FORMULATING DESIGN CRITERIA FOR I IIERMAL COMFORT IN A LEARNING - TEACHING ENVIRONMENT IN THE TROPICS

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Abstract

T he formulation of design criteria for thermal comfort in a learning-teaching environment in the tropics depends on various factors. These factors are the climatic elements of the area such as temperature, humidity, wind, solar radiation and rainfall. These factors further include the building and planning requirements in terms of layout alternatives; spacing for breeze penetration and solar radiation; air movement; the size and position of openings; protection of openings; and the materials used for the construction of the building walls and roofs. The study selected ten buildings used for learning-teaching in the Federal College of Education (Technical), Omoku, Rivers State of Nigeria. The results of the analysis using various indicators (Humid, arid and cold indicators) as well as parameters/criteria for thermal performance revealed that most of the buildings do not meet the thermal performance requirements. Prominent among them were orientation; spacing for breeze penetration; and size and position of openings. The findings were discussed and recommendations were proffered for the formulation of design criteria for thermal comfort.

Introduction

Most learning-teaching activities take place in a built environment. This environment is the surrounding which can be natural, man-made or a combination of these (Chudley, 1996). When this environment is created by man with or without the aid of the natural environment, it becomes a built environment. The built environment includes various levels starting with the geographical regions in which the people live and work, the cities or communities and finally the buildings and the rooms they use (McCormick and Sanders, 1983). They serve different purposes; as a factory, hospital or for the purpose of learning-teaching (educational institutions). A building used for any of these purposes must provide some conducive thermal environment in order to enhance productivity or thermal comfort for the intended users.

In this regard, Forster (1991) said that a building is an environmental envelope by which the natural or external environment may be modified to produce a satisfactory internal environment. Markus and Morris (1980) further added that it is a shelter or structure, which intervene by acting as barriers and as responsive filters between the natural or urban environment and the range of environments required for human activities. From the foregoing, the building fabric, the services and its contents continuously affects the physical and more specifically, the thermal environment. Therefore the building and its parts must satisfy certain requirements related to the environmental factors on which the design of the space within it is based (Forster, 1991).

Various environmental factors affect the formulation of design criteria for thermal comfort. The aspects of primary interest is the climate of the area. Climate is the general weather or meteorological condition with regard to temperature, moisture, humidity, etc. (Chambers 20th Century Dictionary, 1983; and Cassell's English Dictionary, 1976). The climatic elements of immediate interest in thermal design of buildings is solar radiation, temperature, humidity, wind and precipitation (Markus and Morris, 1980).

The climate and its element vary from one geographical region to another. In like manner, the feeling of either thermally comfortable or not of an individual is also determined by the varying climatic elements. For a human being to be thermally comfortable, a balance has to be maintained between the various climatic elements that cause differential in the external and internal environment of any given space (Amasuomo, 2000). In the same vein, formulating design criteria for thermal comfort vary from one geographical region to another according to the climate of that particular region. It is therefore pertinent to understand the meaning of thermal comfort. Thermal comfort is a condition within reasonable limits when most people feel comfortable when the thermal conditions remain fairly stable irrespective of actual values (Burberry, 1979). Markus and Morris (1980) further described thermal comfort as a situation where the termal condition is neither too warm nor too cold; or termally neutral.

However, there is no clear-out definition of thermal comfort because there are evidence that people adapt their clothing and immediate environment to suit prevailing conditions. It is also possible for different individuals to feel too hot and too cold respectively in the same thermal conditions. There is therefore no set conditions, which will satisfy everyone even in one locality (Burberry, 1979; and Neufart, 1980). That is why even when there is evidence that thermal conditions affects the level of arousal, vigilance, fatigue, attention and boredom as well as the performance of both mental and physical tasks through these effects (Markus and Morris, 1980); the level of effect vary from one individual to another in the same thermal condition. Consequently, the aim of formulating design criteria for thermal comfort in a built environment is to satisfy a majority and to reduce to minimum the inevitable proportion of dissatisfied occupants (Burberry, 1979).

Furthermore, the size of the learning-teaching space in relation to the floor area per student or workshops/laboratories combined with the activities that are expected to take place may also affect thermal comfort of the occupants. A room space could be overcrowded when the seating capacity of students or the installed capacity of machines/work benches exceeds the recommended requirements (Jordan, 1979; and Neufart, 1980). The consequence is that with a relatively high external temperature and humidity, the internal temperature and humidity is likely to increase through the excess watt/person/hour of heat and kg/person/hour of vapour that shall be generated and liberated respectively by the occupants as well as heat from machines (Amasuomo, 2000; Burberry, 1979; and Adler, 1979). The amount of heat or vapour generated/liberated depends on the type of activity. These activities range from light work to heavy work. In a classroom situation, the activities are considered medium to heavy work since more energy is dissipated.

In formulating design criteria that shall satisfy a majority in a built environment, the design criteria of interest are layout alternatives; spacing of building for breeze penetration; air movement; sizes of openings; protection of openings; and the type of wall and roofing materials (Evans, 1979). And the purpose of this study is therefore to formulate design criteria for thermal comfort in a learning-teaching built environment in the tropics.

Methodology

Geographic Location of Study Area: The study area is the T ropical Humid Climate Zone of the tropics. This climatic zone lies between latitude 7V4% North and 7/2% South. It is warm with high relative humidity and rainfall (Evans, 1979).

Choice of Study Site. The study site is the Federal College of Education (Technical), Omoku. Rivers State, Nigeria. Omoku is located on latitude 6°20 East and longitude 5°20 North. The college is a tertiary institution and is assumed to have a properly planned layout and buildings for learning teaching. Figure I is a map showing the location of Omoku.

Choice of Buildings. Four lecture halls/rooms and six workshops/laboratories are used for the study. The four lecture halls are from Business Education, Vocational Education. Science Education and Multipurpose Flail. The six workshops/laboratories are from Technical Education. They are technical drawing hall, electrical/electronics laboratory, metalwork machine shop, woodwork machine shop, metal/wood work bench shop and building technology drawing studio.

Data Collection

The following data were collected:

(i) Map showing the location of Omoku (figure 1 and Table I).
(ii) The site layout plan of the college indicating the location of buildings (figure 2).
(iii) Measurement of buildings used for the study to ascertain sizes of openings (windows and doors) and their coverage area of the external walls.
(iv) Examine the walls and roofs in terms of the materials used for its construction.
(v) The temperature, humidity and rainfall of the area as well as the thermal comfort indicators and thermal comfort limits.
(vi) The floor area per student or per equipment in the selected buildings.

Data Analysis

Data shall be analysed as follows:

(i) I lie humid, arid and cold indicators shall be analysed to ascertain the months they occur or felt and the total number of months they occur or felt in the year. The data used shall be the temperature, humidity, rainfall and the thermal comfort limits for various humidity group (Tables 2, 3, 4 and 5).

(ii) With the help of a building, planning and thermal performance table, the design criteria required for thermal comfort shall be analysed (fable 6).

(iii) Compare the existing building, planning and thermal performance of the selected buildings with the recommended design criteria to ascertain whether there was any compliance (fable 7) .

(iv) Compare the floor area per student or per equipment in the selected buildings with that of the recommended requirements to ascertain whether there was any compliance (Table 8).

Results Of The Study

(a) Analysis of Indicators

The analysis of the indicators was carried out using Table V in conjunction with Tables II, III and IV. The analysis of the humid, arid and cold indicators in Table V and specially going through items 5 to 10 gave the following results:

(i) ***Humid Indicators:*** Item 8 in Table 5 showed that, HI is indicated (occurred or felt) for ten months of the year between the months of March and December. During this period, the mean monthly maximum temperature is above day comfort limit and the thermal stress is felt both in the day and night time except in December where the thermal stress is felt only in the day time (Item 6 in Table 5). The implication is that the humidity and temperature is high both in the day and night time. Therefore air movement is essential for ventilation of room spaces for this period. The indicator H2 is not indicated and therefore not applicable. The 113 indicator is indicated or felt for six months of the year between, the months of May and October. During this period, the monthly rainfall is more than 200mm (Table 5, items 7 and 8) . The implication is that, there is high rainfall during the period and rain protection of building surface is necessary.

(ii) ***Arid Indicators-*** Item 9 in Table V showed that, A1 indicator is felt or occurred for the three months of the year in January, February and December. During this period, the mean monthly temperature range is more than 10°C and the relative humidity is between 0-70% while the humidity group is 1 to 3 (Tables 3and 4) and the thermal stress is felt in both day and night time for January and February; and night only in December (Table 5, Item 6). It means that some cold is felt in the three months, which may require thermal storage for protection against cold. Indicator A2 is not felt and therefore not applicable.

(iii) ***Cold Indicators'.*** Item 10 in Table 5 showed that Cl and C2 was not felt or occur in any of the months during the year. It means that, the area is not subjected to prolonged cold. Thus, solar radiation is not desirable and protection from cold is not required.

(b) Analysis Of Building, Planning And Thermal Performance

The results of the analysis of building, planning and thermal performance are presented in fable 6. The total values of HI, H3 and AI (Table 5, items 8 and 9) are recorded in fable 6. Also the acceptable range of months where the thermal indicators (HI, H2, H3, Al, A2, Cl and Cl) could be indicated during the year are also provided. This includes corresponding design criteria options and the assigned codes. The recommended design criteria options are as follows:

(i) ***Layout Alternatives-*** For Codes Al, 2 and 3; the HI indicator with a total of 10 months falls within 6 to 12 months. This corresponds with code A3. The value of 3 months for Al is far less than the indicated value of 1 1 or 12 months and therefore not applicable. Thus A3 is recommended. The recommended design criteria are for buildings to be oriented in North - South axis.

(ii) ***Spacing for Breezes'.*** For codes Bl, 2 and 3; the indicator HI with a value of 10 months falls within 2 to 12 months and this corresponds with B2. Thus B2 is recommended since H3 and

A1 are not indicated. Thus the recommended design criteria is to space buildings apart for breeze penetration with some precaution against cold or hot dry wind.

(iii) ***Spacing for Solar Radiatiorr.*** For codes Cl, 2 and 3; the HI. H3 and A1 indicators are not applicable. Therefore C3 is recommended. That is, spacing of buildings do not depend on solar radiation.

(iv) ***Air Movement.*** For codes Dl, 2; the HI indicator falls within the required value of 3 to 12 months and/or 1 to 2 months of the year. Also, A] with a value of 3 months falls within the required value of 3 to 5 months while H3 is not applicable. Although, there is some influence of arid indicator but the humidity indicator HI is overriding. Therefore, Dl is recommended since it corresponds with the indicated HI value. The implication is that the humidity and the mean monthly maximum day temperature is high and above day comfort limit. The recommended design criteria is for rooms to be single banked with permanent provision for cross ventilation.

(v) ***Openings-.*** For codes El, 2 and 3; the humid indicator HI falls within the value of 2 to 12 months and the arid indicator A1 fall within 2 to5 and/or 0-1 months. However, the HI indicator is overriding. Thus, HI value which corresponds with El is recommended. The design criteria are for openings to be large between 40 - 80% of external walls for adequate ventilation.

(vi) ***Position of Openings-.*** For codes FI, 2 and 3; the indicators HI and A1 fall within the required values of 0 to 12 months and 0 to5 months respectively. The two values correspond to code . FI. The recommended design criteria is for openings to be positioned along the North and South walls at body height on windward sides for adequate ventilation.

(vii) ***Protection of Openings-.*** For codes G1 and 2; the H3 indicator is within the required value of 2 to 12 months of the year. HI and A1 indicators are not applicable. Thus G2 is recommended. The implication is that, there is long period of rainfall. The design criteria is therefore to protect openings from rain.

(viii) ***Outdoor Sleeping.*** For codes HI and 2; the HI, H3 and A1 indicators do not apply. Thus, H2 is recommended. That is, outdoor sleeping is not a requirement.

(ix) ***External Walls-.*** For codes 11 and 2; the A1 indicator value of 3 months fall within the required value of o to 2 months. The HI and H3 indicators do not apply. Thus, II is recommended and the corresponding design criteria is for walls to be light - weight with low thermal capacity.

(x) ***Roofs-.*** For codes J1, 2 and 3; the HI indicator is within the required value of 10 to 12 months and the A1 indicator value of 3 months is also within 0 to 2 months. Therefore, Jl is recommended since it corresponds with the values of HI and A1 indicators. The design criteria are that, the roof covering should be light-weight with reflective surface.

The summary of the recommended design criteria is extracted from Table 6 and presented in Table 7 below, using the applicable codes.

Table 7: _____ Summary of Recommended Design Criteria.

Design Criteria Code Recommended Design criteria codes for building, planning and thermal performance	A A3	B B2	C C3	D Dl	E El	F FI	G G2	H H2	1 IJ	J Jl

(c) Comparison Of Recommended Design Criteria With Data On Building, Planning And Thermal Performance Of Selected Existing Buildings

The results of the recommended design criteria in Table 6and the summary in Table 7 is compared with data collected on the building, planning and thermal performance of the selected buildings. The results of the comparative analysis is presented in Table 8. From the results, five buildings met design criteria A3; six buildings met criteria B2; all the buildings met criteria C3; and Dl. None of the buildings met criteria C3 and Dl. None of the buildings met criteria G2, H2, II and J1. From the foregoing, the following inference could be drawn from the results:

(i) Buildings that are not properly oriented in North and South axis are likely not to be assured of adequate breeze penetration for ventilation and are also likely to have the penetration of unwanted sun light (solar radiation) into the room space.

(ii) Buildings that are not adequately spaced apart from adjacent buildings may not be effectively ventilated because the flow or passage of wind may be blocked/impeded by the adjacent buildings.

(iii) Buildings that do not have adequate openings on their external walls are likely to have inadequate ventilation because small window may not be able to allow the passage of adequate breeze or effective air movement.

(iv) Buildings that do not have their openings positioned in the North and South direction may not get adequate supply for breeze (ventilation) from the prevailing South-West or North-East winds. Also penetration of unwanted sunlight into the room space is likely.

Discussion Of Findings

The findings revealed that thermal comfort can only be achieved in any learning-teaching environment in the tropics when the design and construction of such buildings comply with certain recommended design criteria. The incorporation of these criteria in the design of buildings shall provide a reasonable level of thermal comfort in any learning-teaching environment. However, most of the buildings selected for the study do not meet most of the design criteria recommended for thermal comfort.

On orientation, it was recommended that buildings should be positioned in North and South axis. The implication of buildings not properly oriented is that, they shall not have adequate ventilation. There is also the likelihood of solar radiation into the internal space of the building during sunrise in the East and sunset in the West. Inadequate ventilation of room space may aggravate sweat liberation while the penetration of radiant heat into a learning-teaching space may create a sensational stimulation of the students’ skin if it falls on the heads of the seated students (Amasuomo, 2000). On orientation and solar radiation, Greenberg (1983) said;

> Glass facing North receives least solar radiation, and glass facing South receives next least. Therefore, if a building can be oriented so that most of its glass faces North and South; it will have a much lower solar load than if the principal areas face East and West.

In the same vein, Benneth (1997) said;

> South-facing units are premium. Prevailing winds both local and regional, should be studied so that no building is entirely masked. At the same time, harsh winds should be buffered by planting.

Therefore, to preclude the penetration ventilation, buildings should be designed accordingly in that direction (Evans, 1979 and Burberry, 1979).

Spacing of buildings for breeze penetration was another recommendation for thermal performance. Buildings that are not spaced apart (built closely together) tend to block the flow of breeze or air change rate in the room spaces of the adjacent buildings. This means, the buildings shall not be assured of proper ventilation. Roberts (1997) said;

> Natural air change rate within a building depends on several factors; speed and direction of wind at building site; the external geometry of the building and adjacent surroundings.

All the learning-teaching spaces had provision for air-movement. That is the rooms were single banked and had permanent provision for cross-ventilation. This is because all room spaces had windows on each external side-walls and were located in the opposite walls. The location of windows in both windward and leeward faces is for the building to be cross ventilated.

The openings in the lecture halls and workshops do not meet the recommended 40% - 80% coverage of the external walls. Instead, they occupy between 16% and 30%. The implication was that the window openings shall not be able to admit adequate breeze into the room space. This means inadequate ventilation. Therefore, the admission of breeze into any room space depends on the type and size of the window openings (Roberts, 1997 and Evans, 1997). Furthermore, in the tropics where the humidity and temperature is high above comfort limits practically throughout the year, large window openings that will permit adequate air into a room space for thermal comfort is required (Evans, 1979).

From the findings also, most openings were not properly positioned. The recommendation was that openings should be positioned in the North and South walls at body height on windward side. In this geographical location, the prevailing wind is in the South-West and North-East direction (Oboli, 1978 and; Angaye and Okpara, 1981). When building with the longer fa9ade are oriented in the North and South walls, the openings shall be in the direction of the prevailing wind. Invariably, the room spaces shall have adequate air-movement and ventilation. In this regard, Roberts (1997) said that:

> Ventilation is enhanced by placing windows in side walls due to the increased suction at this locations. And where windows are centered in a room, it forms a free jet.

All the buildings selected for the study were protected from rain. This was achieved by the use of corrugated asbestos/iron/aluminum roofing sheets with extended overhangs (roof eaves). With the very high rainfall in this area, and where external wall are not protected, they may be affected by rainwater which contains chemicals such as compounds of carbon and sulphur. The consequences of unprotected external walls is that paints, wooden doors and frames shall deteriorate and metals shall corrode (Burberry, 1979 and Amasuomo, 1987).

This area do not require provision of outdoor sleeping because there is rain throughout the year. Outdoor sleeping can only be provided where temperatures are extremely high with very low' rainfall and humidity. That is when the mean monthly minimum temperatures are above the night comfort limits and humidity below 5% (Evans, 1979).

The external walls and roof coverings comply with the recommended design criteria because they are light-weight with low thermal capacity. Light-weight walls and roofs are relevant to this area because storage or conservation of heat is not required since the average annual minimum and maximum temperature of I9°C and 36"C respectively; and relative humidity for thermal comfort between 50 - 70% (Evans, 1979; Punmia, 1987; and Burberry, 1979).

The findings also established that most of the learning-teaching spaces were overcrowded (acceptable floor area per student or floor area per equipment/machines were exceeded) except Woodwork machine shop and Building Technology studio. Overcrowded spaces may have the internal temperature and humidity increased in terms of generation of excess watt/person/hour of heat and liberation of excess kg/person/hour of vapour by the increased metabolic activities of the students and the machines in operation. This means the available air in the room space shall be utilized quickly without any corresponding replenishment occasioned by the low wind velocity in this are (Dar-al-Handasah, 1975). That is, the acceptable heat generation per person per hour of between 115- 140 watt/hour and that of vapour liberation per person per hour of 0.05kg/person/hour (Adler, 1979 and Bumberry, 1979) shall be exceeded. When an increase in temperature and humidity is experienced in a room space and combined with low wind velocity and radiant heat penetration, the ventilation of the room space can never be assured except where artificial ventilation is used. The effect is stuffy room environment with body odour from the sweat of students and a contaminated room space. This is likely to affect thermal comfort. Greenberg (1983) therefore noted that:

> The common denomination of these buildings is that large number of people are assembled in an enclosed space for appreciable period of time. The primary problem is to furnish sufficient air and to distribute it properly. Therefore, cooling or heating is required as environment conditions permits.

Conclusion / Recommendations

It is concluded from the findings that in the tropics, various factors affect the formulation of design criteria for the thermal comfort in a learning-teaching environment. These factors are orientation, spacing of buildings for breeze, air movement, size and position of openings, protection of openings and the type of walling and roofing materials used. Also included is the size of the learning-teaching spaces in relation to the number of occupants or equipment/machines. It is when the recommended design criteria in this regard is incorporated into the design of buildings used for learning-teaching that a thermally comfortable environment is likely to be enhanced.

However, the following design criteria is recommended for any learning-teaching environment in the tropics;

(i) Buildings should be oriented in North-South, North-East or South-West directions to ensure adequate ventilation and preclude direct radiant heat penetration in the building space.

(ii) Buildings should not be positioned too close to one another but spaced apart at reasonable distances to allow for breeze penetration into the room spaces.

(iii) Buildings should have their room spaces single banked and there should be permanent provision for cross-ventilation.

(iv) The window openings should occupy between 40% - 80% of the external wall area.

(v) The windows should be positioned in North and South walls at body height on windward side.

(vi) The building should be protected from rain by providing extended roof overhangs (roof eaves).

(vii) The walls should be light-weight with low thermal capacity.

(viii) The roof covering should be light-weight with reflective surfaces.

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Table 2: Thermal Comfort Limits

S/No	Monthly Average Relative Humidity %	Humidity Group	Annual Average Temperature					
			Over 20°C		15°C-20°C		Under 15°C	
			Day	Night	Day	Night	Day	Night
1.	0-30	1	26-34	17-25	23.-32	15-23	21-30	14-21
2.	30-50	2	25-31	17-24	22-30	15-22	21-27	14-20
3.	50-70	3	23-29	17-23	21-28	15-21	19-26	14-19
4.	70-100	4	22-27	17-21	20-25	15-20	18-24	14-18

Source: Evans, 1979.

Table 1: Location of Study Area

Location	Oinoku, Rivers State, Nigeria
Longitude	60° 20’ East
Latitude	5° 20’ North

...ainfall

								J	A	S	O	N	D
1.	Monthly mean max. °C	33	35	34	33	31	30	29	28	29	30	31	36
2.	Monthly mean min. °C	19	21	23	24	23	23	22	24	23	23	22	21
3.	Monthly mean range C	14	14	11	9	8	7	7	4	6	7	9	15
4.	Average relative humidity %	62	65	72	75	80	82	87	86	85	82	76	67

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36 Highest mean temp

19 Lowest mean temp

17 Mean Monthly temp range

5. Rainfall mm 24 34 108 146 234 260 370 344 380 214 70 10 2194 Total

Source: Department of Meteorological Services
Federal Ministry of Aviation, Port Ilarcourt, 1980- 1985.

Table 4: Indications of Requirements for Thermal Comfort for each Month.

Indicators	Thermal Stress Dav and Night	Rainfall	Humidity Group	Mean Monthly Temp. Range
Humid: HI - Air movement essential	Mean monthly max. temp, above day comfort limits		4	
	Mean monthly max. temp, above day comfort limits		2 or 3	Less than 10"C
H2 - Air movement desirable	Mean monthly max. temp, within day comfort limits		4	
H3 - Rain protection necessary		Over . 200mm		
Arid: A1 - Thermal storage necessary A2 - Outdoor sleeping desirable			1 or 2 or 3	More than I0°C
	Mean monthly min. temp, above night comfort limits		1 or 2	
	Mean monthly max. temp, above day comfort limits		1 or 2	More than 10°C
Cold: Cl - Solar radiation desirable	Mean monthly max. temp, below day comfort limits			
C2 - Protection from cold or additional heating required	Mean monthly max. temp, below 15°C			

Source: Evans, 1979

Table 5: Analysis of Indicators

S/N	Indicators	J	F	M	A	M	.1	J	A	S	O	N	D	
1.	Humiditv Group	.3	3	4	4	4	4	4	4	4	4	4	.3	
2.	Monthly mean max. temp.	33	35	34	33	31	30	29	28	29	30	31	36	
3.	Day comfort:													
	Upper limit °C	29	29	27	27	27	27	27	27	27	27	27	29	
	Lower limit °C	7,3	23	22	22	22	27	22	22	22	77	72	7,3	
4.	Monthly mean min. temp. °C	19	21	23	24	23	23	22	24	23	23	22	21	
5.	Night comfort:'													
	Upper limit °C	23	23	21	21	21	21	21	21	21	21	21	23	
	Lower limit °C	17	17	17	17	17	17	17	17	17	17	17	17	
6.	Thermal stress:													
	Day	A1	A1	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	
	Nieht	A1	A1	HI ,	HI	HI	HI	HI	HI	HI	HI	HI	A1	
7.	Rainfall (mm3	24	34	108	146	234	260	370	344	38C	214	70	10	Total
8.	Humid indicators HI			./	j	j	,/	./	,/	«/		./	j	10
	H2		–	. –	-	–	–		–	–	–	–	–	Nil
	H3					./	./	./	./	./	./			6
9.	Arid indicators A1												j	3
	A2													Nil
10.	Cold indicators													
	Cl													Nil
	C2													Nil

Source: Author's Fieldwork, 2001 and Evans, 1979.

Table 6: Building. Planning and Thermal Performance Reauiremer lis ,

Indicators	H1	H2	H3	A1	A2	C1	C2	Item Code	Design Criteria	Recom mendation
Total	10	6	3					A	LAYOUT ALTERNATIVES	
No. of months Indicators occur or felt during the year.						0-2		A1	Building oriented on Fast-West axis	
			11or12			0-4		A2	Compact courtyard olannina	
	6-12							A3	Building oriented on North-Smith axis	y
								B	SPACING FOR BREEZE	
	11or12							B1	Open spacing for breeze penetration	
	2-21							B2	Open spacing with some precautions against cold or hot dry winds	
								B3	To close to adjacent Buildings	
								C	SPACING FOR SOLAR RADIATION	
						0-3		C1	Spacing not dependent on solar radiation	
						4-12		C2	Spacing to allow solar radiation (but high sun angles may still allow close spacing!	
								C3	Spacing for solar radiation not a requirement	
								n	AIR MOVEMENT	
	3-12 VI2			0-5				D1	Rooms single banked, permanent provision for cross ventilation	
		2-12			6-12			D2	Double banked rooms, temporary provision for cross ventilation	
	0	0-1						D3	Cross ventilation not essential	
								F	OPFNINGS	
	2-12			0-1		0		E1	Large, 40-80% of external wall area	
			0-1					E2	Medium, 20-40% of external wall area	
				11or12		0-3		E3	Small, 10-12% of external wall area	
								F	POSITION OF OPFNINGS	
	0-12			0-5				F1	In North and South walls at body height on windward sides	y
	0	2-12		6-12				F2	As above, openings also in internal walls	
								F3	In Fast and West walls	
								G	PROTECTION OF OPENINGS	
						0-2		G1	Exclude direct sunlight	
			2-12					G2	Provide protection from rain	y
								H	OUTDOOR SLEEPING	
					2-12			H1	Spacing required for outdoor sleeping	
								H2	Not a requirement	/
				0-2				I II	EXTERNAL WALL Light walls, low thermal capacity	y
				3-12				I2	Heavy walls, over 8hr. time-lag	

ROOFS				
10-1?	0-2		J1	Light, reflective surfaces_____ /
0-9	6-12	----------TT2---------- ----------	J2 J3	Heavy, over 8hr. time lag wemnsuiatea, Jhr. time la£

Source: Author’s Fieldwork, 2001 and Evans, 1979.

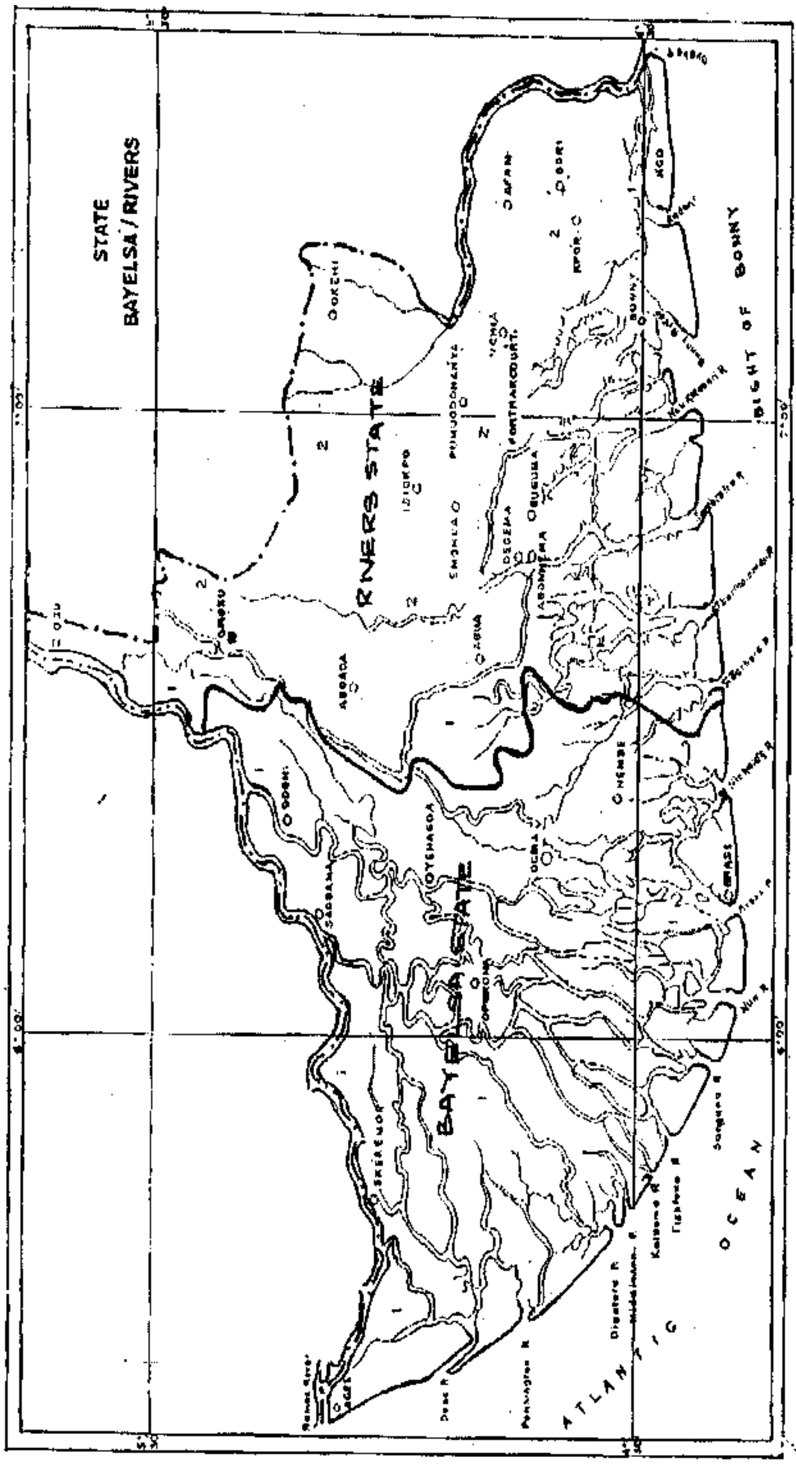

FIGURE 1: LOCATION OF OMOKU IN RIVERS STATE

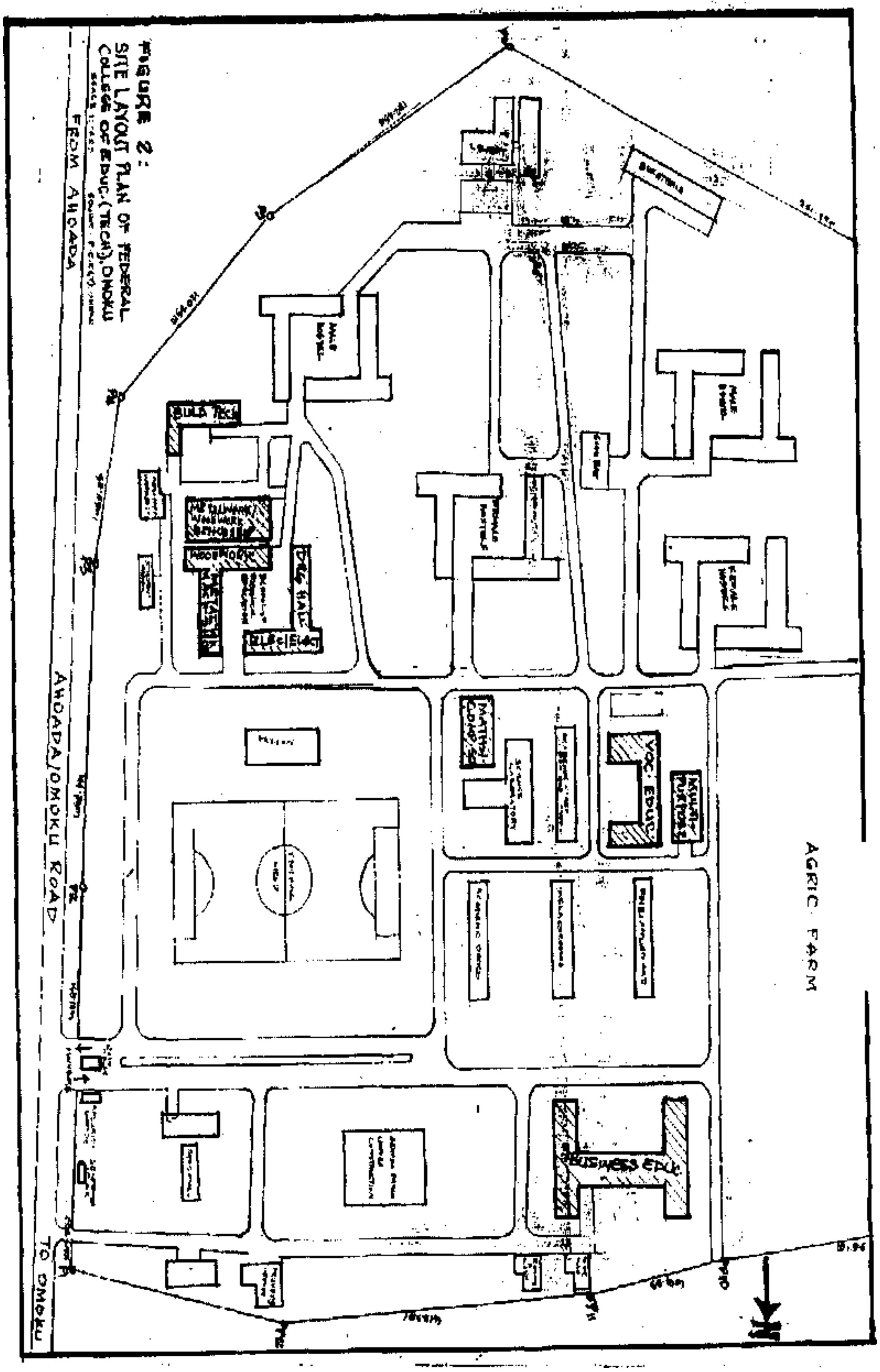
FIGURE 2:
SITE LAYOUT PLAN OF FEDERAL
COLLEGE OF EDUC. (TECH.), OMOKU
FROM AHOADA
AHOADA/OMOKU ROAD
TO OMOKU
AGRIC FARM
BUSINESS EDUC.
VOC. EDUC.
BUILD. TECH.
ELEC/ELEC
MATHS/ EDUC/PSY.

Table 8: Statistical Data of Selected Existing Learning - Teaching Spaces and Recommended Requirements

Selected Buildings	Existing Data of Spaces under Study			Recommended Requirements		Remarks
	No. of Students or Machines or Work benches per space	Floor Area M^2	Floor area per student or machines or work benches M^2	Floor area per students or machines or work benches M^2	No. of students or machines or work benches per space	
Business Education	256	252	0.93	1.10[1]	229	Overcrowded floor area
Multipurpose Hall	272	202	0.81	1.10*	183	As above
Vocational Education	110	116	1.05	1.10'	105	As above
Mathematics/Computer Science	210	189	0.90	1.101	172	As above
Technical Drawing Hall	65	138	2.12	2.39[2]	58	As above
Electrical/Electronics	40	138	3.45	6.0[2]	23	As above
Metalwork Machine Shop	8	138	17.25	24.0-	6	As above
Woodwork Machine Shop	4	138	34.0	20.0[2]	7	Floor area under utilized
Metal/Woodwork Bench Shop	69	447	6.48	I3.50[2]	33	Overcrowded floor area
Building Technology Drawing Studio	14	71	5.07	4.20[2]	17	Floor area under utilized

Source: Jordan, 1979 Neufart, I980[2]

Other data from Author's Fieldwork, 2001.