SPEECH INTELLIGIBILITY AND PRIVACY IN EATING FACILITIE

Submitted by:

Ebru Özgüner

Tuna Zişan Emirtekin

Pardis Taherzadeh

Abstract

This article reports the initial finds of a research that is concerned with the speech intelligibility and privacy in eating facilities within Bilkent University and Middle East Technical University. Three eating facilities in Bilkent university campus and two in METU campus was selected for research. Although there are studies concerned with the acoustical characteristics of eating facilities, there isn't enough research focusing on users' expectation and interpretation of their soundscape environment. This study focused on the user's speech intelligibility and privacy of their surrounded area in different eating facilities. The interviews were through questionnaires. In depth interviews are held with the people sitting in the eating facilities. Based on their subjective responses to the questions, a theoretical framework is generated to gain an insight on the factors that affect most the user's speech intelligibility and speech privacy. Acoustical characteristics of the eating facilities measured through in-situ measurements of sound pressure levels (SPL) and equivalent continuous noise level (Leq). According to the data that were analyzed from questionnaires and in situ measurements, statistical analyzes were done.

Keywords: speech intelligibility, speech privacy, eating facilities

1. Introduction

An eating facility is generally an indoor plaza or common area within a facility that consists of different seating arrangements according to layout of the space and provides a common area for self-serve dinner. This paper focused on the eating facilities and their acoustical comfort because this areas are places with high sound pressure levels. This high sound pressure level is due to higher seating density, the number of seats divided by the floor area, and the Lombard effect where people talk louder as other people talk louder in order to be heard (Bronkhorst,2000).

Speech intelligibility and speech privacy are the factors for providing acoustical comfort. In eating facilities, it is difficult to provide proper speech intelligibility and privacy, which means the rating of the proportion of speech understood by the people at their own table and intruding speech sound come from adjacent tables in a dining room respectively.

Lombard effect is not only an important phenomenon in eating facilities but also in most of the public spaces. Lombard first described it, “the adaptation of speech to overcome the deleterious effects of noise, a nonlinear distortion which depends on the speaker voice level, the background noise level and the type of noise.”(1911). It was concluded that sound pressure level below 45 dB do not seriously influence vocal effort. However while this value is over 55db it effect vocal effort and result in a 0.38-dB increase in speech level for every 1-dB increase in the sound pressure level (Korn, 1954).

Astolfi and Filippi on a study on optimal acoustic conditions in pizzerias. They measured noise levels in same seating densities with different vocal efforts of customers. According to subjective results fair intelligibility can be provided in a seating density of 0.95 p/m^2 with noise level of 72.6 dB due to the Lombard effect and a raised vocal effort. In these conditions enough speech privacy cannot be provided considering the 1.5 m distance between tables. However, if vocal effort become normal and seating density remain the same, speech intelligibility at the table is poor. In another condition, they measured noise levels in same vocal effort of customers and different seating densities. In seating density of 0.4 and 0.2 p/m^2 respectively, and a normal vocal effort of the speaker, the noise levels calculated are 69.4 and 66.7 dBs. The results show that in seating density of 0.2 p/m2 the speech intelligibility and speech privacy targets are achieved (2004).

Background noise such as music, machine sounds, HVAC etc., is another factor which effect the speech intelligibility and speech privacy in food courts. Navarro and Pimentel measured the background noise without any conversation noise in two food court areas. The calculated value of sound pressure level was high in one the food courts. This means that users in this places raised voice in their communication, which is an indication of excessive vocal effort and not ideal from the point of view of acoustical comfort. Therefore, for reaching an appropriate acoustical quality which is lead to proper speech intelligibility and speech privacy, the background noise levels must be reduced (2007).

According to Kang, for improving speech intelligibility in dining spaces, investigating the effectiveness of strategic architectural acoustic treatments are important. Computation using a typical dining hall design shows that a design merely based on the current guidelines for space use, say 1 m2 per diner, and may lead to very poor speech intelligibility. He concluded that the shape of a dining hall is effected with the absorbing material's arrangements (2002).

The aim of this study is to assess the effect of acoustical conditions on speech intelligibility and speech privacy of eating facilities, with emphasis on the number of users in different day times, seating density and calculating background noise in different eating facilities of Ankara. This was carried out through site measurements of sound pressure level and a questionnaire. The sound sources apart from speech were considered here as background noise and their effect was also included in the analysis. Number of customers during daytime is changing and it is affecting the calculated sound pressure levels. Also the measurement of sound pressure level during weekdays may be differ and its effects on speech intelligibility and speech privacy were investigated.

2. Methodology

2.1 Case study settings

Research setting chosen as eating facilities in Bilkent University and Middle East Technical University (METU). Three eating facilities were selected on Bilkent University. Marmara, Café inn, Kirac café are the eating facilities names that were selected in Bilkent University (A3, A4, and A5). Cati café and dining hall are the names of the eating facilities that were selected in METU (A1, A2). The reason of choosing these eating facilities is the lengthwise rectangular shape of all of them and all of them are in the concept of self-service

eating facilities. These eating facilities are of the most popular restaurants of these universities and also used by most of the students and professors.

2.2 Subjective Survey

Social surveys were done through structured questionnaires. Structure questionnaire is a questionnaire that contains only closed-ended questions. In this study the participants were on the enclosed areas of the chosen eating facilities in two different university. The age of the interviewers ranged from 18 to 30. In each of the eating facilities fifteen participants answered the questions. Weekdays were chosen for doing our survey. We started our survey from Monday as the first day of the week and we continue to doing our survey on other weekdays until Friday. With regard to the selection of days and times to carry out the measurements, the option were for the period during lunch break from 12:00 to 14:00 in weekdays.

The questionnaire consist of two type of questions. First type of the questions was about speech intelligibility. The participants were supposed to answer that if they think speech intelligibility exist or not in that eating facility. While the participants thought that there were not speech intelligibility in that place, they were supposed to choose the factors that affect the speech intelligibility. The following sources of residual noise may be identified in eating facilities: background music, HVAC noise, machine noise, other background noises, table distance and table dimensions.

The second type of questions was about speech privacy. On this type again participants were supposed to answer if they have speech privacy on the place or not. If the answer was 'No', they were supposed to answer to other questions of that type. The participants should select the factors that they thought were affecting their speech privacy on that place.

2.3 Objective measurement

Objective measurement of this research includes the in-situ measurement of Sound pressure level (SPL) and equivalent continuous noise level (Leq). In-situ measurements were done in order to analyze the background noise level of the eating facilities. They were conducted at each of the eating facilities using Bruel & Kjaer Sound Level Meter type 2230. Instrument is placed at 150cm height and sound levels are measured over 15 minute intervals. Five measurement points were selected for measuring. On each eating facilities one point at the middle and four corner measurement points were selected (Figure1). In order to carry out

measurements at the five selected points in each food court, a 30-min interval was adopted to accommodate four 5-min records and allow 10 more minutes for moving from point to point and setting up the equipment.

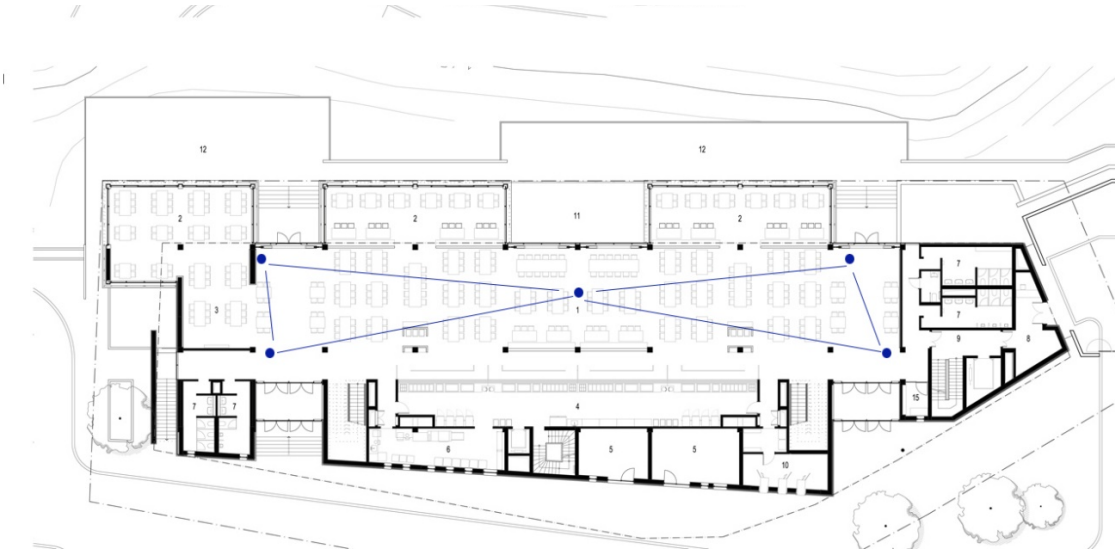

Figure 1.Marmara eating facility's first floor plan and 5 measurement points

In rooms with a low ceiling and high absorption the sound pressure level decreases with the distance from the source, and the average sound pressure level may be lower in eating facilities with a low ceiling. In these eating facilities the ceiling height was studied. The measurements of the total area and volume of these places were measured to understand what the effect of ceiling height is.

In this study, the table dimensions and the distance between tables were measured. In order to analyze these factors, the distance between two tables at one and only direction, which is side by side of chairs not back to back, were measured according to the seating plan. To measure side tables because of estimated effect on speech privacy were preferred (Figure2).

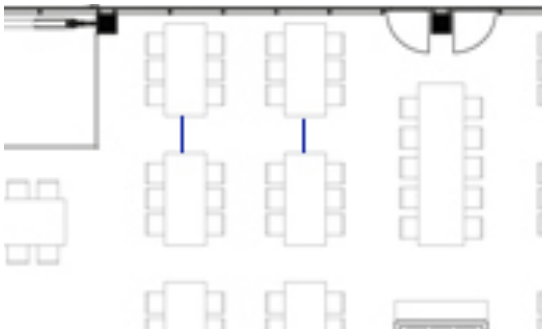

Figure 2. distance between side by side tables

2.4 Data analysis

Statistical analysis were used to analyze the data. Statistical analyses were performed by using SPSS for Windows (version 21.0; SPSS Inc.). According to SPSS for Windows, multivariate regression investigates the relationship between two or more independent variables and a single dependent variable. In this study dependent variables are speech intelligibility and privacy which were studied independently; independent variables are the distance between tables, the background noise, and the volume of the place. With the multivariate model, this study believe that the speech intelligibility and privacy in eating facilities are influenced most by one or more of the distance between tables, the background noise, and the volume of the place. In order to understand which one of these factors has more influence or do they have similar influence on speech intelligibility and privacy multivariate analysis were used. Through the calculation of the regression coefficients and partial correlations for each variable, the precise measures of the respective influence of these independent variables on the dependent ones were calculated.

In order to analyze the background noise there were carried out sound pressure measurement in these places and also with the questionnaire it was examined what people think about the sound level in that place and the ratio of each answer were taken data in this study.

3. Findings

As the study concluded the sound pressure level, volume and table distances were ensured as seen in table below (table1).

Table 1.Sound pressure levels, volumes and table distances of eating facilities

Eating Facilities	Leq (dB)	Volume (m3)	Table Distances (cm)
Kıraç (Bilkent)	71,0	1657,5	18
Inn (Bilkent)	70,3	686,8	50
Marmara (Bilkent)	72,8	3239,5	0
Çatı (ODTÜ)	77,0	1810,0	40
Dining Hall (ODTÜ)	73,0	3423,0	25

According to questionnaire, participants' choice of factors that affect speech intelligibility and speech privacy in five different eating facilities can be seen in Figure 3 and Figure 4.

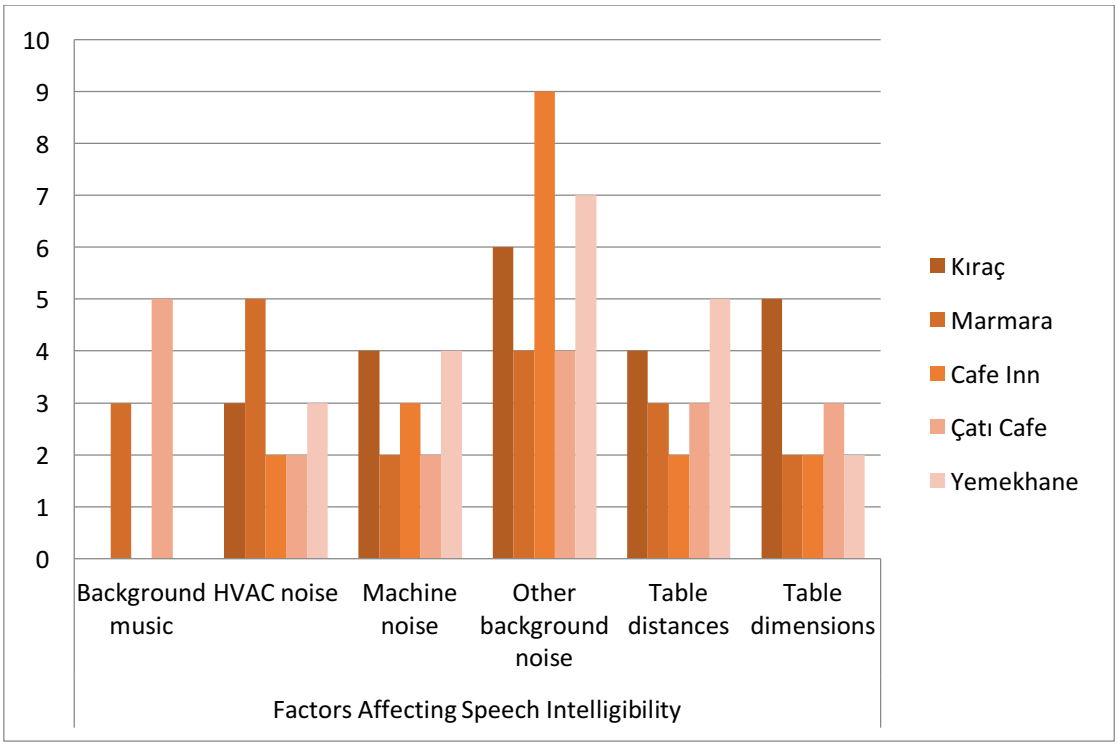

Figure3. Frequency distribution of factors affecting speech intelligibility

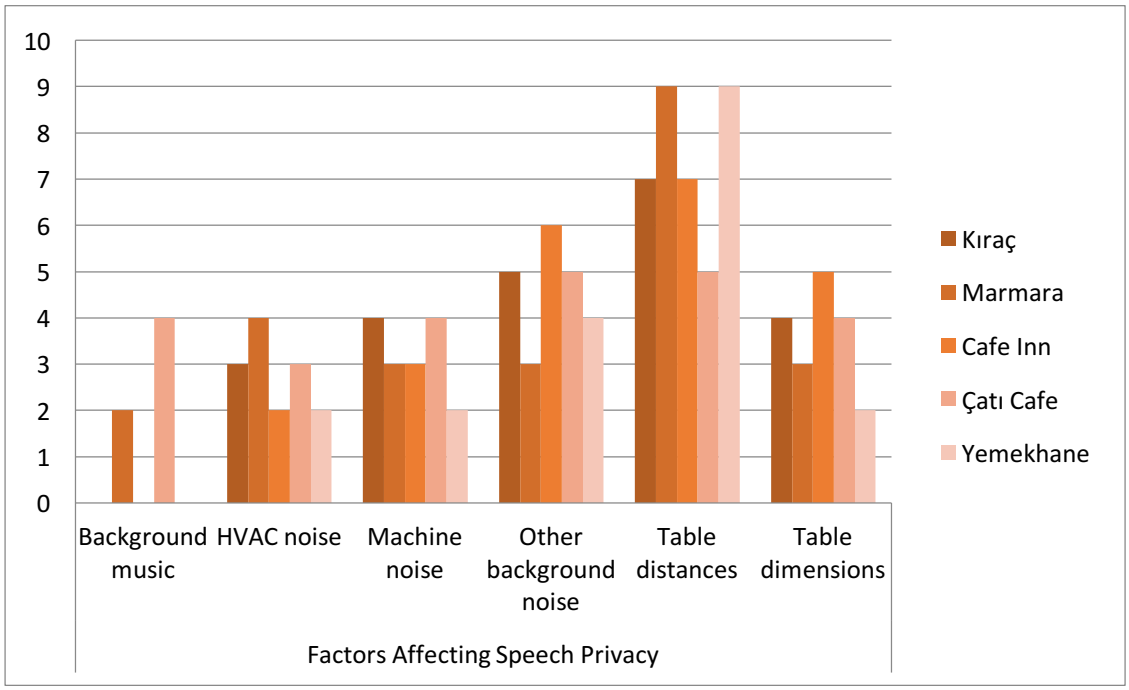

Figure4. Frequency distribution of factors affecting speech privacy

According to frequency distribution of factors that affect speech intelligibility, background noises are the most dominant factor, while according to frequency distribution of factors that affect speech privacy, table distances are the most dominant factor.

When the speech intelligibility was taken as a dependent variable, according to adjusted R square (0,744) there is a strong positive relation between the speech intelligibility and sound pressure level, volume and table distance (Figure 3). It means that all these independent variables are influential on speech intelligibility. Among these variables the most effective one is sound pressure level because its B value is the biggest one (Figure 4).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,967[a]	,936	,744	1,208

a. Predictors: (Constant), Leq(dB), table distance, volume m3

Figure 5 .Adjusted R Square value speech intelligibility as a dependent variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-41,825	18,044		-2,318	,259
	table distance	,025	,050	,206	,505	,703
	volume m3	,001	,001	,526	1,240	,432
	Leq(dB)	,673	,265	,734	2,539	,239

a. Dependent Variable: speech intelligibility

Figure 6 .B values of sound pressure level, volume and table distance according to speech intelligibility

When the speech privacy was taken as a dependent variable, according to adjusted R square(0,784) there is a strong positive relation between the speech privacy and sound pressure level, volume and table distance

(Figure 5). It means that all these independent variables are influential on speech privacy. Among these variables the most effective one is sound pressure level because its B value is the biggest one (Figure 6).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,973[a]	,946	,784	,893

a. Predictors: (Constant), Leq(dB), table distance, volume m3

Figure 7 .Adjusted R Square value speech privacy as a dependent variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-34,651	13,343		-2,597	,234
	table distance	,001	,037	-,001	-,002	,999
	volume m3	,001	,001	,399	1,026	,492
	Leq(dB)	,577	,196	,782	2,944	,208

a. Dependent Variable: speech privacy

Figure 8. B values of sound pressure level, volume and table distance according to speech privacy

4. Discussion

Accordding to Navarro and Pimentel (2008) , for reaching an appropriate acoustical quality which is lead to proper speech intelligibility and speech privacy, the background noise levels must be reduced. Similarly in this study, the background noise level is the most influential factor for speech intelligibility and privacy in these eating facilities. In order to achieve appropriate acoustical quality this level must be reduced.

According to Korn (1954) there is Lombard Effect in public spaces due to noise level higher than 55dBs. Also we found that, there is a strong relation between speech intelligibility and the background noise of measured eating facilities. In order to prevent Lombard Effect the background noise level must be lower than 55 dBs.

According to Astolfi and Filippi(2004) speech privacy cannot be provided while there is 1.5m distance between tables. According to our statistical analysis there is not any significant relation between speech privacy and table distances.

4.1. Limitations

The architectural acoustics treatments were not seen in any of the selected eating facility and that is why it was not a useful criterion for this study. The most dominant factor that effect speech intelligibility and speech privacy in this study was equivalent continuous noise level (Leq), because the measured value for this was very high. So, the effect of the other independent variables, volume and table distances, cannot be measured properly.

5. Conclusion

This study aims to relate the measured equivalent continuous sound pressure level (Leq) with the auditory perception of users: the speech intelligibility and speech privacy of users in eating facilities. According to frequency distribution of questionnaire results, the most effective factor that prevents speech intelligibility of participants was background noises and for speech privacy it was table distances. However, according to statistical analysis with multiple regression, for providing speech intelligibility and speech privacy in eating facilities the most effective independent variable is equivalent continuous noise level (Leq), because as we written in the limitations part the measured value for Leq was very high. In statistical analysis we found that, volume and table distances as independent variables were not as effective as measured Leq. Furthermore, the subjective ratings of noise levels of the users correlated well with the measured Leq values. There is not any difference between the subjective and objective measurements on different weekdays.

Although, there are many studies regarding noise annoyance and the objective acoustical parameters in public spaces, there are few that concentrate on the relationship of the subjective evaluation and the objective conditions with the characteristics of an enclosed space. In this study, we examined relationship of subjective and objective measurements to found factors that affect speech intelligibility and speech privacy.

References

Argyrous, G. (2011). *Statistics for research: With a guide to SPSS*. London: SAGE Publications.

Astolfi A., and Fillipi M.(2004). Good acoustical quality in restaurants: a compromise between speech intelligibility and privacy. *18th International Congress on Acoustics (18th ICA)*, Kyoto.

Bronkhorst, A. W., (2000)."The Cocktail Party Phenomenon: A Review of research on Speech Intelligibility in Multiple- Talker Conditions", ACUSTICA, Vol. 86.

Drullman R, Bronkhorst AW.(2004). Speech perception and talker segregation: effects of level, pitch, and tactile support with multiple simultaneous talkers. *Journal of the Acoustical Society of America* 116(5):3090–8.

Kang J. (2002). Numerical modelling of the speech intelligibility in dining spaces. *Applied Acoustics* 63(12):1315–33.

Korn .T.S.,(1954). "Effect of psychological feedback on conversational noise reduction in rooms," J. *Acoust. Soc. Am*. 26,5, 793-795.

Lazarus H.(1987). Prediction of verbal communication in noise – a development of generalized SIL curves and the quality of communication (Part 2). *Applied Acoustics* ,20(4):245–61.

Lombard E.,(1911). "Le signe de l'élévation de la voix _The characteristics of the elevation of the voice_," Annales des Maladies de l'Oreille, du Larynx, du Nez et du Pharynx, 37, 101–119.

Navarro M.P.N., and Pimentel R.L.(2007). Speech interference in food courts of shopping centres. *Applied Acoustics* 68(3); pp. 364-375.

Navarro M.P.N.,(2008) and Pimentel R.L. Sound pressure levels in food courts of shopping centres. *Noise and vibration worldwide* 39(5), pp. 26-30.

Appendix

Questionnaire

A. Konusma anlasilabilirligi

1. Bu mekanda konusma anlasilabilirligi var mi? (Cevabiniz evetse, bi sonraki soruyu cevaplamaniza gerek yoktur.)

☐ Evet ☐Hayir ☐Bilmiyorum

2. Sizce bu mekandaki konusma anlasilabilirligini etkileyen faktorler hangileridir?

☐ Arka plandaki muzik

☐ Havalandirma ekipmanlarinin sesi

☐ Makine sesleri

☐ Arka plandaki diger sesler

☐ Masalarin arasindaki mesafe

☐ Masanin boyutu

B. Konusma gizliligi

1. Bu mekanda konusma gizliligi var mi? (Cevabiniz evetse, sonraki iki soruyu cevaplamaniza gerek yoktur.)

☐ Evet ☐Hayir ☐Bilmiyorum

2. Bu mekanda masanizda konusurken, yan masalardaki konusmalari duyuyor musunuz?

☐ Evet ☐Hayir ☐Bilmiyorum

3. Bu mekanda masanizda konusurken yan masalarin sizi duydugunu dusunuyor musunuz?

☐ Evet ☐Hayir ☐Bilmiyorum

4. Bu mekanda konusma gizliligini etkileyen faktorler hangileridir?

☐ Arka plandaki muzik

☐ Havalandirma ekipmanlarinin sesi

☐ Makine sesleri

☐ Arka plandaki diger sesler

☐ Masalarin arasindaki mesafe

☐ Masanin boyutu

C. Kişisel Bilgiler

1. Cinsiyet: ☐ Kadın ☐ Erkek
2. Yaş:
3. Eğitim: ☐ Lisans ☐ Yükseklisans / Doktora
4. Fakülte: ☐ Güzel Sanatlar ve Mimarlık Fakültesi ☐ Diğer
5. Meslek: ☐ Öğrenci ☐Öğretim görevlisi ☐ Diğer

A1.Middle East Technical University (Cati café)

A2.Middle East Technical University (Yemekhane)

A3.Bilkent University (Marmara)

A4.Bilkent University (Café Inn)

A5.Bilkent University (Café kirac)