NOISE POLLUTION GENERATED FROM WINDOW AIR-CONDITIONING UNITS IN RESIDENTIAL AND INSTITUTIONAL BUILDINGS IN MAKKAH REGION, KSA.

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***ABSTRACT*— The use of compact (window) air-conditioning units (A/Cs) in residential and institutional building to control indoor climate, has been tremendously increasing in KSA in the past 4 decades. The noise generated from these units could produce noise-pollution problems leading to annoying the occupants, interfering with their communication and causing general stress among them, as well as reducing their productivity and increasing work absenteeism and accidents. The present study, therefore, aimed to evaluating factors affecting A/C noise, and proposing remedial actions for eliminating or minimizing the noise levels. The study comprised a sample of 1,181 residential units in Makkah region, including houses, villas, residential apartments, furnished apartments and hotels, as well as 1,830 institutional buildings, including corner shops, hospitals and polyclinics office buildings, governmental organization and governmental and private schools. Results indicated that the use of A/Cs in building could create noise pollution problem in buildings, particularly in the hotels, furnished and residential apartments and corner shops. Factors affecting levels of generated noise in both residential and institutional buildings include: type (brand) of A/Cs, type of walls, insulations, floors, and windows, the method of fixing A/Cs, type of furniture and level of crowd.It has been recommended to consider these factors when selecting, installing and operating A/Cs, as well as considering their routine and meticulous maintenance.**

***Keywords*:— Noise exposure, Air-Conditioning units, Noise in Residential Buildings, Noise in Institutional Buildings, Makkah, Jeddah, Saudi Arabia.**

I. INTRODUCTION

The oil boom during the last three decades of the 20th century, as well as the first decade of the current century, has been accompanied with considerable rise of the standardof living of the Saudi population. One of the main requirements to deal with modern life and to improve the style of living has been the control of the climate conditions in the living and the work places, through use of air-conditioning technology both central and/or by installment of compact (window) units. The noise emitted from theair-conditioners compact units (A/Cs) may reach up to 60 dB to 70 dB depending on the status of their installment, operation and maintenance. Meanwhile, outdoor noise attributed mainly to road traffic and air traffic substantiate the ventilation and A/C appliances noise, and both represent the main sources for high indoor noise [1]. However, some authors claimed that this noise will not affect the hearing capability of the occupants of the places where such A/Cs are installed [2], since the levels of noise emitted from the A/Cs are lower than the 85 dB standard for noise exposure settled by ACGIH (American Conference of Governmental Industrial Hygienists) [3]. This standard has been recommended for occupational exposure to noise for 8 hrs daily, 5 days/week (40 hrs/week). But, mostly all the occupants of the residential and institutional buildings where A/Cs are installed are exposed to the A/Cs generated noise for much longer durations, approaching 24 hrs daily, particularly among those living in regions with high heat stress. Thus, the traditional permissible levels that are based on only 8 hrs/day (e.g. ACG.1H) [3] are not applicable. Therefore, what should be applied is the dose of noise exposure, and consequently its effect, that is the multiple of both the noise levels and duration of exposure. Moreover, several studies have established that noise exposure affects, beside hearing impairments, cardiovascular stimulation, gastric secretion, suppression of immunity, less fertility for women, awakening, and other physiological indicators [4],[5], as well as causing physiological effects such as annoyance, awakening and nausea [4], [6], [7].Therefore, some other standards for non-occupational noise exposure have been settled as shown in table (1) (e.g. CGCC standards) [8]. These standards consider, also, the extra-auditory effects of noise such as annoyance, interference with communication and general stress, leading, in many cases, to nervous, cardiovascular and digestive disorders, as well as reduced individual's productivity and increased work absenteeism and accidents. Furthermore, the problem of exposure to high noise in residential areas was found to be highly correlated to with socio-economic factors such as population density and traffic intensity [9], [10]. For example, assessment of noise in dense-populated Saudi regions (e.g. Jeddah, Makkah) revealed high noise levels [11], [12], and emphasized the need for more field measurements, and called for implementing noise control solutions. Consequently, a substantial body of research has been conducted to assess comfort in indoor residential and office buildings.A diversity of techniques were applied including subjective surveys and questionnaires [1], [13], direct quantitative measurements [14], [15], and statistical modeling [16]. Most studies measure and report indoor noise exposure levels in two cases; when the ventilation appliances (A/C) are ON and when they are OFF [15], [17]. Researches within this area frequently apply both subjective and objective (or physical) variables. A comparison of both types [18] concluded that utilizing objective measures alone may fail to capture the true sensory feeling of indoor discomfort. Several indicators were suggested to assess noise and personal feel of comfort in residential areas. Susini et, al, [19] proposed using three new indicators to characterize spilt-type air conditioner's noise while comparing a variety of brands. He used noise-to-harmonic ratio, spectral center of gravity, and loudness as indicators and 3-D sound sources for experimentation. Moiseev [20] defined and discussed several noise criteria for indoor measurements as sound level, room criterion, and balanced noise criterion. Tang and Wong [1] used physical noise measurements such as the noise criterion and composite room criterion, and also a questionnaire to assess annoyance and nuisance caused by air conditioners for about 400 respondents. Ayr et, al, [15] applied Stevens and Zwicker loudness criteria with subjective responses for 55 office rooms equipped with air conditioners.Their analysis supported that objective criteria correlate well with the annoyance sensation. Numerous studies have focused on factors influencing noise annoyance [13], [21]. Generally, two sets of factors were revealed: 1) sound-related factors (type of noise, noise level, duration of exposure, frequency spectrum), time of day, and previous habitual experience with noise source, 2) person-related factors including physiological, psychological, and social factors that affect the perception of noise and impair activities(communication, concentration, sleep, recreation or reset). It can be concluded that direct measurements of noise using an objective criterion will lead in most cases to a result that is consistent with an occupant's feel of comfort, but may not help to characterize the noise. It may, also, be noted that the manufacturing, testing, and performance of air conditioners, and ventilation and cooling systems exist either in most engineering standards to regulate the product, or in environmental standards to regulate its impact (such as permissible noise levels). ANSI/ASHRA Estandards [22] are devoted to the engineering aspect of A/C as a product. For example; total noise exposure to occupants, including A/C's as a source, are recommended only by OSHA [17] for offices, and by WHO [23] for residential buildings. BSI [24], [25] are examples of standards that control the measurements and testing of noise emitted from A/C's and cooling systems.

Considering these above-mentioned factors and criteria, the present work stressed on studying the A/C's related noise in both residential and institutional buildings with the objective of:

a. *Evaluating the magnitude of the problem.*

b. *Evaluating the factors affecting A/Cs related noise levels and their significance(s).*

c. *Proposing remedial action(s) for minimizing the noise levels.*

II. METHODOLOGY

The present study comprised 1,181 residential buildings distributed between houses (n = 478), villas (n = 306), residential apartments (n = 37), furnished apartments (n = 307), and hotels (n = 53), as well as 1,830 institutional units including corner shops (n = 425), hospitals and polyclinics (n = 369), office buildings and governmental organizations (n = 398) and schools (n = 638), selected randomly from Makkah region, considering that the owners, tenants, and/or the officials agree to participate in the study.

A study form was designed and tested for data collection including the following six main sections:

a. *Residence information; district classification and type of building.*
b. *Personal information; total number of occupants in the location, and their socio-economic parameters.*
c. *A/C information including its brands, power, sites, fixing methods, insulations, and duration of use.*
d. *A/C site information, describing statusof walls, floors, ceilings, doors, windows and curtains in the location.*
e. *Noise measurements in the location; Leq, Max SPL, Min SPL.*
f. *Sketch(s) for the A/C locations and their fixing method(s)comprising:*
    i. *Method "A": A/C supported on the wall together with a steel sheet plate support enforced with steel angle corner.*
    ii. *Method "B": A/C supported on the wall with steel sheet plate support.*
    iii. *Method "C": A/C supported on the wall only.*

Each location was surveyed for data collection by interviewing the owner/tenant and/or the official personnel, filling the study form, observing for the A/C brand, power, fixing method, insulation and location, duration of use, as well as for the location, walls, floors, ceilings doors, windows and curtains, then measuring the noise in the place with the A/C(s) in operation (ON) and when it (them) was (were) (OFF).

Basic noise exposure assessment procedures and methods for this study were performed according to ISO 1996-1:2003 [26], while calculation and adjustments for sound pressure levels followed ISO 1996-2:2007 [27]. Permissible limits for noise exposure in community areas were adopted from the recommendations of the World Health Organization [23].

Noise was measured using B&K sound level meter (SLM), model number 2236. This model is a type-1 SLM, and it is recommended for field measurements for its precision and cost effective controls [17]. The measurement, testing, and calibration of the instruments were performed as described by B&K manufacture manual [28].Data were introduced into PC and analyzed using EXCEL spread sheet.

III. RESULTS AND DISCUSSION

1. Air-Conditioning Noise Pollution in Residential Buildings

The levels of noise produced by A/Cs in the studied residential buildings are presented in table (2). The levels of noise, and the noise difference between having the units ON and OFF, are the highest in the residential apartment, followed by the furnished apartments. This might be attributed to the nature of the design of these buildings since the rooms there are of relatively smaller areas than the matching rooms in the houses and the villas. However, the highest levels of noise, whether the A/Cs are either operating or not operating, exist in the hotels, which might be attributed to the relatively high community noise outside of the buildings.

2. Air-Conditioning Noise Pollution in Institutional Buildings

In Institutional buildings, the highest noise levels occur in the corner shops and hospitals and polyclinics followed by the governmental schools (Table 3), meanwhile, accompanied with relatively low differences between the levels of noise differences when having A/CsON or OFF. This might be attributed to the relatively high community noise levels outside of the buildings. Also, the noise levels, when operating the A/Csin the private schools, office buildings, and governmental organizations are relatively lower than the levels in the above mentioned institutions that might be attributed to the above mentioned reason.

3. Factors Affecting Air-Conditioning Noise Pollution in Residential Buildings

Table (4) and figure (1) illustrate the A/Cs noise in residential buildings as related the characteristics of the A/Cs, expressed in their brand names and power, and their installment and operation. The highest noise produced by A/Cs, as expressed by differences in the assessed noise levels when having the units ON and OFF, are produced by the Sharp and Hitachi units, followed the National, the York, the Sanyo, the Toshiba, the Carrier, the Falcon, the Mitsubishi, the Samsung, the General units, and the lowest are the Gibson and the Hass units; meanwhile, no differences exist as related to the power of these units, whether 18,000 or 24,000 BTU.

However, the duration of operation of these units, unexpectedly, didn't show any effect. It has been anticipated that more noise would be generated from the relatively older A/Cs that have been operated for relatively longer periods than those operated for shorter durations.

As related to the fixing of the A/Cs, method B, surprisingly, causes the highest levels of noise production as measured by the difference between having the units ON and OFF, as well as when using wood insulation, in comparison to using foam with wood, or foam only. Meanwhile, the A/Cs fixed against street sides or to buildings' ventilation chutes produce higher noise levels than those located against building sides or building fences.

The effect of building construction factors on the A/Cs noise production is presented in table (5) and figure (2), where the noise levels produced by the operation of the A/Cs in the wood constructed buildings are much higher than in the noise produced within building constructed by bricks, but no much effect could be observed of the other construction factors including floors, ceilings, doors, windows and curtains.

The impact of the socio-economic factors of the tenants and users of the residential building onto the noise dissipated by the A/Csare shown in table (6) and figure (3). It seems that the behavior of the community of middle class personnel has some impact on the levels of noise production by the units, since the levels of noise, expressed by the differences in the levels when having the units operating or not operating, are the highest in the middle district classification, and among the high school graduates, but not, practically, affected by the family's monthly income and crowding (number of persons in location).

Meanwhile, the highest noise levels occur in the dining and guest rooms in comparison to other functioning rooms, but not affected by the type of furniture in the location.

4. Factors Affecting Air-Conditioning Noise Pollution in InstitutionalBuildings

Table (7) and figure (4) illustrate A/Cs noise in institutional buildings as related to the characteristics of theunits, expressed in their brand names and power, and their installment and operation. The highest noise produced by A/Cs, as expressed by the differences in the measured noise levels when having the units ON and OFF, are produced by the Gibson and Al-Zamil units, followed by the General, the Falcon and the Carrier, and the lowest are the Samsung units. Meanwhile, surprisingly, the 18,000 BTU units produce more noise than the 24,000 BTU units. As related to the duration of use of the units, those units operating for more than 2 years produce more noise than the relatively recently installed units. Also, the units installed with full support (A-method) produce less noise than those fixed with steel sheet only (B-method, the highest in noise production) and those supported on the walls(C-method). Further, the best insulation as related to noise dissipation is the wood and foam and the worst is the metallic. Meanwhile, the units fixed onto the ventilation chute produce the highest noise, followed by those fixed against the fence of the building and the lowest noise producers are those units fixed against streets.

The effect of building construction factors on A/Cs noise production is presented in table (8) and figure (5). The wood and concrete walls contribute to higher noise levels in comparison to brick walls that might be attributed to the vibration of wood and to the reverberation noise of the concrete. Meanwhile, the concrete ceilings contribute to higher noise levels than the other ceilings construction. Also, wood doors, and aluminum and glass windows contribute to higher noise levels due, probably, to their vibration. The contribution of curtains to noise levels might have been masked by other factors, since, unexpectedly, the blinds and fabric curtains showed higher noise difference between having the A/Cs units ON and OFF, than the glass strips and the others.

The impact of the socio-economic conditions of the users of the institution buildings onto the noise generated by A/Cs are presented in table (9) and figure (6). It appears from results' analyses that the noise generated by A/Cs in the high districts, expressed by the difference in noise levels when having the units ON and OFF, is the highest,which might be an artifact, since the noise levels there when having A/Cs OFF are the lowest, due to the relatively lower community noise than in the other two district levels. Similar picture occurs in the lowest crowded government and office building. However, it seems that the number of occupantsof the shops mask the effect of A/Cs noise since the noise levelswhen having the units OFF are the highest with the highest number of occupants. Meanwhile, in the schools the effect of crowd noise appears only in the highest crowded classes.

The impact of the room function on the A/Cs noise in the waiting rooms of the hospitals and polyclinics, in the employees room of the government and office buildings, and in the offices of the schools is the highest on the current noise levels there, that might be attributed to the same above-stated causes.

IV. CONCLUTIONS AND RECOMMENDATIONS

CONCLUSIONS

It may be concluded from this study that:

1. Compact (window) A/Cs may generate unexpected noise levels leadingto noise pollution problem in some residential and institutional buildings.

2. In institutional buildings, the highest noise levels exist in the hotels and residential and furnished apartments, due, partially, to their location in relatively busy areas. Meanwhile, the type of walls and insulation, as well as the pattern of living in the place in the houses and in the villas have some effect on the levels of noise, due to noise absorption/refraction, and number of occupants. For example, foam insulation, alone or in combination with wood, is the most effective noise absorber used in residential buildings and institutional buildings as well.

3. In institutional buildings, the highest noise levels exist in the corner shops and the lowest in the offices and in the governmental buildings.

4. The type (brand) of A/Cs in both the residential and institutional buildings vary in the levels of their generated noise; for example, "Hass" has been found to be the lowest noise producer, while "Carrier" has been the highest noise producer, with the othertypes (brands) producing noise to different extents.

5. In Institutional buildings, noise has been found to be affected, in addition to the above-mentioned factors, as follows:
   a. *In shops, type of furniture affects noise levels, most probably, due to the absorption/refraction characteristics of the different types of furniture.*
   b. *In hospitals, both crowd and window types affect noise levels.*
   c. *In office buildings and government organization, both crowdand type of walls, and type of furniture affect noise levels.*
   d. *In schools,the noise levels in the class rooms are higher than in the offices, and are affected by the floor and window types; the tile floor and aluminum and glass windows areassociated with higher noise levels; besides, the A/Cs fixing method "B" is associated with higher noise levels than the methods "A" and "C".*

RECOMMENDATIONS

It has been recommended to consider the factors associated with relatively higher noise generation when selecting, installing and operating A/Cs, as well as considering their routine and meticulous maintenance.

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Table I

Recommended Permissible Indoor Noise Levels in Residential and Institutional Buildings*

Building Type	Permissible Noise Level (dBA)
A. Educational Buildings	
Classes	40 – 50
Laboratories	40 – 50
Workshops (indoor)	45 – 50
Offices	35 – 50
B. Health Care Buildings	
Polyclinics	40 – 50
Waiting rooms	40 – 50
Patients' rooms	30 – 45
C. Office Buildings	
Conference rooms	30 – 35
Accounting rooms	45 – 55
Computer rooms	45 – 55
Design offices	40 – 45
Drafting offices	40 – 45
General offices	40 – 50
Private offices	35 – 40
Waiting rooms	45 – 55
Corridors and Lobbies	45 – 50
D. Auditoria	
Motion picture projection halls	35 – 45
Theatres	35 – 45
Restaurants	35 – 45
E. Shop Buildings	
Department stores	50 – 55
Show rooms	45 – 50
Supermarkets	50 – 55
Indoor car parks	55 - 65
F. Housing	
1. Rural Areas Suburbs	
Living rooms	30 – 40
Bed rooms	25 – 30
Leisure time rooms	40 – 45
2. Inner Suburbs (Villas and Luxurious Apartments)	
Living rooms	35 – 40
Bed rooms	30 – 35
Leisure time rooms	40 – 45
3. Hotels	
Conference halls	30 – 35
Dining halls	40 – 50
Bedrooms	30 – 35
Leisure time rooms	45 - 50
3. Libraries	
Reading halls	35 – 40
Administrative office spaces	40 – 45

* CGCC (2008): STANDARDS OF PERMISSIBLE LEVELS OF CHEMICAL AIR POLLUTANTS, NOISE, AND SEWAGE WATER, COUNCIL OF GULF COUNTRIES COOPERATION.

Table II
Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA)
Mean (S.D.)

Building Type	N	Leq (dBA)			MAX (dBA)			MIN (dBA)		
		ON	OFF	D	ON	OFF	D	ON	OFF	D
Houses	478	66.3 (6.5)	62.1 (6.4)	4.2 (0.1)	78.2 (7.8)	72.2 (7.7)	6.0 (0.1)	59.0 (6.7)	55.0 (7.1)	4.3 (-0.5)
Villas	306	64.6 (11.5)	60.4 (11.6)	4.2 (-0.1)	77.1 (13.4)	72.0 (13.2)	5.1 (0.2)	57.5 (11.0)	52.0 (12.9)	5.6 (-1.9)
Residential Apartments	37	70.5 (3.3)	64.0 (2.9)	6.5 (0.4)	83.5 (3.0)	74.4 (7.9)	9.1 (-4.8)	63.3 (3.8)	56.7 (3.5)	6.6 (0.4)
Furnished Apartments	308	68.1 (9.2)	63.2 (9.3)	5.0 (-0.1)	80.8 (11.5)	75.1 (10.9)	5.7 (0.5)	60.0 (8.9)	54.5 (10.3)	5.5 (-1.4)
Hotels	53	73.8 (4.4)	69.4 (4.6)	4.4 (-0.2)	87.0 (4.1)	84.2 (5.7)	2.8 (-1.6)	63.4 (5.4)	58.4 (5.2)	5.0 (0.3)

N: NUMBER OF STUDIED BUILDINGS ON: CONDITIONING UNITS ON OFF: CONDITIONING UNITS OFF
D: DIFFERENCE BETWEEN ON AND OFF VALUES

Table III
Noise Pollution Generated from Window Air-Conditioning Units in the Studied Institutional Buildings in Makkah Region (KSA)
Mean (S.D.)

Building Type	N	Leq (dBA)			MAX (dBA)			MIN (dBA)		
		ON	OFF	D	ON	OFF	D	ON	OFF	D
Corner Shops	425	69.9 (3.9)	66.7 (4.0)	3.14 (-0.1)	84.3 (4.4)	80.2 (4.8)	4.1 (-0.4)	63.1 (4.6)	59.5 (4.6)	3.6 (0.0)
Hospitals	43	68.8 (6.8)	64.4 (8.0)	4.4 (-1.3)	83.5 (8.7)	77.7 (10.8)	5.8 (-2.1)	58.8 (6.0)	54.1 (7.2)	4.8 (-1.2)
Polyclinics	326	65.1 (6.0)	59.1 (4.7)	6.0 (1.3)	77.8 (6.8)	71.8 (6.4)	6.0 (0.4)	58.1 (6.8)	51.3 (5.9)	6.8 (1.0)
Office Buildings	200	65.0 (6.9)	58.5 (8.4)	6.4 (-1.5)	76.1 (4.2)	68.3 (6.4)	7.6 (-2.2)	60.8 (7.9)	55.3 (9.0)	5.5 (-1.1)
Governmental Organizations	198	65.5 (4.8)	59.2 (5.4)	6.3 (-0.6)	75.9 (6.3)	72.2 (6.8)	3.7 (-0.6)	58.2 (6.3)	50.9 (7.0)	7.3 (-0.8)
Governmental Schools	583	65.51 (5.2)	60.7 (5.1)	4.8 (0.2)	77.2 (7.0)	72.1 (5.4)	5.1 (1.6)	57.0 (5.3)	52.7 (5.1)	4.2 (0.2)
Private Schools	53	66.9 (4.4)	59.6 (2.6)	7.3 (1.8)	78.4 (5.2)	71.4 (3.7)	7.0 (1.5)	58.0 (4.3)	52.4 (2.3)	5.7 (2.0)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table IV
Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Their Nature, Installment and Operation
Mean (S.D.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
Brand Name	York	268	66.1 (6.8)	60.4 (8.2)	5.8 (-1.4)	78.8 (7.5)	72.5 (9.2)	6.3 (-1.7)	58.7 (7.0)	52.7 (9.2)	6.0 (-2.1)
	Carrier	202	66.3 (8.9)	61.7 (8.8)	4.6 (0.2)	80.0 (11.9)	74.0 (10.0)	6.0 (1.9)	58.3 (8.3)	52.9 (11.2)	5.4 (-2.9)
	Sharp	108	66.0 (3.3)	58.2 (2.5)	7.8 (0.8)	81.1 (5.3)	72.4 (4.9)	8.7 (0.5)	56.4 (3.3)	48.7 (2.9)	7.8 (0.3)
	Sanyo	106	66.0 (12.4)	60.8 (11.4)	5.3 (0.9)	77.0 (14.2)	70.9 (13.7)	6.1 (0.4)	58.6 (11.4)	54.2 (10.6)	4.5 (0.8)
	National	93	65.6 (5.0)	59.7 (5.8)	5.9 (-0.8)	78.0 (6.0)	70.9 (6.9)	7.1 (-0.9)	58.2 (5.5)	50.8 (8.5)	7.4 (-3.1)
	Falcon	85	70.6 (6.4)	66.4 (6.0)	4.2 (0.5)	83.5 (6.6)	79.2 (8.4)	4.3 (-1.8)	61.4 (5.8)	57.0 (6.1)	4.4 (-0.3)
	Mitsubishi	62	66.0 (6.0)	62.0 (7.8)	3.9 (-1.8)	78.6 (6.2)	73.5 (7.9)	5.2 (-1.7)	59.8 (8.0)	55.0 (8.3)	4.8 (-0.3)
	General	48	64.5 (4.8)	62.1 (4.1)	2.4 (0.7)	76.9 (5.2)	72.9 (7.4)	4.0 (-2.2)	56.9 (4.2)	55.2 (4.9)	1.7 (-0.8)
	Samsung	45	65.4 (7.0)	62.5 (5.5)	2.9 (1.5)	77.2 (5.8)	71.2 (6.7)	6.0 (-0.9)	59.5 (8.5)	55.9 (5.6)	3.6 (2.9)
	Gibson	38	63.6 (16.2)	60.3 (15.8)	3.3 (0.4)	75.5 (19.3)	70.6 (19.0)	4.9 (0.3)	56.7 (14.7)	54.2 (14.4)	2.5 (0.3)
	Hitachi	34	69.6 (5.7)	62.9 (7.6)	6.7 (-1.9)	84.1 (3.6)	77.1 (5.3)	7.0 (-1.7)	59.9 (8.3)	54.0 (10.1)	5.9 (-1.7)
	Toshiba	32	67.6 (5.8)	62.7 (7.9)	4.9 (-2.1)	78.5 (5.5)	71.1 (8.9)	7.5 (-3.4)	61.1 (6.8)	55.7 (9.1)	5.4 (-2.4)
	Hass	21	66.5 (3.9)	64.1 (6.3)	2.4 (-2.4)	79.6 (5.4)	73.4 (6.0)	6.2 (-0.6)	59.4 (3.9)	55.9 (4.9)	3.4 (-0.9)
Power	18,000 BTU	937	67.0 (5.8)	61.8 (6.4)	5.2 (-0.5)	80.1 (7.0)	73.5 (7.8)	6.5 (-0.7)	58.9 (6.0)	54.0 (7.2)	4.8 (-1.2)
	24,000 BTU	245	64.4 (12.8)	59.5 (12.9)	5.0 (-0.1)	76.5 (14.8)	71.5 (14.7)	5.0 (0.1)	58.3 (12.4)	50.2 (13.9)	8.1 (-1.5)
Duration of Use (Years)	One	307	67.2 (5.9)	63.8 (5.4)	3.4 (0.5)	79.5 (5.7)	74.1 (7.5)	5.4 (-1.8)	58.8 (5.6)	56.1 (5.2)	2.7 (0.4)
	Two	322	66.1 (6.0)	59.4 (6.6)	6.8 (-0.6)	79.7 (7.0)	71.7 (8.0)	8.0 (-0.9)	57.8 (6.0)	51.5 (7.4)	6.3 (-1.4)
	3 – 4	234	66.1 (5,7)	60.8 (6.1)	5.3 (0.4)	79.3 (6.8)	73.0 (7.1)	6.3 (0.8)	58.2 (5.7)	52.4 (6.5)	5.9 (0.8)
	5 – 9	255	66.1 (11.4)	61.3 (11.3)	4.8 (0.9)	78.5 (14.1)	73.4 (12.9)	5.1 (2.3)	59.4 (11.0)	52.9 (12.7)	6.5 (2.7)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table IV: (Contd.)

Factor	**Classification**	**N**	**Leq (dBA)**			**Max SPL (dBA)**			**Min SPL (dBA)**		
			ON	**OFF**	**D**	**ON**	**OFF**	**D**	**ON**	**OFF**	**D**
Fixing Method	**A**	383	66.2 (5.5)	62.2 (5.5)	4.0 (0.1)	77.9 (5.2)	71.7 (6.5)	6.3 (-1.3)	58.8 (5.9)	55.1 (6.1)	3.8 (-0.2)
	B	396	66.0 (6.5)	59.1 (7.0)	7.0 (-0.5)	80.4 (7.9)	72.8 (8.5)	7.7 (-0.6)	57.2 (6.4)	49.6 (8.9)	7.6 (-2.5)
	C	403	67.2 (10.5)	62.9 (10.7)	4.4 (-0.2)	79.6 (12.8)	74.9 (12.5)	4.7 (0.3)	60.2 (10.0)	55.1 (10.6)	5.1 (-0.6)
Insulation	**Wood**	621	66.8 (9.5)	60.4 (10.1)	6.4 (-0.6)	80.6 (11.6)	73.8 (11.7)	6.8 (0.0)	58.6 (9.3)	51.2 (11.0)	7.4 (-1.7)
	Foam	460	65.9 (5.6)	62.4 (5.3)	3.5 (0.3)	77.4 (5.0)	71.8 (6.3)	5.6 (-1.3)	58.5 (5.5)	55.7 (5.4)	2.9 (0.1)
	Wood &Foam	64	66.7 (6.0)	62.3 (6.3)	4.4 (-0.3)	79.6 (7.2)	74.9 (7.4)	4.7 (-0.2)	60.0 (6.3)	54.3 (7.3)	5.7 (-1.0)
Location	**Street Side**	436	67.1 (6.5)	60.6 (7.7)	6.5 (-1.2)	80.6 (8.6)	73.6 (9.0)	7.1 (-0.3)	58.5 (6.4)	52.1 (8.0)	6.4 (-1.6)
	Building Side	424	66.3 (7.2)	62.2 (7.4)	4.1 (-0.2)	78.6 (7.8)	73.1 (8.7)	5.5 (-0.9)	59.5 (7.1)	55.0 (8.2)	4.5 (-1.1)
	Fence Side	166	64.9 (13.1)	61.1 (12.7)	3.8 (0.4)	76.8 (15.0)	71.6 (14.8)	5.1 (0.2)	58.0 (12.7)	51.7 (14.3)	6.3 (-1.6)
	Ventilation Chute	138	66.5 (4.9)	61.2 (5.1)	5.4 (-0.2)	80.1 (5.4)	73.2 (6.4)	6.9 (-1.0)	57.6 (5.4)	52.7 (6.5)	4.9 (-1.1)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table V
Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to their Construction
Mean (S.D.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
Walls	Bricks	1060	66.5 (7.9)	61.7 (8.1)	4.8 (-0.2)	79.1 (9.4)	73.2 (9.5)	5.9 (-0.1)	58.9 (7.9)	53.7 (9.2)	5.2 (-1.3)
	Wood	122	66.7 (4.5)	58.6 (6.7)	8.1 (-2.3)	81.3 (4.6)	72.6 (8.6)	8.7 (-4.0)	57.6 (4.0)	49.4 (5.8)	8.2 (-1.8)
Floors	Carpet & Rugs	1091	66.4 (5.6)	61.2 (6.2)	5.1 (0.7)	79.2 (6.2)	73.0 (7.2)	62.0 (1.0)	58.6 (5.8)	53.8 (7.5)	5.5 (1.7)
	Marble &Tile	91	67.9 (4.8)	62.9 (5.3)	5.0 (0.6)	81.2 (8.3)	75.2 (5.9)	6.0 (2.5)	60.7 (4.7)	55.6 (6.3)	5.1 (1.6)
Ceilings	Concrete	1127	66.6 (7.4)	61.4 (7.9)	5.2 (-0.5)	79.5 (8.8)	73.3 (9.2)	6.2 (-0.4)	58.9 (7.3)	53.4 (8.7)	5.4 (-1.4)
	Wood	55	63.7 (14.6)	59.6 (13.8)	4.1 (0.8)	75.8 (16.6)	70.5 (16.4)	5.2 (0.2)	56.8 (14.2)	49.6 (15.6)	7.2 (-1.4)
Doors	Wood	1182	66.5 (7.7)	61.4 (8.1)	5.1 (-0.4)	79.4 (9.0)	73.2 (9.4)	6.2 (-0.4)	58.8 (7.6)	53.3 (9.1)	52.2 (-1.4)
Windows	Aluminum & Glass	1134	66.4 (7.7)	61.3 (8.1)	5.1 (-0.4)	79.3 (9.0)	73.1 (9.4)	6.2 (-0.4)	58.7 (7.6)	53.2 (9.1)	5.5 (-1.4)
	Others	48	67.6 (11.3)	62.8 (11.1)	4.8 (0.2)	81.0 (13.4)	75.5 (13.3)	5.6 (0.04)	59.9 (10.7)	55.2 (10.6)	4.7 (0.1)
Curtains	Fabric	1092	66.3 (7.8)	61.1 (8.2)	5.2 (-0.3)	79.1 (9.2)	72.7 (9.5)	6.4 (-0.3)	58.5 (7.7)	52.9 (9.0)	5.6 (-1.3)
	Blinds & Others	90	69.0 (4.0)	64.8 (5.0)	4.2 (1.0)	82.6 (4.8)	78.3 (5.7)	4.2 (0.9)	61.9 (4.5)	56.7 (7.0)	5.2 (2.5)

N: NUMBER OF STUDIED BUILDINGS ON: CONDITIONING UNITS ON OFF: CONDITIONING UNITS OFF

D: DIFFERENCE BETWEEN ON AND OFF VALUES

Table VI
Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Some Socio-Economic Factors of the Users
Mean (S.D.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
District Classifica-tion	High	187	67.1 (6.4)	62.7 (7.3)	4.4 (-1.0)	79.5 (6.4)	74.4 (8.6)	5.1 (-2.2)	60.8 (7.5)	54.3 (11.0)	6.5 (-3.5)
	Middle	864	66.2 (5.6)	60.8 (6.3)	5.4 (-0.7)	79.2 (6.3)	72.5 (7.1)	6.7 (-0.9)	58.3 (5.9)	52.9 (7.5)	5.4 (-1.7)
	Indigenous	326	67.2 (17.2)	63.1 (16.4)	4.1 (0.8)	80.1 (21.5)	75.7 (19.6)	4.4 (1.9)	59.0 (15.3)	54.3 (14.3)	4.7 (0.9)
Users' Level of Education	Illiterate, Elementary & Intermediate	79	60.7 (17.3)	56.3 (17.3)	4.4 (2.6)	73.0 (20.7)	67.1 (19.6)	5.9 (1.9)	54.6 (15.7)	47.9 (15.5)	6.7 (2.2)
	High School	245	67.1 (4.3)	59.6 (6.3)	7.5 (-2.0)	80.8 (5.4)	72.8 (7.6)	8.0 (4.6)	58.0 (4.6)	51.3 (7.2)	6.7 (-2.6)
	Bachelor	587	65.3 (7.0)	60.6 (6.8)	4.7 (0.2)	77.8 (8.0)	71.5 (8.3)	6.33 (-0.4)	58.3 (7.2)	53.1 (7.8)	5.2 (-0.7)
	Master, Ph.D.&others	271	68.4 (7.2)	63.0 (8.0)	5.4 (1.0)	81.3 (8.4)	75.7 (8.9)	5.6 (1.0)	61.1 (7.8)	54.0 (9.6)	7.0 (2.0)
Users' Monthly Income (SR thous-ands)	< 6	172	67.9 (4.6)	62.2 (5.5)	5.6 (0.9)	79.2 (4.7)	72.8 (5.7)	6.6 (1.0)	60.4 (5.4)	54.5 (6.0)	5.8 (0.5)
	6 –< 9	331	67.1 (5.3)	62.2 (6.4)	4.8 (-1.1)	79.8 (5.7)	74.1 (6.9)	5.8 (-1.1)	59.6 (5.9)	54.8 (7.6)	4.8 (-1.7)
	9 –< 12	401	66.8 (6.5)	61.9 (6.8)	4.9 (-0.3)	80.1 (8.8)	73.8 (8.3)	6.3 (0.5)	59.0 (6.8)	53.5 (8.1)	5.5 (-1.3)
	12 +	277	64.4 (12.0)	59.0 (11.9)	5.5 (0.2)	77.6 (13.9)	71.2 (14.2)	6.3 (-0.3)	56.5 (10.9)	50.2 (12.3)	6.3 (-1.4)
Users' Crowding (Number of Persons in Location)	1	165	65.5 (12.9)	59.7 (13.6)	5.8 (-0.7)	78.3 (15.1)	71.9 (16.0)	6.4 (-0.9)	58.6 (12.2)	51.7 (14.6)	6.9 (-2.4)
	2	435	66.7 (6.8)	61.9 (6.6)	4.8 (0.2)	79.8 (7.2)	73.6 (8.1)	6.2 (-1.0)	58.9 (6.7)	53.6 (7.7)	5.3 (-1.0)
	3 – 4	231	67.6 (3.8)	61.9 (4.5)	5.6 (0.9)	80.4 (5.6)	73.8 (4.7)	6.6 (1.3)	60.1 (4.3)	53.6 (5.5)	6.4 (1.2)
	5 – 13	355	66.0 (5.4)	61.1 (5.7)	4.9 (0.4)	78.4 (6.4)	72.6 (6.7)	5.8 (0.3)	57.8 (5.5)	53.4 (6.2)	4.5 (0.7)
Room Function	Bedroom	581	67.1 (6.4)	61.9 (6.8)	5.1 (-0.4)	79.9 (8.1)	73.9 (8.0)	6.0 (0.04)	59.4 (6.6)	54.0 (8.1)	5.4 (-1.5)
	Living Room	262	66.8 (6.7)	61.7 (7.3)	5.1 (-0.6)	79.8 (7.4)	73.1 (8.2)	6.7 (-0.8)	59.1 (7.0)	53.5 (8.8)	5.6 (-1.8)
	Dining and Guest Room	198	67.0 (5.5)	60.3 (5.7)	6.7 (-0.3)	81.4 (8.8)	73.8 (6.4)	7.6 (2.4)	58.5 (6.2)	51.6 (8.0)	6.9 (-1.7)
	Kitchen & Others	137	66.1 (5.6)	61.1 (6.4)	5.1 (1.3)	78.9 (5.9)	72.8 (7.9)	6.1 (3.0)	58.4 (5.2)	53.5 (6.4)	4.9 (1.6)
Type of Furniture	Living sets with or without cabinet	318	66.9 (3.8)	61.4 (4.3)	5.5 (0.6)	79.6 (5.1)	73.1 (4.8)	6.5 (1.1)	58.9 (4.3)	53.9 (5.5)	5.6 (1.2)
	Living sets, cabinet, beds and / or others	156	67.2 (6.3)	62.8 (7.4)	4.4 (1.3)	79.8 (7.4)	75.4 (8.3)	4.4 (1.3)	59.8 (6.3)	53.4 (9.1)	6.5 (3.2)
	Beds with or without cabinet	451	66.2 (6.0)	60.9 (6.2)	5.3 (0.2)	79.5 (6.4)	72.5 (7.2)	7.8 (0.7)	57.9 (5.8)	52.6 (7.2)	5.4 (1.4)
	Single cabinet or with others	144	65.7 (13.6)	61.2 (13.3)	4.4 (1.6)	77.9 (16.4)	72.9 (16.0)	5.0 (2.4)	59.1 (13.1)	54.6 (13.0)	4.5 (2.6)
	Arabian	72	65.5 (3.8)	60.3 (4.8)	5.2 (1.1)	77.8 (4.2)	71.0 (5.1)	6.9 (0.9)	58.7 (4.5)	53.2 (5.8)	5.4 (1.7)

N: NUMBER OF STUDIED BUILDINGS   ON: CONDITIONING UNITS ON   OFF: CONDITIONING UNITS OFF

D: DIFFERENCE BETWEEN ON AND OFF VALUES

Table VII
Noise Pollution Generated from Window Air-Conditioning Units in Institutional Buildings in Makkah Region (KSA) as Related to Their Nature, Installment and Operation
Mean (S.D.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
Brand Name	Carrier	510	65.3 (4.4)	60.4 (4.5)	5.0 (0.7)	76.7 (5.5)	73.0 (5.6)	3.7 (0.8)	57.6 (5.1)	52.9 (4.9)	4.7 (0.3)
	York	407	66.2 (6.1)	61.6 (5.2)	4.6 (2.0)	78.3 (7.2)	74.0 (6.0)	4.3 (2.2)	58.7 (6.6)	53.5 (6.7)	5.2 (1.7)
	Sanyo	115	68.0 (3.6)	63.4 (3.7)	4.5 (0.4)	81.5 (3.4)	75.6 (3.4)	5.9 (0.9)	61.8 (4.1)	57.7 (4.0)	4.1 (0.6)
	Falcon	82	67.0 (3.5)	61.8 (4.0)	5.2 (0.7)	79.4 (4.0)	73.5 (4.7)	5.8 (1.3)	59.3 (3.9)	54.8 (4.9)	4.5 (1.0)
	Mitsubishi	80	66.2 (4.2)	61.8 (4.2)	4.4 (0.4)	79.1 (5.2)	75.1 (5.5)	4.0 (0.4)	59.9 (4.8)	54.3 (5.2)	5.6 (0.9)
	General	75	63.8 (3.8)	58.1 (4.8)	5.7 (1.0)	75.7 (3.9)	68.0 (4.3)	7.7 (0.7)	56.6 (4.4)	52.1 (4.6)	4.5 (0.2)
	Gibson	68	68.5 (3.1)	60.4 (3.1)	8.0 (0.4)	79.6 (4.8)	72.5 (5.1)	7.1 (0.9)	59.1 (3.8)	51.9 (3.4)	7.2 (0.5)
	Al Zamil	66	67.7 (5.9)	60.7 (4.3)	7.0 (1.6)	83.3 (5.8)	71.6 (5.2)	11.7 (0.7)	60.8 (4.5)	52.2 (4.1)	8.6 (0.4)
	Hitachi	52	75.5 (3.2)	66.5 (4.9)	4.0 (1.7)	86.5 (4.5)	81.0 (6.3)	5.5 (1.9)	62.1 (3.4)	58.1 (4.4)	4.0 (1.3)
	Craft	51	71.1 (2.2)	66.4 (1.7)	4.7 (0.5)	84.8 (2.1)	79.2 (1.7)	5.5 (0.4)	62.8 (2.2)	58.6 (1.7)	4.2 (0.5)
	Gold Star	30	68.4 (1.6)	64.4 (1.0)	4.0 (0.6)	82.3 (1.6)	76.2 (3.7)	6.0 (-2.0)	60.8 (2.1)	56.6 (0.9)	4.2 (1.2)
	Admiral	29	68.1 (5.7)	63.3 (7.7)	4.8 (-2.0)	81.7 (6.9)	75.0 (8.4)	6.7 (-1.6)	56.7 (3.6)	53.1 (6.2)	3.6 (-2.5)
	Samsung	25	66.2 (2.8)	63.7 (1.0)	2.5 (1.7)	83.1 (3.5)	77.4 (1.7)	5.7 (1.8)	62.7 (4.1)	57.0 (0.9)	5.7 (3.2)
Power	18,000 BTU	1450	66.1 (5.4)	60.8 (5.3)	5.3 (0.8)	78.3 (6.3)	73.1 (6.2)	5.2 (1.1)	58.9 (6.1)	53.4 (6.0)	5.5 (0.7)
	24,000 BTU	376	68.1 (4.9)	64.0 (5.6)	4.1 (0.9)	81.0 (5.5)	75.9 (5.9)	5.1 (0.7)	60.5 (5.2)	56.9 (5.7)	3.6 (0.7)
Duration of Use (Years)	One	304	67.4 (5.8)	61.5 (5.0)	5.9 (0.7)	79.1 (5.6)	74.7 (6.1)	4.4 (1.2)	59.8 (5.8)	53.6 (6.1)	6.2 (0.8)
	Two	160	68.0 (2.9)	64.3 (3.1)	3.7 (0.4)	82.1 (2.9)	77.7 (3.9)	4.5 (1.0)	61.6 (3.7)	56.5 (3.5)	5.1 (0.2)
	3 – 4	729	66.3 (5.4)	61.0 (5.9)	5.4 (1.0)	78.8 (5.6)	72.7 (6.2)	6.1 (1.4)	59.8 (6.1)	54.6 (6.7)	5.2 (0.8)
	5 – 8	573	65.5 (5.3)	60.9 (4.7)	4.6 (2.3)	78.4 (6.7)	72.3 (6.2)	6.1 (2.7)	57.2 (5.5)	53.2 (5.1)	4.2 (1.8)

N: NUMBER OF STUDIED BUILDINGS ON: CONDITIONING UNITS ON OFF: CONDITIONING UNITS OFF

D: DIFFERENCE BETWEEN ON AND OFF VALUES

Table VII: (Contd.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
Fixing Method	A	346	66.1 (4.4)	62.1 (4.9)	4.0 (0.7)	79.2 (5.4)	74.6 (5.6)	4.6 (0.5)	59.0 (5.1)	55.4 (5.9)	3.7 (0.8)
	B	1151	66.3 (5.1)	60.9 (5.2)	5.5 (0.6)	78.4 (6.1)	73.2 (7.4)	5.3 (1.4)	58.7 (5.9)	53.3 (5.8)	5.5 (0.6)
	C	316	67.7 (6.0)	63.0 (5.4)	4.6 (2.7)	80.5 (6.5)	74.7 (5.7)	5.8 (3.0)	61.2 (6.2)	56.3 (5.8)	4.9 (1.9)
Insulation	Wood	1413	65.9 (5.5)	60.6 (5.5)	5.3 (0.7)	78.0 (6.5)	72.6 (6.4)	4.1 (0.9)	58.4 (6.1)	53.2 (6.2)	5.3 (0.7)
	Foam	70	69.3 (2.8)	66.1 (3.4)	3.2 (-0.6)	83.3 (3.4)	78.9 (3.1)	4.4 (0.4)	62.9 (3.9)	58.8 (3.2)	4.1 (0.6)
	Foam & Wood	41	71.4 (4.3)	69.5 (3.7)	1.9 (0.6)	85.7 (4.7)	83.3 (4.0)	2.4 (0.7)	63.7 (6.3)	62.2 (5.2)	1.5 (1.1)
	Metallic	258	67.3 (4.6)	62.7 (4.9)	4.5 (0.9)	80.7 (4.5)	75.3 (5.4)	5.4 (1.1)	60.9 (4.9)	56.3 (4.9)	4.6 (0.6)
Location	Street Side	1168	66.5 (5.4)	61.9 (5.7)	(4.6) (0.9)	78.8 (6.0)	74.2 (6.1)	4.6 (1.2)	59.5 (6.1)	55.0 (6.4)	4.5 (0.8)
	Building Side	207	66.9 (4.7)	61.4 (4.8)	5.5 (1.0)	79.3 (6.1)	74.5 (5.9)	4.8 (0.3)	59.7 (5.2)	53.4 (5.8)	6.3 (1.0)
	Fence Side	361	66.1 (4.1)	60.0 (3.3)	6.1 (0.9)	78.8 (5.2)	71.4 (4.7)	7.4 (0.8)	58.0 (4.0)	52.1 (3.4)	5.9 (0.7)
	Ventilation Chute	55	66.4 (4.4)	59.7 (4.9)	6.7 (-0.5)	78.7 (5.2)	73.1 (7.5)	5.6 (-2.3)	59.9 (6.2)	51.7 (6.0)	8.3 (0.2)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table VIII

Noise Pollution Generated from Window Air-Conditioning Units in Institutional Buildings in Makkah Region (KSA) as Related to their Construction

Mean (S.D.)

Factor	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
			ON	OFF	D	ON	OFF	D	ON	OFF	D
Walls	Bricks	1686	66.6 (5.2)	61.5 (5.4)	5.0 (0.5)	78.9 (6.0)	73.7 (5.8)	5.2 (1.8)	59.2 (5.8)	54.2 (6.1)	5.0 (2.6)
	Concrete	64	66.2 (2.1)	60.1 (1.7)	6.4 (0.6)	80.6 (2.2)	72.8 (1.9)	7.8 (0.3)	59.9 (2.7)	54.3 (1.7)	5.6 (1.3)
	Wood	33	63.7 (4.2)	56.8 (5.4)	6.9 (-1.2)	74.5 (5.6)	72.0 (6.0)	2.5 (-0.3)	57.6 (5.9)	48.8 (6.4)	9.0 (-0.6)
Floors	Carpet & Rugs	535	66.3 (5.4)	60.9 (6.4)	5.4 (1.0)	77.9 (5.0)	72.8 (6.3)	5.2 (1.4)	60.3 (6.8)	54.6 (7.7)	5.7 (1.0)
	Marble & Tiles	1145	66.8 (5.2)	62.0 (4.8)	4.8 (1.0)	79.7 (6.3)	74.2 (6.2)	5.6 (1.0)	59.3 (5.4)	54.4 (5.1)	4.9 (0.8)
Ceilings	Concrete	1448	66.5 (5.5)	61.4 (5.3)	5.1 (0.5)	78.6 (6.6)	73.6 (6.9)	5.0 (1.6)	58.8 (6.1)	53.7 (6.0)	5.1 (0.6)
	Bricks	240	66.0 (3.6)	60.9 (4.3)	5.1 (0.9)	79.2 (2.6)	72.4 (3.5)	6.8 (1.0)	60.5 (4.2)	56.6 (4.7)	4.8 (0.8)
	Wood	63	66.7 (2.0)	61.8 (2.2)	4.9 (0.5)	79.9 (2.7)	75.8 (2.2)	4.1 (0.5)	59.8 (2.8)	54.5 (2.9)	5.3 (0.9)
	Metallic (Steel & Others)	54	69.6 (2.6)	66.3 (2.5)	3.4 (0.3)	84.7 (2.9)	79.9 (2.5)	4.8 (0.6)	64.7 (2.9)	59.3 (2.2)	5.5 (0.7)
Doors	Wood	1450	65.7 (5.2)	60.3 (5.4)	5.4 (0.7)	78.2 (6.4)	72.3 (5.7)	5.5 (1.9)	58.3 (6.0)	52.9 (5.9)	5.5 (0.8)
	Glass	116	68.4 (2.2)	64.9 (1.7)	3.5 (0.5)	83.2 (3.0)	78.0 (2.8)	5.3 (0.2)	61.1 (2.8)	57.7 (2.2)	3.4 (0.6)
	Aluminum, Glass & Others	245	70.2 (5.3)	66.5 (5.7)	3.7 (0.9)	82.8 (5.8)	78.9 (5.9)	3.5 (0.4)	63.5 (6.2)	59.8 (7.0)	3.7 (1.0)
Windows	Aluminum &Glass	927	66.6 (5.7)	60.3 (5.6)	6.3 (1.2)	78.6 (6.1)	72.4 (6.5)	6.2 (0.9)	59.6 (6.5)	53.2 (6.6)	6.4 (1.0)
	Wood & Glass	712	65.6 (3.9)	61.6 (3.9)	4.0 (0.5)	78.2 (5.0)	73.8 (3.3)	4.4 (2.0)	58.2 (4.3)	54.4 (4.2)	3.8 (0.8)
	Others	175	69.4 (5.8)	66.5 (6.4)	2.8 (0.6)	82.7 (7.0)	79.4 (7.4)	3.3 (0.6)	61.0 (6.3)	57.8 (7.1)	3.2 (0.8)
Curtains	Fabric	321	66.5 (5.4)	61.2 (6.3)	5.3 (1.3)	78.4 (4.4)	72.1 (5.3)	6.3 (2.0)	60.9 (6.3)	55.7 (6.6)	5.2 (1.5)
	Glass Strips	150	68.4 (2.2)	64.8 (1.7)	3.6 (0.4)	83.1 (2.9)	77.8 (2.6)	5.3 (0.4)	61.1 (2.8)	57.5 (2.2)	3.6 (0.6)
	Blinds	776	65.8 (5.8)	60.0 (5.2)	5.8 (1.0)	77.8 (7.1)	73.1 (6.5)	4.7 (1.0)	58.1 (6.6)	52.0 (6.2)	6.1 (0.9)
	Others	648	66.6 (5.1)	62.1 (5.2)	4.5 (0.2)	79.3 (6.1)	77.4 (6.2)	5.6 (0.7)	59.0 (5.3)	54.8 (5.6)	4.3 (0.4)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table IX

Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Some Socio-Economic Factors of the Users

Mean (S.D.)

Factor	Institution	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
				ON	OFF	D	ON	OFF	D	ON	OFF	D
District	**Schools**	**High**	111	69.1 (5.1)	62.0 (5.2)	7.1 (-0.1)	80.7 (6.4)	73.4 (7.9)	7.3 (-1.5)	60.0 (4.9)	53.8 (4.0)	6.2 (0.7)
		Middle	498	64.7 (4.8)	60.2 (4.7)	4.6 (0.1)	76.4 (6.6)	71.7 (5.9)	4.7 (0.8)	56.4 (5.1)	52.5 (5.0)	4/0 (0.1)
		Indigenous	27	67.7 (5.7)	62.2 (6.7)	5.4 (-1.0)	81.2 (6.9)	73.6 (7.0)	7.6 (-0.1)	56.4 (3.5)	52.5 (5.7)	4.0 (-2.2)
Users' Crowding (Number of Persons in Location)	**Shops**	**1**	132	68.5 (2.7)	65.0 (2.2)	3.5 (0.4)	82.8 (3.5)	78.8 (2.6)	4.5 (0.9)	61.5 (3.6)	57.9 (2.6)	3.6 (1.0)
		2	153	70.0 (4.2)	66.4 (3.9)	3.7 (0.3)	85.2 (4.7)	79.9 (5.1)	5.3 (-0.5)	63.5 (4.7)	59.0 (3.9)	4.5 (0.8)
		3 & 4	95	70.3 (2.5)	67.6 (3.7)	2.7 (0.5)	84.1 (2.8)	81.2 (3.7)	2.8 (0.9)	63.8 (3.5)	60.8 (4.1)	3.0 (0.9)
		5 – 15	44	72.4 (5.0)	71.0 (4.4)	1.5 (0.6)	86.8 (5.3)	85.0 (4.6)	1.8 (0.7)	65.0 (5.2)	63.1 (5.7)	1.9 (-0.5)
	Govern-ment and Office Buildings	**1**	154	64.9 (6.4)	58.2 (7.2)	6.7 (-0.8)	75.4 (5.1)	69.4 (6.9)	6.0 (-1.8)	59.7 (7.0)	52.6 (8.3)	7.1 (-1.3)
		2	168	65.6 (5.9)	59.1 (7.0)	6.5 (-1.1)	76.5 (5.5)	70.7 (6.3)	5.7 (-0.9)	59.4 (7.7)	53.8 (8.9)	5.6 (-1.2)
		3	64	64.8 (4.8)	59.6 (7.0)	5.1 (-2.1)	75.9 (5.4)	71.7 (8.1)	4.3 (-2.7)	58.8 (7.1)	52.4 (7.6)	6.3 (0.5)
	Schools	**29 & 30**	83	68.9 (3.6)	63.4 (3.8)	5.5 (1.0)	80.5 (4.9)	73.5 (6.2)	7.0 (2.5)	59.8 (2.9)	55.2 (3.2)	4.6 (0.4)
		31 – 33	83	64.3 (2.1)	61.2 (7.1)	3.0 (0.6)	77.5 (3.9)	73.8 (4.3)	3.7 (1.6)	57.7 (2.3)	54.7 (3.1)	3.0 (0.8)
		35	61	66.9 (4.8)	60.9 (4.6)	6.0 (0.2)	83.1 (4.7)	72.0 (4.9)	11.1 (-0.2)	60.6 (3.6)	52.8 (4.0)	7.8 (-0.4)
		36 – 38	88	64.2 (2.7)	60.7 (3.2)	3.5 (0.5)	75.2 (3.7)	69.3 (3.6)	5.7 (0.8)	56.3 (3.2)	53.4 (2.3)	2.9 (0.2)
Room Function	**Hospitals and Polyclinics**	**Employee Rooms**	27	63.9 (4.8)	58.2 (4.7)	5.8 (0.1)	77.7 (5.9)	70.8 (5.8)	6.9 (0.1)	55.3 (5.8)	49.7 (5.8)	5.6 (0.0)
		Reception Rooms	23	67.0 (5.0)	60.7 5.1	6.2 (-0.1)	80.8 (4.7)	72.9 (5.3)	7.9 (-0.5)	58.9 (4.6)	53.8 (7.4)	5.2 (-2.8)
		Examination Rooms	233	65.0 (6.7)	59.4 (5.1)	5.6 (1.6)	77.7 (7.8)	72.3 (7.0)	5.4 (0.8)	57.9 (7.3)	51.1 (5.5)	6.7 (1.8)
		Waiting Rooms	86	67.1 (5.0)	60.7 (6.5)	6.4 (-1.5)	80.1 (6.2)	73.3 (8.6)	6.8 (-2.3)	60.0 (5.3)	53.1 (6.9)	6.9 (-1.7)
	Govern-ment and Office Buildings	**Employee Rooms**	392	65.2 (5.9)	58.8 (7.1)	6.4 (-1.2)	75.9 (5.3)	70.3 (6.9)	5.6 (-1.6)	59.4 (7.3)	53.0 (8.4)	6.4 (-1.2)
	Schools	**Class Rooms**	470	66.0 (4.9)	61.3 (4.7)	4.8 (0.1)	78.1 (6.4)	73.4 (4.8)	4.7 (1.6)	58.1 (4.7)	53.8 (4.6)	4.3 (0.1)
		Offices	152	64.2 (5.8)	58.4 (4.9)	5.9 (0.9)	74.5 (7.6)	68.2 (6.5)	6.4 (1.1)	53.5 (5.2)	49.0 (4.1)	4.5 (1.2)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Table IX: (Contd.)

Factor	Institution	Classification	N	Leq (dBA)			Max SPL (dBA)			Min SPL (dBA)		
				ON	OFF	D	ON	OFF	D	ON	OFF	D
Type of Furniture	Shops	Living sets, Cabinets & Others	88	72.4 (4.7)	69.8 (4.1)	2.6 (0.8)	86.6 (5.5)	84.2 (5.3)	2.4 (0.4)	64.8 (4.4)	62.4 (6.4)	2.4 (2.2)
		Others (unclassified)	110	68.4 (2.1)	64.9 (1.6)	3.5 (0.5)	83.0 (2.7)	78.1 (2.6)	4.9 (0.1)	61.9 (3.5)	57.8 (2.2)	4.1 (1.3)
		None	184	69.8 (3.9)	66.2 (4.1)	3.6 (-0.3)	85.3 (4.3)	80.0 (4.7)	5.3 (-0.4)	63.4 (4.2)	59.1 (4.4)	4.3 (-0.1)
	Hospitals and Polyclinics	Living set with or without Cabinets	122	65.5 (3.8)	59.7 (4.4)	5.9 (0.6)	79.1 (4.3)	72.4 (5.4)	6.8 (1.2)	57.5 (4.2)	51.6 (5.0)	5.9 (0.8)
		Beds, Living sets, Cabinets and Others	201	65.0 (5.2)	59.0 (3.0)	6.0 (2.2)	77.7 (6.0)	71.4 (4.1)	6.2 (2.1)	57.8 (5.7)	51.1 (4.0)	6.7 (1.7)
	Govern-ment and Office Buildings	Living sets, Cabinets &Others	205	65.7 (5.0)	59.5 (5.7)	6.2 (-0.7)	76.1 (6.3)	72.4 (6.9)	3.7 (-0.6)	58.4 (6.7)	51.3 (7.6)	7.2 (-0.9)
		Cabinet and Others	177	65.2 (6.8)	58.6 (8.4)	6.5 (-1.6)	76.1 (4.2)	68.7 (6.3)	7.4 (-2.1)	60.7 (8.1)	55.4 (9.1)	5.3 (-1.0)
	Schools	Living sets	168	68.2 (5.2)	60.2 (3.8)	8.0 (1.3)	81.7 (5.9)	71.9 (6.1)	9.8 (-0.2)	59.9 (4.8)	52.2 (3.8)	7.6 (1.1)
		Cabinets & Others	77	62.7 (4.9)	57.8 (4.9)	5.0 (-0.1)	72.7 (6.5)	66.8 (6.6)	5.9 (-0.1)	52.4 (4.0)	49.0 (3.9)	3.4 (0.1)
		Others	391	65.1 (4.8)	61.3 (5.1)	3.8 (-0.4)	76.4 (6.3)	73.2 (30.6)	3.2 (-0.3)	56.8 (4.8)	53.6 (5.2)	3.1 (-0.4)

N: Number of studied buildings ON: Conditioning units on OFF: Conditioning units off

D: Difference between ON and OFF values

Factor	Classification	N
Brand Name	York	268
	Carrier	202
	Sharp	108
	Sanyo	106
	National	93
	Falcon	85
	Mitsubishi	62
	General	48
	Samsung	45
	Gibson	38
	Hitachi	34
	Toshiba	32
	Hass	21
Power	18,000 BTU	937
	24,000 BTU	245
Duration of Use (Years)	One	307
	Two	322
	3-4	234
	5-9	255
Fixing Method	A	383
	B	396
	C	403
Insulation	Wood	621
	Foam	460
	Wood & Foam	64
Location	Street Side	436
	Building Side	424
	Fence Side	166
	Ventilation Chute	138

N: Numbers of A/C Units

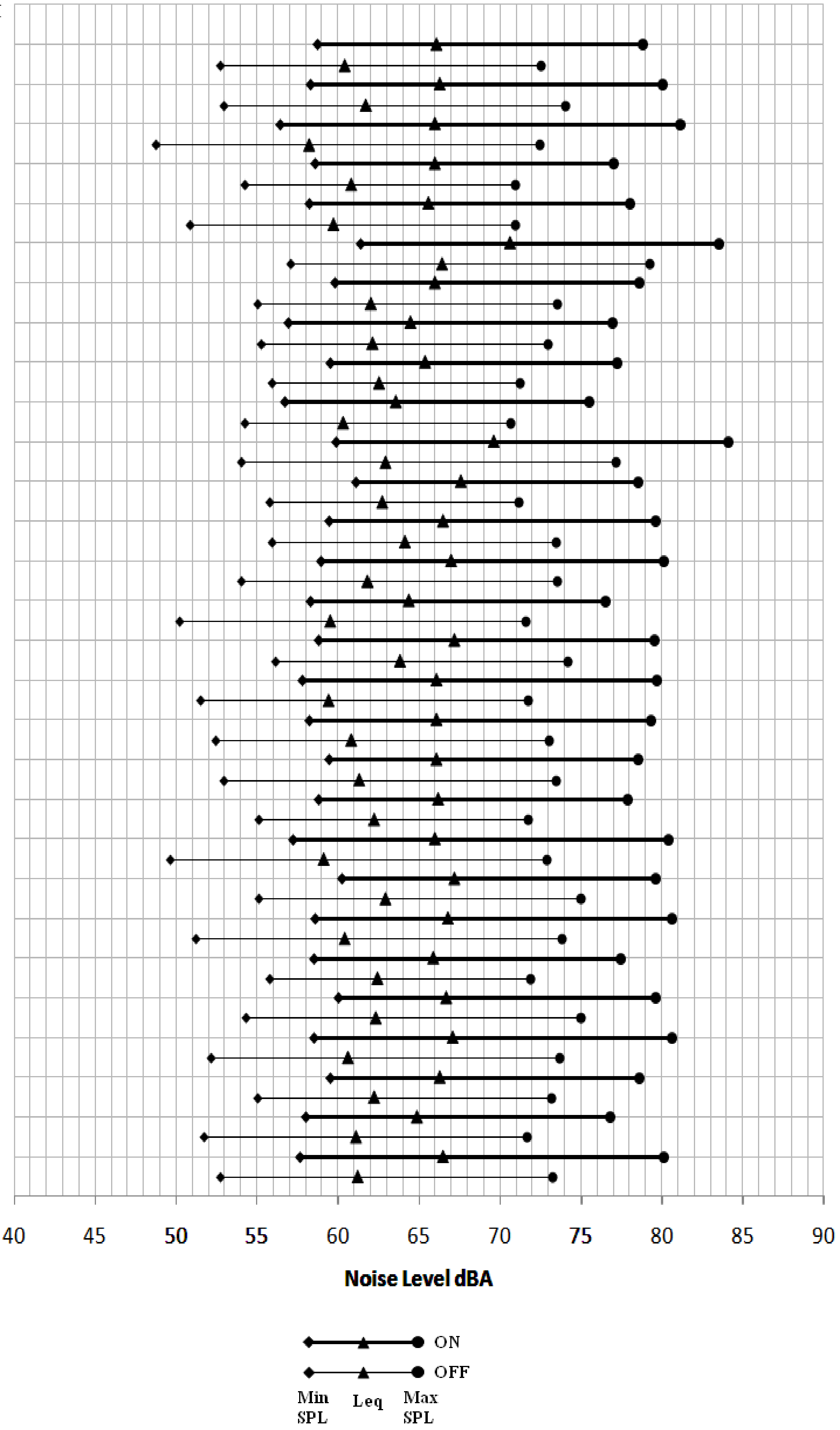


Figure 1: Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Their Nature, Installment and Operation (Means)

Factor	Classification	N
Walls	Bricks	1060
	Wood	122
Floors	Carpet & Rugs	1091
	Marble & Tile	91
Ceilings	Concrete	1127
	Wood	55
Door	Wood	1182
Windows	Aluminum & Glass	1134
	Others	48
Curtains	Fabric	1092
	Blinds & Others	90

N: Numbers of A/C Units

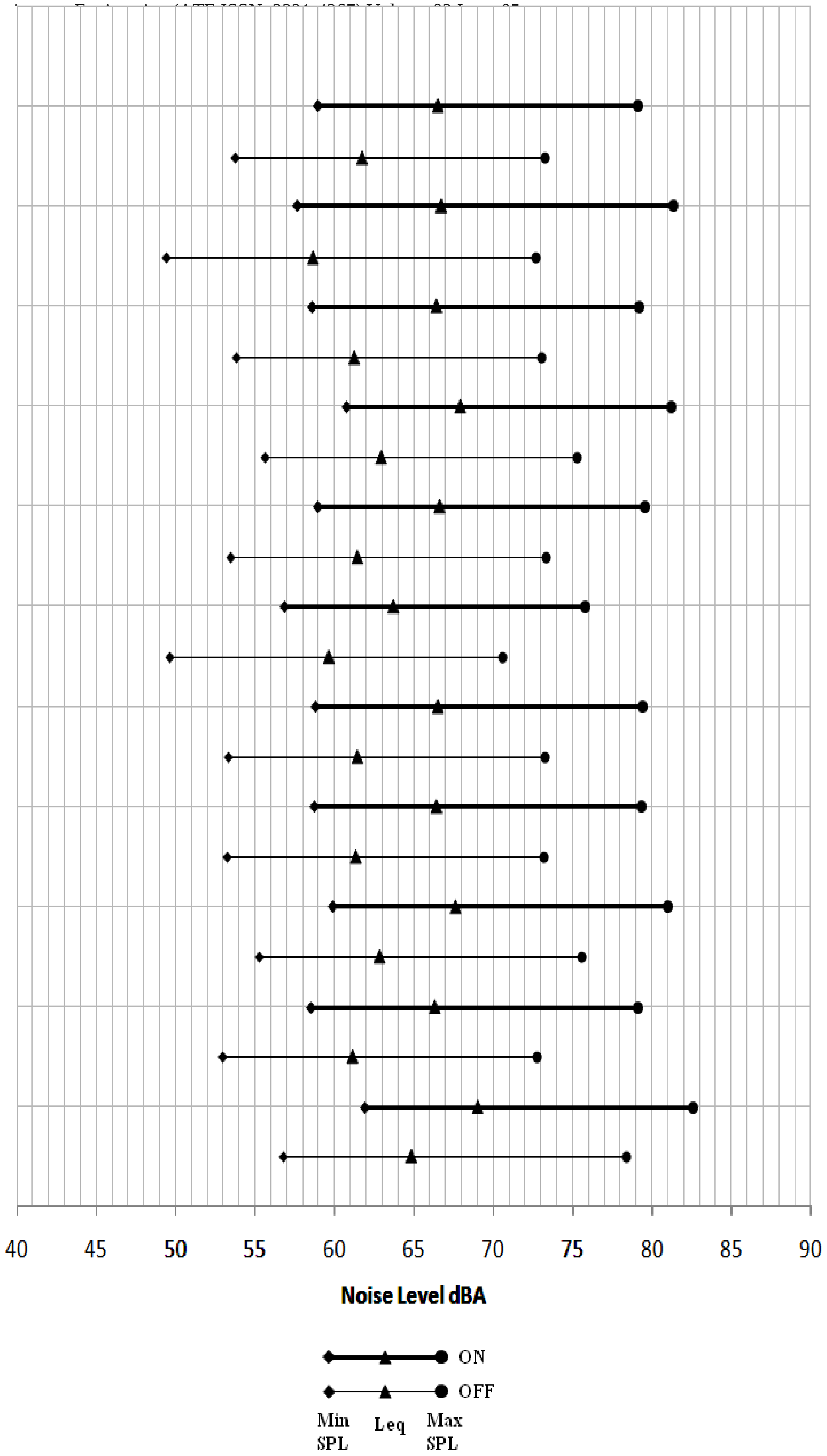


Figure 2: Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Their Construction (Means)

Factor	Classification	N
District Classifica -tion	High	187
	Middle	864
	Indigenous	326
Users' Level of Education	Illiterate, Elementary & Intermediate	79
	High School	245
	Bachelor	587
	Master, Ph.D. & others	271
Users' Monthly Income (SR thousands)	<6	172
	6 - <9	331
	9 - <12	401
	12+	277
Users' Crowding (Number of Persons in Locations)	1	165
	2	435
	3-4	231
	5-13	355
Room Function	Bedroom	581
	Living Room	262
	Dining & Guest Room	198
	Kitchen & Others	137
Type of Furniture	Living Sets with or without Cabinet	318
	Living sets,cabinet,beds	156
	Beds with or without cabinet	451
	Single cabinet or with others	144
	Arabian	72

N: Numbers of A/C Units

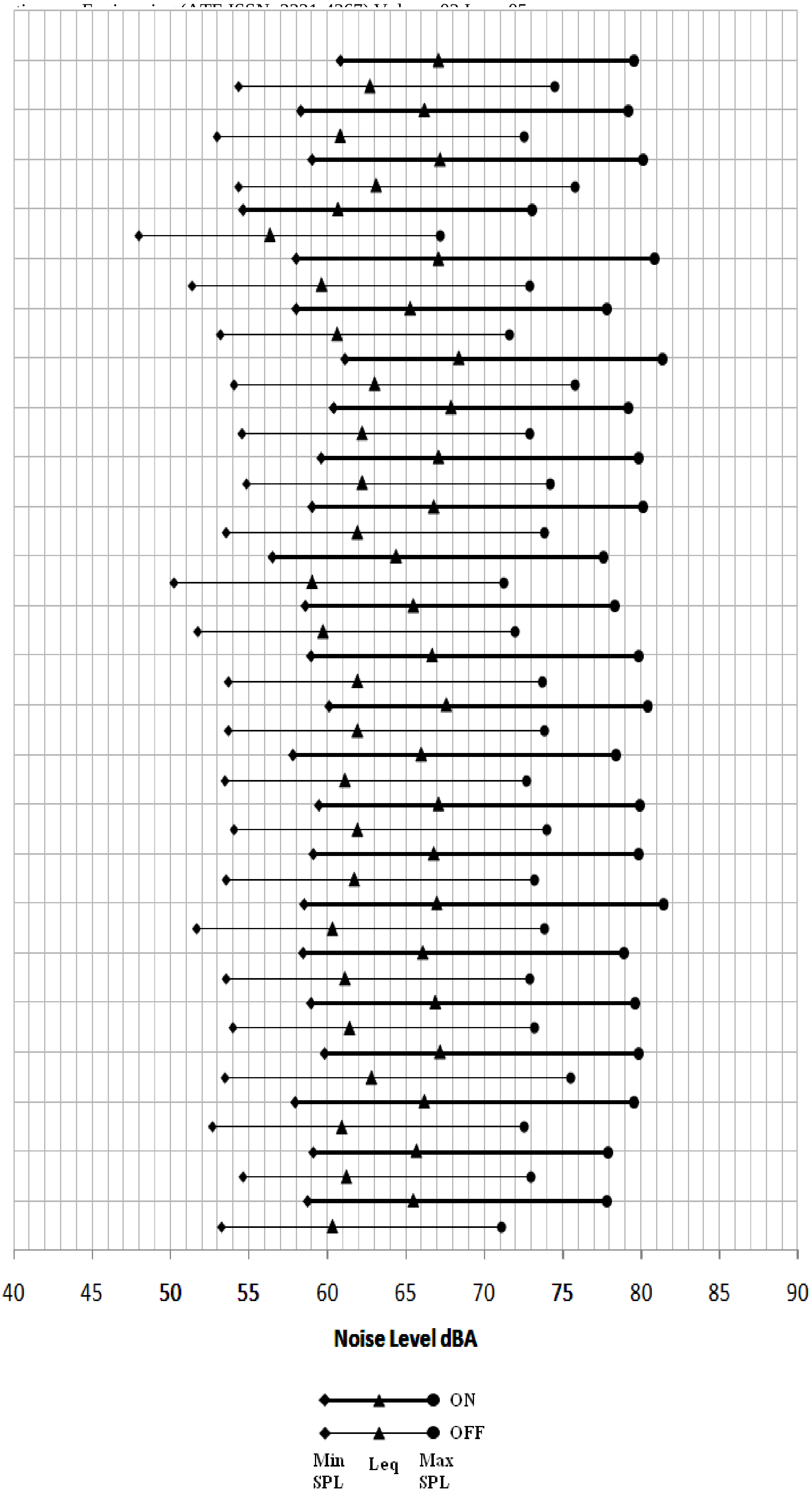
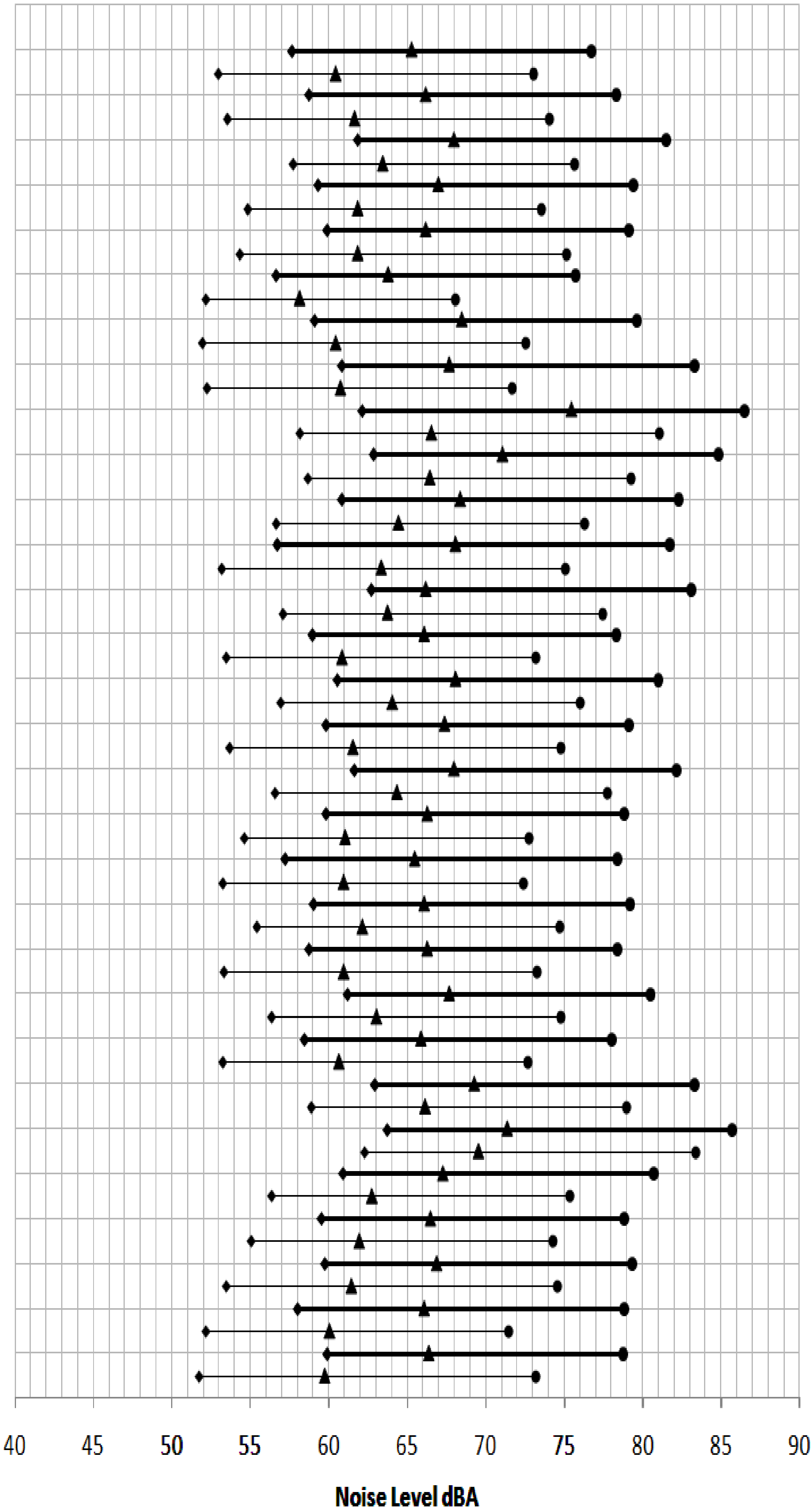


Figure 3: Noise Pollution Generated from Window Air-Conditioning Units in Residential Buildings in Makkah Region (KSA) as Related to Some Socio-Economic Factors of the Users (Means)

Factor	Classification	N
Brand Name	Carrier	510
	York	407
	Sanyo	115
	Falcon	82
	Mitsubishi	80
	General	75
	Gibson	68
	Al Zamil	66
	Hitachi	52
	Craft	51
	Gold Star	60
	Admiral	29
	Samsung	25
Power	18,000 BTU	1450
	24,000 BTU	376
Duration of Use (Years)	One	304
	Two	160
	3 – 4	729
	5 – 8	573
Fixing Method	A	346
	B	1151
	C	316
Insulation	Wood	1413
	Foam	70
	Foam & Wood	41
	Metallic	258
Location	Street Side	1168
	Building Side	207
	Fence Side	361
	Ventilation Chute	55



N: Numbers of A/C Units

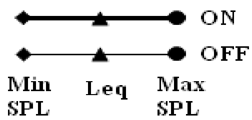


Figure 4: Noise Pollution Generated from Window Air-Conditioning Units in Institutional Buildings in Makkah Region (KSA) as Related to Their Nature, Installment and Operation (Means)

Factor	Classification	N
Walls	Bricks	1686
	Concrete	64
	Wood	33
Floors	Carpet & Rugs	535
	Marble & Tiles	1145
Ceilings	Concrete	1448
	Bricks	240
	Wood	63
	Metallic (Steel & Others)	54
Door	Wood	1450
	Glass	116
	Aluminum, Glass & Others	245
Windows	Aluminum & Glass	927
	Wood & Glass	712
	Others	175
Curtains	Fabric	321
	Glass Strips	150
	Blinds	776
	Others	648

N: Numbers of A/C Units

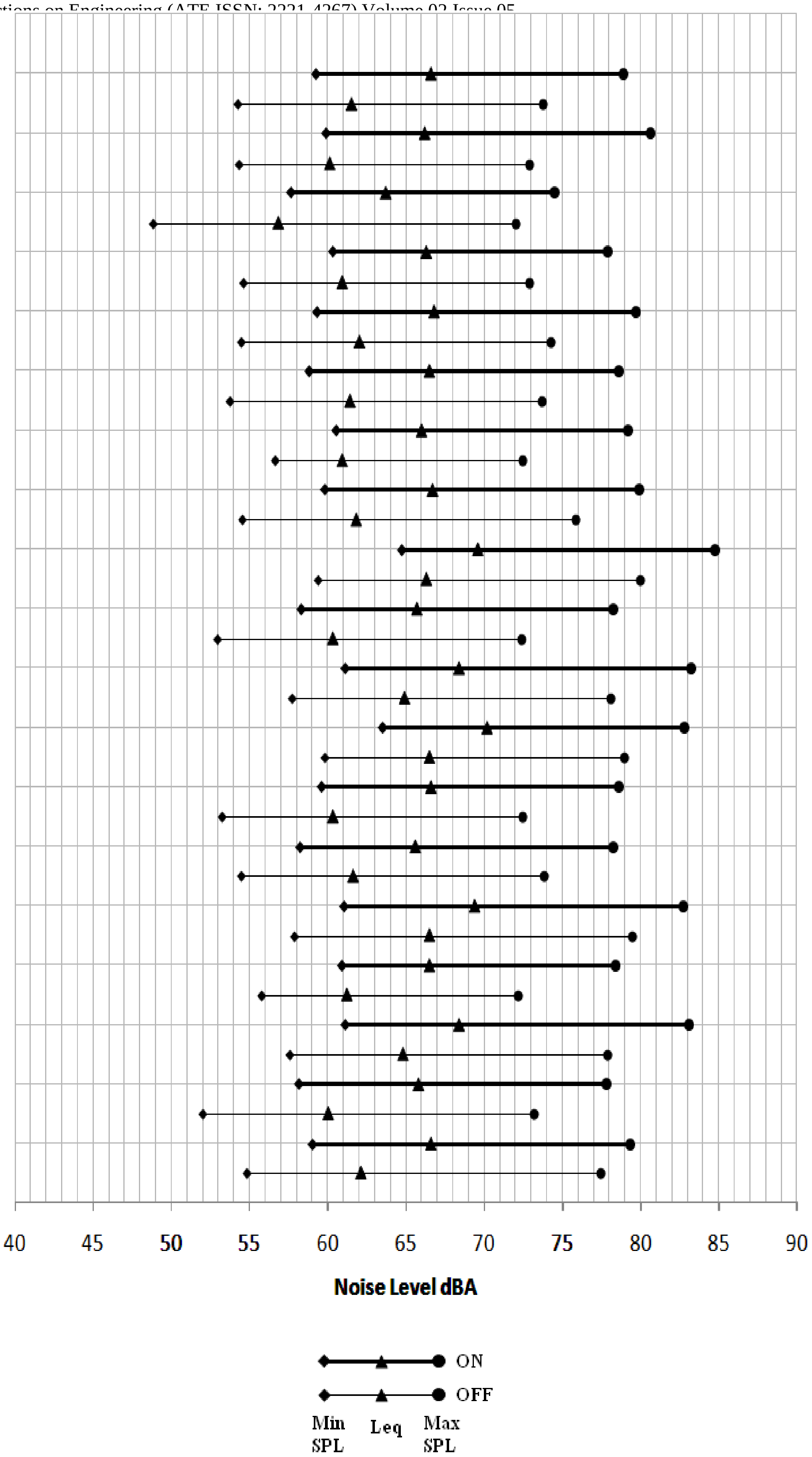


Figure 5: Noise Pollution Generated from Window Air-Conditioning Units in Institutional Buildings in Makkah Region (KSA) as Related to Their Construction (Means)

Factor	Institution	Classification	N
District	Schools	High	111
		Middle	498
		Indigenous	27
Users' Crowding (Number of Persons in Location)	Shops	1	132
		2	153
		3 & 4	95
		5 – 15	44
	Government & Office Buildings	1	154
		2	168
		3	64
	Schools	29 & 30	83
		31 – 33	83
		35	61
		36 – 38	88
Room Function	Hospital & Polyclinics	Employee Rooms	27
		Reception Rooms	23
		Examination Rooms	233
		Waiting Rooms	86
	Government Buildings	Employee Rooms	392
	Schools	Class Rooms	470
		Offices	152
Type of Furniture	Shops	Living sets, Cabinets	88
		Others(unclassified)	110
		None	184
	Hospitals & Polyclinics	Living sets with/without Cabinets	122
		Beds Living set, Cabinets	201
	Government & Office Buildings	Living sets, Cabinet & Others	205
		Cabinet & Others	177
	Schools	Living sets	168
		Cabinet & Others	77
		Others	391

N: Numbers of A/C Units

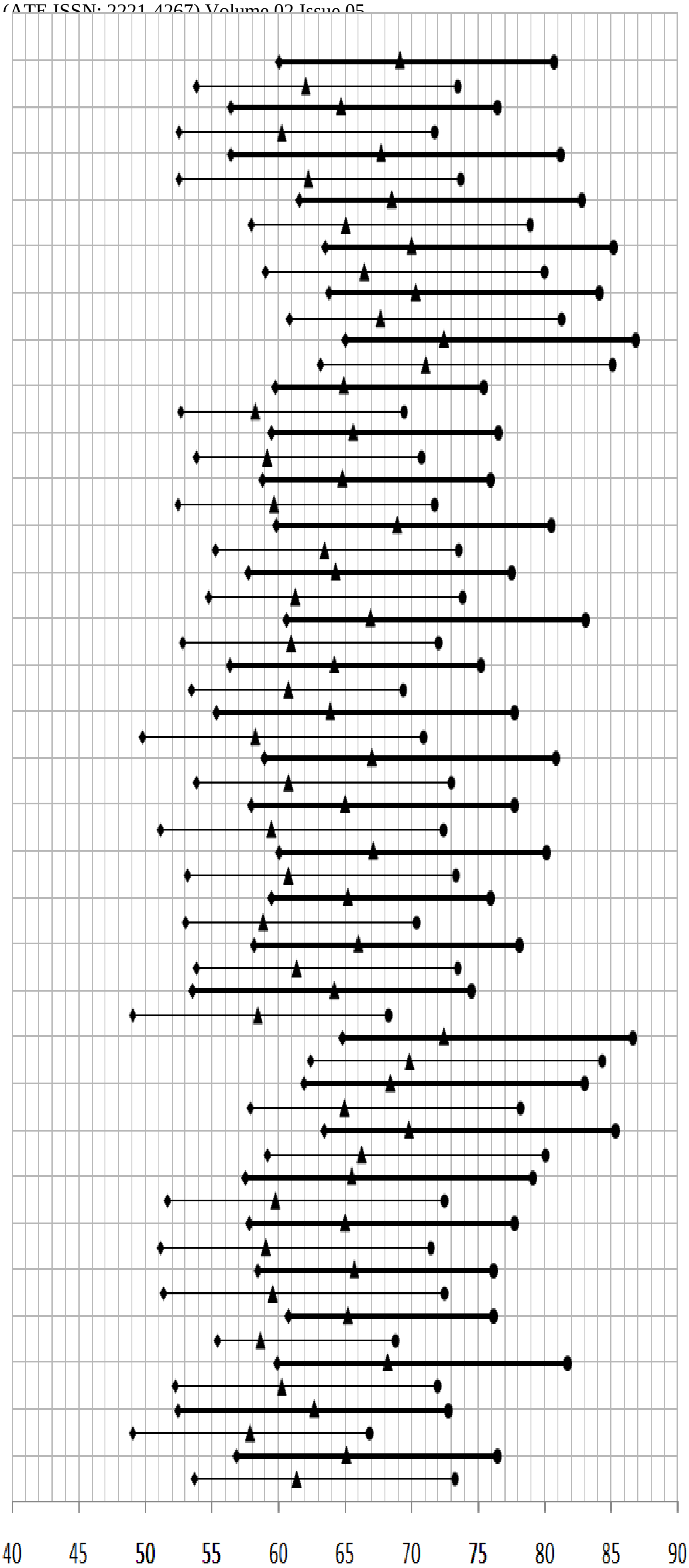


Figure 6: Noise Pollution Generated from Window Air-Conditioning Units in Institutional Buildings in Makkah Region (KSA) as Related to Some Socio-Economic Factors of the Users (Means)