The Validation of 3D Simulation for Collaborative Urban Design: A Quantitative Approach

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Abstract

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Communicative planners insist that decision making should be "communicatively rational" to the degree that it is reached consensually through deliberations involving all stakeholders, where all are equally empowered and fully informed. However, seamless communication and equal information sharing, especially in the urban design process, are not easy goals to achieve. A recent technology, three-dimensional (3D) urban simulation, can be an alternative that facilitates better information sharing for collaborative urban design. This paper presents a case study that conducts quantitative measurement of information delivery capabilities of a 3D simulation tool. Developing and applying a 3D urban simulation tool to a town redevelopment project, this study conducted a survey research for comparing the 3D simulation tool with conventional urban design communication media.

Keywords: Collaborative Planning, 3Dsimulation, Information Sharing, Linear Discriminant Analysis, Public Participation

Ⅰ. Introduction

In the planning profession, the concept of public participation is not a new idea, and has been applied to a variety of contemporary planning projects. The concept of public participation has been used in urban planning since the late 1960s when advocate planning was established by Davidoff (1965). Based on the idea of public involvement that Davidoff asserted, collaborative planning develops the idea of consensus building that reaches an agreement by all stakeholders rather than by the rules of the majority (Innes and Booher, 1999). Recently, communicative planners insist that decision making should be "communicatively rational" to the degree that it is reached consensually through deliberations involving all stakeholders, where all are equally empowered and fully informed, and where the conditions of ideal speech are met (Healey, 2003). However, seamless communication, especially in the urban design process, is not an easy goal to achieve. The communication in urban design process is the exchange of a diversity of expressions, design ideas, and planning solutions among participants with a variety of different backgrounds. In this sense, clear communication is a crucial element of collaboration in urban design.

Although communication and information exchange have been understood as important issues for collaborative urban design, present communication media such as maps, two-dimensional plans, and perspective sketches, are inefficient in transferring design ideas since participants in the urban design process often experience difficulty understanding the spatial relationships portrayed by such media . The problem of communication worsens when the general public is involved in the design process. Public participants with no educational background or understanding of design find it difficult to share information based on a communication media that they do not understand. A recent technology, three-dimensional (3D) urban simulation, can be an alternative that facilitates better information sharing for collaborative urban design. Three-dimensional urban simulation refers to a technology that allows a user to enter a virtual scene to experience and manipulate the environment once a 3D geometric model of an urban scene is constructed (Chen, 1999). A variety of 3D simulation technologies have been developed and applied to a variety of urban design projects as a communication medium for the last decade (Day, 1994b; Edward, 1998; Hall, 1993; Levy, 1995). Although literatures reported the applications and the advantages of the simulation technology, there are limited numbers of studies that provide quantitative evidences proving the advantages of the 3D simulation technology in urban design process. No study has focused what extents the 3D simulation can improve information sharing.

This paper presents a case study that conducts quantitative measurement of information delivery capabilities of a 3D simulation tool. Developing and applying a 3D urban simulation tool to a town redevelopment project, this study conducted a survey research for comparing the 3D simulation tool with conventional urban design communication media. This paper will summarize the survey research study. This paper will at first introduce the background information of this case study. Then, it will describe survey research methodology including research design, survey setting, and the employed statistical method. Finally, this paper will discuss the results of statistical analysis from the survey research.

Ⅱ. High Springs' Town Redevelopment Plan

The area of focus for this research is the City of High Springs located on the northwest corner of Alachua County, Florida. According to Census 2000, the total population of High Springs is 3,863 and total housing units are 1,668. The area of the city is 18.48 square miles. As a rural community located at the edge of the Gainesville metropolitan area, High Springs recently experienced rapid growth. The increasing volume and speed of traffic in High Springs has contributed to a decrease in the quality of living by affecting walking, bicycling, and shopping. Thus the city government and the residents need to control the problems caused by the new growth. In addition to growth management, the city would like to preserve the community's historic downtown and ensure that the city becomes more pedestrian and bicycle friendly. The city also wishes to keep the historic and traditional, small town character of the urban area.

In this context, the city wants to redevelop the town center of the city. Throughout this redevelopment process, the city desires to have a clear vision of physical changes and conditions of the town center. For the physical improvement of the town center the city planners desire to develop a design proposal for about 15.4 acres of land that is located at the heart of the town center. Currently, a few institutional buildings such as the city hall, a church, a police department, an abandoned school, and a historic building occupy the site. However, a large portion of the site is left as vacant land. The city hopes to develop the site in a way that revitalizes a walkable town center and at the same time encourages greater economic vitality in the town center.

The design alternative development process is mainly preceded by collaborative efforts between a group of students in the Department of Landscape Architecture at the University of Florida and the citizens of High Springs. Throughout several meetings, the residents in High Springs provided information regarding the history, the current physical condition, and socio economical circumstances of the city. The residents explained the visions and wishes for the site as well. Based on the information collected from the meetings, the students generated design alternatives for the site. At the completion of the exercise, they had a design presentation for the residents.

A 3D urban simulation tool was created for facilitating the communication in the collaborative meetings for the design alternative development process. The 3D urban simulation refers “a simulation environment that permits an end user to insert himself into a dynamic, visual model of an urban environment by means of a visual simulation system employing on-line generation of color projections onto large screens with as much as 360 degrees of vision. By means of controls which direct his speed and the direction, as well as the movement of his eye, the viewer will be able to ‘walk’, ‘drive’, or ‘fly’ through sequences of existing, modified, of totally new urban environment (Kamnitzer, 1972, p. 315)”. The main purposes of the 3D urban simulation tool are to support information transfer regarding current conditions of High Springs from the residents to the design students and to facilitate information flow from the design students to the residents by visualizing a design alternative.

Ⅲ. Survey Research Methodology

As the High Springs town center redevelopment was proceeding, a survey research was designed to measure the information delivery capabilities of the 3D simulation tool. The main purpose of the survey analysis is to compare the 3D simulation tool with conventional urban-design presentation media. This test evaluates the effectiveness of the simulation tool as an information delivery tool in a collaborative urban-design process. The hypothesis tested is that a 3D urban simulation tool improves information sharing among the participants in public meetings more than conventional media. Thus, the 3D urban simulation tool encourages better information sharing and seamless communication between the stakeholders, ultimately improving collaborative urban design.

1. Four-group survey analysis setting

For the purposes, a four-group survey analysis sets two different groups of experiment participants, High Springs residents and design students. The survey analysis with High Springs residents was planned to measure the information delivery from design professionals to the general public. The purpose of the survey analysis with design students is to evaluate the roles of the presentation tools in information sharing among design professionals. The exactly same survey conditions are enforced for both surveys.

The survey participants are randomly broken into four different groups (Table 1). The first group, named Group A, is presented with a design proposal with a conventional 2D plan drawing and sketches. After the presentation, the participants were asked to complete a questionnaire. The same design proposal was presented to the second group (Group B) with only the 3D urban simulation tool and they were asked to complete the same questionnaire as Group A. Unlike groups A and B, Group C is exposed to two design presentations. The design proposal is presented to the group with the conventional 2D plan at first, and then the proposal is subsequently presented with the 3D urban simulation tool. The group was asked to fill out the questionnaire after each presentation so that the group fills out the same questionnaire twice. Like group C, group D was also exposed to two presentations, but the order of the presentation media was switched. At the end of each presentation, the group was also asked to complete the questionnaire.

<Table 1> Survey research design

Respondent Group	Presentation Tools	Surveys
Group A	2D plans and sketches	Survey 1
Group B	3D simulation	Survey 1
Group C	2D plans and sketches	Survey 1
	3D simulation	Survey 2
Group D	3D simulation	Survey 1
	2D plans and sketches	Survey 2

It is necessary that several critical test conditions be controlled in order to increase the validity of this research analysis. The first condition concerns the same presentation time for every group. A test facilitator ensures that precisely the same time was assigned to every group. Second, this research design must control a testing confound validity, which refers that survey subjects get used to being tested for indicators on dependent variables (Bernard, 2000). Since the group C and D have two consecutive presentations, the survey respondents evaluate the second presentation medium based on the information that they acquired from the first presentation medium. However, by design, the tests for groups C and D was controlled with a switched order for the presentation media testing confound validity. Interpreting the results from groups C and D and comparing the results to the results from groups A and B result in a survey analysis that is not influenced by the testing confound validity. The last variable that this research must address is the quality of the presenters, as well as presentation methods. The presenters are one of the most crucial subjects in terms of delivering information in a presentation. For this reason, it is important to minimize the influence of different presenters delivering presentations. In order to minimize the bias from the different presenters, there is no verbal communication in any presentation. The test participants only watched a visual presentation with no verbal explanation of the design proposal. Having no verbal presentation also eliminates the possibility of varying information that is verbally delivered. Since the purpose of this research is to measure the information delivery capacity of two presentation tools, other methods of information delivery needed to be excluded from measurement. For that reason, verbal presentations were not allowed in this research.

Although two separate survey analyses were conducted, the same administrative methods and test settings were used for both surveys. The following strategies were used to administer the survey sessions.

- Before the survey sessions began, an orientation session was set up for the survey participants. Regardless of the nature of the survey groups, all of the participants were gathered in a room for the orientation session. During the session, the purposes and general guidelines of the surveys were explained. Furthermore, questions from survey participants were answered. After the introduction session, the participants were broken into each survey group.

- Each group spent ten minutes viewing a design proposal. Depending on the group each participant examined the proposal by a conventional drawing, the 3D simulation tool, or both.

- Discussions or questions regarding to the design alternative were not allowed among survey participants. This prevented information delivery through sources other than the design presentation tools.

- After ten minutes of examination, each participant was asked to complete a questionnaire.

- While the participants were completing the questionnaire, they were allowed to ask survey facilitators any questions regarding the questions on the questionnaire form. However, questions regarding the design alternative were not allowed.

- While the participants were completing the questionnaire, they were not allowed to view the presentation tool again. This prevented them from acquiring the additional information for this survey.

2. Questionnaire Form

At the end of every presentation, each participant was asked to complete a questionnaire survey form. The questionnaire was prepared to measure how well each design proposal presentation tool conveyed the design idea. To prepare questions in the questionnaire, it was necessary to explore what was the essential information that should be delivered through design presentation. One approach to address this issue was to research criteria used for urban design evaluation. The urban-design literature discusses elements, which are of concern for urban and landscape design evaluation (Bishop and Philip, 1989; Groat, 1983; Oh, 1994; Pomeroy et al. 1989; Rahman, 1992; Smardon et al. 1986). Although there are minor differences between scholars, most of them agree that the design criteria for visual impact analysis and assessment should include the following elements: pedestrian circulation, vehicular movement, alignment, landscaping, topography, and site size.

Based on the review of urban-design evaluation criteria, a questionnaire survey form was developed. The survey form contains 29 questions categorized into six different categories: project site, proposed buildings, automobile movement, pedestrian circulation, landscaping, and relationship with surroundings. These categories cover the urban-design evaluation criteria and elements of a good urban design. Each question asks respondents' level of understanding on detailed design ideas in each category. All of the questions regarding design elements required test participants to answer their level of understanding with numbers. The number 1 represents the least understanding while the number 7 means the best understanding. After the survey analysis, data were analyzed with a specific statistical method, Linear Discriminant Analysis.

3. Linear discriminant analysis

Linear Discriminant Analysis (LDA) is a procedure for obtaining weightings of variables to discriminate between populations (Srivastava, 2002). Discriminant analysis is a function that measures the distance between two populations. This statistical method is often used for distinguishing the existence of differences on data collected from two or more groups. This method served the purpose of this survey analysis well with an evaluation of effectiveness (means) of two different presentation tools (two groups) in terms of information delivery. Although there is another popular statistical method called The Analysis of Variance (ANOVA), and it is used for evaluating the difference of measurements from two or more groups, ANOVA can be only used when the dependent variables are interval (Welch and Comer, 1988). However, the data collected through the survey sessions are ordinal data that is necessary for measuring respondents' preference on presentation media. For this reason, ANOVA was not a suitable method for this research. However, LDA can be used for ordinal categories of the dependent variable, although it works best for nominal dependent variables (Welch and Comer, 1988).

Ⅳ. Survey Research Results

1. Analysis of the Test Results from Design Students

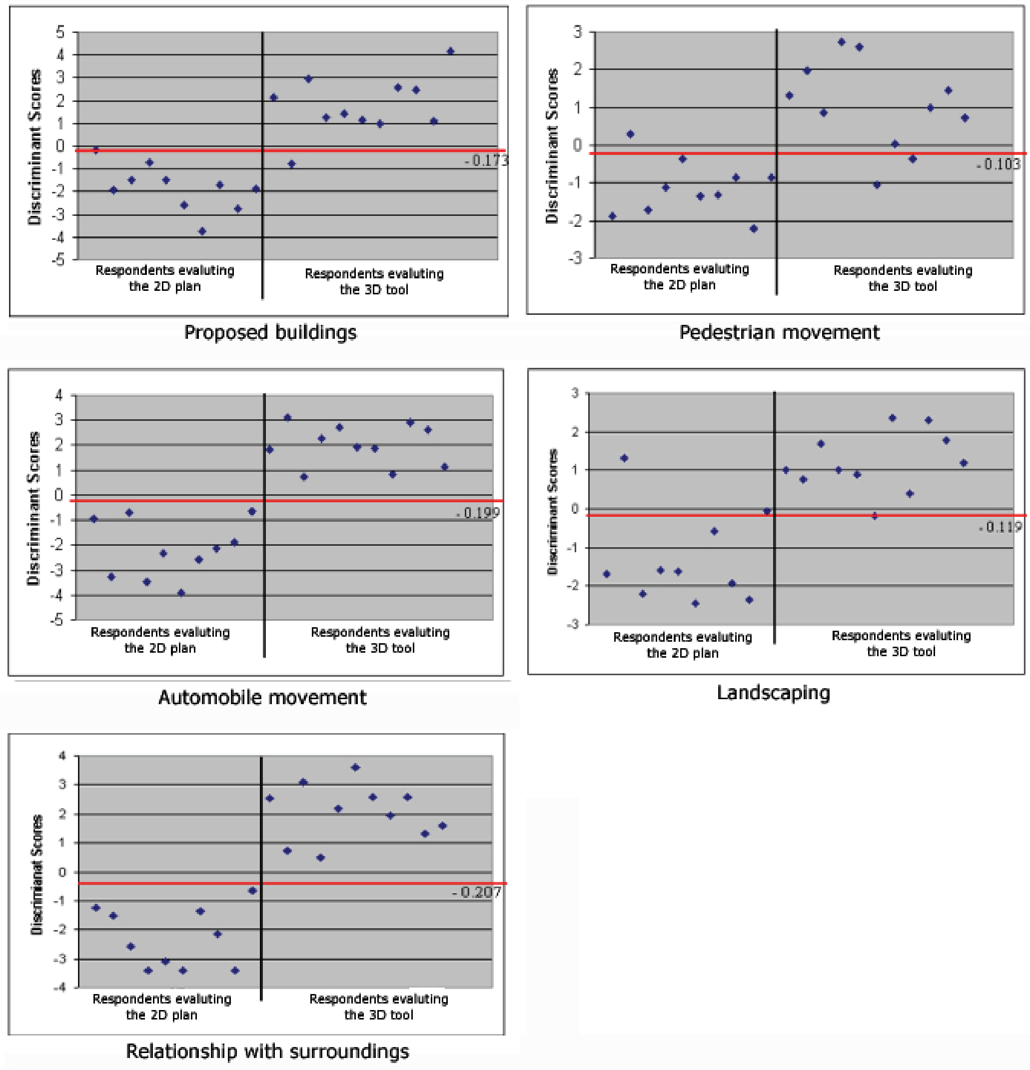
Priori to LDA, mean value of each question from test groups was compared to understand overview data. With 95% of confidence level, the design students showed preference on the 3D simulation tool 20 questions out of total 29 questions. However, with the same level of confidence, they showed preference of the 2D plan none of questions. Table 2 illustrates the number of questions showing preference on the 3D simulation tool by question categories. This result clearly explains which design information the 3D simulation tool effectively delivers. The 3D simulation tool was effective on transferring proposed buildings, pedestrian circulation, automobile movements, and relationship with surroundings.

<Table 2> Preference on the 3D simulation tool with 95 % confidence level

Design Element Categories	Total Questions	Preference on 3D	Preference on 2D	No difference on preference
Project Site	5	0	0	5
Proposed Buildings	5	5	0	0
Pedestrian Circulation	4	4	0	0
Automobile Movement	5	5	0	0
Landscaping	5	1	0	4
Relationship with Surroundings	5	5	0	0
Total	29	20	0	9

LDA was followed by the mean value comparison. LDA aggregates all mean values by design categories, and calculates thresholds that determine the difference in the mean values in each category. The results from LDA were consistent with the mean value comparison. The design students answered that the 3D simulation tool delivered design ideas 5 out of total 6 design categories better than the 2D plan, except project site. Figure 1 illustrates the discriminant thresholds that LDA classifies test participants' answers. Each point represents each respondent' answers; the red lines are the thresholds of discriminant scores that divide level of understanding; and the black vertical lines indicate respondents' preference on the 2D plan or the 3D tool. The results of LDA analysis for each design category turn out very similar to mean value comparison of each question. There is discrepancy on only the landscaping category. Only one question out 5 questions in the category shows the preference on the 3D tool, but LDA results prove that the 3D tool delivered landscaping design idea better than the 2D plan. The reason of this discrepancy seems to be driven by the last question in the category. While the mean values from the two groups for all other questions are similar to, the mean of the last question shows a large difference. The large difference on the last question makes it possible to distinguish the mean values of the two test groups.

In summary, design students responded that the 3D simulation tool was better design communication tool than the 2D plan 5 out 6 design categories. Especially, design students answered that the 3D tool had exceptional advantages in delivering information regarding proposed buildings and relationship with surroundings. Their answers also showed the moderate strength of the 3D tool in delivering information of pedestrian circulation and automobile movement.



<Fig 1> LDA analysis of design students

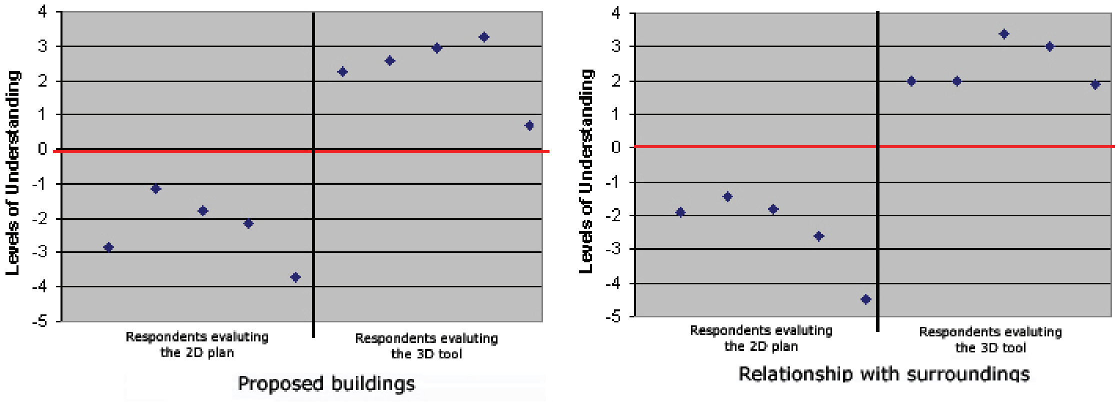
2. Analysis of the Test Results from High Springs Citizens

Priori to LDA, mean value of each question from test groups was compared to understand overview data. With 95% of confidence level, the citizens showed preference on the 3D simulation tool 17 questions out of total 29 questions. However, with the same level of confidence, they showed preference of the 2D plan none of questions. Table 3 illustrates the number of questions showing preference on the 3D simulation tool by question categories. Although this result indicates moderate preference on the 3D simulation tool comparing to the result from the design student group, this result clearly explains that the 3D tool effectively delivers design information. The 3D simulation tool was effective on transferring automobile movements and relationship with surroundings.

<Table 3> Preference on the 3D simulation tool with 95 % confidence level

Design Element Categories	Total Questions	Preference on 3D	Preference on 2D	No difference on preference
Project Site	5	1	0	4
Proposed Buildings	5	3	0	2
Pedestrian Circulation	4	3	0	1
Automobile Movement	5	4	0	1
Landscaping	5	1	0	4
Relationship with Surroundings	5	5	0	0
Total	29	17	0	12

LDA was followed by the mean value comparison. The results from LDA were different from the mean value comparison. The citizens answered that the 3D simulation tool delivered design ideas 2 (proposed buildings and relationship to surroundings) out of total 6 design categories better than the 2D plan. Figure 2 illustrates the discriminant thresholds that LDA classifies test participants' answers. Each point represents each respondent' answers; the red lines are the thresholds of discriminant scores that divide level of understanding; and the black vertical lines indicate respondents' preference on the 2D plan or the 3D tool.



<Fig 2> LDA analysis of High Springs Citizens

In summary, High Springs citizens responded that the 3D simulation tool was better design communication tool than the 2D plan 2 out 6 design categories. The responses from the citizens were clearly categorized into two extreme sides, strong preferences on the 3D tool in two categories, proposed buildings and relationship with surroundings, and no preferences on two design presentation media in other design categories.

3. Discussion of Survey Analysis

The survey results clearly proves that the 3D simulation tool has great advantage in terms of delivering design ideas compared to the 2D plan drawings. Both study groups showed strong preference of the 3D tool in the categories of proposed buildings and relationship with surroundings, and presented no differences of two media in delivering project site information. However, the survey results identifies that the 3D simulation tool helped to improve understandings of design students rather than of High Springs citizens. Few interesting observations were deducted from the survey results and interviews followed by the survey research.

First, the 3D simulation tool was not good enough to deliver abstract and delicate design ideas. There are three categories (pedestrian circulation, automobile movement, and landscaping) that design students showed preference on the 3D tool, but the citizens showed no preference. Those three design categories are abstract and subtle design ideas compared to other design categories. Since design students are educated and trained as design professionals know how to view and analyze spaces and structures that a design proposal depicts, they could extract the information regarding to those design categories from the 3D simulation tool. However, the 3D tool was not good enough to help the citizens with no training and background on design to understand the subtle design idea.

Second, the reality of the 3D simulation tool did not convince the High Springs citizens. Although the 3D simulation tool has achieved a great deal of reality at a city scale, the simulation tool is not capable of representing the detail presented by real world condition. The simulation tool visualized mostly buildings and major trees, but did not visualize small-scale objects in urban space such as billboards, street signs, urban furniture, and streetlights. The absence of those objects made the 3D simulation tool less realistic especially for High Springs residents that were very familiar with the area. For example, a couple of the residents brought up an issue regarding a billboard that exist in the real world, but are not shown in the simulation scene. Due to the absence of that billboard, they thought that the simulation tool was not realistic. Meanwhile, several student participants mentioned that all the buildings and details including the proposed design and the surrounding area are so realistic in the simulation tool, that they were confused because they were unable to correctly point out which aspect of the 3D model is the proposed or surrounding area. One interesting point is that the residents have different standards and expectations of the levels of reality for the 2D plan. Since they know that it is almost impossible for the 2D plan to realistically depict those trees, they did not expect much reality from the 2D plan, and just accepted the absence of those trees in the 2D plan. This factor may become part of the reason why the residents graded lower than the students for the design categories when asked detailed design issues such as landscaping.

Another issue brought up by the resident participants is the sense of control, which refers to the ability of people to manage, control, and use the tool. During the survey sessions, a test facilitator operated the 3D simulation tool. He navigated the scene by himself unless the survey participants required assistance. As the researcher constantly navigated the simulation scenes, the resident participants complained that the constant movement disturbed their concentration. On the other hand, the 2D plan and sketch drawings were hung on a wall, so that the participants could inspect them without assistance. Although the 2D plan does not have any dynamic visualization options, it provides the participants with the stable sense of control. Evaluating the 2D plan, they were able to look at essential parts of the design proposal, think about it, and move on to another aspect of the proposal. A brief orientation about the interfaces and navigation functionalities of the simulation tool was provided before the survey session. During the presentation, the resident participants passively followed the navigation of the facilitator, rather than attempt to navigate the simulation scene themselves. Unlike the resident participants, the design students actively asked to visualize the scenes from a variety of different perspectives. The students' knowledge in navigation functionalities and active requirements for visualization indicated that they did not have problems with the sense of control for the 3D simulation tool.

V. Conclusion

Although recent research reported the applications and the advantages of 3D urban simulation technology, there are limited numbers of studies that provide quantitative evidences proving the advantages of the 3D simulation technology in urban design process. This case study was conducted to fill this research gap by providing quantitative evidences measuring the capabilities of the 3D simulation technology as a communication medium in an urban design process. The statistical evidences from the analysis of this survey research prove that the 3D technology showed its superiority of design information delivery compared to a conventional method, a 2D plan and perspective drawings. Especially, the 3D simulation technology helped design students to understand design ideas rather than citizen participants, and it also showed great advantages in delivering design information regarding proposed buildings and relationship with surroundings, while it did not show any difference from the 2D plan in terms of delivering project site information. In addition, the results proved that the 3D technology did not improve the citizen participants' understanding on pedestrian circulation, automobile movement, and landscaping, but it improved the design students' level of understandings on the same categories. It can be deducted from the difference between two study groups' answers that the 3D simulation tool has limitations on delivering delicate urban design ideas. The 3D tool has also some limitations on level of reality and sense of control. Although the 3D simulation tool has few limitations, the tool more improves communication among design professionals than between design professionals and general publics due to the design professionals education and experiences. Thus, future research should focus on improving information sharing between design professionals and general publics and minimizing gap in the level of understanding between those two groups of stakeholders in order to achieve better collaboration.

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