COMPARISON BETWEEN USERS' RESPONSES FOR STATIC 3D MODEL AND VR APPLICATION IN ZEYREK URBAN HISTORIC SITE

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ABSTRACT:

Throughout the urban conservation process, a spatial evaluation of an urban historic site conducted by the design professions in an analytical paradigm is crucially important. The utilization of innovative visualization techniques within this evaluation plays an effective role in urban conservation, as well. This study examines and compares the efficiency of two visualization techniques: the static 3D urban model and the VR application, developed for the case area known as the Zeyrek Urban Historic site. The examination in this study was conducted with the use of a questionnaire which compares the perceived communication and interaction levels between these techniques. Graduate students in the Faculty of Architecture department were given the questionnaire. Accordingly, the Semantic Environmental Description Scale is used to systematically measure how graduate students describe the urban historic site. The results suggest that the VR application is more capable of enhancing the sense of orientation, the cognition of urban historic site and the sense of spatial enclosedness than static, 3D urban models.

1. INTRODUCTION

An investigation of the efficiency of three dimensional (3D) urban models is essential because of their changing contexts in communication and the interaction process of urban planning and conservation. In an analytic paradigm, the design professions' evaluation of these models is vital in improving the tasks and functions of the innovative visualization techniques. In this context, most urban planning and design studies have been conducted using static 3D models which are occasionally used as a documentation or final representation tool to express the urban structure and design proposals. In contrast, virtual reality (VR) applications are described as having more capability to attain communication as a design aid tool than the static models.

This study examines the efficiency of the static 3D urban model and the VR application that was developed for the case area, Zeyrek Urban Historic site, which is located in the north of the Historical Peninsula of Istanbul, on the slopes, viewing Golden Horn. In 1983, the site was included in the World Heritage List because of its historical, aesthetical and architectural characteristics.

The aim of this study is to improve the tasks of VR application as an active communication tool that is integrated with urban conservation and to investigate how graduate students in the Faculty of Architecture department, experienced the static 3D model and VR application of the Zeyrek Urban Historic site. This investigation was conducted using a questionnaire which compared perceived communication and the level of interaction between the static and animated 3D models.

In the questionnaire, the responses of graduate students in the Istanbul Technical University (ITU), Faculty of Architecture, were gathered from two different groups after two separate presentations: the static 3D urban model and the VR application. Accordingly, Küller's Semantic Environment Description Scale (SMB) was used to systematically measure how individuals describe the built environment. Results of this study were intended to contribute to the development of the communication process in the urban conservation process by means of using 3D urban models and VR applications.

1.1 3D Urban Models and VR Applications

3D urban models are defined as visualization techniques in architectural and urban design which provide efficient communication and visualize more spatial content and information than conventional techniques (Pietsch, 2000). In the urban conservation and design process, these models produce realistic images and views and provide a realistic experience of both the existing and the proposed urban structure and form in order to evaluate spatial characteristics and planning decisions (Hall, 1999).

Two main parameters are identified in describing and developing the efficiency of computer-aided, 3D urban models. These are the spatial abstraction level from high to low geometric content and the functionality on spatial data analysis and visualization (Batty et al., 2000). Spatial abstraction parameters determine the level of geometric and spatial content which is represented by visualization technique on the computer software interface. The 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 (Pietsch 2000).

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Computer Aided Design (CAD) software is conventionally used to generate 3D models in urban planning and design and mostly to evaluate the spatial characteristics of urban structure and design proposals. As a conventional CAD application, static 3D urban models provide geometric modelling in volumetric and manual measurements (Levy, 1995). Within the improvements in computer-based visualization techniques, rendering functions are developed in 3D models which generate more realistic, rich and impressive visual content. With the animation and interaction functions of 3D models, Virtual Reality (VR) applications perform as communication media and design aid tools (Bertol, 1997).

Virtual Reality applications are designed to sustain Web-based and user-oriented dynamic recovery of urban contextual information from an architectural and urban design viewpoint (Peng and Blundell, 2004). By means of accuracy and functionality features, these applications are formed within a structural and visual point of view in documenting and visualizing both spatial characteristics and design proposals in an interactive design process (Batty et al., 2000). Developments in VR applications also improved the functions as well as the purposes of 3D urban models while they achieve an efficient interface in the communicative urban design process (Al-Kodmany, 2002).

As the fundamental function of VR applications, communication and interaction functions facilitate the participation and collaboration processes in urban planning and conservation. VR applications also develop the learning skills (Hamilton et al., 2001) and cognition and the perception abilities of users and stakeholders (Westerdahl et al., 2006). Then the efficiency of the visualization techniques can be examined along with the users' and stakeholders' learning, and cognition abilities and their evaluation processes. Therefore, this examination was especially conducted for the design professionals and is necessary to improve the tasks of using the VR application as an active communication tool that can be integrated with urban conservation.

1.2 Investigation 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 have increased recently (Day, 2002). Many of these investigation studies use semantic (meaning) measurement scales which systematically describe the perceived environment (Bates Brkljac, 2007; Neto, 2001; Westerdahl et al., 2006; Houtkamp & Oostendorp, 2007).

In describing how users experience their environment, the first semantic measurement scale study that was produced by Osgood, Suci and Tannenbaum (1957) was titled, "The Measurement of Meaning". Osgood and his colleagues asked respondents to provide sets of a large number of adjectives that described various context and terms. Then, the seven-step scaled answers were factor-analysed to cluster these adjectives into seven dimensions such as, evaluation, potency, activity, stability, tautness, novelty and receptivity.

The second study titled, "A semantic model for describing perceived environment", was written by Küller (1972) and aimed to measure and describe the experiences of built environments systematically. Küller criticized Osgood, Suci and Tannenbaum's study as being limited in measuring the perception of built environments.

With the semantic environmental scale (SMB from Swedish ''semantisk miljö beskrivning), Küller also used the same procedure in methodology such as clustering subjective responses into dimensions. But in this study, the respondents were asked to describe not the context or terms but the images from real environments and living spaces. To describe the experience of the respondents with respect to the built environment, Küller comprised eight dimensions or factors as listed in Table 1.

Factor	Definition
Pleasantness	The environmental quality of being pleasant, beautiful and secure
Complexity	The degree of variation or, more specifically, intensity, contrast and abundance
Unity	How well all the various parts of the environment fit together into a coherent and functional whole
Enclosedness	A sense of spatial enclosedness and demarcation
Potency	An expression of power in the environment and its various parts
Social status	An evaluation of the built environment in socioeconomic terms, but also in terms of maintenance
Affection	The quality of recognition, giving rise to a sense of familiarity, often related to the age of the environment
Originality	The unusual and surprising in the environment

Table 1. The eight factors of the SMB scale (Küller, 1991)

In order to investigate the efficiency of 3D urban models, Osgood, Suci and Tannenbaum's semantic differential scale was used mostly to compare these techniques with their functions such as, accuracy, realism and abstraction (Bates Brkljac, 2007). But Küller's SMB scale attained such comparison to such an extent where these techniques represented the real environment (Westerdahl et al., 2006). In addition, the SMB scale can efficiently be used in either built environments or with representation tools and visualization techniques such as sketches, collages, three-dimensional models, films or TV techniques (Küller, 1991). For all these reasons, the SMB scale was chosen in this study to compare users' responses to static 3D models and VR applications in the Zeyrek Urban Historic site.

2. METHODOLOGY

In this study's questionnaire the users' responses were investigated in two separate groups: the static 3D urban model and the animated 3D urban model with VR application. Users were defined in the questionnaire study as graduate students from the departments of Architecture, Urban and Regional Planning and Landscape Architecture at ITU. The first questionnaire study was held in 2007 in which respondent groups assessed the static 3D urban model and second questionnaire study was held in 2008 in which a new group assessed the VR application.

As included in the World Heritage List, the case area, known as the Zeyrek Urban Historic site reflects a variety of cultural structures in its urban space. The most important monument of the site is the Mosque of Zeyrek which was the Monastery of Christ Pantokrator in the Byzantium Period. Zeyrek has a

traditional organic pattern consisting of authentic, wooden, Turkish houses (Gulersoy-Zeren et al., 2008). Both the static 3D model and the VR application were prepared in the same structural and visual content that all the schemes, analyses and proposals were accomplished for Zeyrek Urban Historic site to represent site's physical environment and townscape features.

2.1 Material and Procedure

For the first questionnaire, the static 3D urban model of the Zeyrek Urban Historic site was created using AutoCAD 2004©. For the second questionnaire, the static 3D urban model was transformed into VRML format using Cortona VRML Client Version 5.1©. This was done in order to produce an animated and immersive virtual environment and to visualize the application using the internet explorer interface. The static 3D urban model and the VR application had the same physical elements which were formed with buildings, tombs and religious buildings as monumental buildings and finally streets (Figure 1 and 2).

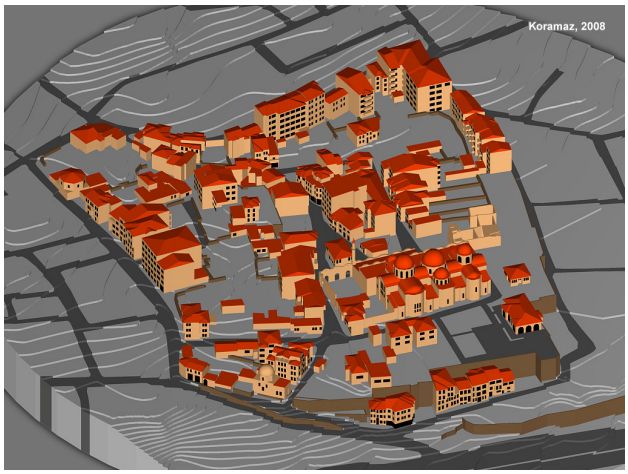

Figure 1. Static 3D Urban Model in Zeyrek Urban Historic Site

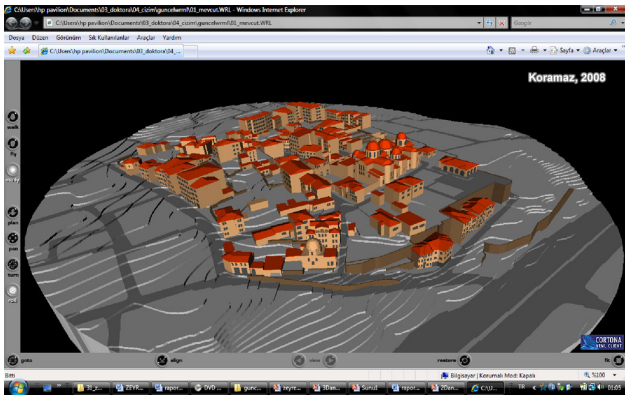

Figure 2. VR Application in Zeyrek Urban Historic Site

Both of the questionnaires concerning the evaluation of users' responses for static 3D models and VR applications were conducted after the presentations. The presentations and questionnaires were held in a meeting room in the faculty building. Presentations were made by projecting the models and VR applications onto the wall. The computer that was used was an Intel Centrino Duo that was running at 1,66 GHz ,contained 1 GB RAM and supported the GeForce 8400M GS. Respondents watched a 10 minute-long presentation which consisted of the schemes and analysis, representing the Zeyrek Urban Historic site. Then, respondent groups completed the same questionnaire form in order to evaluate the static 3D model and the VR application they were presented.

The questionnaire mainly consisted of two sections: the perception level of site characteristics in the urban historic site and the perception of semantic environmental scale components. Each separate group answered the same questions, covering the extent to which they comprehended and perceived each figure and illustration and how they perceived the site in the components of SMB. All questions in the questionnaire were conducted with a seven level - Likert scale with a "1" being poor and a "7" being excellent.

In the first section of the questionnaire, respondents were asked to describe their perception level for site characteristics in the Zeyrek Urban Historic site. While answering those questions, a related slide was presented to respondents. The second section was to describe respondents' own perception level on the SMB components of pleasantness, complexity, unity, enclosedness, potency, social status, affection and originality.

2.2 Respondent Profile

Fifty-five graduate students, educated in the MSc. and PhD. programs at ITU's Faculty of Architecture department took part in the presentations and questionnaire study. The age of the respondents ranged from 22 to 31 years, with an average of 25, 27 years (S.D. = 2.016, median 25). Graduate students assessed the static 3D urban model and the VR application in separate groups after separate presentations were presented within this model and application. Twenty-five respondents evaluated the static 3D urban model in the experiment that was conducted in 2007 and thirty respondents evaluated the 3D urban model with VR application in the experiment that was conducted in 2008. In the first group (n:25) seventeen respondents, in the second group (n:30) eighteen respondents stated that they were using 3D modelling software (3D Max, 3D Viz, etc). Between respondent groups, no statistically significant differences were found for the variables of education and computer experience.

3. RESULTS

The results according to responses from graduate students have been examined in two parts regarding the format of the questionnaire by means of a statistical software package, SPSS 17.0©. Variables related to perception level of the characteristics of the site, were factor analyzed in order to group the variables into components. Responses from separate groups, first and second groups, were compared with T-test to examine the equality of means.

3.1 Users' Responses to Perception Level of Site Characteristics

In the first section of the questionnaire, which was concerned with the perception level of site characteristics, 18 questions were asked. First, graduate students responded as to what extent they perceived the location, size, boundaries and topography of the site. Table 2 summarized the comparison of means for both groups' answers of these questions.

Variables	1. Group Static 3D model n: 25		2. Group VR application n: 30		t.	Sign. one-tailed
	Means	S. D.	Means	S. D.		
location	3,20	1,52	**4,60**	1,55	-3,36	0,001
size	5,00	1,38	**5,70**	0,84	-2,31	0,025
boundaries	5,52	1,15	**5,80**	0,96	-0,98	0,332
topography	4,68	1,49	**6,13**	0,90	-4,27	0,000

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

Table 2. Results of perception level of site characteristics

Overall, all of the mean values from second group were larger than the mean values from first group. However, T-test significance indicated that statistically significant mean differences existed in these questions except for one question concerning "boundaries of the site" (sign. = 0,332).

Since the mean values from the second group in those three questions were significantly larger than the mean values from first group, it can be concluded that 3D model with VR application delivered information regarding the location, size and topography of the site better than static 3D urban model. Additionally, mean differences between the groups within the variables of topography and location were relatively sharp when compared to other variables.

To investigate the perception level of site characteristics, factor analysis was also performed with a varimax rotation of 14 variables and developed indices for the whole data with the combination of two groups. These variables were built using: height, material, and structural condition, built-up and in-built up areas, listed buildings. The townscape characteristics of structural size, visual quality, privacy, harmony and proposal characteristics for structure, façade, accessibility and architectural quality were also used. The variables of location, size, boundaries and topography were not included in the factor analysis because they decreased the sampling adequacy and had conflicts with the contribution of factor components in expected scales. On the other hand, these four variables could be individually interpreted with their sharp statistical differences in group mean values. A three-factor solution was chosen for the variables of the perception level of site characteristics (Kaiser-Meyer-Olkin measure of sampling adequacy: 0,779, Significance level within Bartlett's Test of Sphericity: 0,000).

A percentage of 68,82 of the cumulative case load was explained in the component analysis with a 1,106 Eigen value level. These levels reflected that factor analysis was adequately representing the case load in the sample size. These three factors could be termed as townscape characteristics, structural characteristics and proposal characteristics respectively (Table 3).

As the result of factor analysis, components reflected the same categories which were also identical in the questionnaire. Only the loading scores of building height was reported in another component of townscape characteristics. This was because building height analysis defined the site adequately in the second group (VR application) as the townscape characteristics did.

Variables	1. Group Static 3D model n: 25		2. Group VR application n: 30		t.	Sign. one-tailed
	Means	**S. D.**	**Means**	**S. D.**		
Townscape C	- 0,42	1,15	**0,35**	0,70	-2,93	0,006
Structural C	- 0,21	1,12	**0,17**	0,87	-1,40	0,168
Proposal C	- 0,29	1,14	**0,24**	0,81	-2,00	0,050

Note: Highest mean values for each component from factor analysis are printed in bold.

Table 3. Scores of factor-analyzed components related to spatial survey and analyses

The first group evaluated the presentation with a static 3D urban model. The second group evaluated the 3D urban model with the VR application. A comparison was assembled in order to measure the difference between these presentations in terms of delivering information for the perception of the urban historic site. Within the mean values of each component from factor analysis, (Table 3) all three components had positive mean values in the second group but negative values in the first group. However, the T-test indicated the statistically significant mean differences in the components of townscape characteristics and proposal characteristics.

Since the group mean values from the second group in these components were significantly (95% confidence interval) positive and higher, it was reported that the VR application delivered more information on the components of townscape and proposal characteristics of urban historic site. As the most distinctive component, townscape characteristics (M: 0,35 in the second group and M: - 0,42 in the first group; Sig : 0,006) which refer to visual quality, accessibility, structural condition, built-up and in-built up areas, harmony and building height were better represented in the VR application than in static 3D urban model. The other component, proposal characteristics (M ; 0,24 in the second group and M: - 0,29 in the first group; Sig: 0,050) which refer to proposal characteristics for façade, structural size and mass and architectural quality were also defined better in the VR application than in the static 3D model.

Components of structural characteristics have higher mean values in the second group but a 90% confidence interval (sign. = 0,168). It was stated that the static 3D urban model was considerably adequate to represent or to deliver information about building use, condition and materials in the urban historic site.

3.2 Users' Responses Measured by Semantic Environmental Scale

The two groups' means and standard deviations for SMB factors were presented with their significance levels in Table 4. The highest difference between the responses for the static 3D urban model and the VR application was for enclosedness factor. The mean values of pleasantness, complexity, enclosedness, social status and originality were higher for the second group to whom VR application was presented (Figure 3). As less-significance levels occurred between two groups, it was reported that significance values were on the level more than 0,08 which were not statistically significant. But the most distinctive result was that enclosedness had the highest mean difference (sign. = 0,08; in 90% confidence interval) when compared to other SMB factors.

Variables	1. Group Static 3D model n: 25		2. Group VR application n: 30		t.	Sign. one-tailed
	Means	S. D.	Means	S. D.		
Pleasantness	3,76	1,39	**4,07**	1,08	-0,92	0,36
Complexity	4,68	1,60	**4,90**	1,18	-0,59	0,56
Unity	**4,36**	1,08	4,23	1,22	0,44	0,69
Enclosedness	4,20	1,66	**4,93**	1,26	-1,82	0,08
Potency	**5,00**	1,19	4,80	1,38	0,57	0,57
Social status	3,76	1,09	**3,90**	1,16	-0,46	0,65
Affection	**5,40**	0,91	4,97	1,22	1,47	0,15
Originality	5,04	1,43	**5,10**	1,32	-0,16	0,87

Table 4. Results of SMB Scale for static 3D model and VR application

Variables	Visited the site		Not visited the site			
	Joint Group n : 27		In the 1. Group Static 3D, n: 10		In the 2. Group VR, n: 18	
	Means	S. D.	Means	S. D.	Means	S. D.
Pleasantness	3,67	1,27	4,00	1,16	4,28	1,18
Complexity	4,74	1,51	4,50	1,27	5,06	1,26
Unity	4,11	1,09	4,70	0,95	4,33	1,33
Enclosedness	**4,63**	1,60	**3,60**	1,27	**5,11**	1,18
Potency	4,74	1,20	5,30	0,95	4,89	1,57
Social status	3,85	1,20	4,20	1,03	3,61	1,04
Affection	5,44	0,93	5,10	0,99	4,78	1,31
Originality	**5,59**	1,28	**4,40**	0,97	**4,67**	1,41

Table 5. Results of SMB Scale for static 3D model and VR application comparing the joint group, visited site previously

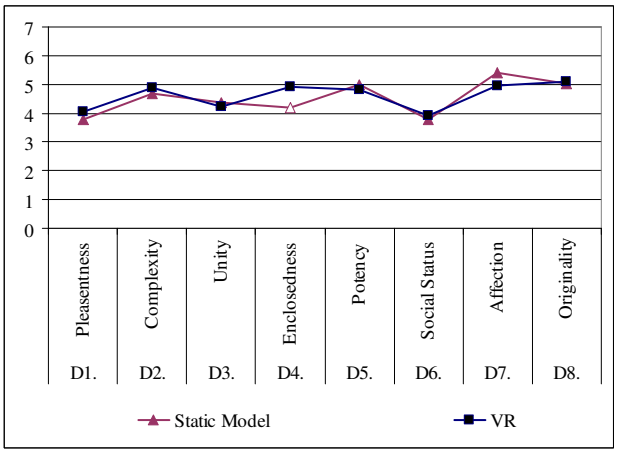

Figure 3. Results of SMB Scale for static 3D model and VR application

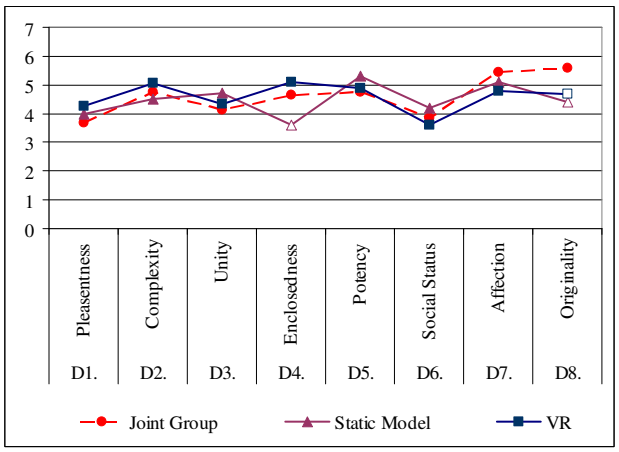

Figure 4. Results of SMB Scale for static 3D model and VR application comparing the joint group, visited site previously

Then SMB results were compared with whether respondents had visited the site previously or not. The F-test showed a significant difference in the SMB factors Enclosedness (F = 3,665, df = 54, sign. = 0,032) and Originality (F = 4,529, df = 54, sign. = 0,015). But when a paired F-test is applied to compare the SMB results for the respondent group who had not visited site previously, a significant difference was reported only for the SMB factor Enclosedness (F = 9,997, df = 27, sign. = 0,004).

When computed for two groups to whom the static 3D urban model and the VR application were presented, the comparison showed significant differences in only two factors: enclosedness and originality. The group mean value for the enclosedness factor provided from the first group (that had not visited the site previously) was lower than that from the second group (M = 4,63 for joint group, M = 3,60 in the first group and M = 5,11 in the second group). The group mean values for the originality factor provided from both groups (that had not visited the site previously) was lower than the joint group that had visited site previously (M = 5,59 for joint group, M = 4,40 in the first group and M = 4,67 in the second group) (Table 5 and Figure 4).

The enclosedness factor gained its importance in accordance with the delivering information about the urban historic site. When the results were computed according to the respondent profile, professional background variable correlated significantly with only this factor. Professional background which was defined as graduation discipline correlated only with the SMB factor-enclosedness (Spearman's r = 0,266, sign. = 0,050).

Briefly, this comparison regarding SMB factors showed that the perception of the 3D urban model and the VR application were mainly similar to pleasantness, complexity, unity, potency, social status, affection and originality factors. But only the enclosedness factor determined a significant difference between the perception of the static 3D urban model and the VR application. It means that VR application increased the sense of spatial enclosedness even better than the real environment.

Another distinctive finding was that all of the SMB factors except the originality factor tend to have a similar perception level for both the VR application and the real environment. Both the static 3D urban model and the VR application, modeled in this study were relatively less capable of representing real urban environments in the originality factor because of not having material or texture characteristics on façade with a realistic rendering function.

4. CONCLUSION

In conclusion, graduate students' responses for the VR application were different from those for the static 3D urban model in several parameters. As reported in the study, the significant differences, termed as perception of location, size and topography, were those concerning the orientation sense of users in a virtual environment. The study also indicated that another distinctive parameter was the cognition level of the townscape characteristics of the urban historic site.

In order to evaluate the validity of the SMB-scale used in this study, data was checked with the internal consistency of the responses for each factor. When reliability analysis was performed, overall Cronbach's alpha coefficient for entire SMB factors which in this case was 0,768 was above 0,7 so the scale was considered reliable with the sample (Cronbach's alpha for entire SMB factors which were changing from 0,720 to 0,759, were not higher than overall alpha value). In brief, the SMB scale could be stated as a validated measurement scale for comparing users' responses for the static 3D urban model and the VR application. Overall, the results showed that the methodology was valuable in comparing the efficiency of visualization techniques in representing urban historic sites.

The results also indicated the fact that graduate students commonly gave higher scores when rating their perception level of site characteristics and SMB factors by the VR application than the static 3D urban model. However, the value for the factor originality differed between the respondents who either experienced only the VR application or those who experienced the real urban environment. On the other hand, the values for factors originality and enclosedness differed between the respondents who either experienced only the static 3D urban model or those who experienced the real urban environment.

In summary, the VR application was reported to have given a fairly better representation of users' experiences regarding the sense of orientation, cognition of the urban historic site and a sense of spatial enclosedness than the static 3D urban model.

5. REFERENCES

Al-Kodmany, K., 2002. Visualization Tools and Methods in Community Planning: From Freehand Sketches to Virtual Reality. *Journal of Planning Literature*, 17(2), pp. 189-211.

Bates-Brkljac, N., 2007. Investigating perceptual responses and shared understanding of architectural design ideas when communicated through different forms of visual representations. In: *11th International Conference Information Visualization, (IEEE, IV'07),* 10.1109/IV.2007.74 pp. 348-353.

Batty, M., Chapman, D., Evans, S., Haklay, M., Kueppers, S., Shiode, N., Smith, A., and Torrens, P.M., 2000. "Visualizing the City: Communicating Urban Design to Planners and Decision Makers". http://www.casa.ucl.ac.uk/working_papers/Paper26.pdf, ISSN: 1467-1298 (accessed 09.08.09)

Bertol, D., 1997. *Designing Digital Space, an architect's guide to virtual reality*, John Wiley & Sons Inc., New York, USA.

Day, A., 2002. Urban visualization and public inquiries: the case of the Heron Tower, London. *Architectural Research Quarterly*, 6(4), pp. 363-372

Gulersoy Zeren, N., Tezer, A., Yigiter, R., Koramaz, T.K. and Gunay, Z., 2008. *Istanbul Project: Istanbul Historic Peninsula Conservation Study; Zeyrek, Suleymaniye and Yenikapi Historic Districts, Volume 2: Zeyrek Case*, Istanbul Technical University, Istanbul, Turkey.

Gulersoy Zeren, N., and Koramaz, T. K., 2001. Evaluation of Townscape in Spatial Information Systems Throughout Urban Conservation Application, In: *International Symposium of Surveying and Documentation of Historic Building-Monuments-Sites, Traditional and Modern Methods, CIPA 2001*, Potsdam, Germany, pp. 282-285.

Hall P., 1999. The Future of Cities, *Computers, Environment and Urban Systems*, 23 (1999), pp. 173-185.

Hamilton, A., Trodd, N., Zhang, X., Fernando, T. and Watson, K., 2001. Learning through visual systems to enhance the urban planning process, *Environment and Planning B: Planning and Design*, 28(6), pp. 833-845.

Houtkamp, J. and van Oostendorp, H., 2007. Virtual Vandalism: The Effect of Physical Incivilities on the Affective Appraisal of 3D Urban Models. In: *11th International Conference Information Visualization (IEEE, IV'07),* 10.1109/IV.2007.74 pp 559-566.

Küller, R., 1991. Environmental assessment from a neuropsychological perspective. In: T. Gärling, G.W. Evans (Eds.), *Environment, Cognition and Action: An Integrated Approach*, Oxford University Press, New York, 1991, pp. 111-147.

Küller, R., 1972. A semantic model for describing perceived environment. Document No. 12:1972, National Swedish Institute for Building Research, Stockholm, Sweden.

Levy, R., 1995. Visualization of urban alternatives. *Environment and Planning B: Planning and Design* (22)3, pp. 343-58.

Neto, P.L., 2001. Evaluation of an urban design project: imagery and realistic computer models. *Environment and Planning B: Planning and Design,* 28(5), pp. 671-686.

Osgood, C., Suci, G. and Tannenbaum, P., 1957. *The Measurement of Meaning,* University of Illinois Press, Urbana, USA.

Peng C. and Blundell J. P. 2004. Reconstructing Urban Contexts Online for Interactive Urban Designs. *Design Studies* 25(2), pp. 175-192.

Pietsch, S.M., 2000. Computer visualisation in the design control of urban environments: a literature review. *Environment and Planning B: Planning and Design,* 27(4), pp. 521-536.

Westerdahl, B., Suneson, K., Wernemyr, C., Roupe, M., Johansson, M. and Allwood C.M., 2006. Users' Evaluation of a Virtual Reality Architectural Model Compared with the Experience of the Completed Building, *Automation in Construction*, 15(2), pp. 150-165.