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Users' Responses to 2D and 3D Visualization Techniques in Urban Conservation Process

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Abstract— **This paper compares efficiency of two and three-dimensional visualization techniques which are developed for representation of spatial content of an urban historic site. The aim of this paper is to measure users' perception regarding the performance of these visualization techniques. Methodology is based on a questionnaire which is gathering the user's responses regarding comprehension and perception level of the case area's characteristics. The case study, which was held in Zeyrek urban historic site, comprises the application of 2D and 3D figures and schemes in order to represent the site characteristics, survey and analysis and proposals. As the fundamental finding of the study, it is concluded that spatial attributes and characteristics in 3D urban models are better defined than in 2D mapping technique. The study indicates that orientation sense of users and cognition of the townscape characteristics are the most prominent components of 3D urban model, generated within this case study.**

Keywords- urban conservation; visualization techniques; 3D urban model; CAD

I. INTRODUCTION

Investigation of visualization technique's efficiency is important with the reliability of the technique regarding representation level of the spatial content in the process of urban planning, communication and interaction among user groups. Computer aided three-dimensional (3D) urban models as innovative visualization techniques, have more capability to attain communication between user groups and to visualize comprehensive spatial information than conventional two-dimensional (2D) visualization techniques [1]. But 3D urban models are occasionally used to represent the final view of the urban structure and expressions of planning and design proposals. In urban conservation and design process, these models produce realistic images and views to facilitate not only the actual urban pattern but also proposed urban structure and form in order to evaluate the planning decisions [2], [3].

Comprehensive spatial analyses and investigations are required in urban planning and conservation studies devoted to evaluation of urban historic sites. Efficiency levels of visualization techniques may vary in the different stages of urban conservation process. Then examination of negative and positive aspects of these techniques has been anticipated to provide contributions directly to communication and interaction between professions and other stakeholders in urban conservation process.

Two main parameters are identified in describing and developing the efficiency of visualization techniques. These are spatial abstraction level from high to low geometric content and functionality on spatial data analysis and visualization [4]. Spatial abstraction parameter investigates the level of geometric and spatial content that visualization technique represents in computer interface. Functionality parameter defines the reliability and accuracy level of visualized information in the technique while interpreting the representation level of real space in virtual interface [1].

By the technological improvements in CAD, especially 3D models offer more efficient and practical processes throughout developing capability of representation and abstraction level of spatial content [1]. Another function of these models is the communication and interaction capability in urban planning and design process among users in different background [2]. As the technology growth in CAD applications, 3D urban models are used not only for the purpose of a mere visualization media but also a design aid while achieving an efficient interface in communicative urban design process [5].

As the fundamental function of 3D urban models, communication and interaction function facilitate the participation and collaboration processes in urban planning. Then such communication and interaction tools develop learning skills [6] and cognition and perception abilities of users and professions in planning and design disciplines [7], [8]. Hence the discussions related to these abilities of learning, cognition and evaluation processes of users and stakeholders, especially professions and other authorities is necessary to enhance the functional efficiency of 3D visualization techniques.

The number of studies concerning the investigation of users' subjective responses for 3D visualization techniques in urban planning and architectural design processes has increased recently. These studies mainly focus on two research questions. The first one is to which degree of realism 3D virtual environments can represent the real environment [9], [10], [11]. The second research question in related literature is to what extent various visualization techniques can represent the spatial or visual content [12], [13].

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Then this paper examines the efficiency of 2D and 3D visualization techniques those were developed for the case area, Zeyrek Urban Historic site, which is located in the north of the Historical Peninsula of Istanbul, Turkey.

The aim of this paper is to measure users' perception regarding the performance of 2D and 3D visualization techniques. Motivation of this paper is based on improving especially the tasks of 3D urban model as an active communication tool that is integrated with urban conservation. This examination was conducted using a questionnaire which compared the perceived level of spatial content of the site, represented by 2D mapping technique and 3D models.

II. METHODOLOGY IN THE QUESTIONNAIRE

This paper is based on the research held within the PhD study in 2009 [14]. A broader questionnaire study in 2008 was conducted to gather responses from various kinds of users, respectively graduate students in Faculty of Architecture, professions in planning and conservation institutions and high school students as the representatives of inhabitants. In the questionnaire, results of which are given in this paper, graduate students' responses have been investigated in two different groups; 2D mapping as the conventional representation technique and 3D urban model (in separate groups after separate presentations). Planning and design graduate students who are familiar to visual communication tools have assessed visualization techniques in terms of representation capability on urban conservation.

A. Visualization Techniques in Zeyrek

Zeyrek is located in the north of Historical Peninsula of Istanbul, on the slopes, viewing Golden Horn. In 1983 Zeyrek, as a quarter of Istanbul was included in the World Heritage List because of historical, aesthetical and architectural characteristics. Most important monument of the site is Mosque of Zeyrek that had been Monastery of Christ Pantokrator in Byzantium Period. Variety on cultural structure of the site is reflected to urban space that has traditional organic pattern, constituted with authentic timber Turkish houses [15].

In separate presentations, prepared within these 2D and 3D visualization techniques, "Zeyrek Urban Conservation and Design Project" [15] have been re-arranged within the purpose of the questionnaire. Presentation of "Zeyrek Urban Conservation and Design Project" which takes approximately ten-minute long is mainly formed of three stages. The first stage is preparation of base map and 3D urban model (Figure 1).

All maps and figures in both presentations, uses the same data, based on digital maps from municipality, on-site survey, and previous conservation and design studies and inventories prepared for Zeyrek urban historic site. Of all stages, as a CAD system AutoCAD 2004© is used to constitute 2D mapping technique and 3D urban model.

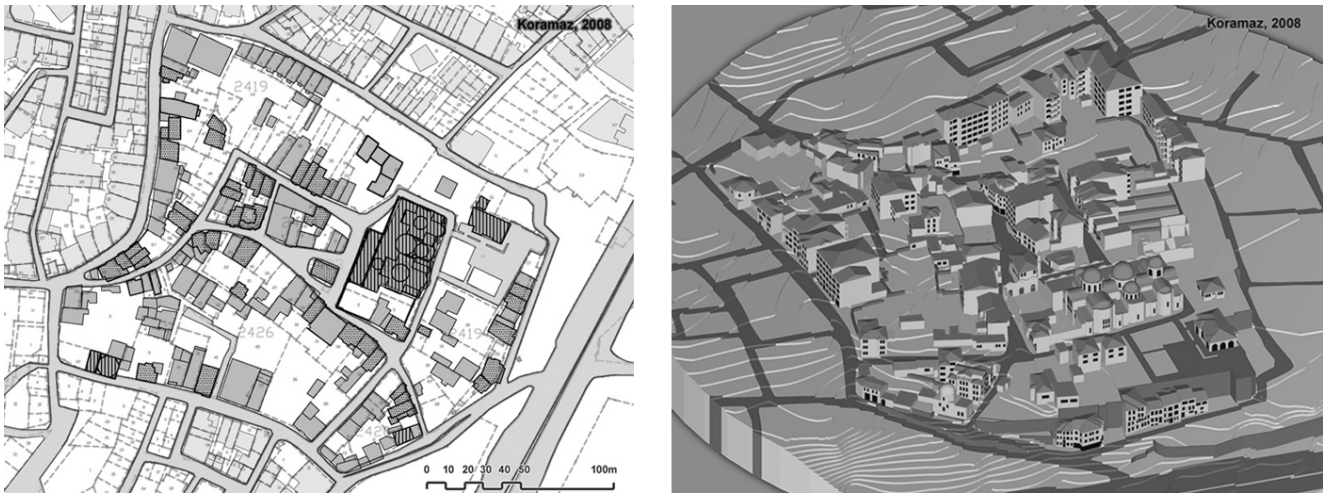

Figure 1. Existing Townscape on 2D Map (left) and 3D urban Model (right) (coloured in original)

After the preparation of the base map and 3D urban model, the second stage is surveying and evaluation of townscape. Survey and physical analysis was held in firstly conventional analysis which contains common evaluation of building and structures as, building uses, condition, construction material, built-up and inbuilt-up areas, and finally listed buildings. Then evaluation of townscape and conservation potential of the historic urban pattern was assessed in parameters titled as structure, façade, accessibility – privacy, and harmony with local architectural characteristics. All these survey and analysis were first constructed in 2D maps and then 3D urban model in the same topics and titles. The last stage is developing a plan proposal for the conservation of Zeyrek Urban Historic Site.

While the survey and analysis were held in both 2D mapping and 3D urban model techniques, opportunities were determined to define townscape and urban pattern parameters [14]. Contrary to the conventional survey and analysis, spatial data mostly related to privacy and façade characteristics were better represented in 3D urban models.

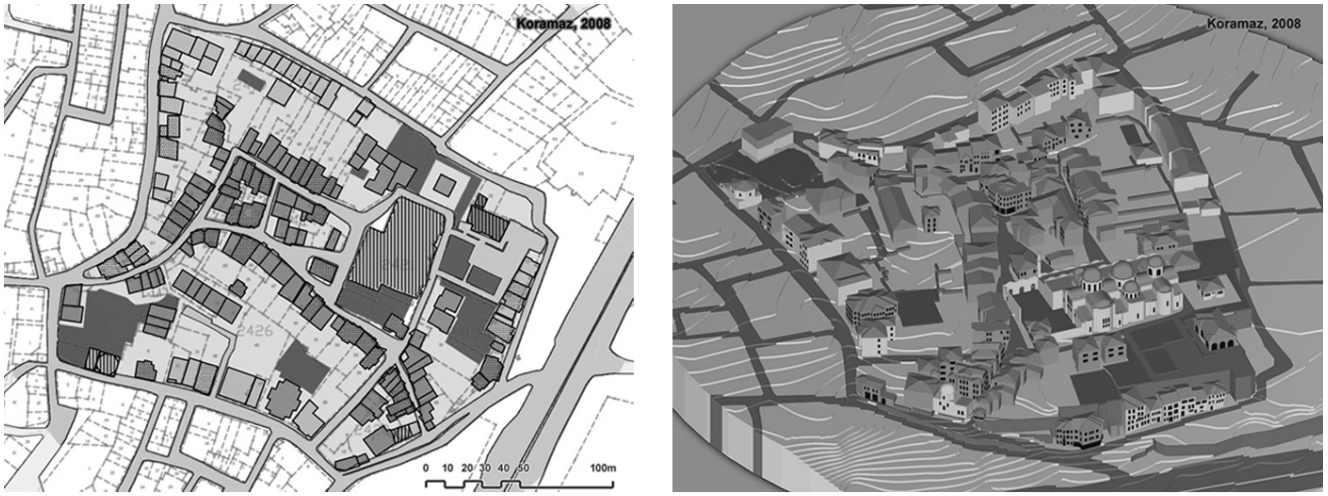

Figure 2. Proposal for Townscape on 2D Map (left) and 3D urban Model (right) (coloured in original)

B. Questionnaire

Questionnaire mainly consists of three parts as comprehension – perception level of site characteristics in the conservation and design project; efficiency of visualization and representation technique; and perception of components described in semantic scale. This paper comprises only the results of the first section the questionnaire. Each separate groups answered the same topics, covered the extent how they comprehend and perceived each figure and map and how they evaluated the efficiency of each techniques as 2D and 3D visualization technique.

All the questions in the questionnaire were conducted in a seven level - Likert scale with 1: "poor" and 7: "excellent". Ten-minute long presentations which were prepared with 2D mapping and 3D urban model were presented to two separate groups. Then respondents were asked to describe their comprehension and perception level for site characteristics in Zeyrek Urban Conservation and Design Project.

Results according to responses from graduate students have been analyzed with a specific statistical method, Linear Discriminant Analysis (LDA) which is a statistical analysis to attain weightings of variables to discriminate between separate groups [16]. LDA, which uses a function based on measuring the distance between two groups, has F-test analysis application module in SPSS software that allows indicating the significance of differences of means from separate groups.

C. Participants

Forty-five graduate students, studying in Istanbul Technical University, Faculty of Architecture (30 urban planners, 8 architects, 7 landscape designer), took part in the questionnaire. First group, twenty students (12 PhD and 8 master students) were asked to evaluate the 2D mapping technique and the second group, twenty-five students (9 PhD and 16 master students) were asked to evaluate 3D urban model.

The respondents' ages in the professional group ranged from 21 to 32 years, with an average of 24,40 years (S.D.=2.624, median 24). Computer experience in the sample has been taken into consideration as the profile of respondents. 14 respondents have been using computer for less than nine years; 22 respondents between 10-14 years and 9 respondents between 15-19 years. Another indicator for computer experience is the use of computer aided design software. Of all respondents, only three graduate students do not use any computer aided design software in their professional and educational works or studies. But less respondents use 3D modelling software as in the quantity of 15 respondents. Of respondents in the first group, only four respondents use 3D modelling software. In the other group who evaluated 3D urban model, eleven persons use these techniques. Between respondent groups, no statistically significant differences were found for the variables of age or computer experience.

III. RESULTS: COMPREHENSION – PERCEPTION LEVEL OF SITE CHARACTERISTICS

Comprehension and perception level of site characteristics of Zeyrek Urban Conservation Study is computed within four categories as general characteristics of the site (location, size, boundaries and topography of the site), conventional survey and analyses (building use, height, material, condition analysis, built-up and inbuilt-up and listed building), survey and analyses of townscape (analysis of structural condition, visual quality, accessibility and harmony) and proposal for the site (proposal for structural size and mass, façade characteristics, accessibility and architectural characteristics). Initially, it can be observed that respondents who were presented 3D urban model gives fairly higher scores to questions in the categories of general characteristics of the site, survey and analyses of townscape. On the contrary, first group who were presented 2D mapping techniques have higher mean scores in the categories of conventional survey and analyses and proposal for the site.

TABLE I. GROUP MEANS FOR COMPREHENSION – PERCEPTION LEVEL OF SITE CHARACTERISTICS

Variables / Questions		1. Group 2D map n:20		2. Group 3d model n:25	
		Mean	*S.D.*	*Mean*	*S.D.*
General Site Characteristics					
To what extent do you perceive these?					
A1.	the location of the site	2,85	1,69	3,20	1,53
A2.	the size of area	4,15	1,95	5,00	1,38
A3.	the boundaries of the site	4,80	1,47	**5,52**	1,16
A4.	the topography of the site	2,10	1,21	**4,68**	1,49
Conventional Survey and Analyses					
To what extent can following building analysis define the site?					
A5.	use analysis	**5,15**	0,67	4,92	1,55
A6.	height analysis	4,40	1,50	**4,72**	1,59
A7.	material analysis	**5,60**	0,94	5,28	1,21
A8.	condition analysis	**5,35**	1,35	5,00	1,12
A9.	built-up, inbuilt-up analysis	**4,95**	1,36	4,44	2,08
A10.	listed building analysis	**4,60**	1,60	4,28	1,79
Survey and Analyses of Townscape					
To what extent can following analysis define the site?					
A11.	structural condition	3,35	1,87	**5,08**	1,04
A12.	visual quality	2,45	1,61	**4,24**	1,48
A13.	accessibility	2,35	1,57	**4,04**	1,79
A14.	harmony	4,60	1,27	**5,00**	1,26
Proposal for the Site					
To what extent are following proposals comprehended?					
A15.	structural size and mass	**4,90**	1,65	4,00	1,58
A16.	façade characteristics	**4,80**	1,64	4,56	1,78
A17.	accessibility	**4,10**	1,74	3,56	1,47
A18.	architectural characteristics	**4,15**	1,69	3,96	1,79

Note: Question response format was seven-step scale from 1 to 7and highest mean values for each variable are printed in bold (S.D.= standard deviation).

To investigate comprehension – perception level of visualization and representation techniques, factor analysis is also performed with varimax rotation of 17 variables and developed indices for the whole data with the combination of two groups. The question of "To what extent do you perceive the location of the site?" (A1) has not been included in factor analysis because it decreased the sampling adequacy and had conflicts in the contribution of factor components in expected scales.

A four-factor solution has been chosen for the variables of comprehension – perception level of visualization and representation techniques (Kaiser-Meyer-Olkin measure of sampling adequacy: 0,679, Significance level within Bartlett's Test of Sphericity: 0,000). 67,07% of cumulative case loadings has been explained in component analysis with 1,201 Eigen value level. These levels reflect that factor analysis is adequately representing the case loadings in the sample size. These four factors could be termed as respectively townscape characteristics (Comp. 1), proposal characteristics (Comp. 2), conventional characteristics (Comp. 3) and general characteristics of the site (Comp. 4).

TABLE II. COMPONENT LOADINGS AFTER VARIMAX ROTATION

Variables		Components			
		1	*2*	*3*	*4*
Comp1 Townscape Characteristics					
A12.	visual quality	**0,91**			0,26
A13.	accessibility	**0,82**			
A11.	structural condition	**0,73**			0,45
A14.	harmony	**0,68**	0,27	0,31	
A6.	building height	**0,53**	0,29		
Comp2 Proposal Characteristics					
A16.	façade characteristics		**0,85**		
A18.	architectural characteristics	0,26	**0,80**		
A15.	structural size and mass		**0,75**		
A17.	accessibility	0,47	**0,54**		
Comp3 Conventional Characteristics					
A7.	material analysis		0,26	**0,83**	
A8.	condition analysis		0,33	**0,81**	
A5.	use analysis			**0,66**	0,38
A9.	built-up, inbuilt-up analysis	0,36		**0,61**	
A10.	listed building analysis		0,46	**0,55**	
Comp4 General Characteristics					
A4.	topography of the site	0,34			**0,76**
A3.	boundaries of the site		0,27		**0,70**
A2.	size of area		0,33	0,34	**0,69**

Note : All component loadings > 0.25 are reported. Highest loadings for every variable are printed in bold. Kaiser-Meyer-Olkin measure of sampling adequacy is 0,679. Significance level within Bartlett's Test of Sphericity is 0,000.

As the result of factor analysis, components reflect the same categories which were also identical in the questionnaire form. Only the loading scores of building height has been reported in another component terming townscape characteristics (Comp. 1), because building height analysis define the site more adequately in the second group (3D urban model) as the townscape survey and analysis.

As the first group examines and interprets a presentation with only 2D mapping techniques and the second group examines and interprets other presentation with only 3D urban model, a comparison has been assembled how much difference exists between two visualization and representation techniques in terms of delivering information for urban conservation study to the respondents. LDA processes each variables/questions and calculates values indicating whether there is a statistically significant difference.

As LDA analysis determines the mean values of each component from factor analysis and from each test group with the results of the F-test in the table n., Overall four components, townscape characteristics (Comp. 1) and general characteristics (Comp. 4) have positive mean values in the second group but negative values in the first group. However F-test significance indicates that statistically significant mean difference in the same components.

TABLE III. LDA WITH GROUP MEAN VALUES

Variables / Questions		*1. Group 2D n:20*	*2. Group 3D n:25*	F	Sig.
Comp1	Townscape Characteristics	-0,449	**0,359**	8,502	0,006
Comp2	Proposal Characteristics	**0,307**	-0,246	3,602	0,064
Comp3	Conventional Characteristics	**0,274**	-0,219	2,819	0,100
Comp4	General Characteristics	-0,586	**0,469**	16,823	0,000

Since the group mean values from second group in component 1 and 4 are significantly (95% confidence interval) positive and higher, it can be reported that 3D urban model delivers more information on the components of townscape and general characteristics of urban conservation study. As the most distinctive component, general characteristics (M: 0,469 in the second group and M: - 0,586 in the first group; Sig : 0,000) which refer to size, boundaries and the topography of the site have been more intelligent to deliver information by means of 3D urban model rather than 2D mapping techniques. This finding may refer to the ability of visualization technique in terms of orientation sense of the use. Other component townscape characteristics (M ; 0,359 in the second group and M: - 0,449 in the first group; Sig: 0,006) which refer to analysis of structural condition, visual quality, accessibility, harmony and building height analysis have also been more intelligent to define the conservation site by means of 3D urban model.

Comp. 2 and Comp. 3 have higher mean values in the first group but in 90% confidence interval, because these components have significance level as respectively 0,064 and 0,100. It can be stated that to deliver information about decisions and proposals about the conservation study and conventional analysis such as building use, material, condition, built-up and inbuilt-up analysis and listed building analysis 2D mapping techniques are considerably adequate.

LDA calculates not only difference between group mean values but also Fisher's Linear Discriminant Function (FLDF), which is used as a threshold for dividing the answers into two groups at what extent these variable correspond these identical difference. Test of this function has been held by a chi square test for Wilk's lambda, too. The classification which is constructed by FLDF, is mainly measured on the discriminant scores, and the scores calculated with a linear equation. Classification for comprehension – perception level of defined characteristics in this case, which has been resulted with factor analysis with a four-factor component analysis have been calculated with the following equation;

$$D = 0{,}815 \cdot \times \text{Comp1} - 0{,}558 \cdot \times \text{Comp2} - 0{,}498 \cdot \times \text{Comp3} + 1{,}064 \times \text{Comp4} \quad (1)$$

Where D = Discriminant Function
Comp (n) = values for each component as comprehension – perception level of site characteristics

The coefficients of each component reflect the pre-eminence in the discriminant function as Comp4 have highest coefficient value as 1,064 and Comp3 has the lowest one as – 0,498. Test of this function has been proved with Chi Square test for Wilk's lambda (Chi-square = 36,069 and Significance = 0.000). This function indicates the similar trends with dominant components as F-test results represent, either. LDA gives possibility to estimate whether the group cases classifies correctly in a classification table as follows:

TABLE IV. CLASSIFICATION TABLE OF LDA

Variables / Questions		Predicted Group Membership		Total
		1. Group 2D - n:20	*2. Group 3D - n:25*	
Count	1. group - 2D	**18**	2	20
	2. group - 3D	6	**19**	25
%	1. group - 2D	**90**	10	100
	2. group - 3D	24	**76**	100

Note : 82,2% of original grouped cases correctly classified.

Classification table indicates number and percent of respondents that belongs to correct groups. For instance, discriminant score from 18 out of 20 respondents in the first group could be grouped into first group. It means that only two respondents' answers in the first group had been more likely close to the scores of the second group. But on the contrary from 19 out of 25 respondents in the second group could be grouped into the same group. As 82,2% of original grouped cases correctly classified, it can be concluded that there are significant differences in comprehension level of defined characteristics of urban conservation study between separate presentations as 2D mapping and 3D urban model tools, and that the graduate students, who were presented 3D urban model, have higher perception level of urban conservation study's defined characteristics than the ones who were presented 2D mapping techniques.

IV. CONCLUSIONS

As the fundamental finding of the study, it is concluded that spatial attributes and characteristics in 3D urban models are better defined by the comprehensive spatial analyses and investigations than in 2D mapping technique. 3D urban model has higher group mean values for most of the variables but the most prominently for variables describing "the comprehension of general characteristics" and "cognition of townscape characteristics" of urban historic site. In addition to the conclusion remarks of this paper, 3D urban models with virtual reality applications also strengthen the immersive experiences regarding the sense of orientation in virtual urban environments [17].

In accordance with the responses from graduate students, as one of the user groups among the planning and design professions, the most important skill of 3D urban models is stated as explanation ability of conservation project and

interventions to structural and visual quality of urban historic environments. Representation ability of change and enhancement of cognition and perception level in urban historic townscapes are the other important capabilities of 3D visualization techniques. Responses of graduate students also overlapped with the community appraisals, especially for the statement which considers the 3D urban models' capabilities on representing the sense of historic site affection [18]. These community appraisals were described by the help of the research findings in 2009 [14] that main focus on the representation capability of 3D urban model is related to definition of architectural vernacular characteristics.

Graduate students in planning and design schools use 3D urban model mostly as "last visualization media" which is improved with material, texture and light modelling, in enriched artistic and realistic details. But planning and conservation project require visualization techniques in order to describe and represent spatial content in details. In conclusion, 3D models improve the user's perception regarding the representation of townscape characteristics and enhance the communication and interaction of spatial information among user groups in order to develop collaborative processes in urban conservation.

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