academicJournals

Vol. 8(12), pp. 707-715, December, 2014
DOI: 10.5897/AJEST2013.1625
Article Number: C8BB2B449140
ISSN 1996-0786

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Adequacy of ventilation systems: An explorative study of the perspectives of designers and occupants of high rise buildings in Nairobi, Kenya

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Received 14 November, 2013; Accepted 9 December, 2014

Passive ventilation systems have the potential for reduced operating costs in office buildings while maintaining ventilation rates consistent with acceptable indoor air quality. There is a surge of interest in more developed economies for passive ventilation technology but much work is needed before this potential can be realized in sub-Saharan Africa. This explorative study reviews the adoption and adequacy of alternative ventilations systems in office buildings located in the central business district (CBD) of Nairobi, Kenya. Data for the study was obtained through questionnaires and interviews with architects and office building occupants purposively sampled. Thirty four tenants and thirty two architects of these high rise buildings were selected as units of the study analysis. Analysis of their responses is presented using simple descriptive and interpretative techniques. The study concludes that installed ventilation systems rarely meet the needs of occupants and that greater flexibility in ventilation design could provide a measure of individual control of air circulation that would enhance their general comfort.

Key words: Office buildings, Nairobi, Kenya, ventilation systems.

INTRODUCTION

Natural ventilation in large office spaces is becoming less fashionable in major cities in sub-Saharan Africa. Modern building designs incorporate mechanical ventilation systems with a few relying on the natural gifts of air flow. During the last two decades many contemporary high-rise office buildings within the central business district (CBD) in Nairobi, Kenya have adopted mechanical air-conditioning systems as their main form of ventilation (Swinborne, 1998). Even though the outlay and use costs of mechanical systems are relatively expensive and unsustainable, current design practices do not seem to take these into cognizance enough to cause a change in design practices in Kenya.

Since the advent of mechanical ventilation systems in office buildings (beginning with the New York Stock Exchange in 1901), modern glass-walled multi-storey

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buildings have become commonplace. These development altered traditional footprints, interior layouts and exterior appearances. For example, mechanical cooling freed designers from conventional methods of orientating office buildings in relation to the sun or ventilating them with operable windows. There was a marked shift away from traditional building designs based on T, H or L-shaped floor plans that were designed to allow maximum number of operable openings for natural ventilation. However, this made buildings more highly dependent on air conditioning systems to be able to function effectively. To design for natural ventilation is now more complex and involves a good understanding of aerodynamic concepts.

Rationally, the use and adequacy of mechanical ventilated systems needs to be continuously evaluated in different environments, considering that some climatic environments enjoy good air circulation for longer periods of the year. For example, it is useful to know if the initial outlay and use costs of mechanical ventilation systems are justifiable in a place like Nairobi, Kenya. This study therefore investigates the adequacy of the different ventilation systems designed for high rise office buildings within the Nairobi central business district. The investigation sought the opinions of both the users (occupants) and the architects (designers) of office buildings on their installed systems. The study focuses on office buildings because they have served as important laboratories for air conditioning advances since ages. Details of the investigation are presented in this paper with concluding remarks that could serve to change existing design practices. However before this, the paper reviews briefly, climatic conditions of the study area (Kenya) and gives brief descriptions of ventilation systems to underpin the study investigations.

Background

Climatic conditions in Nairobi, Kenya suggest that passive ventilation systems will be suitable for its building designs. Nairobi is situated close to the equator, where differences between its climatic seasons are minimal. Sunrise and sunset do not vary significantly throughout the year, with two distinctive seasons: the wet season and dry season. The altitude makes for some chilly evenings, especially in the June/July season when the temperature could drop to 10°C, while the sunniest and warmest parts of the year are from December to March, with temperatures averaging the mid-twenties during the day. Nairobi climate is well suited to natural ventilation on account that it is endowed with reliable outdoor air ventilation rates, which is adequately admissible within office buildings, if duly harnessed (UNEP, 2007). The UNEP report evaluated Nairobi climatic suitability based on a single-zone model of natural ventilation heat transfer in office buildings and through the application of Bioclimatic Charts (UNEP, 2007).

However, contrary to the UNEP finding, a good number of office buildings located in the CBD area in Nairobi have installed air-conditioning systems. Several reasons addressed in the following paragraphs may account for this practice in spite of its suitability to natural ventilation. Chadderton (1997) articulates that mechanical ventilation systems may be installed in buildings for a variety of motives that could range from a real necessity for the systems, to aesthetic appeal. For aesthetic reasons, mechanical systems could help with marketing the building product when compared with other products. Makachia (1998) had identified an obsession for glass curtain walling as facade for most buildings in Kenya. This trend is set to continue unabated if a recent example, like the Afya House on Tom Mboya Street Nairobi, is anything to go by. Given that aesthetics is more of a subjective matter than objective, no convincing arguments can be offered to dissuade project owners and professionals from opting for mechanical systems.

Nairobi's cosmopolitan nature and orientation places it in an ambivalent position as it aspires to incorporate contemporary systems in its buildings which often conflicts with environmental considerations of human comfort at the micro level and as well as the urban macro climate. Designers in Kenya are often confronted with briefs requiring the utilization of contemporary materials in its large buildings (Makachia, 1998). In which case, products that are environmentally suitable in other geographical locations are imported and implanted with little prove of their environmental performance in Kenya. As was suggested by Rotimi and Kiptala (2012), there now exists in Nairobi a landscape whose creation, maintenance and survival depends not on natural determinants, but on technology and high energy inputs. Swinborne (1998) had suggested that the trend in high rise construction, where plot sizes are maximized (but with less heed to environmental considerations), negates sustainable design principles. Much building designs are aesthetic-oriented and built to maximize plot coverage. Through revision of planning density requirements, minimum plot sizes have been made lesser. Thus, the upscale Karen residential zone in Nairobi for example has changed from a minimum acreage of 2.5 acres to down to 0.5 acres in some parts. This has had an implycation of increased building and infrastructure density. For the environment, this means an increase in use of solar absorptive and reflective materials in modern buildings and road infrastructure. Consequently absorbed radiation in these products is re-radiated as heat that warms up the entire city.

Little consideration is given to orientation, natural ventilation and spatial requirements for natural vegetation (Saateri, 1998). These buildings are completed with blind aping of aesthetics that could create ventilation problems (Swinborne, 1998). Consequently, recourse is made to mechanical ventilation systems to redress the anomalies emanating from these environmentally alien designs. However as Heiselberg (2000) suggests, the use of

centralized mechanical systems are largely wasteful and bear no reference to the specific requirements of individual occupants. Kavanaugh (2000) explains for example that in the UK, two-thirds of the total energy consumed for cooling is caused by mechanical fans. Brodrick and Westphalen (2001) have shown that significant gains (20 - 60 kWh/m^2 offset) are possible annually when buildings are naturally ventilated. Although these refer to situations in the UK, reverting to natural ventilation in climatically suitable locations such as Kenya, should confer more benefits. Swinborne (1998) concludes that the comfort derived from mechanical systems is short-lived, while it is difficult and costly to modify these installed systems to meet highly variable comfort requirements of occupants.

Leyten and Kurvers (2006) commenting on robustness of systems (measure by which a system lives up to its design purpose in a real life situation) conclude that mechanical systems lack robustness. Leyten and Kurvers (2006) suggest that mechanical systems lack robustness because they may be particularly sensitive to 'aberrations' in their underlying design assumptions, maintenance requirements of systems may not be feasible or simply not addressed, integration of heating (or cooling) and ventilation places conflicting demands on their operation and control, systems sensitive to the regulation of airflow rates (especially recirculation airflow rates) may not be feasible, and difficulties in understanding system operation on the part of both occupants and building operators. Therefore, the more complicated mechanical systems tend to be less robust, as compared to simpler more comprehensible systems. Importantly, they conclude that natural ventilation systems tend to rank high in terms of robustness (Leyten and Kurvers, 2006).

The actual health, comfort and productivity impacts of mechanical ventilation systems often fall short of expectations (Fisk and Rosenfeld, 1997; Fisk, 1998; Mendell et al., 1996). In comparisons of negative health symptoms of office building workers in a limited number of naturally and mechanically ventilated systems in Europe, naturally ventilated buildings reported lower symptom prevalence as compared to mechanically ventilated systems and especially air conditioned buildings (Seppänen and Fisk, 2002); though much of scientific findings provide conflicting conclusions, and the fundamental reasons behind these findings are not self-evident (Mendell and Fisk, 2007).

What seems of growing importance is adaptation in thermal comfort considerations (Nicol and Raja, 1997) which could be linked to Leyten and Kurvers' (2006) identification of system legibility or transparency as a prerequisite of robustness. If a system is transparent to the occupants of the building, the occupants can act directly to identify the causes of problems that compromise their health, comfort and productivity. If, in addition, office building occupants are offered control of these systems they will make changes to mitigate these problems. This leads to the conclusion that natural ventilation systems that offer occupant control over ventilation rates (and solar gain) can be effectively designed for slightly larger comfort zones than commonly used mechanical systems (Conte and Fato 2000).

On the other side of the mechanical vs. natural ventilation systems debate, proponents of mechanical systems argue that natural ventilation is unreliable, and cannot be controlled. For example, natural ventilations systems may under-ventilate (resulting in overheating) or over-ventilate (resulting in unnecessary heating and energy consumption) because natural air flow/tem-perature cannot be controlled. Thus in line with Randall (1990) mechanical systems produce and maintain desired internal air environment, despite the variability of external/natural air conditions. Modern mechanical systems therefore are able to heat and cool, humidify and dehumidify, and respond automatically to changes in external air. Lee (1990) argues also that air-conditioning permits a sealing off from harsh external conditions that could protect against problems associated with health and comfort in buildings. This assertion is debatable and data collected in the current study on the adequacy of ventilation systems (which is presented later) should inform this debate.

While it is tempting to conclude from these arguments that natural ventilation systems can provide healthier, comfortable and productive environments, it may be more reasonable to conclude that robust natural ventilation systems may offer this advantage. There is a trend in the design of natural ventilation systems towards complexity. These complex natural ventilation systems may well prove to be less robust and thus may suffer shortcomings similar to those of the more complex mechanical ventilation systems. Beyond quantitative evaluations of health, comfort and productivity benefits that natural ventilation systems may offer, it is important to recognize that many if not most building occupants may simply prefer natural ventilation systems qualitatively. Largely for this reason alone, designers have accepted natural ventilation as one of several objectives of high quality sustainable designs. Thus natural ventilation systems have become a fundamental aspect of passive designs, which is an integrative design approach involving the use of daylight, thermal mass, insulation, and solar radiation in ventilation design (Yao et al., 2005). Passive venti-lation should confer the least in operational costs, allowing much of natural elements to provide comfort requirements of occupants, and are environmentally friendly. This hybrid alternative, wherein mechanical devices are added to enhance system performance and control seems to be the rational solution to the debate.

From the foregoing, one could conclude that when human comfort is at risk, mechanical devises could be positively necessary but when conditions are such that only a degree of discomfort is in question, the use of mechanical devises could be made optional. The level of environmental controls could be reduced to social-economic conditions. A value judgment is involved in

deciding what degree of comfort is desired and at what cost. While passive ventilation is becoming more common design practice in developed economies, signi-ficant questions exist concerning current design practice in Kenya particularly Nairobi office buildings. Thus, the current study investigates the adequacy of installed ventilation systems through perspective views of designers and occupants of high rise office buildings in Nairobi, Kenya. Hoping that the results will provide information necessary to steer design practices towards one that takes advantage of the strength of both natural and mechanical systems.

METHODOLOGY

Study approach

The paper is based on an investigation into the adoption and adequacy of installed ventilations systems in office buildings located in the central business district (CBD) of Nairobi, Kenya. Data for the study was obtained through questionnaires and interviews with office building occupants and designers (architects) that were purposively sampled to become the units of the study analysis. The aim of the study was to provide information on the adoption and adequacy of installed ventilation systems so that improvements to design practices could be made evident.

Data was collected from 48 high rise buildings located in Nairobi CBD in 2010. Previous studies had indicated that there were 140 high-rise buildings (target population) that are over five storeys within the CBD area. The sample size (48) was determined for the tenant survey after Frankfort-Nachmias (1996) formula for sample size determination (Equation 1). Using the same formula, the number of architects to be surveyed was determined to be fifty (50). There are 152 registered architectural firms based in Nairobi, according to the list provided by the Board of Registration of Architects & Quantity Surveyors of Kenya (BORAQS).

$$n = \frac{Z^2pqN}{e^2(N-1) + Z^2pq} \quad (1)$$

Where N = Population size; n = sample size; p = sample population estimated to have characteristics being measured (95% confidence level of the target population assumed); q = 1 – p; e = acceptable error (e = 0.05, since the estimated should be 5% of the true value); Z = The standard normal deviate at the required confidence level = 1.96.

For the tenant surveys, one tenant for each building was purposely selected on the basis of those who could provide the best information to achieve the objectives of the study (Kumar, 2005). The criteria for their selection included tenants: whose office spaces are deeply placed within the buildings, who have ever raised complaint to the property manager with respect to their installed ventilation systems, and who have altered or modified their office ventilation systems at their own costs. For the architects, simple random sampling technique was employed for the questionnaire distribution.

Thirty four completed and usable questionnaires were received from the tenants corresponding to a 71% response rate, while 32 were received from architects (see Table 1 for the response rates). Mugenda and Mugenda (1999) had suggested that a 50% response rate is adequate for the analysis and reporting of questionnaire surveys. Simple interpretive and descriptive means of presentation (tabulation, charts and general statistics) in line with McQueen and Knussen (2002) are used in this study so that the findings could be communicative to readers.

RESULTS AND DISCUSSION

This section presents the results of the questionnaires and interviews to the two groups of research participants: office building occupants and architects. The results are discussed separately under the themes covered by each questionnaire survey, and thereafter a summary of the combined findings from both groups of participants is presented.

Result of tenant survey

Adequacy of ventilation systems

The questionnaire for office building occupants within the CBD in Nairobi, covered three main themes. The first theme covered the adequacy of ventilation systems provided within the office spaces. There was a need to cluster the tenants into two groups so that the pattern of response from tenants with natural ventilation and those with mechanically ventilated systems can be determined. Therefore tenants were asked to comment on the operability of window openings within the building envelope and their adequacy in ventilating their office spaces. 35% (12) of the tenants said their windows were operable and that they relied solely on natural air circulation. The remaining 65% (22) said that their office windows were not operable because their offices were air-conditioned and therefore completely sealed from the external environment.

The 12 tenants who relied on natural ventilation were asked to comment further on the adequacy of air circulation within their office environment. Their response is given in Table 2 and it shows that 58.3% felt air circulation was adequate while 41.7% disagreed. 83.3% of this category of tenants were unaffected by power failure and ventilation system maintenance. This result could suggest that naturally ventilated office buildings within the CBD are able to harness the climatic endowment of air circulation in Nairobi. Though on closer observation, this category of tenants were not deeply placed within the office buildings. The remaining 16.7% that were deeply placed within the buildings required some mechanically-assisted ventilation to ensure adequate air circulation in the event of power outages.

Notwithstanding the benefits associated with natural ventilation, the survey found that 66.7% of the tenants desire supplementary ventilation systems, while 33.3% do not. This would suggest that the quality of air circulated naturally was inadequate and some form of mechanical aid was needed to complement natural ventilation.

Further, the 22 tenants that had mechanically ventilated office spaces were asked to comment on the adequacy of their installed ventilation systems. A summary of their

Table 1. Survey response rate.

Respondents	Total number posted	Response	Response rate (%)
Architects	50	32	64
Tenants	48	34	71
Total	98	66	67

Table 2. Tenants opinion on ventilation systems in office buildings.

Ventilation attributes	Naturally ventilated office spaces (n=12)		Mechanically ventilated office spaces (n=22)	
	Yes (%)	No (%)	Yes (%)	No (%)
Adequacy of air circulation within the office	58.3	41.7	41.2	58.8
Ventilation inadequacy during system maintenance and/or power failure	16.7	83.3	54.5	45.5
Desire to have alternative ventilation system	66.7	33.3	95.5	4.5

Table 3. Desired means of control of existing environment.

Environmental control types	Naturally Ventilated Office Spaces (n=12)		Mechanically Ventilated Office Spaces (n=22)	
	Yes (%)	No (%)	Yes (%)	No (%)
Using drapes or blinds	96.9	3.4	63.4	36.6
Open or close window to external environment	98.6	1.4	95.6	4.4
Using heater	60.2	39.8	80.2	19.8
Using local fan	90.3	9.7	85.3	14.7
Open or close a door to interior space	62.7	37.3	57.5	42.5

responses is given in Table 1. 41.2% of this group of tenants felt that air circulation provided by their air-conditioning systems were adequate while 58.8% had alternative views. The latter response implies that installed air-conditioning systems do not adequately meet comfort needs of these tenants. Also responding to the question relating to their personal experiences when those mechanical ventilation systems were undergoing maintenance or periods of power failure, 12 (54.5%) out of the 22 tenants confirmed that air-circulation was inadequate. The remaining 45.5% of these tenants do not experience discomfort during down periods. 95.5% of had a strong desire for alternative ventilation systems. Surprisingly tenants (45.5%) who had indicated that air circulation was adequate during power failure or shut down maintenance also desired alternative sustainable ventilation systems. Their reasons for desiring alternative ventilation systems include: the need for lower energy consuming units and to have more easily accessible units when maintenance is being carried out on the installed systems.

Control required for existing ventilation systems

The second theme covered by the tenant survey is on the form of control they would like to see available for ventilation systems within their office spaces. The objective is to confirm the responses received in the first theme on the adequacy of ventilation systems in office buildings. Tenants were to indicate among a list of five alternative means by which they could improve or control air circulation within their office spaces. A summary of the results obtained from the two clusters of tenants is given in Table 3.

For tenants that rely on natural ventilation systems, there was a strong desire to control ventilation in the office spaces using all five means of control presented to them. The least was 60.2% for the use of local heating units during cold weather. While the generality of tenants would turn on a local fan to assist in cooling the office environment, or drawing the drapes or blinds to block direct sun rays into the office spaces.

For tenants occupying mechanically ventilated office

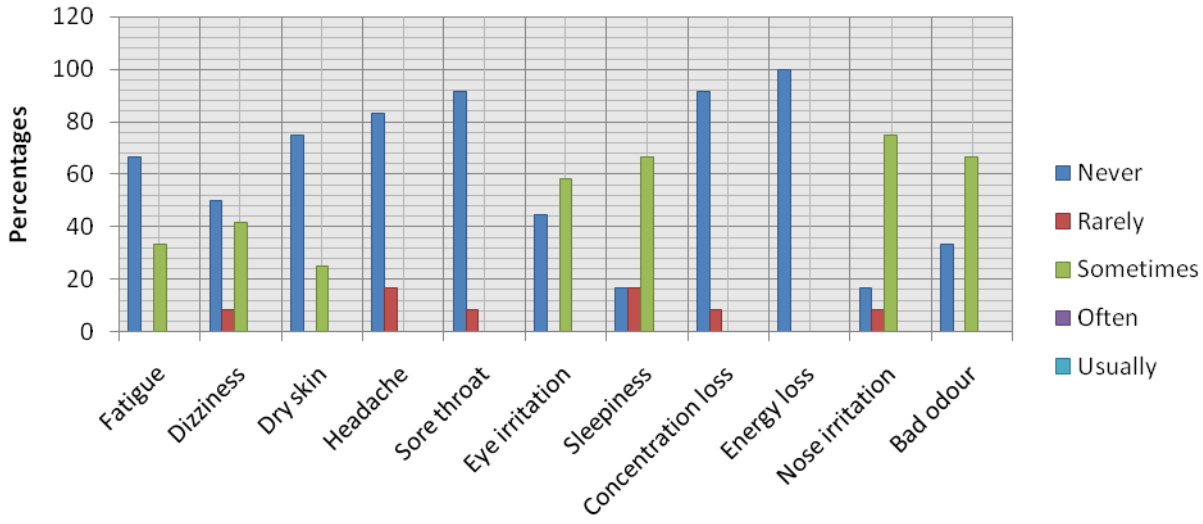

Figure 1. Manifestation of inadequate natural ventilation systems in office buildings

spaces, the highest percentage (95.6%) would like to be able to improve or at least control environmental conditions within their office spaces. The least percentage recorded was 57.5%, which implies overall that despite the incorporation of air-conditioning systems in office buildings, users desire some control of the internal environment (air flow and circulation) in which they operate. These results are significant to building designers as they suggest the need for wider scale consultation with end-users of office facilities so that proposed ventilation designs integrate their needs. Thus, in the event of ventilation system inefficacies, users could be provided with options for varying the internal environment to meet their individual needs.

Manifestations of inadequate ventilations systems

The last theme covered by the tenant survey was designed to give an indication of the effect of inadequate ventilation systems on the comfort of office building occupants. 11 possible effects were presented to the tenants so that they could indicate how often they experienced each of these 11 effects as a result of poor ventilation. Graphical representation of the result is presented in Figures 1 and 2 for the two clusters of respondents. For tenants occupying naturally ventilated office buildings (Figure 1), most of the manifestations, except for a few were never or rarely experienced. The exceptions include: bad odour experienced sometimes when windows were opened to promote air circulation, dizziness, nose irritation, sleepiness and eye irritation. According to the tenants, nose irritation results from cold weather which was prevalent around the month of July. This would suggest that building designs for naturally ventilated buildings have to take proper cognisance of external environmental conditions as this could affect the quality of air within office spaces. Pollution is a key consideration in ventilation design for densely populated city centers which could manifest as poor health of building occupants.

Tenants in inadequate mechanically ventilated office buildings are affected in many ways. The different manifestations of these inadequacies are presented in Figure 2. With the exception of dry skin, concentration loss, and energy loss, which office tenants did not experience significantly, the remaining effects were significantly experienced by the tenants. In one instance, bad odour experienced within the office space was the result of dust accrual within a duct system that was not well maintained. This result suggests that buildings with installed mechanical ventilation systems need to be continuously evaluated during operation and maintained.

Result of architect survey

Ventilation design principles

The results of questionnaires distributed to 32 architects based in the Nairobi area are presented in Table 4. The purpose of the questions was to determine the design considerations for ventilation systems incorporated in office buildings in Nairobi, Kenya. As observed from the table, not a convincing percentage of architects (59.4%) are aware of the suitability of Nairobi climate for passive ventilation systems. These respondents do not translate their awareness into advocacy for passive design. The response could imply that these respondents are ignorant of the fact and the issue of climatic suitability is never considered in their designs.

As is observed from the second question on Table 4, about 78% of architectural firms either rarely or never considered local weather information in ventilation

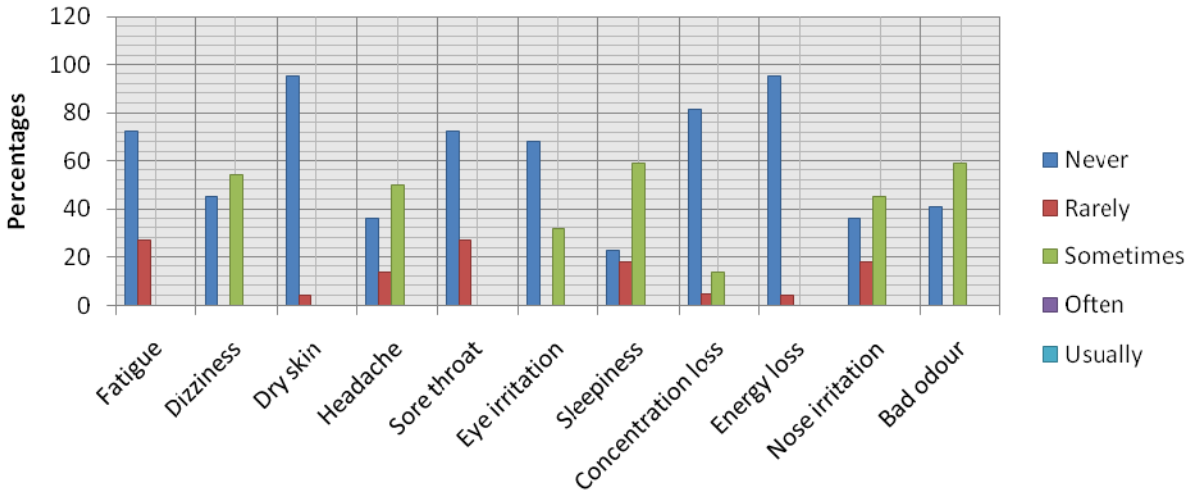

Figure 2. Manifestation of inadequate mechanical ventilation systems in office buildings.

Table 4. Design considerations for ventilations systems in office buildings.

No	Questions asked	Options	Freq	%
1	Level of awareness to climatic suitability in designing ventilation systems (n=32)	Very aware	19	59.4
		Partially aware	10	31.3
		Unaware	3	9.3
2	Extent of consideration of local weather data in ventilation design (n=32)	Never	12	37.5
		Rarely	13	40.6
		Often	7	21.8
3	Do you always consider natural ventilation during design (n=32)	Yes	23	71.9
		No	9	28.1
4	Is there relationship between building design and ventilation (n=32)	Yes	17	53.1
		No	15	46.1
5	Does natural ventilation concept affect architectural works? (n=32)	Yes	30	93.8
		No	2	6.3
6	Could the concept mentioned in qs.5 be a reason for installing mechanical systems (n=32)	Yes	26	81.3
		No	6	18.7

designs. This could explain why a high number of office buildings use mechanical ventilation over naturally ventilated systems in the Nairobi CBD. Design innovativeness would suggest that some measure of understanding and the incorporation of contextual data/information would determine their design principles. Even though responses to question 3 to 6 imply that contextual information guided the installation of mechanical systems, data obtained from the tenant surveys, suggest otherwise.

The respondents were required to indicate out of a list of five design variables, which ones were considered the most in the design ventilation systems for office buildings. The result is presented in graphical form in Figure 3. It is observed that on aggregate 'fashion' seems to have been given a lot more consideration in ventilation design than 'energy consumption efficiency'. These are followed by other design variables such as 'maintenance', 'occupancy health' and 'orientation' in that order. This result implies that aesthetics and fashion prevail over other design variables and also confirms the manner of responses obtained from questions 1 to 6 in Table 4.

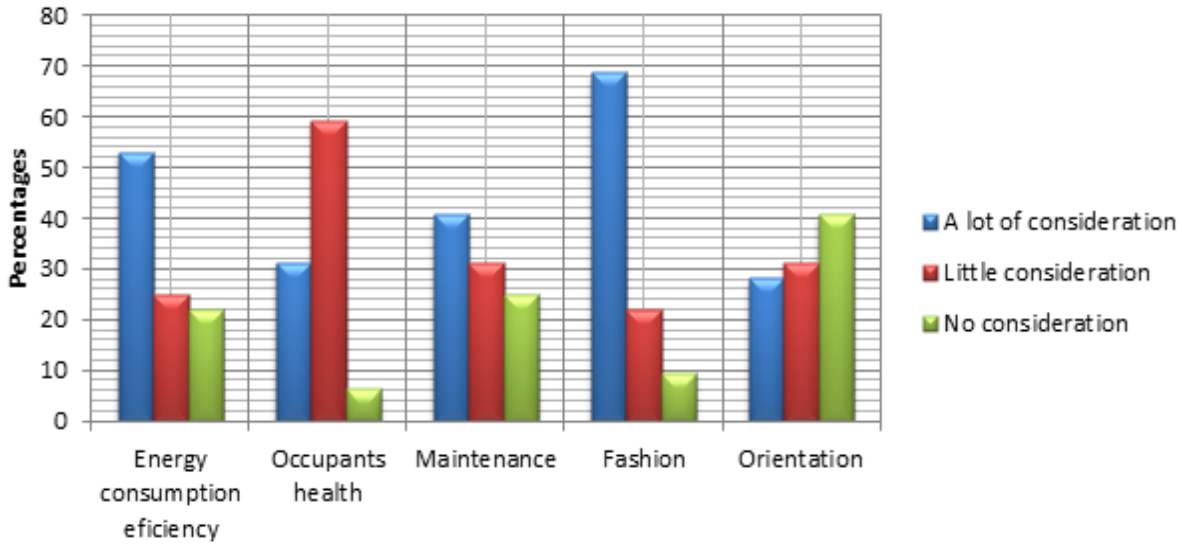

Figure 3. Consideration of design variables during ventilation design.

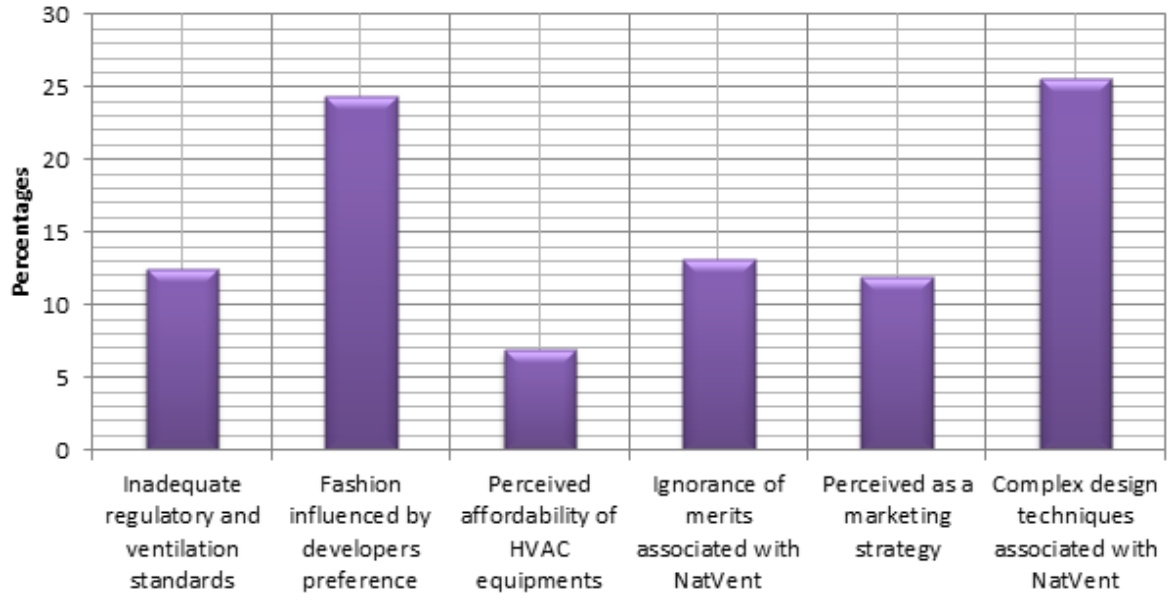

Figure 4. Reasons for mechanical ventilation systems in high rise buildings.

Further, the survey required architects to provide information on the reasoning behind mechanical ventilation systems in the CBD Nairobi, Kenya. The information gathered is presented in Figure 4. According to the architectural firms sampled, the complexities associated with designing for sustainable passive ventilation was rated the highest (25.6%) factor. Therefore, designers considered mechanical ventilations systems more because of its simplicity in design.

Following closely is developers' preferences (24.4%) for aesthetical pleasing buildings. This factor seems to supersede designers' ventilation design options probably because developers see the installation of mechanical systems as a marketing strategy (11.9%) as well. Other important factors are the ignorance of the merits of natural ventilation (13.1%); inadequate regulatory and ventilation standards (12.5%); and affordability issues (6.9%).

On regulations and standards, some respondents express the opinion that the Local Government Adoptive Bye Laws (1968) concerning natural ventilation systems is being circumvented by designers. For example, the

bye law provides that mechanical air supply will not be required if the council is satisfied that the standard of ventilation prescribed can be maintained by natural means. However, because imported building designs with extensive glazed facades have become fashionable, mechanical ventilations systems, though expensive and unnecessary, are now inevitable fixtures in most office buildings. Further, building bye laws and regulations addressing the ventilation comfort standards in Kenya are not clear thus designers are given the carte blanche to circumvent the ventilation clause through imported or local designs that give little heed to local environmental conditions.

Conclusion

The incorporation of mechanical ventilation systems in high-rise office buildings within the Nairobi CBD would seem from this study investigation not necessitated by unsuitable climatic conditions. The major reasons for their use are aesthetics and convenience in design practices, not necessarily its functional benefits over natural ventilation systems. Climatic conditions in Nairobi are not relatively unsuitable as would be the case in temperate regions where significant measure of control over air circulation is essential. The conclusions from this exploratory study will suggest that more consideration be given to inoperable stack effects in naturally ventilated buildings. Also in mechanically ventilated office buildings, a review of cladding materials (used on buildings facades) may be necessary so that they are compatible with the Nairobi climate.

Considerable flexibility in the design and installation of ventilation systems is highly desired by the end users as evidenced by this study. Therefore, achieving an optimum balance between both natural and mechanical systems would need to be evaluated in future designs. It was observed that tenants within the sample surveyed had installed single isolated air conditioning units because they found the central air-conditioning provided inefficient. Thus, a lot more end-user evaluation of office building designs are needed across a wide range of modern buildings. This way the benefits of an integrated approach to ventilation designs are better appreciated by end users.

Whereas this exploratory study has reached some useful conclusions, it is recommended that future work be carried out within the study area on a wider scale for the purposes of generalizability. Also, it will be useful to capture the opinions of independent HVAC engineers on ventilation designs in Nairobi. Architects have been used in this study as proxies, though the group of architects used in the study, employed their own in-house HVAC designers in addition to their spatial design competencies.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Brodrick JR, Westphalen D (2001). Uncovering auxiliary energy use. *ASHRAE* J. 58-61.

Chadderton D (1997). *Natural Ventilation in Buildings: A Design Handbook*. James and James Science Publishers Ltd. London.

Emmerich SJ, Dols SW, Axley JW (2001). *Natural Ventilation Review and Plan for Design and Analysis Tools*. National Institute of Standards and Technology: USA.

Frankfort-Nachmias C (1996). *Research Methods in the Social Sciences*. Hodder Arnold Ltd.

Gratia E, De Herde A (2007).Guidelines for improving natural daytime ventilation in an office building with a double-skin façade. Solar Energy. 81:435-448.

Heiselberg P (2002). Design principles for natural and hybrid ventilation. In: Proceedings of Healthy Buildings 2000. 6th International Conference on Healthy Buildings, Helsinki, Finland, August, Volume 2, pp. 35-46.

Kavanaugh S (2000). Fan demand and energy. *ASHRAE* J. 47-52.

Kumar R (2005). *Research Methodology*. Sage Publications Limited.

Khan N, Su Y, Riffat, SB (2008). A review on wind driven ventilation techniques. Energy and Building. 40(8):1586-1604.

Lee W (1990). AIVC Technical Note 54 – Residential Passive Ventilation Systems.

Leyten JL, Kurvers SR (2006). Robustness of buildings and HVAC systems as a hypothetical construct explaining differences in building related health and comfort symptoms and complaint rates. Energy and Buildings. 38:701-707.

Makachia PA (1998). Control of energy in offices in Nairobi.Research reports.

Mcqueen R, Knussen C (2002). *Research Methods for Social Science*. Prentice Hall: Harlow.

Mendell MJ, Fisk WJ (2007). Is health in office buildings related only to psychosocial factors? *Occupational and Environmental Medicine*, *64* (1):69.

Mugenda OM, Mugenda AG (1999).*Research Methods: Quantitative & Qualitative Approaches*. Acts Press. Nairobi.

Omer AM (2009).Constructions, applications and the environment of greenhouses. Afr. J. Biotechnol. *8* (25):7205-7227.

Seppänen O, Fisk WJ (2002). Association of ventilation system type with SBS symptoms in office workers. Indoor Air. 12:98-112.