in cool (NVcool) and hot (NVhot) seasons. The Cramer's V values ranged from .075 (NVcool and OPPdoor, $\chi^2 = 9.903$, $df = 4$, $\rho < .05$) to .190 (NVcool and OPPfan, $\chi^2 = 62.861$, $df = 4$, $\rho < .001$). In addition, participant's allowance and daily thermal experience were only found to significantly correlate with NVhot with ρ-values = .001.

Next, multinomial logistic regression (MLR)[3] was employed in order to estimate the magnitudes of perceived adaptive opportunity on NVcool and NVhot. For NVcool, focusing on the probability of 'Agree' against 'Disagree' votes, the final trial of MLR shows that as the opportunity of window operation decreased from medium-high to low, the change in the odds of students voting 'Agree' compared to 'Disagree' was 0.360, $B = -1.022$, Wald $\chi^2 = 12.280$, $\rho < .001$. In addition, as the opportunity of fan operation decreased from medium-high to low, the change in the odds of students voting 'Agree' compared to 'Disagree' was 0.303, $B = -1.196$, Wald $\chi^2 = 15.736$, $\rho < .001$. In short, students are more likely to select 'Agree' if the window or fan operation opportunities increase. Based on the results, the estimated probabilities of an individual student's vote on the potential of NV in the cool season were calculated

[2] Cramer's V values express the strength of the association between two categorical variables used when one or both of these variables have more than two categories. Cramer's V values range from 0 (no association) to 1 (complete association) (Field, 2009).
[3] Multinomial Logistic Regression (MLR) is a statistical tool equivalent to multiple linear regression, but used when the outcome variable is nominal scale with more than two categories (Field, 2009).

(Table 3). Notably, the values multiplied by 100 can also be interpreted as the percentages of frequencies in each cell.

Table 3 Estimated probabilities of student's vote on the potential of natural ventilation in the cool season (PASW[4] output)

OPPwindow	**OPPfan**	**NVcool vote**		
		Disagree	**Uncertain**	**Agree**
Low	**Low**	0.15	**0.46**	0.38
	Medium-High	0.07	0.33	**0.60**
Medium-High	**Low**	0.08	0.35	**0.57**
	Medium-High	0.03	0.21	**0.76**

MLR analysis was repeated for NVhot. The results show that as the OPPfan decreased from medium-high to low, the change in the odds of students voting 'Agree' compared to 'Disagree' was 0.354, B = -1.038, Wald χ^2 = 28.934, ρ < .001. With respect to participant's daily thermal experience, as it changed from non-fully AC to fully AC, the change in the odds of students voting 'Agree' compared to 'Disagree' was 0.559, B = -.581, Wald χ^2 = 6.672, ρ = .01. Furthermore, the odds of students with an allowance of 5,000 baht/month or less to choose 'Agree' rather than 'Disagree' was 1.55 times greater than for those with allowances higher than 5,000 baht/month, B = 0.437, Wald χ^2 = 5.442, ρ < .05.

Table 4 Estimated probabilities of student's vote on the potential of natural ventilation in the hot season (PASW output)

OPPfan	**TExp**	**Allowance (baht/month)**	**NVhot vote**		
			Disagree	**Uncertain**	**Agree**
Low	**Fully AC**	**≤5,000**	0.40	**0.46**	0.14
		>5,000	**0.53**	0.35	0.12
	Non-fully AC	**≤5,000**	0.37	**0.40**	0.23
		>5,000	**0.49**	0.31	0.20
High	**Fully AC**	**≤5,000**	0.24	**0.52**	0.24
		>5,000	0.35	**0.43**	0.22
	Non-fully AC	**≤5,000**	0.21	**0.42**	0.37
		>5,000	0.30	**0.36**	0.34

[4] Predictive Analytics Software (PASW) is a statistical analysis software previously known as SPSS.

In summary, students who have non-fully AC experience, a lower income, and perceive higher OPPfan are more likely to agree to the NVhot than those in the opposite groups. The estimated probabilities of the student's vote on the potential of NV in the hot season were then computed (Table 4), giving different values of independent variables.

In order to summarise the extent of the effect of the explanatory variables on the outcomes, the predicted probabilities of the students' votes for NVcool and NVhot are exhibited in terms of the percentage categorised by the relevant independent variables. For NVcool, the findings (Figure 3) suggest that an increase in OPPfan in the cool season have a slightly larger positive effect on the students' votes than OPPwindow. If OPPfan increases from low to medium-high, the percentages of the Agree category rise;

- from 38% to 60% (22% increase) for low OPPwindow group
- from 57% to 76% (19% increase) for medium-high OPPwindow group.

On the other hand, whilst the OPPfan is constant, as the OPPwindow rises from low to high, the approximation of an increase in the percentage of Agree votes is 16%-18%, slightly smaller than that of the OPPfan.

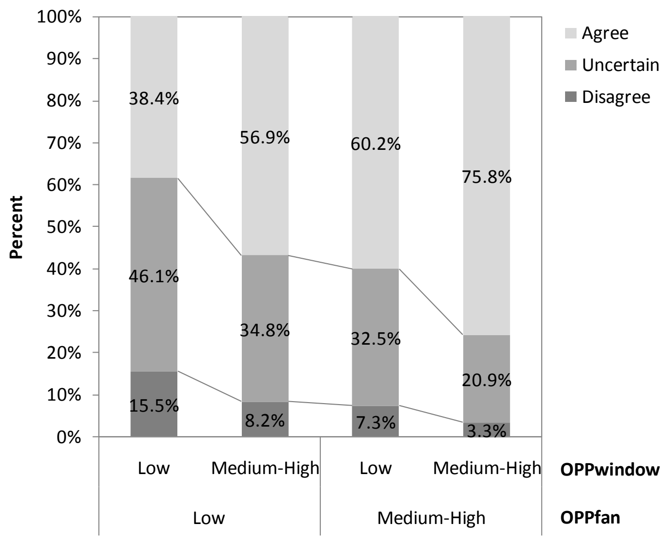

Figure 3 Predicted percentages of the outcomes (NVcool) by independent variables

Likewise, in the hot season, increasing the OPPfan is the most advantageous to the perceptions of NV. From **Error! Reference source not found.**, when the personal variables (i.e. participant's thermal experience and allowance) are held constant, as the OPPfan level increases the percentages of Agree votes improve;

- from 12% to 22% (10% increase) for fully AC and high income group,
- from 14% to 24% (10% increase) for fully AC and low income group,
- from 20% to 34% (14% increase) MM or fully NV and high income group, and
- from 23% to 37% (14% increase) for MM or fully NV and low income group.

The effects of personal variables are small. Widening thermal experience from fully AC to non-fully AC could raise the frequency of Agree votes by approximately 8%-13%. Lastly, the percentage of Agree votes only increases by 2%-3%, when comparing students with low and high incomes.

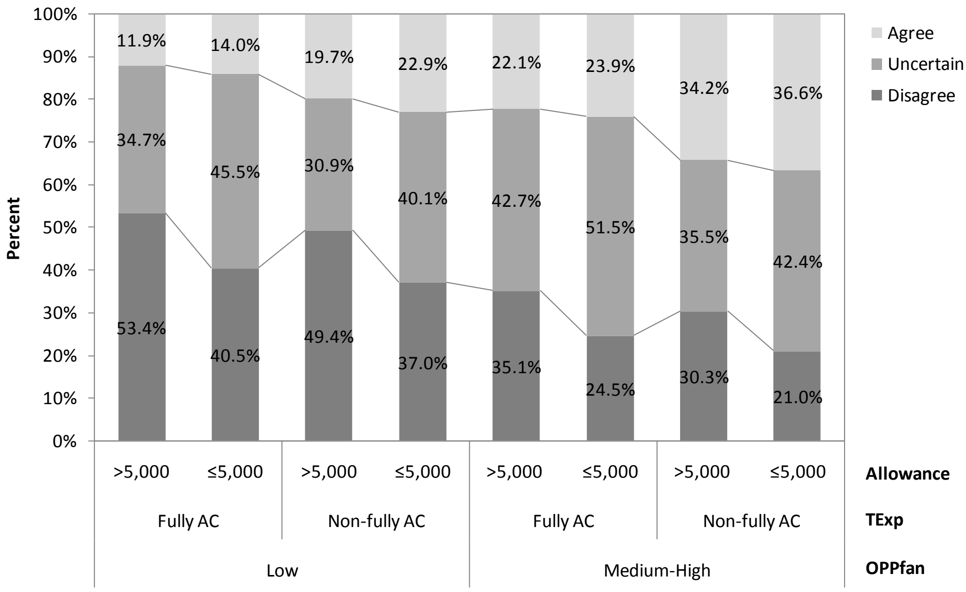

Figure 4 Predicted percentages of the outcomes (NVhot) by independent variables

A comparison of the perceived potential of natural ventilation in hot and cool seasons

In the cool season, when students sense that the outdoor climate is pleasant enough, using windows to let fresh air in is believed to be sufficient to improve thermal comfort. In contrast, whether students perceive low or high OPPwindow does not fundamentally affect their opinions about the potential of NV in the summer. It is probably because the outdoor air is exceptionally hot, so only opening windows is ineffective. On the other hand, fan operation is perceived as being important in both seasons. Considering the personal variables included in this study, i.e. participant's daily thermal experience and monthly incomes, it is interesting that these variables only have an influence on the students' perceptions of the NV in the hot season. It is possible that both variables reflect the students' familiarity with NV conditions that affects their long-term physiological and psychological thermal adaptations. As the data analysis shows that these effects only emerge in the hot season case, it could be that the physiological and psychological tolerance to heat is not necessary when it is comfortable in the cool season but is vital for overcoming the discomfort due to heat in the summer.

Regarding the perceptions of the NV, the percentages of Agree votes for NV in the cool season (38%-76%) are approximately double the size of those in the hot season (12%-37%). According to historical climatic data, the average outdoor temperatures in the hot-rainy season is 28.3°C (mean min. 24.8°C – mean max. 32.8°C), 79%RH. In the cool season, the average outdoor air temperature is 26.1°C (mean min. 21.1°C – mean max. 31.7°C), 70%RH (Thai Meteorological Department, 2008). Whilst all variables remain the same, the distinction between NVcool and NVhot votes is presumably due to differences in perceived climatic conditions between seasons.

3.2 The Possibility of Implementing Mixed-Mode Strategies in HE estates:

This section presents the results from the FM Interviews. Out of the 35 facility managers invited, in total 25 heads or representatives of the Division of Building and Physical Plants from 25 faculties in 4 universities participated in the interviews.

Air-conditioning operation and user controls

This issue explores how HE buildings are thermally operated, the level of user control, and the service standards maintained in this building type. With regard to thermal operation, interviewees were asked who operates the AC system and sets the thermostats, and whether or not users are allowed to adjust the thermostats. Interestingly, the majority of faculties (14 cases out of 25) formally assigned local FM staff to turn-on and off the air-conditioners as a part of their daily routine jobs. In these faculties, air-conditioners (split-type) were turned-on approximately 10-15 minutes before classes begin – called pre-cooling (11 cases). There were nine faculties leaving this responsibility to end-users. That is, users controlled the thermostats by themselves. There were only two faculties that both staff and end-users are co-responsible for system operation.

Of the total 25 faculties, end-users in 13 faculties were free to adjust the temperatures. The remaining 12 faculties did not allow users to adjust the thermostats, normally set at 25°C. This was done, for instance, by hiding the fixed controllers in a box or removing remote controllers from the rooms. If teachers or students felt uncomfortably cool they could turn-off one or more air-conditioners instead of raising the temperatures, which they could not do. But the case was rare. Students seemed to adjust very well to the cold air, by wearing more clothes. They usually complained more about discomfort due to heat.

From the interviewees' experiences and perceptions, students were likely to use air-conditioners improperly to serve their extreme demand for AC. Once they had entered the rooms from the outside, they would set the temperature unacceptably low, for example at 12°C, to get very quick cool air. Consequently, that often caused a system failure and corresponding high maintenance costs. Therefore, from a facility manager's viewpoint, to prevent students from using the thermostats would be more beneficial to their organisation than letting them have freedom of control over the system.

The possibility of and barriers to adaptive thermal operational strategies in higher-education buildings

In this section, the participants were asked about the possibility of and barriers to the implementation of adaptive thermal operational strategies in their buildings. For this part of the interview, one faculty was excluded since they had no direct control over the building service systems. Therefore, there were only 24 cases included in this analysis.

In general, facility managers were not convinced that the proposed MM strategies would be practical in reality (Figure). Comparing all three strategies, the use of air-conditioners in an economic mode with fans (Strategy 1) was considered the most viable strategy, in consideration of the condition of existing HE buildings. To use only NV and fans when the outdoor temperature is not too hot (Strategy 2) did not sound very satisfactory. For the last strategy, to preserve or increase NV space also had low positive responses from the interviewees but with dissimilar reasons. Further explanations for each strategy are provided in the following sections.

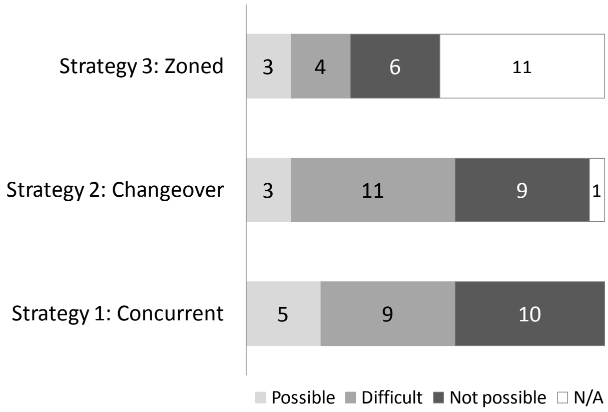

Figure 5 The possibility of adaptive thermal operational strategies from 24 facility managers

Strategy 1: Concurrent

Out of 24 informants, there were 5 facility managers responding that Strategy 1 was possible in their faculties. All of these faculties had both NV and AC classrooms with fans. Basically, the informants said that this strategy would be acceptable as long as the air-conditioners were not turned-off, so that students would not complain.

The main barrier to this strategy was clearly the absence of fans in most existing classrooms – a design constraint. However, even in the rooms that fans were available, a number of facility managers stated that concurrent operation of electric fans and air-conditioners was not the norm for Thai users. Fans were occasionally used to relieve the heat during air-conditioner start-up time then turned-off, or to assist air-conditioners when occupancy level was high. Therefore, users might find this strategy contradicted their habitual AC use. Lack of user interest and lack of FM power and motivation to change occupants' habit were also noticeable during the interview.

Strategy 2: Changeover

Out of the 23 interviewees who gave an opinion about Strategy 2, there were only three faculties that agreed with this strategy basically because they currently used NV throughout the year. That was even more than what the strategy required. In contrast, for the faculties with fully AC buildings this strategy was viewed from the opposite side. That is, this strategy was asking users to sacrifice their constant comfort for energy saving. Eleven participants claimed that the strategy was difficult. A further nine facility managers stated that it was impossible. Students would refuse to use NV in existing MM classrooms if air-conditioners were available. However, they seemed to complain less when using existing NV spaces, such as laboratories, studios, or workshops, if it was for health and safety reason.

Habitual AC use was claimed the most significant barrier to the Changeover strategy, with nine responses. This is possibly because the climate in tropical zone has small variations. There are only a few cool months per year, or a few cool hours per day. Therefore, the building occupants do not notice the seasonal differences. Additionally, students were very passive and did not bother much to adjust themselves or the environment to harmonise themselves with the outdoor climate.

The second noteworthy barrier was personal attitudes towards the right to use AC. From a student viewpoint, AC use was strongly related to the fees they paid, which also referred to the socio-economic status of the users. Teachers had more access to AC than students. Similarly, postgraduate students' requirements were treated with higher regard than those of undergraduate students. It was mentioned several times that reducing AC use for evening or night classes was difficult because most of the classes were organised for postgraduate students who paid higher tuition fees. Therefore, they expected better facilities and higher service standards.

Strategy 3: Zoned

The final strategy is the one on which most facility managers felt reluctant to give an opinion. Eleven informants gave no answer due to the fact that they had no strategic role to make a decision on this. There were only 13 responses to this proposed strategy. Six faculties confirmed that the strategy was impossible and four faculties said that the strategy was difficult. Of these 10 faculties in total, there were plans to install more air-conditioners in existing NV spaces in three of the faculties.

Only three interviewees said that the strategy was partially possible, i.e. to conserve existing NV areas. Basically, the main reason was that it was not worth investing in an AC system in existing NV spaces (e.g. main halls, workshops, canteens, circulation areas, and toilets). Some common attributes to these spaces were that they were for casual use with a low density compared to classrooms. In contrast, to increase NV areas sounded impossible by any means. According to the informants, the current trend of new HE buildings were changing from the conventional design (i.e. medium rise buildings with open-air hall on the ground floor and open-air circulation) to high-rise, fully AC, office-like buildings.

The most important barrier was not directly stated by the interviewees, because they had little opportunity to get involved in current building design or refurbishment at strategic level. However, if considering the reasons behind building refurbishment in the education sector, the main barrier to the preservation of existing NV spaces is possibly the growing population in the sector and rising price of land. The enlargement of undergraduate classes and the proliferation of postgraduate courses have made HE campuses and buildings more densely populated. For the latter group of students, AC is highly expected. Overall, it could be said that from the supply side it is an economic-led development and from the demand side it is the user lifestyle that, in combination, minimise the chance of proposing NV at the design stage.

4. Discussion

The thermal adaptive opportunity in non-residential buildings is very limited as opposed to adaptive behaviour at home, particularly for users who are already accustomed to AC. The findings show that both individual and organisational adaptability can be limited by both personal and contextual factors.

In private spaces, adaptive behaviours are more various and practical, such as dressing casually, taking a shower, and minimising activities. The level of adaptive opportunity and the alternatives of thermal design in buildings also interrelate. That is, the higher opportunity to adapt, the wider the range of design temperatures are possible, as shown by the positive correlation between thermal adaptive opportunity and acceptance of NV. From the survey, all the criterion for behavioural adaptations, i.e. climate, design, organisational customs, and economics (Brager & de Dear, 1998), play their roles in how students perceive the effectiveness and the probability of given thermal adaptations. But the two most obvious factors that differentiate user behaviours in different building types may be design and organisational customs. These two factors are manageable.

According to this study, only some adaptive actions are meaningful to users to relieve themselves from heat discomfort. The findings reveal that for existing HE buildings, using fans and windows and drinking cold water are the most effective and possible thermal adaptations. On the other hand, adjusting clothes, which is frequently mentioned as an effective thermal adaptation especially for cold and temperate climates (e.g. Morgan & de Dear, 2003; Yao, Liu, & Li, 2010), is viewed as being ineffective and somehow inappropriate if students wear fewer clothes than usual in classrooms. Accordingly, the level of adaptive opportunity cannot only be measured by the availability of adaptive options. This agrees with other research studies which state that adaptive opportunity is variable, and very contextual and person dependent (e.g. Hwang, et al., 2009; Nicol & Humphreys, 2002; Raja, Nicol, McCartney, & Humphreys, 2001; Wei, Buswell, & Loveday, 2010). The method proposed for quantifying thermal adaptive opportunity in this study, although crude, can provide some insight into the user's priority for behavioural adaptations in non-residential buildings or in other specific contexts.

For the role of the FM in enhancing thermal adaptability, the interview reveals that the tendency is reversed. First of all, the impact of some building alterations on thermal operation during the post-occupancy period is not realised among facility managers. In this study, the obvious case is fan removal. From thermal comfort research, the fan has been referred to several times already as an effective subsidiary cooling device for hot and hot-humid zones (for example, Candido, de Dear, Lamberts, & Bittencourt, 2009; Khedari, Yamtraipat, Pratintong, & Hirunlabh, 2000; Nuntavicharna, 2004; Scheatzle, Wu, & Yellott, 1989). Yet, the message has not been very well received and integrated into practice, particularly in non-residential buildings. The idea of using fans to assist AC in non-residential buildings has not been widely adopted among facility managers and designers.

The second observation obtained from the interviews is the effects of FM practice on the user's thermal experience and expectations. From the survey, the diversity of thermal background is found invaluable when experiencing warm thermal discomfort. However, the way HE buildings are nowadays thermally operated is to avoid this thermal variation by all means. Since user satisfaction is one of FM performance indicators, the FM staff will do their best to deliver comfort to users rather than trying to save energy by reducing unnecessary AC use. The potential risks are that with this current practice the AC addiction may be accelerated. The combination of over supply and demand inevitably impinges on the physiological and psychological thermal adaptations of users in the long term.

5. Conclusions and Implications

The results of this study show that the FM role in regulating how buildings are routinely operated has a deep impact on the thermal adaptability of individual users and organisations. With respect to users' thermal adaptability, fans and windows are still the most important design features for maintaining thermal comfort in hot-humid countries. Users' thermal experience and economic status only have an influence on thermal tolerance during hot summers. However, from an organisational viewpoint these factors are overlooked. For FM in HE estates, the mentality is that an environment of cool comfort must be maintained at all time. According to these findings, changes to strategic and operational FM should be addressed in order to enhance thermal adaptability. User satisfaction cannot be used as a reliable thermal performance indicator since users, particularly those who have a high income or higher social status, tend to demand more AC. The AC service standards should be restricted at an optimum level with some degree of user control provided. In the long term, provision of a greater diversity of thermal environments, e.g. increasing NV to AC space and/or time ratios where possible, rather than fully AC, would be beneficial to the user's thermal tolerance. Under the banner of climate change, increasing thermal adaptability should gain more attention from building designers and facility managers than just in delivering user satisfaction alone.

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