

# A SURVEY ON AUDITORY, VISUAL, THERMAL COMFORT AT A LIBRARY

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## ABSTRACT

A research project is designed to evaluate different aspects affecting human comfort in an architectural space. One of the basic parts of the research project is the evaluation of the auditory, visual and thermal comfort. A university library in Istanbul is selected as the subject of the research. The library building, which has unusual settlement and design peculiarities, is an interesting case from acoustical view point as well, because of the closeness to a heavy traffic road and architectural properties. This study deals with the investigation and the evaluation of the library building from physical environment comfort conditions. Measurements are repeated throughout seasons of the year to demonstrate the various effects of the differences that may occur at outdoor and indoor. A questionnaire survey developed for the purpose of the general evaluation of the building is also carried out. The study clearly showed that the library building needs an important renovation in order to improve users comfort.

## KEYWORDS

Acoustics, lighting, thermal, comfort, library.

## 1. INTRODUCTION

Each building has special requirements originating basically from its function, design and location to achieve comfort conditions. Occupants or users satisfaction on a building or a space depends on the combination of several factors that affect human beings in an interactive way. The abundance of the factors increases the complexity to evaluate the results as a whole.

A research project has been developed to evaluate different aspects affecting human health and comfort in an architectural space. The aims of the project are to determine the physical and social environmental properties of the buildings, to investigate their biological, psychological and sociological effects on users and to develop a methodology to evaluate the buildings as a whole. The building chosen to work on at the project is the library of Yıldız Technical University in Istanbul. Physical indoor and outdoor properties such as; environmental, architectural, visual, acoustical, sense of touch (hardness, roughness, sharpness, slipperiness, warmth, dirtiness), atmospheric (heat, humidity, air movement, micro-organisms, dust, radon, electromagnetic sources, fire protection) etc. have been planned to be examined during one year period and evaluated interactively. This paper presents the results of work done to show the auditory, visual and thermal comfort at the library.

Subjective and objective means of evaluations namely measurements and surveys are realised in order to examine the situation. In the evaluation of the library, the following order is pursued; measurement results are compared with the recommendations/regulations, social

surveys are analysed, objective and subjective findings are compared. Trimonthly four sequences of measurements, spread out seasonally on one year, have been carried out, however a control measurement has also been realized. Third and fourth sequences are within the educational term. Measurements concerning acoustical, visual and thermal comfort have been realized at the same time and during working days. A questionnaire survey covering 21 questions related with the general profile and pleasance of the users from the building, besides acoustical, visual and thermal comfort evaluations has been designed. Two sequences of questionnaire surveys, related with the third and the fourth measurement sequences have also been made.

## 2. BUILDING PROPERTIES AND USERS PROFILE

The library building is located at the edge of a heavy traffic road. Building has got two galleries connecting its three floors and entrance perpendicularly. The basement of the building is being used as a saloon for periodicals. At the entrance floor there is check-in, copying facilities and the Internet center. Reading saloons as well as stores and offices take place at first, second and third floors. Reading saloons are located at the backside therefore somehow protected from the road traffic noise. Second floor plan and a section of the building are given in Figure 1.

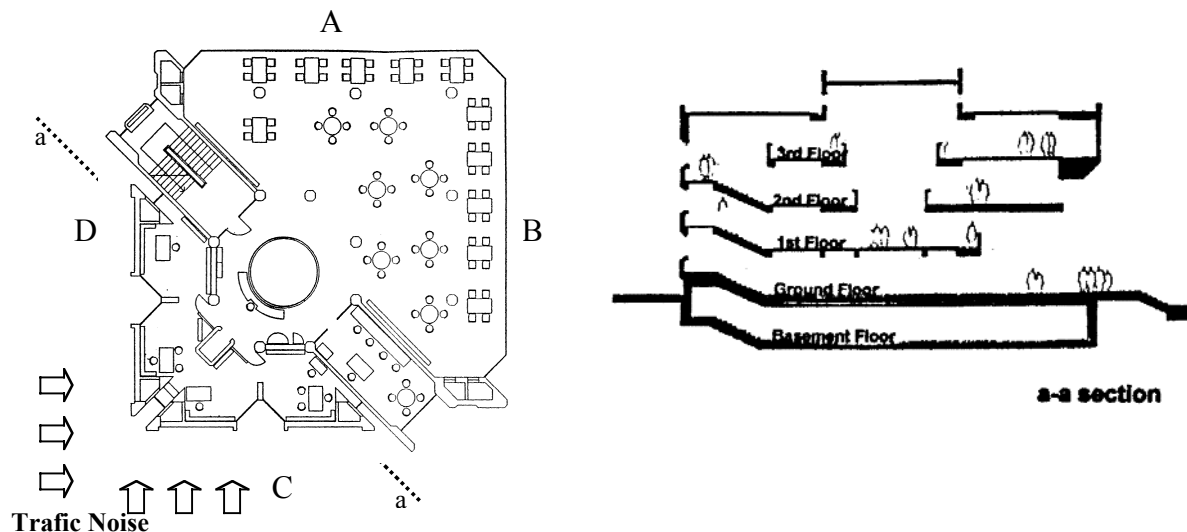


Figure 1: Second floor plan and a-a section of the library

Students and members of the university use the library during working days and hours. The service capacity of the building is 250 people and the general percentage of occupancy is 35%. The area per person at the reading saloons is 2.66 m<sup>2</sup>. Users profile of the library determined by questionnaire surveys is shown in Table 1.

TABLE 1  
The results of questions related with users' profile

Questions	Options	%	Questions	Options	%
Q2 Age group	16-24	89,4	Q6 Frequency of usage	Seldom	39,2
	25-34	8,3		1-2 times a week	46,7
	35-44	1,5		3-4 times a week	12,5
	45-54	0,8		Each day	1,7
Q5 Usage aim	Study	74,2	Q7 Time of usage (hour/day)	>1 hour	11,7
	Research	22,7		1-2 hours	53,3
	Internet	16,7		2-3 hours	28,3
	Staff	9,1		4 < hours	6,6

## 2. EVALUATION OF ACOUSTICAL COMFORT

Table 2 gives the summary of the results of the acoustical measurements done according to Noise Control Regulation (of Turkey) in Leq dBA.

TABLE 2  
Indoor and outdoor Leq dBA levels measured trimonthly

	M. p o i n t	1 <sup>st</sup> measurement sequence Summer / 21.July.99				2 <sup>nd</sup> measurement sequence Autumn / 01.Oct.99				3 <sup>rd</sup> measurement sequence Winter / 31.Jan.00				4 <sup>th</sup> measurement sequence Spring / 12.Apr.00				5 <sup>th</sup> measurement sequence Summer / 26.July.00			
		Indoor				Indoor				Indoor				Indoor				Indoor			
		Out	1 <sup>st</sup> F	2 <sup>nd</sup> F	3 <sup>rd</sup> F	Out	1 <sup>st</sup> F	2 <sup>nd</sup> F	3 <sup>rd</sup> F	Out	1 <sup>st</sup> F	2 <sup>nd</sup> F	3 <sup>rd</sup> F	Out	1 <sup>st</sup> F	2 <sup>nd</sup> F	3 <sup>rd</sup> F	Out	1 <sup>st</sup> F	2 <sup>nd</sup> F	3 <sup>rd</sup> F
Leq dBA	A	60	43,6	47,1		59,9	46,0	46,9		61,3	49,8	47,6		60,2	47,0	51,8		61,7	44,7	45,7	
	B	62	45,3	46,5	39,9	61,8	44,4	46,3	35,5	63,6	50,7	46,0		62,0	48,3	51,3	35,3	63,3	45,7	44,1	
	C	70	59,2	50,1	52,0	70,9	49,9	49,7	51,5	70,5	53,5	52,8	51,5	69,7	53,9	53,9	54,1	70,4	61,7	51,3	58,8
	D	68	57,5		48,8	66,7	48,7	47,4	48,1	67,0	54,6	47,6	47,0	66,7	49,1	47,4	50,9	63,0	51,4	46,5	59,8

A and B measurement points, illustrate the situation in reading spaces, whereas C and D points illustrate offices and stores (traffic noise affects basically C and D façades). Table 3 shows the average values of A and B points upon floors and measurement sequences. Measurements sequences are grouped to illustrate the educational and non-educational terms. The analyze of the Table 3 demonstrates that although outdoor noise does not vary seasonally, there is significant changes at indoor noise. Average results of summer and autumn indoor LeqA levels are lower than those of winter and spring. Taking into consideration the acceptable levels given in the latest WHO publication which are 55 LeqA for outdoor and 35 LeqA for indoor, all of the measured levels are seen to be significantly higher than the requirements. On the other hand, outdoor noise levels at C and D points (average 68 LeqA) are significantly higher than those measured at A and B points, causing high indoor noise levels at offices. Indoor noise levels on this side of the library depend on the floor and the façade; they are higher at first floor and at façade C.

TABLE 3  
Average (A and B points) Leq dBA values at the reading saloons as to floors and measurement periods

	Measurement Sequence No	Outdoor	Indoor		
			1 <sup>st</sup> Floor	2 <sup>nd</sup> Floor	Average
Non-Educational Term (summer- autumn)	1	61,0	44,5	46,8	45,6
	2	60,9	45,2	46,6	
	5	62,5	45,2	44,9	
Educational term (winter- spring)	3	62,5	50,3	46,8	49,1
	4	61,1	47,7	51,6	
Average		61,6			

At the surveys, 36% of the participants reported annoyance from the outdoor noise and 56% from the indoor noise. 32% of the users think that noise affects their performance, 58% mention that they are intermediately annoyed from noise. Comparison of the measurements with the survey results shows good accordance. Average level of the rarely occupied period (non-educational term) may be regarded as the background noise caused by outdoor noise. There is a four dB (approx.) difference, between mostly occupied (educational term) and rarely occupied periods, which is basically caused by the presence of the occupants. The high indoor noise levels can explain the reported high relationship between the general feeling of comfort and annoyance from indoor noise and also between the disturbance from indoor noise and working performance. Objective and subjective studies carried out within this study have shown that the acoustical environment of the library building does not fulfil the required conditions, neither for the offices nor for the reading saloons.

### 3. EVALUATION OF VISUAL COMFORT

Objective and subjective evaluation related to the natural and artificial lighting conditions are carried out in the reading saloons and offices of the library. Lighting quantity (illuminance), lighting quality (light colour and direction, shadows, illuminance distribution) and features such as light reflectance surfaces, colours of the interior are taken as the basic criteria in the objective measurements for visual comfort. In the evaluation of the objective measurements, the recommended international literature values are used. All rooms have window and artificial lighting system (fluorescent luminaries with diffuser; direct lighting) providing general lighting. The objective evaluation results of the natural and artificial lighting are summarized below and shown in Table 4.

**Illuminance:** Natural and artificial illumination levels on the working plan are below the recommended values (500 lm/m<sup>2</sup>). Also, integrated lighting conditions (natural+artificial) do not provide necessary illuminance. Daylight is higher than the required values at the vicinity of the windows in the first and second floor reading saloons. But, these situations have not been taken into account in the evaluation, since the ratio of the sufficiently illuminated areas to the total working plan area is very small.

**Colour of light:** Lamps used at the rooms are fluorescent with 2A colour-rendering index. Therefore, colour of the artificial light is not good.

**Direction of light and shadows:** Direction of light and shadow quality can be accepted within the literature values, except the basement reading room.

**Illuminance distribution:** Illuminance distribution on the working plan is not uniform ( $0.8E_{avg} \leq E_{min}$ ) in the examined rooms.

**Specification of the internal surfaces:** Interior surfaces are mat and have appropriate conditions for light reflectance. On the other hand table surfaces are not mat and cause glare. Light reflectance of the tables is lower than the recommended values.

TABLE 4  
Objective evaluation of natural (N) and artificial (A) lighting  
(*"+" shows appropriate and "-" shows inappropriate conditions*)

Floor	Room Function	Lighting Quantity		Lighting Quality							
		N	A	Light colour		Light direction		Shadows		Illu.distribution	
				N	A	N	A	N	A	N	A
Basement	Reading	-	-	+	-	-	+	-	+	-	-
Ground	Computer	-	-	+	-	+-	+	+-	+	-	-
First	Reading	-	-	+	-	+-	+	+-	+	-	-
	Office	-	-	+	-	+-	+	+-	+	-	-
Second	Reading	-	-	+	-	+-	+	+-	+	-	-
	Office	-	-	+	-	+-	+	+-	+	-	-
Third	Office	-	-	+	-	+-	+	+-	+	-	-

According to the survey results, the illumination level is well (26%) and sufficient (54%) for the users. 20% of the users have stated that the illuminance is insufficient. For lighting quality, most of the users (60%) are not satisfied. For example, 39% of them told that they were moderately disturbed from the illuminance differences on the desk, and 40% of users have mentioned slight annoyance.

The objective and subjective evaluation results of visual comfort can be compared as below:

- The interiors examined have lower values of illuminance than the recommended values. However 80% of users think that the illuminance is sufficient. Surprisingly there is no harmony between objective and subjective evaluation on the lighting quantity.

- Lighting quality of the examined spaces is not sufficient. The users declared similar reactions, in other words, there is good accordance between measurements and survey results for lighting quality.

#### 4. EVALUATION OF THERMAL COMFORT

The parameters that have been measured are those that affect thermal comfort. These are;

- External climate conditions: external air temperature, humidity and air velocity.
- Thermal comfort factors of the interior: Internal air temperature, relative humidity, air velocity, the internal surface temperature of the building envelope and floors.

In the evaluation of the objective measurements, comfort graphics developed by P.O. Fanger are used. The objective evaluation results are summarized and shown in Table 5.

TABLE 5  
Objective evaluation of thermal comfort  
(*"+" shows appropriate and "-" shows inappropriate conditions*)

Floor	Room Function	Internal air temperature		Internal surface temperatures						Relative humidity		Air velocity	
		Cold Period	Hot Period	Glass		Wall		Floor		Cold Period	Hot Period	Cold Period	Hot Period
				Cold Period	Hot Period	Cold Period	Hot Period	Cold Period	Hot Period				
Basement	Reading	-	+			-	+	-	+	+	+	-	-
Ground	Computer	-	+	-	+			+	+	+	+	-	-
First	Reading	+	+	-	+			+	+	+	+	-	-
	Office	+	+	+	+	-	+	+	+	+	+	-	-
Second	Reading	+	+	-	+			+	+	+	+	-	-
	Office	+	+	+	+	-	+	+	+	+	+	-	-
Third	Office	+	+	+	+	+	+	+	+	+	+	-	-

**In the hot season,** when temperatures exceed 25 -C the building become uncomfortable. Below 25 -C living conditions within the building are comfortable in terms of thermal comfort. The internal temperature increases from the basement to the third floor. However, the difference in temperature doesn't exceed 2 -C, therefore it can be said that the distribution of temperature is relatively homogenous. Measured floor temperatures are inside the comfort zone.

**In the cold season,** on days with an outside air temperature of 6-7 -C the basement and ground floor temperatures are outside of the comfort range but 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> floors are within the comfort range. Inside the building the temperature differences are not great and a homogenous distribution of temperature is found. During the overcast sky conditions internal temperatures of window surfaces are outside the comfort zone. On the clear sky conditions temperatures of these surfaces are inside the comfort zone. In addition, the internal surface temperatures of small opaque components of the building envelope are outside of the comfort range.

**In the cold and hot season,** measured relative humidity values within the building is between 30% and 60%, consequently humidity values are inside the comfort range

Results of the survey realized on January and April months in the educational term are summarized in Table 6. According to the survey results, the internal air and floor temperatures are sufficient for the majority of users but most of the users are not satisfied in terms of internal temperatures of the glass surfaces and air velocity.

The objective and subjective evaluation have shown that thermal performance of the building changes according to the stories of the building and usage period. In the cold period,

majority of the required conditions in terms of thermal comfort have been obtained on the upper floors of the buildings but not on the basement and ground floors. In the hot period, when the outdoor air temperatures are below the 25 -C thermal comfort is obtained.

TABLE 6  
Subjective evaluation of thermal comfort

Thermal comfort parameters	Winter term (January)	Spring term (April)
Internal air temperature	% 69 sufficient, % 31 insufficient	%81 sufficient, %5 excessive
Temperature of the glass surfaces	% 46 sufficient, %54 insufficient	%35 sufficient, %65 excessive
Floor temperature	%58 sufficient, %42 insufficient	%75 sufficient, %25 insufficient
Air velocity	% 14 pleasantly, % 38 airless	%23 sufficient, %50 airless

## 5. CONCLUSION

Objective studies carried out within this study showed that acoustical, visual and thermal environment of the library building do not fulfill the required conditions, neither for the offices nor for the reading saloons. Although the results are not extremely bad, it is seen that for a great part of the investigated parameters, required conditions are not achieved.

Findings of the questionnaire survey related with the general opinion on the building are given in Table 7. The perceived comfort at the building is at moderate level and does not reflect the findings of objective studies.

TABLE 7  
General opinion on the library

Options	General impression (%)	Comfort feeling (%)
High	14.8	16.3
Medium	70.3	66.0
Low	14.9	17.7

Next challenge of the research is to find a way to evaluate interactively the various factors affecting human comfort. Data obtained on the acoustical, visual and thermal situation of the building will be evaluated as to the general feeling of comfort and working performance, trying to create a weighted evaluation model. If a significant way of weighted rating can be detected among different factors affecting human perception of the physical environment, it can even be suggested that the design or improvements of the built environment could be done according to the importance of the factor.

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