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Abstract

Public involvement in highway improvement presents a set of complex problems involving many stakeholders.Since visualizations are increasingly regarded as essential tools in this process, a clearer understanding of the specific merits of advanced visualization techniques and their potential contributions must be developed.As a step towards integrating visualizations into an improved public planning paradigm termed Structured Public Involvement (SPI), this paper investigates the utility and performance of three visualization modes, termed *2D*, *3D* and *VR* (Virtual Reality), for a case study highway in Central Kentucky.

Visualization scenarios were designed and engineered according to the principle of elemental decomposition.Using a combination of iterative focus group public involvement and an electronic scoring system to solicit rapid feedback the research team investigated the efficiency and performance of the visualization modes.Further focus group feedback on the merits of each mode was solicited.The preferred 3D visualization mode was then employed to gauge public preference for (a) specific highway design elements and (b) three composite design scenarios.Cross-tabulation of focus group data enabled the team to generate a fine-grained analysis of public preference.Problems and future research directions are highlighted.

Summary of key project findings:

- 3D visualization (rendering) is preferred to Virtual Reality (VR) and 2D modes when certain conditions prevail:(i) the specified public involvement format is adhered to, (ii) the scenario to be modeled is rural, with a visual environment comprised of many non-geometric shapes, and (iii) a limited choice of highway design options is offered.
- Preference for visualization is dependent on previous experience with this medium.Education regarding the capabilities and features of visualization is appreciated prior to viewing.
- Preference for specific design options varies depending on whether composite scenarios or single design elements are presented and scored. Composite scenarios appear more appropriate, since they form a more realistic resource for planners and designers.Benefit/cost information is appreciated by participants and affects their preference for visualization mode.

Background and Objectives

Public involvement in transportation infrastructure decision making is increasingly regarded as critical by all stakeholders.These stakeholders include commuters, recreational road users, companies whose business depends on transportation, local residents and businesses, and local and national government agencies responsible for infrastructure maintenance, such as State Departments of Transportation.Computer generated visualizations are increasingly favored as essential tools to present alignment and construction options and to solicit public feedback at all scales, from large freeway constructions to specific alignment options at the block level.However, regardless of its technical sophistication and esthetic appeal, visualization does not by itself enhance planning if it is superimposed on traditional planning processes.

A skeptical reading of current public involvement in infrastructure planning holds that a small set of pre-formed options are prepared behind the scenes, by consultants or engineers, and then presented at public forums.Feedback on these options is then gathered and used to determine which one should be built.This limited involvement and restricted-choice paradigm, which we term DAD (Decide, Announce and Defend), reinforces the suspicion that many stakeholders exhibit toward public planning processes.This suspicion can manifest itself in hostility toward consultants and planners at public forums, or, worse, in a feeling of pointlessness: that since the options are preordained by means of a highly opaque process there is no point in participating in public forums.Responsible authorities are then more reluctant to initiate public input processes and in some cases see them as an unproductive requirement rather than as an opportunity to improve the design product.Such a negative feedback loop ensures that satisfaction with the planning process remains low on all sides.Under these circumstances there is a danger that an engineering-driven focus on developing and applying sophisticated technologies, such as visualization, could further obscure or override the global process goals of increased public satisfaction and better service provision.

Structured public involvement (SPI), by contrast, involves determining clear project goals, setting decision parameters by consulting with professionals and other representatives, designing a public engagement process incorporating forums such as focus groups or public meetings, obtaining information directly related to the project goals and then incorporating this information into design options before soliciting iterative feedback.Participants in the public forums must participate in ways that reassure them that their voice counts.A realistic maximum of authority is devolved.This process is intended to benefit the planners, designers, builders and users of transportation infrastructure.SPI can be thought of as a protocol or framework, integrating visualization technologies, decision theory and facilitation methods.SPI requires a specific implementation depending on the design question at hand.Visualization can contribute to effective SPI, and simultaneously a well-designed SPI process can maximize the utility of visualization.As a first step toward integrating visualization effectively into an SPI protocol, the capacities and efficiency of various visualization technologies must be assessed.

This paper describes the design and build of a set of highway improvement scenarios using three distinct geographic visualization technologies (*2D*, *3D* and *VR* or Virtual Reality) and evaluates their efficacy in comparing design options for highway corridor improvement in a pilot case in the Bluegrass region of central Kentucky.Public preferences for specific modes of visualization are presented and the advantages and shortcomings of each mode are discussed.Emphasis is placed on how visualization can best be integrated into the public involvement process.Two innovative components of the project are highlighted: the structured approach to creating visualization scenarios and the use of an electronic voting system to increase transparency and efficiency.

Project Outline

As part of the FHWA Transportation and Systems and Community Preservation program (FHWA 2001), a structured public involvement protocol was designed by the Policy and Systems Analysis Team of the Kentucky Transportation Center.A one-half mile length of US highway running through the Bluegrass region of Central Kentucky was selected.The road is located in a rapidly growing area that serves Georgetown, including an automobile factory and other commercial enterprises.This area requires provision for increased traffic.Simultaneously, residents and community groups want to respect the traditional cultural landscape of the region which includes a tradition of thoroughbred horse farming.The potential for conflict over highway development in this area is high and it is therefore critical for transportation professionals to solicit and incorporate different opinions into the design process (for more details please refer to the team's TCSP Home Page).To investigate community response to potential highway improvement options, the team created a series of scenarios, or visualizations, and used the principle of elemental decomposition to disaggregate each scenario into a set of constituent design elements.

In collaboration with partners, a cross-section of the local community was identified, including local officials, residents and representatives of community groups.These people were approached and asked to participate in a set of three focus group meetings at the local courthouse.Visualizations of specific highway improvements were presented and the participants were asked to score the various scenarios.Three modes of visualization were evaluated:
(i)Two dimensional, static images (2D).2D images are photorealistic images, sometimes enhanced digital photos.

(ii)Three dimensional static images (3D).3D images provide perspective and depth in the landscape.These allow the landscape to be viewed from one location or they can be used to export renderings, that is, animations that followed prescribed trajectories.

(iii)Virtual Reality (VR).In a VR scenario the observer has complete control over an objective viewpoint that can be moved through a virtual landscape in real time.Velocity, heading, and all derivatives of location can be controlled by mouse or keyboard input.

Casewise Visual Evaluation

To structure the evaluation of stakeholder preference for design options the research team designed a methodology called Casewise Visual Evaluation (CAVE).The objective was to provide stakeholders with a quantitative evaluation of public preference for specific design properties, such as shoulder treatment, lane width, median treatment and others.CAVE specifies a protocol for building a knowledge base that can be queried to show the preference increment or decrement for a specific change in the highway design elements.CAVE draws on techniques used in non-linear, partial knowledge system dynamics.Visualizations were engineered showing a small subset of possible design element combinations.Public preference for each visualization scenario was measured at focus group meeting using the *SharpeDecisions*Ò electronic scoring system.Using this information, a preference knowledge base was built using *FuzzyKnowledgeBuilderÒ*.This approach has shown a reliable and robust predictive capacity when used to model non-linear marine ecosystems under partial knowledge conditions (Meesters et al 1998, Ridgley and Fernandes 1999).Once built, the preference knowledge base can then be queried to investigate how public preference changes in response to variation in a specific pair of design elements, even if all the potential combinations of this pair have not been scored.CAVE offers several advantages when compared with other visual assessment methodologies such as Nelessen’s (1994) Visual Preference Survey (VPS):

i. Offers quantitative analysis of how preference responds to changes in design elements

ii. Does not require exhaustive scoring of every elemental combination

iii.By integrating electronic scoring, the process is accelerated and errors are reduced

The research team will discuss CAVE in more detail elsewhere.

Selection of Design Options

While there are an almost infinite number of design elements that can be modeled in a corridor visualization, it is not feasible to attempt to model all of these given real-world resource constraints.Additionally, in this case certain design elements were not under the control of the designers or planners.A combination of practical, legal and resource limits defined the properties we modeled and set the parameter boundaries.

A list of potential design elements was solicited and drawn up during facilitated meetings with design partners.This list was then reduced by elimination.Two factors governed final selection of the design elements.Some ideal elements were considered too difficult to model and were not included in this project, leaving ten design elements.Further limitations were established once the team began to model the environment: for example, generating and integrating realistic traffic flow models into the VR scenario would have been too costly to implement within the project budget.Other elements were controlled by planning and zoning legislation or design practice and the project participants were not at liberty to influence them.Certain elements, such as highway lane width, are variable within limits framed by the highway engineers design handbook (AASHTO Blue Book 1995).For example, although 11 feet was a feasible and legally permissible road width, image evaluation by the research team suggested that the difference between 10 and 11 feet was hard to discern and therefore it did not justify the creation of a separate set of renderings.A similar process of visual inspection of other prototype scenarios further reduced the number of combinations chosen.

Table 1 shows the highway environment design properties selected for modeling.Only a few of the potential combinations were created, allowing the project to proceed within budget and on time despite the steep learning curve of the VR software.

Table1: Design Elements used to create scenarios

Design Element	Minimum	Maximum	Number of Classes	Class names
Lane Width	10 feet	12 feet	2	Narrow, wide
Shoulder width	4	8 feet	2	Narrow, wide
Shoulder type			3	Grass, gravel, paved
Median type			3	Grass, paved, Jersey barrier
Guardrail type			3	None, rock fence, CoreTen rail
Number of lanes	2	4	3	2,3,4

Visualization Build

The study area included the half mile length of U.S. highway and encompassed surrounding terrain extending out for several hundred meters on both sides of the road and a secondary road.Data was gathered and assimilated for this study area within Esri's Arcview, including a USGS digital elevation model (DEM), orthophotos, vector data including roads and streams, and additional data layers.This terrain database was used to calibrate and map the visual simulations.

2D Images

The 2D images used for the project began as actual digital photographs of the study area.These were imported into *Adobe Photoshopâ*, where they were modified to reflect the differing design alternatives (improved two lane, 3 lane, 4 lane divided, etc.).This was accomplished by a manual process of digitally altering the source photographs, cutting and modifying the pictures to depict the intended future condition.Benefits of this approach include a relatively low learning curve to use the Photoshop software, as well as the relatively low cost of image editing software. However, the images are only as accurate as the ability of the editor, and it was found to be difficult to accurately portray perspective, etc. with freehand image manipulation.Also, each individual image needs to be created individually; there is no ability to build a terrain database which could then be used to create multiple images or visualizations.Additional data was presented in the form of a table of road attributes shown underneath the 2D form.This included *Level of Service*, an engineering term that captures perceived operational conditions for road users.

3D Images

The 3D images were created exclusively with 3D Nature's *World Construction Setâ*. This is an image rendering package which is tailored to creating natural environments.The package allows for DEM input to define the topography of the study area.Over the terrain skin the user has almost infinite control over variables of shading, texture, vegetation, ground cover, etc. This allows the user to define areas of particular vegetation type, either by drawing regions in a map window and manually defining vegetation types, or by establishing rules to define what vegetation or ground cover type will sheath areas of the terrain that have certain characteristics (southern exposure and slope less than 10%, for example).In this way the entire database is populated with colors, textures, vegetation in the form of either digital images or 3D objects, and other 3D objects such as buildings.Roads and streams are defined by drawing vector lines over a map view of the database, and then the characteristics of the road or stream can be specified.These characteristics include the color and texture of the water or road surface, and the limits of the vertical placement of the vector feature either above or below the surrounding terrain.These vectors allow for the linear feature to actually sculpt the underlying DEM, so that a road can form a cut through a hillside, and the stream can be shown as depressed by 10 meters into the digital terrain, for example.Nonlinear features such as lakes are defined by polygonal areas, and these characteristics are also user configurable.

Once all of the input parameters are set within the *World Construction Setâ* software, then an image or sequence of images can be rendered.The user specifies a particular position and viewing angle, defining both the “camera” and also the target, and then an image is rendered. A sequence of images along a path can be defined in order to allow for animation. The strength of this approach is that a very high level of detail can be achieved, creating a highly realistic final rendering.However there is a fairly steep learning curve to the software. Also, since the component images need to be rendered in advance, only predefined animations can be viewed.If a client desires to see another viewpoint or motion sequence, another day to several days is required in order to have sufficient rendering time to create the images.

Virtual Reality Images

The VR images were created with Multigen-Paradigm’s *Creator Proâ* and *Vegaâ* software packages.This software approach differs from the above 3D images and animations in that a terrain database is constructed for realtime playback, in a true simulation environment.*Creator Proâ* software was used to create the terrain database.This was a time-consuming process, particularly since multiple iterations were necessary to determine the best display/performance tradeoffs.The software takes a DEM or other digital terrain data as an input, and then creates a polygon-based surface out of the terrain.Playback speed, measured in frames per second, is inversely proportional to how many polygons are onscreen at any given time.Recommended playback rate for near-video quality viewing is around 30 frames per second (FPS); on the equipment we had available, our database had a playback rate of about 8 FPS when complete.This frame rate limit acted as a constant constraint on the level of detail (number of polygons) that could be added to the database.The project model region is a densely overgrown stream corridor, full of vegetation and natural detail, and with a constrained polygon budget, the VR or virtual reality simulation appeared rather stark and artificial.Also, since there is only one main road through the simulation area, the ability to choose different paths through the simulation (driving in real time) was compromised.

The most time-intensive portion of both *World Construction Setâ* and also *Creator Proâ* software was the steep learning curve involved in operating the software.There were also multiple iterations of the database within both packages, but they took different forms. Within the VR software (*Creator Proâ*), the most time-intensive stage was in creating the terrain database, and then seeing how it performed with a particular level of detail/polygon count.There are also different methods available for creating the terrain database, some of which give better results depending on the type of terrain.However once a change was made within the VR database it was immediately viewable, in real time.With *World Construction Setâ*, in order to view the final product, it was necessary to render a preview of the scene.This required anywhere from several minutes to an hour or more, depending on the level of detail of the scene and the finished scene size in pixels.So the 3D process was iterative as well, in the sense that making changes to the terrain database required a subsequent rendering to monitor the outcome of the updates.

A selection of the visualizations created for this project are available at the team’s TCSP Visualization Library, and also at 3D Nature’s Artist of the Month page.

Focus Group Meeting Format

Three focus group meetings were held at a local county courthouse, each attended by between 16 and 20 people.At each meeting we explained the evening’s objectives and introduced the visual presentation media.For the 2D pictures, the group was shown the complete set of images in order, and then preference voting was conducted during a second run through.For the VR and 3D images, a complete run through was offered to the participants but was judged unnecessary by a show of hands.Therefore, voting was conducted immediately on presenting the image.

The judgment criterion employed was termed “preference” and was presented as scale from 1 to 10 points, with integer scoring being used.Table 2 shows the list as presented to the group:

Table 2: Judgment criterion “preference”

Score	Meaning

1	Intolerable
2	
3	Not desirable
4	
5	OK
6	
7	Desirable
8	
9	
10	Wonderful

After seeing the appropriate scenario, participants voted using their numeric keypads.First, it was clarified that in each case numbers other than the ones associated with the preference terms given could be used i.e. 6 was a valid vote, representing a preference approximately midway between “OK” and “Desirable.”Descriptive terms were not matched for all 10 categories because this created cluttering of the display and would have resulted in none of the categories being legible.Following the preference vote, comments were solicited and written on a whiteboard.At the conclusion of the meeting, further comments about the process were solicited.The small group size encouraged open participation and a number of comments were recorded.

Two independent computers and projectors were used and the scoring was displayed in real time.In addition, five demographic and social questions were asked before beginning the scoring.These investigated gender, previous experience with visualization, frequency of use of the highway, residency location and occupation.This permitted a finer grained analysis to be generated by cross-referencing of preference data.All focus group preferences were solicited using the *SharpeDecisions* electronic scoring system.Each meeting was scheduled for a maximum of two hours, although the final one lasted considerably less.

Prior to implementing the project, concerns had been expressed regarding the time required for the focus groups to vote.Experience showed that voting proceeded efficiently and swiftly after a very brief initial test vote had been conducted.It proved feasible to evaluate 20 scenarios in a short meeting without experiencing the problems often encountered when administering the VPS (paper management, coaching respondents to score in the correct location, transfer of attention from the screen to the paper and so on).The electronic voting system was largely error-free in operation and was well liked by participants.In response to the final question “How useful is this electronic voting system?” the focus group scored a mean preference of 8.7.

Results and Discussion

Mean preference scores were computed for each vote and standard deviations were displayed to show polarization of opinion.The primary finding was that 3D visualization was clearly preferred when compared with the VR and 2D modes.Unlike the other modes, it received an absolute preference score significantly better than “desirable.”3D mode registered a mean preference 24.6% greater than VR and 47.2% higher than 2D (see Table 3).

Table 3:Direct Preference for Visualization Modes

Mode	Mean	Std.Dev
2D	5.5	2.0
VR	6.5	1.9
3D	8.1	2.3

The standard deviation for the 3D vote was slightly larger than the others, but not significantly so.When the research team asked the participants why, the responses indicated that the 3D renderings exhibited significantly more realistic detailing and texturing.Further, the ability to move through the virtual landscape in real time was not considered an advantage when compared with the ability to rotate around a fixed origin and observe a complete panorama in 3D rendering.Although the 2D mode was considered to offer satisfactory viewing quality, its overall functionality did not exceed a minimal level because of the viewer's complete inability to pivot or traverse and observe how changes in viewing angle alter environmental perception.

Although the magnitude of preference differed between visualization modes, the preference ordering for scenarios showed little change across modes.This shows that the focus group judged relative design element preferences relatively consistently across visualization modes.This implies that when using CAVE, the selection of visualization mode is not critical: similar results will be generated whichever mode is used to score the scenarios.

One unexpected problem was in clarifying to non-computer literate participants the differences between the three visualization modes.This proved particularly problematic when assessing the VR mode since the VR presentations were given by demonstration.In the interests of reducing the total meeting time budget, the meeting participants were not given the opportunity to operate the mouse and experience the VR landscape for themselves.For each VR scenario, one of the team moved the mouse and commanded a trajectory that approximated the road alignment, appearing as if driving along the road.Although we demonstrated moving backwards and off the road, the participants felt that there was not a great deal of difference in the utility of the 3D and VR modes as displayed.

The research team believes that the lower preference for VR compared with 3D was at least partly due to the lower resolution of the VR compared with the 3D mode.Although it can be argued that this mismatch was partly an artifact of resource limits, we believe that these resource limits are very real limitations and should be recognized as a valid project constraint when using visualization to assess public infrastructure improvements.This view was supported by the focus group's response.After seeing the VR scenarios one participant requested a direct tradeoff, asking how much it had cost in total to generate the 3D and VR scenarios.He then stated that he would use a benefit/cost calculus to determine preference for visualization mode.His view was seconded by several others.

We solicited preference for the 3D visualization mode compared with other forms of information delivery typically used in public planning forums.Table 4 presents the results.*Written plans* describe traditional visualization media, such as enhanced aerial photographs, artists' impressions, charettes, diagrams and engineering drawings.*Performance properties* means display of abstract information such as maximum flow capacity, predicted level of service and so on, typically displayed numerically.

Table 4: Preference for form of data presentation

How useful are:	Mean	Std. Dev
3D visualizations	7.8	1.8

Written plans	6.6	1.6
Performance properties	7.9	1.5

Cross tabulation showed that previous experience with visualization projects was significant in determining preference for the 3-D renderings when compared with traditional plans and engineering information (performance properties).People familiar with visualization clearly preferred it.This suggests that education about visualization is important in deriving maximum benefit from the technology.

Elemental Preference Vote

For a four-lane highway design, each of the design elements was presented separately using the preferred 3D medium and the participants were asked to vote on their preference for it.Table 5 presents the results:

Table 5:Mean preference results by design element

Description	Mean	Std. dev
Lane width narrow	6.1	1.9
Lane width wide	6.5	2.0
Core ten guardrail	6.0	2.1
Steel guardrail	4.7	2.0
Rock fence	6.6	2.8
Shoulder width narrow	3.0	2.4
Shoulder width wide	7.1	2.5
Turf shoulder	7.2	2.2
Paved shoulder	5.5	2.5
Grass median	7.0	2.5
Jersey barrier	3.6	2.4
Concrete median	3.1	1.5

Hedge median	5.9	1.8

This interrogation suggested that the most popular road would feature a combination of:

a.Wide lanes

b.Rock fence

c.Wide shoulder

d.Grass median

A narrow lane width was preferred more by people who did not regularly drive down KY460.Nobody who drove the road six or seven times per week scored narrow lane width as better than “OK,” while a number of infrequent users scored the narrow lane between 8 and 10 (between “desirable” and “wonderful”).While this information appears intuitively obvious, it does confirm that user surveys and traffic forecasting are critically important in determining preferred road width since regular users weight the utility of the road much higher than aesthetic considerations.The women preferred the steel guardrail much less than the male respondents, and there was also some gender difference in the preference for CoreTenâ rails.Preference for the rock fence was polarized with a bimodal distribution and only two scores of 5, 6 or 7.A narrow shoulder width was generally regarded as undesirable except by two respondents.

The preferred composite scenario indicated by the abstract vote was then generated using 3D rendering and presented to the focus group.The group showed considerable interest in the appearance of the option they had “built” this way.

Final Composite Scenario Analysis

Three composite visualizations conforming to preferred “packages” of design elements were then engineered in 3D mode.These were termed *original*, *context sensitive* and *maximum capacity* highway options.Each option was a design “bundle” of elements that were considered to fit together.For example, the *context sensitive* option followed guidelines specified in the Context Sensitive Design course.*Maximum capacity* comprised maximum road width, wide shoulders and Jersey barriers i.e. it conformed to a road specification that permitted the highest possible traffic flow.For calibration, a third option was shown that was identical to one presented at an earlier meeting, called *original*.These were shown and scored as before.Table 6 shows the results.

Table 6:Preference for Composite 3D scenarios

Scenario	Mean
Context sensitive	5.2
Maximum capacity	5.2
Original	6.7

A clear preference was shown for the option *original*, rated as almost “desirable.”A visual examination was made of the design elements with regard to each of the five demographic and social factors.Preference for the context-sensitive design option was different between professionals and non-professionals, with non-professionals preferring it by 1.4 units.This may be connected with the presence at the focus group meeting of transportation professionals who had taken a recent Context Sensitive Design course, and who had effectively been educated to regard the features of such designs as preferable.It is interesting that non-professionals did not prefer this package, which was originally designed to address some issues of public dissatisfaction with highway design and planning.Preference for the maximum capacity design was gender-split with females scoring it 1.2 units less than males.

Tables 4 and 5 in conjunction suggest that asking participants to score individual design elements in the abstract does not generate the same results as scoring the composite scenarios.This has important implications for highway agencies considering soliciting public opinion on specific highway improvements, since it suggests that preference for a design element may differ depending on its context.For example, in the abstract vote the preference difference between the rock fence and the steel guardrail was small (6.6 vs 6.0).But when complete scenarios were considered, those that showed the rock fence when compared with the steel guardrail were significantly preferred.The implication is that aesthetic values matter more when they are presented in ways that can be clearly appreciated and when they are combined with other elements in real configurations.Therefore, complete visualization scenarios are preferred and should be scored relative to other complete scenarios.Scoring individual design elements is simpler but less realistic and could result in designs that are not preferred by the community. To unpack the complete scenarios, elemental decomposition methodologies such as CAVE show promise.Such methodologies will allow designers to analyze and quantify how each design element influences the perception of the complete image.

Conclusion

3D renderings are a very effective visualization mode for presenting small scale rural road corridor options where visualization modeling requires use of digital photos of existing road environment and fine detail of fence treatment, vegetation and the immediate road surroundings.3D was preferred significantly to VR, which was in turn slightly preferred to 2D.But, based on the focus group response, no form of visualization can be regarded as a direct replacement for performance properties (traditional measures of road performance, such as maximum capacity and Level of Service).The focus group explicitly requested these properties be displayed to augment the visualizations.It is possible that further development of the 3D and VR landscape, populating the road with agents such as people, animals and traffic governed by rules that present a visual impression of realistic behavior, may diminish the requirement for these properties.However, this remains to be researched.

The demographic and employment questions revealed some significant factors that must be considered when using visualization to facilitate such projects.Previous experience with visualization was shown to influence preference for modeled scenarios.Further, to be fully effective, visualization technologies should be integrated into a structured public involvement protocol that gathers maximum input from focus group or public meeting participants.In this case the structured combination of the visualizations and electronic scoring was effective in presenting options, eliciting feedback and thereby enhancing stakeholder involvement.The participants' genuine, if conditional, enthusiasm for the capacities of the technologies was encouraging.

However, the strengths of specific forms of visualization should be investigated further in other, more complex, design contexts, particularly urban.Larger focus groups and more elemental design variation are required to maximize the utility of the SPI protocol.Further development of the VR package would allow the landscape to be populated with moving objects, such as cars, trucks and people.The trajectories of these objects and their interactions could be governed by rules that controlled realistic motions.The research team will be investigating these options when applying CAVE to public involvement in a transit-oriented development in a metropolitan area (Grossardt, Brumm and Bailey 2001).Nevertheless, achieving this is substantially more difficult computationally and more time will be required for designing and building scenarios.

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