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# Management and Enhancement of Livable Urban Streetscape through the Development of the 3D Spatial Multimedia System

*A Case Study of Provincial Street Corridors in Malang, Indonesia*

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**Abstract:** Maintaining the continuity of a valuable and livable visual experience is very important for the quality of urban streetscape planning and design. One of the impacts of the rapid development of urban streetscape is unsatisfying pedestrian space for spatial and visual comfort. In line with establishing good governance, it is necessary to evaluate the quality of urban visuals by involving community participation through online participation. The case study on the five provincial streets in Malang, Indonesia, has become a strategic route for the uncontrolled rapid growth of commercial districts alongside these streetscapes. This study promoted spatial multimedia development as a decision support system in the planning process as one of the recent developments in design planning activity by developing a multimedia 3D spatial system based on public preferences in the local community. A combination of three sequential stages was conducted, starting with investigating public preferences that produced spatial and visual comfort assessment through the Semantic Differential method and regression model analysis, followed by the 3D streetscape modeling ends with the development of a Spatial Multimedia System. This study resulted in several findings. The investigation of public preferences determined dominant variables and significant variables that affect the streetscape's spatial and visual comfort aspects. This outcome guided the development scenario of 3D modeling construction and 3D simulation of each streetscape and the development of a decision-making system in the 3D spatial multimedia system. This finding also revealed the significance of the leveling strategy of user interactive advancement in the system.

## 1. INTRODUCTION

The streetscape is the appearance and view of the street. Streetscape also contributes to the local character and overall legibility of settlements because streetscape is the primary way to travel through and function as space for a successful visual experience ([Rehan, 2013](#)). A valuable streetscape will persuade people to leave the car at home and walk to their destinations. It is necessary to enhance walkability and the pedestrian environment to create accessible pedestrian corridors, both functional and attractive ([Sutikno, Surjono, & Kurniawan, 2012](#)). Well-designed streetscapes absolutely will contribute to the visual quality and livability of communities ([Kashef, 2016](#)). The design appearance of streetscape includes all the elements that constitute the prominent perceptual features of the street, such as building façade, sidewalk, lighting, street furniture, landscaping, signage, billboard and also include amenities for pedestrians and bicyclists, incorporate public art, and also any space that properly accommodate every human activity and social interaction in the city ([Nasar, 1998](#)).

Moreover, the aesthetic experience of the streetscape is an essential part of the determining factors in the success of the cityscape ([Hoelscher & Porteous, 1996](#)). The streetscape must create a favorable environment for people to visit and gather to be the center of the community interactions, both socially and economically. Streetscape should have its character formed from established prominent features within a particular street environment and determined by how the streetscape is likely to be used by the local people as well as the need for consideration of the history and image of the local area ([Rapoport, 1978](#); [Tutuko & Son, 2018](#); [Nasar, 1998](#)). The community must have access earlier and more intense to participate in the planning project determining the streetscape character to avoid the appearance of urban streetscape products that are not in harmony with the community ([Wu, He, & Gong, 2010](#)).

Malang was known as a city with specific architectural style characteristics based on the historical development of the citizens' city and socio-cultural. At the beginning of the development of Malang city in the Dutch colonial era, Dutch architects had planned and designed Malang city corridors with well-planned urban patterns and visual images. In a further development, Malang city experienced rapid growth of buildings and the city's population and was not well controlled. Urban planning regulations are not able to keep up with the speed of growth of new urban areas. On the other hand, five provincial streetscapes are the intercity path between cities, becoming inter-city transport mobilization mode. These roads have become a strategic route in business and trade activities, triggering commercial districts' uncontrolled rapid growth alongside thus streetscapes. Further, one of the forceful impacts of the ungoverned rapid development of urban streetscape is the emergence and growth of discomfort spatial and visual arrangements along urban corridors.

In order to encourage the realization of good governance in urban planning, the quality and characteristics of urban space require evaluation measures through continuous observation of architectural developments in road corridors. Aesthetic experiences in urban spaces are essential in forming urban corridor landscapes; as Jackson (as cited in ([Hoelscher & Porteous, 1996](#)), the city is obliged to provide sensory experiences and aesthetic comfort for all its citizens. Further, creating a favourable urban

image will generate appropriate perceptions and meanings and encourage people to act and react positively to the urban space. [Nasar \(1998\)](#) stated that physical and non-physical embodiments in the urban environment would shape patterns and peculiar perceptions and appreciation for every human being. Perceptions embedded in the formation of urban space will determine the values of people's preferences for urban streetscapes. Hence, the preferred quality of spatial and visual aspects for passers-by in the provincial streetscapes is a significant issue to improve space comfort and a better city living environment.

Spatial multimedia development as a support system in the planning process is a recent development in design planning activity associated with public participation. Spatial multimedia systems are intended as a medium of interaction between the planning concepts of the built environment with the community as a user ([Muenzer, Seufert, & Bruenken, 2009](#)). The spatial multimedia system is packaged in the web interface design through programming languages. The system commonly also supplies 3D modeling data that acts as a virtual world. With the help of virtual world data, users are allowed to conduct a spatial exploration of the planning concept. In order to make a better exploration in the virtual world, users require an understanding of spatial knowledge ([Burigat & Chittaro, 2007](#); [Ibanez & Delgado-Mata, 2011](#)).

Researchers related to pedestrians' space comfort quality are strongly related to spatial and visual aspects shaping pedestrian space. As mentioned by Rapoport, as cited in [Nasar \(1998\)](#), each place will contain three categories of features, namely permanent features, semi-permanent features, and changeable features. Establishing good urban planning needs various studies involving groups of participants to determine the essential features of urban space. Moreover, evaluating and controlling pedestrian comfort's spatial and visual quality requires performing spatial and visual judgments through public participation for making proper spaces. Lately, the public participatory conventional method is incapable of handling the rapid development of Malang. The online public participation method approach through web-based virtual reality technology has begun to demand and develop ([Al-Kodmany, 2001](#); [Honjo & Lim, 2001](#); [Howard & Gaborit, 2007](#)). Also, according to ([Conniff et al., 2010](#)), the dynamic presentations presenting a future environment can evoke perceptions and reactions closer to reality. Accordingly, the development of 3D spatial multimedia must be preceded by investigating public preferences involving local communities.

The combination of the public preference method with the development of a spatial multimedia system for decision-making tools has been widely developed in studies related to streetscape evaluation. Several early researchers have shown adequate study results of those couple methods for streetscape evaluation studies ([Koba & Kishimoto, 2009](#); [Koizumi, Kishimoto, & Koba, 2009](#)). Other researchers evaluated the streetscape through typology methods and visual image analysis with the help of computer graphics software ([Dokyu & Yamamoto, 2003](#); [Seta, Matsumoto, & Tanabe, 2003](#); [Yoshimura & Tsukamoto, 2010](#)). On the other hand, some researchers developed a public consensus system through a virtual environment system embedded in a web interface. In Kanazawa city, ([Kawakami & Shen, 2006](#)) assisted consensus in public participation by developing a decision support system for district planning. ([Takiguchi et al., 2003](#)) developed multimedia tools to support town-planning workshops. Later, ([Koga et al., 2008](#)) developed a public participation model in the

landscape planning support system as a decision-making tool. Then, ([Shen & Kawakami, 2010](#)) promoted a public consensus model for urban landscape design by developing a multi-user platform combined with traditional presentation materials. Further, well-designed visualizations and interactive tools have to be created to improve public participation ([Wu, He, & Gong, 2010](#)).

Research on the urban streetscape planning system in commercial corridors in Malang has been implemented in the Kayutangan corridor, the historical streetscape in Malang, through a series of continuous research stages. It covers public preference assessment of visual and spatial comfort in the commercial streetscape and also landscapes support systems development through interactive 3D visualization ([Santosa, Herry, Ikaruga, & Kobayashi, 2013](#); [Santosa, H., Ikaruga, & Kobayashi, 2014](#)). This study expects to produce a series of research and system development in the commercial streetscape in Malang, which is in harmony with the previous study's method. Hence, this study performed the construction process of 3D spatial of the five provincial streetscapes and a spatial multimedia system development. This study also emphasizes that the investigation of public preferences method involving local communities became the foremost basis for the development of the system Decision making on the development of spatial 3D multimedia.

## **2. RESEARCH METHODS**

### **2.1 The case study area and the system development**

This study aims to construct the development of the 3D spatial multimedia system based on people's preferences for spatial and visual comfort in the provincial streets of Malang. The research focus is located along the provincial street, which consists of five street corridors, namely Tlogomas Street, MT Haryono Street, Soekarno-Hatta Street, Borobudur Street, and Ahmad Yani Street, which stretches from the west to the north of Malang City. These streetscapes are strategic trade and service areas connecting Surabaya City as the provincial capital with the tourist area of Batu City. (see *Figure 1*).

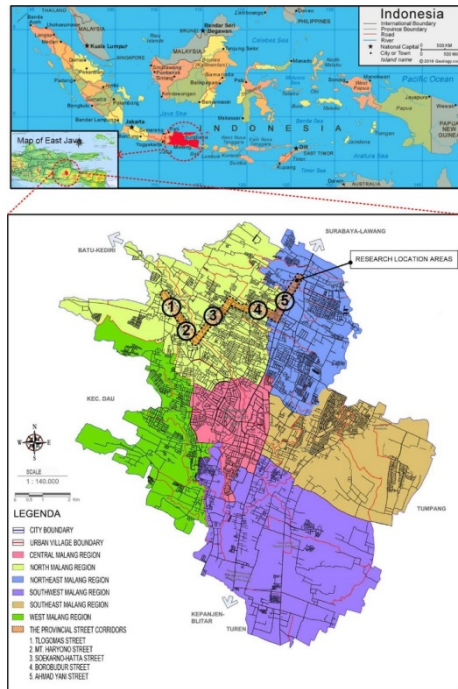


Figure 1. Map of the study area

This study involved three prominent stages: public preference investigation, digital interactive tools, and system evaluation (see Figure 2). First, the public preference investigation produced spatial and visual comfort assessment through the Semantic Differential method and regression model analysis. Second, the development of digital interactive tools consisted of three procedures, i.e., 3D visualization stages, 3D interactive simulation scenarios, and 3D spatial multimedia scenarios. Third, the system evaluation contained the operation evaluation of three types of the application system, i.e., UID passive 3D simulation, UID active 3D simulation, UID interactive 3D simulation.

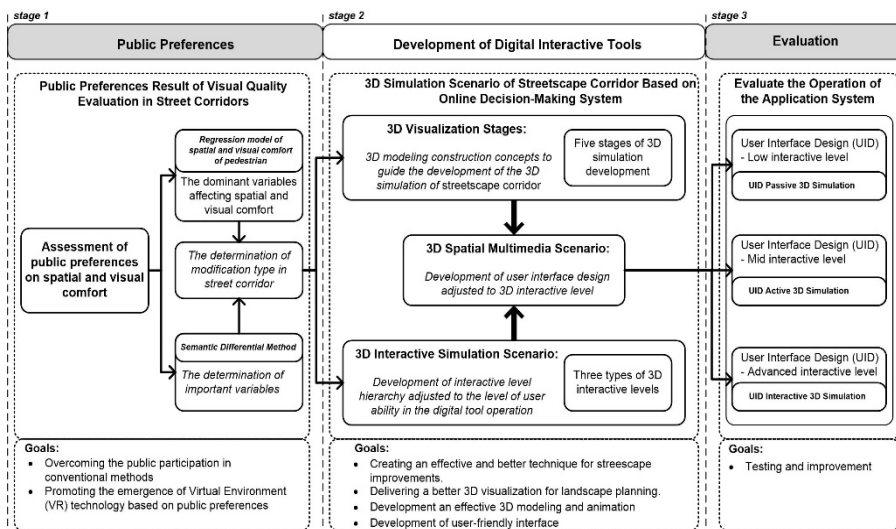


Figure 2. The grand scenario of 3D spatial multimedia system development

Table 1. The research variables of spatial and visual comfort

		Variable					
		Spatial Comfort		Visual Comfort			
		category	sub category	category	sub category		
Sub Variable	Sidewalk		Sidewalk function	X <sub>1</sub>	Building	Visual appearance variety	X <sub>13</sub>
			Sidewalk position	X <sub>2</sub>		Building appearance uniqueness	X <sub>14</sub>
			Sidewalk dimension	X <sub>3</sub>		Building height proportion	X <sub>15</sub>
			Sidewalk material	X <sub>4</sub>	Street Corridor	Region dominant color	X <sub>16</sub>
			Walking continuity	X <sub>5</sub>		Street corridor transparency	X <sub>17</sub>
	Building		Building border width	X <sub>6</sub>	Scale	Human height and building height proportion	X <sub>18</sub>
			Building setback	X <sub>7</sub>		Human height and street furniture proportion	X <sub>19</sub>
	Street Furniture		Street furniture position	X <sub>8</sub>		Visibility	Visibility proportion
			Street furniture type	X <sub>9</sub>	Signage		Signage visibility
	Vegetation		Vegetation type	X <sub>10</sub>			
			Vegetation function	X <sub>11</sub>			
			Vegetation position	X <sub>12</sub>			

At the first stage, the study performed a public preference method through questionnaires to assess the quality of the spatial and visual comfort levels of urban spatial features along each street corridor. The questionnaires consist of two sets of independent variables, which consist of four categories of spatial comfort and five categories of visual comfort (see Table 1). The study utilized non-probability sampling through the purposive sampling technique. The total number of respondents was 450 persons, with 90 pedestrians as respondents in each provincial street corridor. Respondents are required to be 18 years of age and over in order to have a good understanding of each question and have the ability to provide an appropriate assessment of the spatial and visual quality of street corridors. Distributing questionnaires carried out at 20-point locations are divided into both sides of the road corridor on each of the street corridors. The questionnaire refers to two variables of spatial and visual comfort, which are divided into four categories and 12 sub-categories for spatial comfort, as well as five categories and nine sub-categories of visual comfort. Data analysis utilized descriptive analysis and multiple linear regression to determine the most dominant sub-variables and influence on spatial and visual comfort in each street corridor. The result will determine the critical modification parameter elements in spatial and visual comfort and guide the scenario of a 3D simulation development of each streetscape.

In the second stage, research constructs the development of digital interactive tools consisted of three procedures, i.e., 3D visualization stages, 3D interactive simulation scenario, and 3D spatial multimedia scenario. The process of 3D visualization making involved 3D modeling application software that requires several primary procedures, i.e., 3D simulation scenario, data collection, 3D modeling, geometry optimization, texture application, and the entity object. This step was related to the 3D interactive simulation scenario that was divided into three types of interactive levels adjusted to the level of user ability in the digital tool operation. Overall, 3D model data is processed in 3D spatial multimedia application authoring platforms to develop user interface design adjusted to 3D interactive levels.

In the final stage, the 3D spatial multimedia system's evaluation is accomplished by testing the system through interactive variables embedded in the system. The evaluation of the system operation is related to the most critical variable affecting spatial and visual comfort in each streetscape as the result of public preferences.



## 2.2 The investigation of public preferences

Investigating public preference of spatial and visual comfort quality on five province street corridors in Malang performs descriptive statistical analysis methods (frequency) combined with multiple linear regression analysis. The descriptive analysis method requires distributing questionnaires to respondents to assess 12 variables of spatial comfort and nine variables of visual comfort values. The preference rating utilizes a semantic differential method measured using seven scales according to the Likert scale method. Respondents expressed their preference for each statement item in one of the attitude scores from the seven scale categories whose intensity ranges from very uncomfortable (negative) to very comfortable (positive). The respondent's preference produces a score data table that contains the mean score of the respondent's assessment of the quality of the spatial and visual comfort of each street corridor. Data mean scores on the respondent's preferences produce a ranking of the variables of visual and spatial quality that are positive (indicated by the mean score above 4) and negative (indicated by the mean score below 4). The highest positive scores indicate the most comfortable visual and spatial comfort conditions and vice versa; the lowest negative scores indicate the worst visual and spatial comfort conditions. The lowest negative score for each sub variable, namely four sub-variables for the spatial comfort category (building, sidewalk, street furniture, vegetation) and five sub-variables for the visual comfort category (building, street corridor, scale, visibility, signage) are the determinants modification parameters for each street corridor.

In the next stage, the further analysis of respondents' preference data employs multiple linear regression analysis to find out the most significant or dominant variable influencing spatial and visual comfort in each street corridor through multiple linear regression equations as follows:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n \dots \dots \dots (1)$$

Where Y is the predicted or expected value of the dependent variable (Visual and Spatial comfort), X<sub>1</sub> through X<sub>n</sub> are n distinct independent or predictor variables (21 variables of visual and spatial comfort), a is the value of Y when all of the independent variables (X<sub>1</sub> through X<sub>n</sub>) are equal to zero, and b<sub>1</sub> through b<sub>n</sub> are the estimated regression coefficients. Moreover, the research instrument requires a validity and reliability test to determine the validity or reliability of the question items summarized in the questionnaire. In this study, the validity test used the Corrected item-total Correlation validity test with the Pearson Product Moment formula, as follows:

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2} \sqrt{n(\sum y^2) - (\sum y)^2}} \dots \dots \dots (2)$$

where r is Pearson's Product Moment Correlation Coefficient, N is a number of pairs of values or scores, Σxy is the sum of the products of paired scores, Σx is the sum of x scores, Σy is the sum of y scores, Σx<sup>2</sup> is the sum of squared x scores, and Σy<sup>2</sup> is the sum of squared y scores. The test used a two-sided test with a significance level of = 0.05. The test criteria are as follows: r count > r 0.05 = valid, r count ≤ r 0.05 = invalid. While the reliability test uses the Alpha Cronbach formula, as follows:



$$r_{11} = \left[ \frac{n}{n-1} \right] \left[ 1 - \frac{S_i^2}{S_t^2} \right] \dots\dots\dots(3)$$

where n is the number of components (items or tests),  $S_i^2$  is the variance of the observed total test scores, and  $S_t^2$  is the total variance score for each item. The criteria for reliability testing with the Cronbach Alpha formula are if the Cronbach's Alpha value is > 0.60, then the questionnaire is declared reliable or consistent. If the Cronbach's Alpha value is < 0.60, then the questionnaire is declared unreliable or inconsistent.

Multiple linear regression analysis requires verification through a series of classical assumption tests to meet the requirements of the regression model, namely the multicollinearity assumption test, heteroscedasticity assumption test, normality assumption test, partial regression parameter test, simultaneous regression parameter test, and F test. The final results of multiple linear regression analysis indicate two categories of variables: the partially influential variable (significant p-value less than 0.05) and the most influential variable (indicated by significance p-value, which is less than 0.05, and the unstandardized coefficient, which is furthest from 0).

Eventually, the results of descriptive statistical analysis and multiple linear regression are the basis for determining the type and number of modification parameters employed in the interactive spatial multimedia development scenario.

### 2.3 The system evaluation

The 3D spatial multimedia system's evaluation is accomplished by testing the system through interactive variables embedded in the system. The review of the system operation is related to the most critical variable affecting spatial and visual comfort in each streetscape due to parameter modification resulting from the investigation stage of public preferences. The determination of the interactive simulation components depends on the modification parameters, which are categorized into two parts, namely, non-adjustable/fixed variable ( $V_f$ ) and adjustable variable (important modification parameters). Adjustable variables consist of two variables, the primary variable ( $V_p$ ) and the significant variable ( $V_s$ ). The primary variable is the result of descriptive statistical analysis, indicating that the sub-variable of visual and spatial comfort has the lowest means score (<4.00). At the same time, the supporting variable is the result of multiple linear regression analysis, which indicates the most and partially influential variable (significant p-value less than 0.05 and unstandardized coefficient which is furthest from 0) of 21 sub-variables, visual and spatial comfort (see *Table 2*).

Table 2. The rules of modification's parameter

variable	sub variable		modification parameters for interactive simulations		
			non-adjustable/ fixed variable (Vf)	adjustable variable (important modification parameters)	
				primary variable (Vp)	significant variable (Vs)
category	sub category				
spatial comfort	Sidewalk	Sidewalk function	X <sub>1</sub>	sub variables (X <sub>1</sub> - X <sub>5</sub> ) which has the lowest negative means score (< 4.00)	sub variables (X <sub>1</sub> -X <sub>12</sub> ) which has a significance p-value < 0.05 and also has unstandardized coefficient which is furthest from 0 (based on the regression model analysis)
		Sidewalk position	X <sub>2</sub>		
		Sidewalk dimension	X <sub>3</sub>		
		Sidewalk material	X <sub>4</sub>		
		Walking continuity	X <sub>5</sub>		
	Building	Building border width	X <sub>6</sub>	sub variables (X <sub>6</sub> - X <sub>7</sub> ) which has a positive means score (> 4.00)	
		Building setback	X <sub>7</sub>		
	Street Furniture	Street furniture position	X <sub>8</sub>	sub variables (X <sub>8</sub> - X <sub>9</sub> ) which has the lowest negative means score (< 4.00)	
		Street furniture type	X <sub>9</sub>		
	Vegetation	Vegetation type	X <sub>10</sub>	sub variables (X <sub>10</sub> - X <sub>12</sub> ) which has the lowest negative means score (< 4.00)	
		Vegetation function	X <sub>11</sub>		
		Vegetation position	X <sub>12</sub>		
visual comfort	Building	Visual appearance variety	X <sub>13</sub>	sub variables (X <sub>13</sub> - X <sub>15</sub> ) which has the lowest negative means score (< 4.00)	
		Building appearance uniqueness	X <sub>14</sub>		
		Building height proportion	X <sub>15</sub>		
	Street Corridor	Region dominant color	X <sub>16</sub>	sub variables (X <sub>16</sub> - X <sub>17</sub> ) which has the lowest negative means score (< 4.00)	
		Street corridor transparency	X <sub>17</sub>		
	Scale	Human height and building height proportion	X <sub>18</sub>	sub variables (X <sub>18</sub> - X <sub>19</sub> ) which has a positive means score (> 4.00)	
		Human height and street furniture proportion	X <sub>19</sub>		
	Visibility	Visibility proportion	X <sub>20</sub>	sub variables (X <sub>20</sub> ) which has the lowest negative means score (< 4.00)	
			X <sub>21</sub>		
	Signage	Signage visibility	X <sub>21</sub>	sub variables (X <sub>21</sub> ) which has the lowest negative means score (< 4.00)	

The development of interactive spatial simulations in each provincial street corridor focuses on the ability of the spatial multimedia system to organize the primary and supporting variables interactively. In addition, the design of a decision-making system in interactive simulations emphasizes the method of handling focus on spotted cases, which aims to reduce the level of complexity of case exposure. The spotted cases method also creates a short field of view coverage in the interactive simulation plane, which is expected to make it easier for users to make decisions and shorten the estimated user response time. The determination of spotted cases in each street corridor refers to the public preference for the quality of visual and spatial comfort at one of the 20 location survey points on the street corridor, which is considered the worst.

The evaluation of system development also considers the implementation of User Interface Design (UID) design, which accommodates the level of interactive complexity of users in decision-making systems in three categories: low-level, mid-level, and advanced-level (Santosa, Herry, Ikaruga, & Kobayashi, 2013; Santosa, H., Ikaruga, & Kobayashi, 2014). The low level represents the interactive level of passive observation through various predefined walkthrough animations (passive 3D simulation). The mid-level represents the interactive level of active navigation through various active 3D simulations in the 3D virtual environment. Meanwhile, the advanced level represents the interactive level of active navigation and object interaction through an interactive 3D simulation display. The development of various choices for types and forms of animation and 3D simulations developed at three levels of user interactive complexity is also based on modification parameters and the spotted case method based on public preferences (see Table 3).

Table 3. The indicators of developing user-interactive levels in a 3D spatial multimedia system

indicators	user interactive levels		
	Low-level	Mid-level	Advanced-level
Simulation type	passive 3D simulation	active 3D simulation	an interactive 3D simulation
Type of user interaction	passive observation	active navigation	active navigation & interaction
Type of simulation media	predefined walkthrough animation	3D virtual environment	3D virtual environment
Modification formulas in interactive simulations	Vf + Vs1	Vf + Vs1	
	Vf + Vs2	Vf + Vs2	Vf + Vp + Vs
	Vf + Vsn	Vf + Vsn	
User assessment method	exploration of a predefined 3D walkthrough animation	independent-exploration of a predefined 3D virtual environment	independent exploration and modification of 3D virtual environments
Decision-making system tools	5 scale of conformity rating (very bad - very good)		independent modification of the adjustable variable

note:

Vf = non-adjustable/ fixed variable (sub variables ( $X_7$ -  $X_{11}$ )) which has a positive means score (> 4.00)

Vp = primary adjustable variable (sub variables ( $X_1$ -  $X_{11}$ )) which has the lowest negative means score (< 4.00) of each variabel category)

Vs = significant adjustable variable (sub variables ( $X_1$ -  $X_{11}$ )) which has a significancy p-value < 0.05 and also has unstandardized coefficient which is furthest from 0)

### 3. RESULT AND DISCUSSION

#### 3.1 Investigation of public preferences

The investigation process of public preferences involves two primary procedures, i.e., the determination of important variables and the dominant variable level. The result of public preferences on spatial and visual comfort produces the positive-scored rank elements in which the scores are above four and negative-scored elements in which the scores are less than 4. The highest score in a positive zone indicates that the ideal condition supports spatial and visual comfort; meanwhile, the lowest score in the negative zone represents the worst condition that needs improvement.

In the meantime, the dominant variables influencing spatial and visual comfort based on the regression analysis result lead to the determination of the dominant variable level divided into a primary, secondary, and tertiary variable. The primary variables are those with p-values less than 0.05, and the Standardized Coefficients are the furthest from zero, while the secondary variables are those with the Standardized Coefficients that are closer to zero.

Meanwhile, the tertiary variables consist of those with p-values more than 0.05, ranked based on the distance between Standardized Coefficients and zero, from the farthest to the closest distance. Second, the determination of modification type in each Provincial street corridor. This step determinates the essential modification parameter elements in spatial and visual aspects in the particular provincial street corridor. The results of both stages will be used to develop a 3D modeling construction concept to guide the development of a 3D simulation of each streetscape (see Table 4).

Table 4. The determination of modification parameters in each the provincial street corridor

variable of spatial and visual comfort	street corridors														
	Tlogomas			MT Haryono			Soekamo-Hatta			Borobudur			Ahmad Yani		
	Positive Score <sup>a</sup>	Negative Score <sup>b</sup>	P-value	Positive Score <sup>a</sup>	Negative Score <sup>b</sup>	P-value	Positive Score <sup>a</sup>	Negative Score <sup>b</sup>	P-value	Positive Score <sup>a</sup>	Negative Score <sup>b</sup>	P-value	Positive Score <sup>a</sup>	Negative Score <sup>b</sup>	P-value
Sidewalk function		3,57***	0,72	3,61	0,48		3,57***	0,44		2,96***	0,09		4,00	0,48	
Sidewalk position	3,84	0,03**		3,61	0,18		3,66	0,31		3,17	0,37		4,00	0,06	
Sidewalk dimension	3,62	0,55		3,31***	0,70		3,91	0,59		3,39	0,54		3,64	0,33	
Sidewalk material	3,64	0,24		3,58	0,64		3,77	0,17		3,52	0,37		3,8	0,62	
Walking continuity	3,88	0,48		3,89	0,64		3,78	0,05		3,19	0,99		3,6***	0,07	
Building border width	3,6	0,14		3,48***	0,14	4,09		0,16		3,33	0,20		3,5***	0,59	
Building setback		3,51***	0,91	3,48	0,034**		3,78***	0,55		3,29***	0,33		3,75	0,78	
Street furniture position		3,91***	0,40	3,41***	0,12	4,22		0,21		3,06***	0,95		3,52***	0,67	
Street furniture type		3,97	0,50	3,7	0,62		3,83***	0,20		3,41	0,18		3,6	0,76	
Vegetation type	5,03		0,13	4,52		0,33	5,12		4,00		0,62	4,28		0,26	
Vegetation function	5,09		0,09	4,83		0,55	5,53		4,62		0,29	4,78		0,01	
Vegetation position	4,79		0,77	4,47		0,97	5,01		0,04		3,88***	0,20	3,97***	0,54	
Visual appearance variety	4,12		0,51		3,92	0,08	4,29		0,47		3,94	0,025**	4,21		0,32
Region dominant color	4,12		0,38		3,87***	0,25	4,33		0,93		3,78***	0,25		3,78***	0,51
Street corridor transparency	4,07		0,048**		3,87	0,45	4,38		0,72		3,91	0,18		3,85	0,72
Building appearance uniqueness	4,09		0,34		3,91	0,96	4,38		0,99		3,81***	0,21	4,07		0,13
Building height proportion	4,07		0,63		3,9***	0,08	4,46		0,88		3,84	0,14	4,16		0,54
Visibility proportion		3,76***	0,20	4,04		0,12	4,32		0,95		3,93***	0,52	4,23		0,09
Human height and building height proportion	4,03		0,89	4,01		0,51	4,38		0,58		3,86***	0,21	4,09		0,33
Human height and street furniture proportion	4,27		0,12	4,03		0,05	4,32		0,56		3,79	0,15	4,03		0,50
Signage visibility	4,13		0,92		3,9***	0,003**	4,24		0,06		3,42***	0,27		3,93***	0,73

<sup>a</sup>) The result of public preferences on spatial and visual comfort produces the positive-scored rank and negative-scored rank on each variable.  
<sup>b</sup>\*) The most and partially influential variable (Significance p-value less than 0.05) based on the regression model  
<sup>c</sup>\*) The lowest negative score of each sub variable of spatial and visual comfort

### 3.2 The scenario of digital interactive tools development

The concept of the 3D spatial multimedia involved three essential processes related to digital interactive tool development that consisted of constructing the 3D modeling streetscape elements, constructing the 3D interactive simulation by utilizing the multimedia application authoring platform, and designing User Interface Design (UID) accommodating 3D interactive simulation process (see Figure 3).

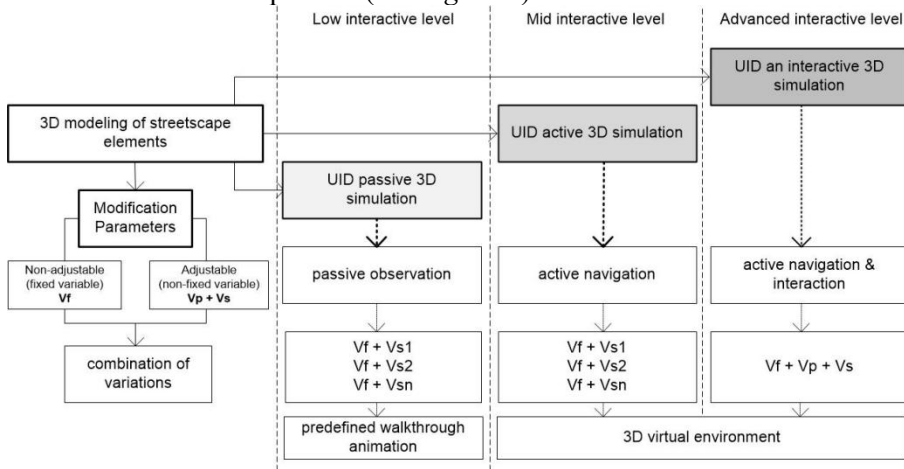


Figure 3. The scenario of interactive spatial multimedia development

The 3D modeling stage refers to the two aspects. First, the three User Interface Design (UID) development products consist of UID passive 3D simulation, UID active 3D simulation, and UID interactive 3D simulation. Second, the modification parameters consist of non-adjustable variables (Vf) and adjustable variables (Vp & Vs) resulting from public preference. The UID passive 3D simulation development product is a predefined walkthrough animation that only displays a passive simulation without user interaction (passive observation). UID only offers a wide variety of animation options, which are variations in the combination of fixed and significant variables (Vf + Vs). The UID active 3D simulation offers user interaction for independent exploration in a predefined 3D virtual environment.

Meanwhile, the UID interactive 3D simulation shows further interaction for users to carry out independent exploration and self-modification on primary and significant variables (Vf + Vp + Vs). The decision-making method for determining each combination of UID passive 3D simulation variations and UID active 3D simulation uses a scoring panel with a five scale of conformity rating (very bad - very good). Meanwhile, the decision-making method for the UID interactive 3D simulation can be determined by an independent modification of the adjustable variable by the user. *Table 5* below describes the results of modification parameters variation between the non-adjustable variable (Vf) and the primary adjustable variable (Vp) and the significant adjustable variable (Vs) for interactive simulations on each street corridor based on public preferences.

*Table 5.* The results of modification parameters variation for interactive simulations

variable	sub variable	modification parameters for interactive simulations															
		Tlogomas			MT Haryono			Soekarno-Hatta			Borobudur			Ahmad Yani			
		Vf	Vp	Vs	Vf	Vp	Vs	Vf	Vp	Vs	Vf	Vp	Vs	Vf	Vp	Vs	
spatial comfort	Sidewalk	X <sub>1</sub> Sidewalk function		X <sub>1</sub>		X <sub>1</sub>		X <sub>1</sub>		X <sub>1</sub>		X <sub>1</sub>		X <sub>1</sub>		X <sub>1</sub>	
		X <sub>2</sub> Sidewalk position			X <sub>2</sub>		X <sub>2</sub>		X <sub>2</sub>		X <sub>2</sub>		X <sub>2</sub>		X <sub>2</sub>		X <sub>2</sub>
		X <sub>3</sub> Sidewalk dimension		X <sub>3</sub>			X <sub>3</sub>		X <sub>3</sub>		X <sub>3</sub>		X <sub>3</sub>		X <sub>3</sub>		X <sub>3</sub>
		X <sub>4</sub> Sidewalk material			X <sub>4</sub>		X <sub>4</sub>		X <sub>4</sub>		X <sub>4</sub>		X <sub>4</sub>		X <sub>4</sub>		X <sub>4</sub>
		X <sub>5</sub> Walking continuity		X <sub>5</sub>			X <sub>5</sub>		X <sub>5</sub>		X <sub>5</sub>		X <sub>5</sub>		X <sub>5</sub>		X <sub>5</sub>
	Building	X <sub>6</sub> Building border width		X <sub>6</sub>			X <sub>6</sub>		X <sub>6</sub>		X <sub>6</sub>		X <sub>6</sub>		X <sub>6</sub>		X <sub>6</sub>
		X <sub>7</sub> Building setback			X <sub>7</sub>		X <sub>7</sub>		X <sub>7</sub>		X <sub>7</sub>		X <sub>7</sub>		X <sub>7</sub>		X <sub>7</sub>
	Street Furniture	X <sub>8</sub> Street furniture position			X <sub>8</sub>		X <sub>8</sub>		X <sub>8</sub>		X <sub>8</sub>		X <sub>8</sub>		X <sub>8</sub>		X <sub>8</sub>
		X <sub>9</sub> Street furniture type			X <sub>9</sub>		X <sub>9</sub>		X <sub>9</sub>		X <sub>9</sub>		X <sub>9</sub>		X <sub>9</sub>		X <sub>9</sub>
	Vegetation	X <sub>10</sub> Vegetation type		X <sub>10</sub>			X <sub>10</sub>		X <sub>10</sub>		X <sub>10</sub>		X <sub>10</sub>		X <sub>10</sub>		X <sub>10</sub>
		X <sub>11</sub> Vegetation function			X <sub>11</sub>		X <sub>11</sub>		X <sub>11</sub>		X <sub>11</sub>		X <sub>11</sub>		X <sub>11</sub>		X <sub>11</sub>
		X <sub>12</sub> Vegetation position		X <sub>12</sub>			X <sub>12</sub>		X <sub>12</sub>		X <sub>12</sub>		X <sub>12</sub>		X <sub>12</sub>		X <sub>12</sub>
visual comfort	Building	X <sub>13</sub> Visual appearance variety		X <sub>13</sub>		X <sub>13</sub>		X <sub>13</sub>		X <sub>13</sub>		X <sub>13</sub>		X <sub>13</sub>		X <sub>13</sub>	
		X <sub>14</sub> Building appearance uniqueness			X <sub>14</sub>		X <sub>14</sub>		X <sub>14</sub>		X <sub>14</sub>		X <sub>14</sub>		X <sub>14</sub>		X <sub>14</sub>
		X <sub>15</sub> Building height proportion			X <sub>15</sub>		X <sub>15</sub>		X <sub>15</sub>		X <sub>15</sub>		X <sub>15</sub>		X <sub>15</sub>		X <sub>15</sub>
	Street Corridor	X <sub>16</sub> Region dominant color		X <sub>16</sub>			X <sub>16</sub>		X <sub>16</sub>		X <sub>16</sub>		X <sub>16</sub>		X <sub>16</sub>		X <sub>16</sub>
		X <sub>17</sub> Street corridor transparency			X <sub>17</sub>		X <sub>17</sub>		X <sub>17</sub>		X <sub>17</sub>		X <sub>17</sub>		X <sub>17</sub>		X <sub>17</sub>
	Scale	X <sub>18</sub> Human height and building height proportion		X <sub>18</sub>			X <sub>18</sub>		X <sub>18</sub>		X <sub>18</sub>		X <sub>18</sub>		X <sub>18</sub>		X <sub>18</sub>
		X <sub>19</sub> Human height and street furniture proportion		X <sub>19</sub>			X <sub>19</sub>		X <sub>19</sub>		X <sub>19</sub>		X <sub>19</sub>		X <sub>19</sub>		X <sub>19</sub>
	Visibility	X <sub>20</sub> Visibility proportion		X <sub>20</sub>			X <sub>20</sub>		X <sub>20</sub>		X <sub>20</sub>		X <sub>20</sub>		X <sub>20</sub>		X <sub>20</sub>
	Signage	X <sub>21</sub> Signage visibility		X <sub>21</sub>			X <sub>21</sub>		X <sub>21</sub>		X <sub>21</sub>		X <sub>21</sub>		X <sub>21</sub>		X <sub>21</sub>

note:  
Vf = non-adjustable/ fixed variable; Vp = primary adjustable variable; Vs = significant adjustable variable

The final development stage of the 3D spatial multimedia system rests on the 3D interactive simulation programming process on the multimedia application authoring platform. The interactive simulation development process depends on three main aspects: the type and form of 3D object interaction, the type of interaction control panel, and decision-making techniques. Types of 3D object interactions must perform adjustment procedures on the primary variable (Vp) and the significant variable (Vs) that have been determined in the results of public preferences. The adjustment procedure affects the determination of the type of control panel in the user interface design (UID) system and the suitability of decision-making techniques.

The complexity of variable adjustment techniques lies at the advanced interactive level, which must accommodate interactive 3D model simulations following the interests of each primary and significant sub variable in spatial and visual comfort. Not all variable adjustment techniques can accommodate the need for interactive simulations of primary and significant variables because they are not directly related to the arrangement of physical objects of street corridor elements or caused by the limitations of existing street

corridor conditions. The scenario for developing variable modification procedures in the 3D interactive simulation system became the basis for developing interactive tools and a decision-making system for each of the primary and significant sub-variables for spatial and visual comfort (see Table 6).

Table 6. Variable modification procedures in the 3D interactive simulation system

variable	sub variable	variable adjustment techniques	control panel	decision making techniques	
SPATIAL COMFORT	Sidewalk	X <sub>1</sub> Function*	clarity of the sidewalk functions as a pedestrian space.	excluded in the operating system	recommendation
		X <sub>2</sub> Position***	selection alternative of street profile variations.	selection panel	scoring panel
		X <sub>3</sub> Dimension*	increase or decrease the width dimension of the sidewalk.	sidewalk dimension modification panels	saving file of modified 3D model data
		X <sub>4</sub> Continuity*	add to the length dimension of the sidewalk.	sidewalk dimension modification panels	saving file of modified 3D model data
	Building	X <sub>6</sub> Border width*	adjustments cannot be made, because the building border width is bound by the boundary of the land lot.	excluded in the operating system	recommendation
		X <sub>7</sub> Setback*	increase or decrease the building setback distance.	building setback modification panels	saving file of modified 3D model data
	Street Furniture	X <sub>8</sub> Position*	change or add street furniture position.	street furniture modification panels	saving file of modified 3D model data
		X <sub>9</sub> Type*	change or add street furniture type.	street furniture modification panels	saving file of modified 3D model data
	Vegetation	X <sub>12</sub> Position*	change or add vegetation position.	vegetation modification panels	saving file of modified 3D model data
VISUAL COMFORT	Building	X <sub>13</sub> Visual Appearance variety***	add a new 3D building model	excluded in the operating system	recommendation
		X <sub>14</sub> Appearance uniqueness**	add a new 3D building model	excluded in the operating system	recommendation
		X <sub>15</sub> Height Proportion**	increase or decrease the building height	building height modification panels	saving file of modified 3D model data
	Street Corridor	X <sub>16</sub> Region dominant color	change the building facade color	building facade modification panels	saving file of modified 3D model data
		X <sub>17</sub> Street corridor transparency	arrangement of street furniture and advertising of street corridors	street furniture & advertising modification panels	saving file of modified 3D model data
	Scale	X <sub>18</sub> Human height and building height proportion**	increase or decrease the building setback distance and the building height	building setback & building height modification panels	saving file of modified 3D model data
	Visibility	X <sub>20</sub> Proportion**	increase or decrease the building setback distance and the building height	building setback & building height modification panels	saving file of modified 3D model data
	Signage	X <sub>21</sub> Visibility***	selection alternative of signage position	signage panel	saving file of modified 3D model data

note:

\* A primary adjustable variable in spatial comfort variable

\*\* A primary adjustable variable in visual comfort variable

\*\*\* A significant adjustable variable in spatial or visual comfort variable

### 3.2.1 3D Visualization Stages

The 3D visualization stages in 3D modeling application software were the most critical stage related to the degree of difficulty and different challenges in each 3D object. Optimizing the number of polygon geometry is indisputably required to lighten up the spatial multimedia system's embedding process. Therefore, optimizing the polygon geometry to figure out the degree of urgency of the 3D streetscape element's primary form. The 3D modeling streetscape construction covered several 3D element modeling, i.e., 3D building, 3D sidewalk, 3D street, 3D street median, 3D Tree and park, 3D street lighting, 3D advertising, and 3D billboard (see Figure 4). Each 3D object is organized into one entity or group in short and straightforward naming because it will be related to the 3D object scripting process. The modeling of each streetscape object must be attempted to have the file size as light as possible due to the multimedia application authoring platform's limited capabilities.

One crucial 3D modeling of streetscape elements was the building façade and tree object. The surface detail of the building façade will determine the detailed level of 3D building visualization. Therefore, the detailed building

surface construction employed photo mapping techniques to lighten the 3D building file size. In line with the building facade, constructing the tree element employed the lightest tree object file based on the same image mapping technique. The 3D modeling of the five provincial street corridors on each element must also follow the scenario for developing variable modification procedures to adjust each of the primary and significant variables in each street corridor.

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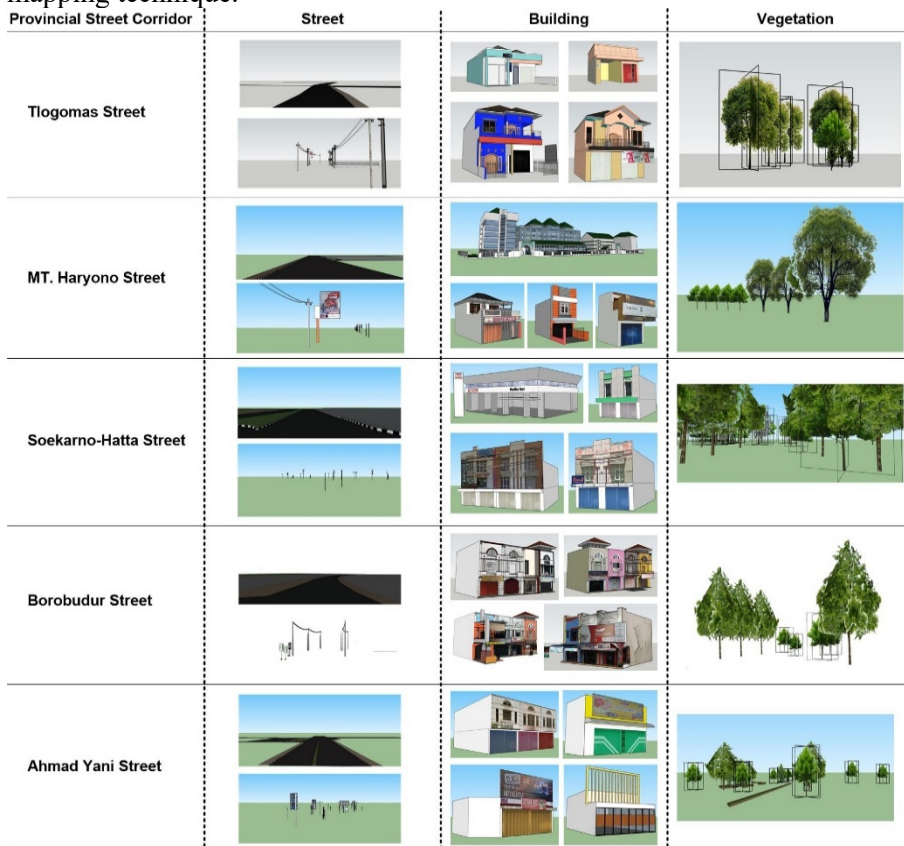


Figure 4. The 3D modeling of five provincial street corridors on each element

### 3.2.2 3D Interactive Simulation Scenario

Overall, building interactivity 3D modeling requires three types of software applications: 3D modeling software, 3D visualization software, and a multimedia application authoring platform. 3D modeling software produces various types of modeling of each 3D object on each streetscape element, while 3D visualization software produces the 3D animated files or predefined walkthrough animation for each provincial street corridor and its alternatives. The results of the two 3D modeling and visualization processes are used to produce three levels of 3D interactive simulation, which are



grouped into low interactive levels, mid interactive levels, advanced interactive levels.

3D modeling software produces various kinds of 3D objects at the low-interactive level, which are then processed in 3D visualization software into 3D animated files. The resulting 3D animation is a predefined walkthrough animation that aims to provide an opportunity for users to explore each streetscape in a 3D virtual environment at the interactive level of passive observation. Whereas at the mid-interactive level, various 3D objects from 3D modeling software were changed to 3D shockwave files in the multimedia application authoring platform. Each 3D shockwave file is embedded in a 3D virtual panel with the help of three types of instant Lingo scripts, i.e., 3D behavior script, 3D public action, and moving camera. This level produced passive 3D simulation so that users can self-explore the 3D virtual environment at the interactive level of active navigation. On the other hand, at the advanced-interactive level, each 3D shockwave file is embedded in 3D virtual panels with the help of three different types of instant scripts, i.e., 3D behavior scripts, 3D local action, and 3D independent action. This level carried out the interactive 3D simulation so that users can self-exploring the 3D virtual environment and adjust the 3D object at the interactive level of active navigation and interaction. *Figure 5* shows the overall development scenario of building interactivity 3D simulation.

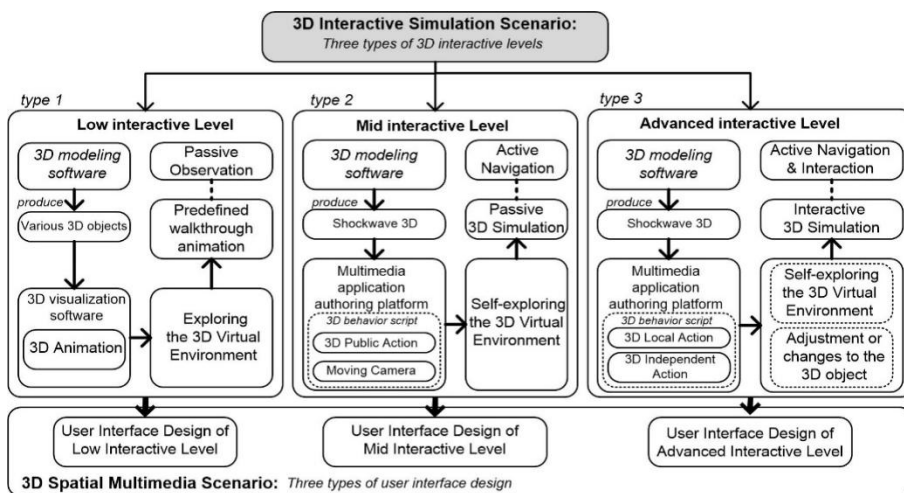


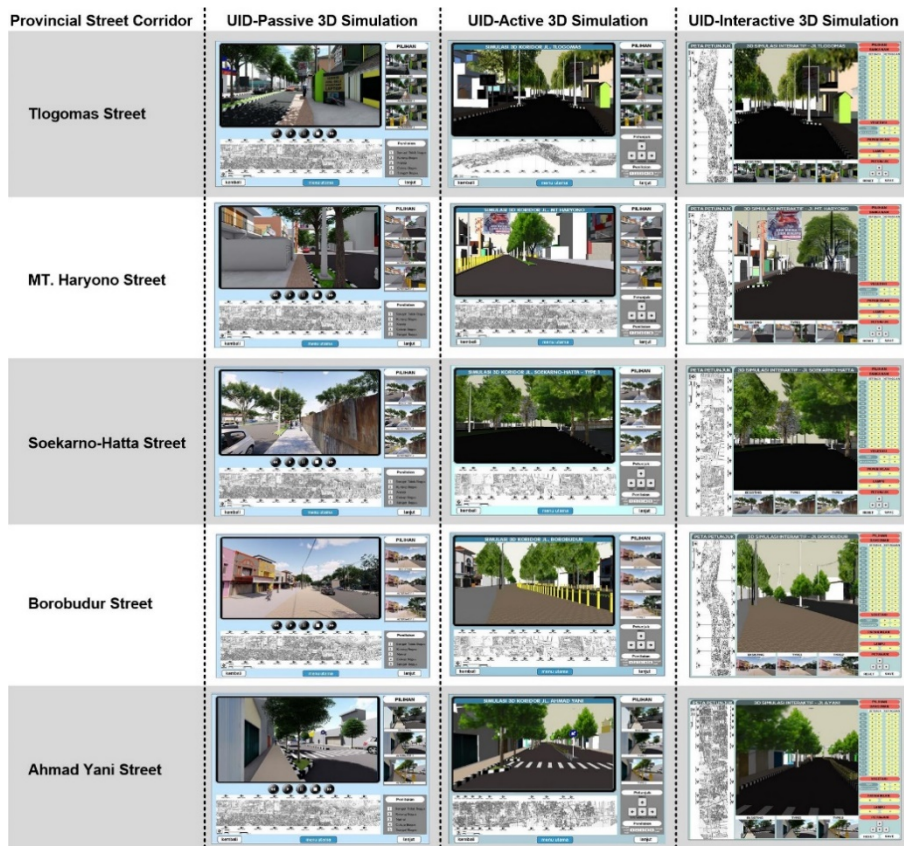
Figure 5. The diagram of the 3D interactive level hierarchy

### 3.2.3 The Development of UID Spatial Multimedia System

The types of User Interface Design (UID) in the development of the spatial multimedia system are divided into three categories according to the interactive level, i.e., UID passive 3D simulation, UID active 3D simulation, and UID interactive 3D simulation. UID passive 3D simulation contains predefined walkthrough animation and a selection panel consisting of animation of existing conditions and two animation alternatives of the improved streetscape. The user is capable of observing the walkthrough animation of various streetscape compositions during the predefined animation. At the same time, UID active 3D simulation offers a Virtual Reality of various streetscape compositions for a user to perform a walkthrough and affect their motion in the virtual environment through navigation aids. At the same time, UID interactive 3D simulation performs the active-observation and 3D interactive. Users can interact with 3D objects

in the Virtual Reality environment is running walkthroughs, feeling their motion in the Virtual Reality streetscape, and interacting with 3D objects in the virtual environment through provided control panels. The prototype development of three interactive UID levels on the five provincial street corridors can be seen in *Figure 6*.

The development of the UID spatial multimedia system accommodates three main components according to variable modification procedures in the 3D interactive simulation system, namely the type of 3D object interaction, the kind of interaction control panel, and decision-making techniques. The interactive simulation development strategy focuses on the spotted cases method to increase the effectiveness of user interaction responses and lighten the overall system operating workload.



*Figure 6.* The development of interactive levels of UID on the five provincial street corridor

### 3.3 The evaluation of the system

The 3D spatial multimedia system's evaluation is accomplished by testing the system through the operation of the system application built on each interactive level. The interactive variables built into the spatial multimedia system are attempted to refer to the results of modification parameters variation for interactive simulations between the non-adjustable variable ( $V_f$ ) and the primary adjustable variable ( $V_p$ ) and the significant adjustable variable ( $V_s$ ) and also the procedures of variable modification in the 3D interactive simulation system generated from the public preference in the previous stage. The primary and essential test to be simulated is the advanced interactive level UID due to 3D spatial interactivity that occurs in systems involving users and 3D objects. Some streetscape elements that

were simulated in testing included the streetscape profile, building element, tree element, street furniture, and billboards.

The streetscape selection test lies in the ability of the link control panel to each choice for existing streetscape conditions as well as the two improved types of streetscape alternatives. In an improved streetscape profile, the streetscape design was improved by adding garden elements on the curb, the addition of boulevard gardens, and the addition of bollards. In the building element, the 3D object interactivity simulated was the setting of building height and the building setback. In tree elements, the 3D object interactivity simulated was the elevation and the reduction of tree height. Whereas in the street furniture element, the 3D object interactivity simulated was the addition of bollards and billboard removal. An example of the test running simulation of the spatial multimedia system can be seen in *Figure 7*.



*Figure 7.* An example of the test running simulation of the spatial multimedia system

Evaluation of system development also performs qualitative description methods by comparing the distinguishing characteristics and peculiarities of the system development strategy with the previous system. The system review component can be described in six aspects: the general system information aspect, completeness of attributes, 3D visual quality, 3D simulation technical, adjustment variables in advanced interactive, and user interface design (see *Table 7*). In the comparison results, it can be seen that there are differences in characteristics and specificities in the system caused by differences in case handling strategies in the case study. There are four primary differences in the general system information point: the number of study cases handled, the characteristics of the type of area, the complexity of the building mass volume, and the prerequisite before carrying out the system development process. The current system is developed in more than one road corridor, namely five provincial road corridors, modern trade

corridors with high building density and mass. Another significant differentiator is that the previous system required a prerequisite investigation of a physical characteristic, while the current system required an investigation of public preferences as the basis for determining cases in each street corridor.

Significant differences can also be examined in the four points of technical 3D simulation, namely the characteristics of the field of view coverage, degree of complexity of case exposure in simulation, user orientation, and estimated user response time. The previous system developed a modeling simulation along the street corridors with the result that the user's field of view in the simulation can cover a longer distance than the current system. This strategy is in conjunction with handling the degree of complexity of case exposure along the corridor or just a spotted area. The current system is more suitable to employ a user orientation strategy that focuses on the spotted degree of complexity of case exposure, which is expected to shorten the estimated user response time. Previous and current systems performed variable adjustments in an advanced interactive simulation, but the previous system made the streetscape public element variable separate from the private element. Due to the spotted case-based, the two categories of elements can be adjusted in one user interface in the current system, thereby streamlining user responses. Furthermore, the different types of collaboration in the development of the simulation level on the user interface design in the current system categorize into low, mid, and advanced levels, which are intended to emphasize the level of collaboration between the three simulations.

Table 7. A comparative descriptive evaluation of spatial multimedia system development

3D spatial multimedia system		Previous System *)	Current System
<b>General System Information</b>	1 Multimedia application authoring platform	Adobe Director	Adobe Director
	2 Programming language	Lingo Script	Lingo Script
	3 Operating System	executable file	executable file
	4 Language	National language	National language
	5 Number of case study	<b>one corridor **)</b>	<b>multi corridor **)</b>
	6 Regional characteristics	<b>historical district **)</b>	<b>commercial district **)</b>
	7 The complexity level of the building mass in the street corridor	<b>medium **)</b>	<b>high **)</b>
	8 User response recording method	a scoring panel and a recording panel of user change results	a scoring panel and a recording panel of user change results
	9 Prerequisite	<b>investigation of a physical characteristic **)</b>	<b>investigation of public preferences **)</b>
<b>Completeness of attributes</b>	1 Presence of Guidance Information	Yes	Yes
	2 Presence of Guidance Map	Yes	Yes
	3 Presence of Alternative Panel	Yes	Yes
	4 Presence of Scoring Panel	Yes	Yes
<b>3D Visual Quality</b>	1 Building Façade appearance	high-reality in passive 3D simulation and medium-reality in active and interactive 3D simulation	high-reality in passive 3D simulation and medium-reality in active and interactive 3D simulation
	2 Street appearance		
	3 Greenery appearance		
	4 Street Amenity appearance		
	5 Advertizing appearance		
<b>3D Simulation Technical</b>	1 Field of view coverage	<b>long **)</b>	<b>short **)</b>
	2 Degree of complexity of case exposure	<b>along the corridor **)</b>	<b>Spotted **)</b>
	3 User orientation	<b>depends on the user's observations along the corridor **)</b>	<b>focus on the spotted cases **)</b>
	4 Estimated user response time	<b>long time and unpredictable **)</b>	<b>short time **)</b>
	5 Type of motion control	forward, backward, and nodal video (360-degree rotation)	forward, backward, and nodal video (360-degree rotation)
<b>Adjustment variables in advanced interactive</b>	1 Adjustment the building height	<b>Yes (separated User Interface Design/ UID) **)</b>	<b>Yes (in one User Interface Design/ UID) **)</b>
	2 Adjustment the building setback		
	3 Adjustment the billboard		
	4 Adjustment the streetlight & bollard		
	5 Adjustment a tree and plants		
	6 Selection of street profile types		
<b>User Interface Design</b>	1 Layout design	A grid-based layout type	A grid-based layout type
	2 Interaction type	Direct manipulation and Menu selection	Direct manipulation and Menu selection
	3 Collaboration type	<b>Basic, intermediate, and advanced interactive level **)</b>	<b>Low, mid, and advanced interactive level **)</b>
	4 Type of 3D contents	Predefined walkthrough animation, and Virtual Reality	Predefined walkthrough animation, and Virtual Reality
	5 Type of simulation	Passive observation (animation), passive simulation, and active-interactive simulation	Passive observation (animation), passive simulation, and active-interactive simulation

\*) Adapted from "Development of Landscape Support System Using Interactive 3D Visualization" by Santosa H., Ikaruga S., Kobayashi T., 2014, *Journal of Architecture and Planning*, 79, 706, pp 1995-2005.

\*\*\*) Several emphasize different system development strategies related to the characteristics and peculiarities of problem handling in the case study.

## 4. CONCLUSION

In summary, this paper's contribution is the importance of a decision-making system's scenario by developing a 3D spatial multimedia system based on public preferences in the local community. This study emphasized the essentials of three prominent stages in constructing a 3D spatial multimedia system that consisted of public preference investigation, development of digital interactive tools, and system evaluation. Investigation through public preferences helps determine dominant variables that significantly influence the streetscape's spatial and visual comfort features in the five provincial street corridors in Malang. This study also promotes three essential integrated stages of developing digital interactive tools, consisting of 3D visualization stages, 3D interactive simulation scenarios, and 3D

spatial multimedia scenarios that contribute to interactive user levels on the system. The development of a 3D spatial multimedia system also promotes three types of User Interface Design (UID) as an implementation of three interactive levels that consisted of UID passive 3D simulation, UID active 3D simulation, and UID interactive 3D simulation.

This study's findings are significant in the early stages of rigorous determination and selection of the most critical and dominant variables in influencing the street corridors' visual and spatial comfort by investigating people's preferences. This selection process will determine the number of modification parameters in the interactive tools developed in the 3D interactive simulation scenario. In the case of long street corridors, the decision-making system is strived to be divided into case spot points to ease the burden on the interactive system and ease user access.

The results of the development of 3D spatial multimedia systems still require better improvements related to the quality of real-time visualization, increased ability to accommodate the number of 3D objects, and the possibility of integration with spatial GIS data. For future work, the 3D spatial multimedia system's final authoring for online participation requires gradual tests and dissemination to establish system reliability.

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## REFERENCES

- Al-Kodmany, K. (2001). "Visualization Tools and Methods for Participatory Planning and Design". *Journal of Urban Technology*, 8(2), 1-37. doi: <https://doi.org/10.1080/106307301316904772>.
- Burigat, S., & Chittaro, L. (2007). "Navigation in 3d Virtual Environments: Effects of User Experience and Location-Pointing Navigation Aids". *International Journal of Human-Computer Studies*, 65(11), 945-958. doi: <https://doi.org/10.1016/j.ijhcs.2007.07.003>.
- Conniff, A., Craig, T., Laing, R., & Galan-Diaz, C. (2010). "A Comparison of Active Navigation and Passive Observation of Desktop Models of Future Built Environments". *Design Studies*, 31(5), 419-438. doi: <https://doi.org/10.1016/j.destud.2010.04.003>.
- Dokyu, N., & Yamamoto, A. (2003). "A Study on the Historic Streetscape from View Point of Homogeneity and Diversity : Case Study in the Old Town of Stockholm, Gamla Stan". *Journal of Architecture and Planning*, 68(565), 241-248.
- Hoelscher, S., & Porteous, J. D. (1996). "Environmental Aesthetics: Ideas, Politics and Planning". *Geographical Review*, 87(3), 422.
- Honjo, T., & Lim, E. M. (2001). "Visualization of Landscape by Vml System". *Landscape and Urban Planning*, 55(3), 175-183. doi: [https://doi.org/10.1016/s0169-2046\(01\)00152-9](https://doi.org/10.1016/s0169-2046(01)00152-9).
- Howard, T. L. J., & Gaborit, N. (2007). "Using Virtual Environment Technology to Improve Public Participation in Urban Planning Process". *Journal of Urban Planning and Development*, 133(4), 233-241. doi: [https://doi.org/10.1061/\(asce\)0733-9488\(2007\)133:4\(233\)](https://doi.org/10.1061/(asce)0733-9488(2007)133:4(233)).
- Ibanez, J., & Delgado-Mata, C. (2011). "Lessons from Research on Interaction with Virtual Environments". *Journal of Network and Computer Applications*, 34(1), 268-281. doi:

- <https://doi.org/10.1016/j.jnca.2010.07.005>.
- Kashef, M. (2016). "Urban Livability across Disciplinary and Professional Boundaries". *Frontiers of Architectural Research*, 5(2), 239-253. doi: <https://doi.org/10.1016/j.foar.2016.03.003>.
- Kawakami, M., & Shen, Z. (2006). "Study on Decision Support System for District Planning in Public Participation- a Case Study in Kanazawa City, Japan, Van Leeuwen Jp and H J P Timmermans (Eds.)". *Progress in Design & Decision Support Systems in Architecture and Urban Planning*, Eindhoven: Eindhoven University of Technology, 5, 203-218.
- Koba, N., & Kishimoto, T. (2009). "Impression Evaluation of Streetscape by Super High-Rise Buildings Set-Back in High-Rise Part". *Journal of Architecture and Planning*, 74(645), 2435-2442.
- Koga, M., Ikaruga, S., Tadamura, K., Ohgai, A., & Matsuo, M. (2008). "Study on Image Sharing Support Method in Landscape Planning Using Information Technology". *Journal of Architecture and Planning*, 73(633), 2409-2416.
- Koizumi, K., Kishimoto, T., & Koba, N. (2009). "Streetscape Analysis Focusing on Unity of the Unity of the Streetscape and Identity of Building Façade in Yokohama Motomachi Street". *Journal of Architecture and Planning*, 74(636), 393-400.
- Muenzer, S., Seufert, T., & Bruenken, R. (2009). "Learning from Multimedia Presentations: Facilitation Function of Animations and Spatial Abilities". *Learning and Individual Differences*, 19(4), 481-485. doi: <https://doi.org/10.1016/j.lindif.2009.05.001>.
- Nasar, J. L. (1998). *The Evaluative Image of the City*. London & New Delhi: Sage publications, Thousand Oaks.
- Rapoport, A. (1978). "Human Aspects of Urban Form : Towards a Man Environment Approach to Urban Form and Design / Amos Rapoport". *Contemporary Sociology*, 8(2).
- Rehan, R. M. (2013). "Sustainable Streetscape as an Effective Tool in Sustainable Urban Design". *Hbrc Journal*, 9(2), 173-186.
- Santosa, H., Ikaruga, S., & Kobayashi, T. (2013). "Visual Evaluation of Urban Commercial Streetscape through Building Owners Judgment : Case Study in Malang City, Indonesia". *Journal of Architecture and Planning*, 78(691), 1995-2005.
- Santosa, H., Ikaruga, S., & Kobayashi, T. (2014). "Development of Landscape Planning Support System Using Interactive 3d Visualization". *Journal of Architecture and Planning*, 79(706), 2699-2709.
- Seta, S., Matsumoto, N., & Tanabe, J. (2003). "A Study on Usefulness of Fourier Transform Method for Evaluating Streetscapes : Studies on Disorder and Regularity in the Central Business District Part 4". *Journal of Architecture and Planning*, 68(569), 85-92.
- Shen, Z., & Kawakami, M. (2010). "An Online Visualization Tool for Internet-Based Local Townscape Design". *Computers Environment and Urban Systems*, 34(2), 104-116. doi: <https://doi.org/10.1016/j.compenvurbsys.2009.09.002>.
- Sutikno, F. R., Surjono, & Kurniawan, E. B. (2012). "Walkability and Pedestrian Perceptions in Malang City Emerging Business Corridor". *Proceedings of 3rd International Conference on Sustainable Future for Human Security (SUSTAIN)*, Kyoto Univ, Kyoto, JAPAN, 424-433.
- Takiguchi, H., Arima, T., Sakai, T., & Hagishima, S. (2003). "Multimedia Computer System Supporting Park-Planning Workshop". *Journal of Architecture and Planning*, 68(574), 129-135.
- Tutuko, P., & Son, Y.-H. (2018). "Editorial Introduction Urban-Rural Regeneration and Cultural Sustainability". *International Review for Spatial Planning and Sustainable Development*, 6(4), 1-4. doi: [https://doi.org/10.14246/irspsd.6.4\\_1](https://doi.org/10.14246/irspsd.6.4_1).
- Wu, H., He, Z., & Gong, J. (2010). "A Virtual Globe-Based 3d Visualization and Interactive Framework for Public Participation in Urban Planning Processes". *Computers Environment Urban Systems*, 34(4), 291-298.
- Yoshimura, H., & Tsukamoto, Y. (2010). "Study of Streetscape and Building Frontage in Suburban Roadside Areas". *Journal of Architecture and Planning*, 75(649), 751-758.