

# Towards an Integrated Web-based Visualization Tool

## A Comparative Survey of Visualization Techniques for Enhancing Stakeholders' Participation in Planning

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### Abstract

Digital visualization tools are widely used in planning nowadays around the world by various contributors to the field and in different planning scales. Visualization facilitates perception of underlying thoughts and objectives of planning alternatives and consequently assists with communication of the plan to different stakeholders. This, in turn, enables them to actively and efficiently participate in the procedure from the very initial stages to the implementation phase thanks to the insight provided by user-friendly visualization tools. Available visualization tools for planning, however, are either not integrated and efficient enough or too resource- or expertise-demanding and thus not entirely fulfilling the qualities mentioned above. This study is a search for a conceptual framework for an integrated web-based visualization tool. Web-accessibility diminishes temporal and spatial distance among the users and planning agents and provides the possibility for more participation in and interaction with planning projects. Within this study, major characteristics of an integrated tool have been investigated through literature, online resources, contacts with experts and practitioners, a survey over off-the-shelf products and comparative analysis of the outcomes. An evaluation cube was initially developed and used as the basis for provision of a set of dual criteria. A selection of visualization tools were examined against those criteria and results were demonstrated visually. Eventually, findings were used to provide a back-casted example of the integrated tool.

**Keywords:** visualization, participatory planning, web-based, CAD, GIS, urban planning

Categories and Subject Descriptors (according to ACM CCS): I.3.8 [Computer Graphics]: Applications

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### 1. Visualization as a means for participatory planning

Demise of rationalism in planning due to social movements and widespread activities of non-governmental organizations in recent decades has paved the way for a more participatory approach towards planning [Rut85]. Terms such as *communicative planning*, *collaborative planning* and *participatory planning* swiftly found their way into the planning literature [Hea03] representing the fact that the borderline between providers and users of the plans is now blurred – if not fully lifted. Communicative planning helps strengthening social sustainability within the society by propelling planning processes towards micro levels and grassroots [MW08]. How to promote a participatory approach towards planning in practice, however, has always been a ground for discussion specifically when it comes to methods, practicalities and tools to be deployed [Bra09][CR04][Wat03][Hea03][Tew98].

Contemporary planning tools and techniques should facilitate collaboration among stakeholders during all plan-

ning phases. The more comprehensive, informative and interactive these tools are, the more equipped the planner will be to attain her/his facilitating role [CR04]. A shift in planning paradigms has thus occurred in favor of more visual approaches. Visualization is considered as a *Public Participation Spatial Decision Support System* (PP-SDSS) which is aimed at consensus-making [SK09]. The need for perceivable visualizations as a means for a widespread inclusion is perpetually emphasized by scholars [Sie06][Sim01]. Yao, Tawfik, and Fernando contend that visual models are required in different stages of planning within collaborative urban planning support systems [YTF06]. Considering tremendous technological advances in visualization tools, it is deemed necessary to reformulate planning procedures based on these potentials aiming at more democratic planning routines.

## 2. Contemporary visualization tools: technological advances and empirical shortcomings

Planning instruments of our age should be capable of bidirectional transaction of ideas among planners and stakeholders and provide maximum authority for all stakeholders to participate in the process regardless of temporal or spatial distance [BCW08]. On the other hand, due to incredible technological improvements in display quality, realistic effects and Internet technology, 3D environments are now fairly available and workable similarly for experts and non-experts. It is no longer unrealistic to envision planning environments where all stakeholders can easily interact with planning proposals, submit their contributions in real-time [Ban11] and create own ideas while the simplicity and feasibility of the approach largely relies on the powerfulness of the methods for visual communication of planning proposals.



**Figure 1:** The spectrum of contemporary visualization tools according to their efficiency, availability and ease of use.

The term *Visualization in planning* refers to the optimal data representation framework designed for both planners and public within a planning procedure which uses Internet as an infrastructure for rapid, cheap and efficient dissemination of data [HJH01]. Such a combined use of visualization tools and Internet is more than essential for an efficient communicative planning practice [Bra09][See08][SDD98]. Visualization environments are largely diverse in magnitude of use, usability and efficiency. Some techniques are extensively resource-demanding such as Cubes. The most efficient and integrated available visualization systems are too complex and resource-demanding and require high level of expertise and experience to handle. This is not intrinsically a pitfall; but in practice, this has proved to notably hinder public participation i.e. in the form of digital divide [Bra09]. On the opposite end are applications which operate on ordinary PCs and laptops through the web which, in turn, are not as productive, integrated and planning-oriented as the tools of the first group. Figure 1 depicts the spectrum of contemporary visualization tools based on parameters such as efficiency, availability and ease of use.

Visualization environment for a web-based participatory planning procedure should ideally be workable for different groups of users and fairly integrated so as to bring all diverse planning issues together within a simplified and unified planning tool [Sta00]. In addition, the final product should be flexible enough to feature customized interfaces for different planning scales.

## 3. Digital visualization and modelling tools

The two major families of digital applications deployed in modelling and visualization for planning purposes are CAD and GIS applications. CAD applications have traditionally been common to small-scale planning projects (e.g. architecture) while GIS tools have governed the realm of territorial and regional planning. CAD solutions are usually more accurate due to their geometric base. They are often used to create three-dimensional models of built environment while GIS normally deals with two-dimensional maps. GIS applications are generally known as analytic tools compared with CAD tools which are mainly used based on their visual representation capabilities. A summarized comparison of generic characteristics of the applications within the two categories is provided in Table 1: *Analytic comparison of capabilities and limitations of CAD and GIS applications.*

**Table 1:** Analytic comparison of capabilities and limitations of CAD and GIS applications.

	CRITERIA	
	CAD	GIS
Common Use in Planning and Design	Architecture, Urban Design	Urban Planning, Community Planning, Regional Planning
Scaling to Needs	Scales Not (Too Geometric)	Scales Well (Geography to Geometry)
Planning And Design Capabilities	Limited Flexibility And Possibility For Design	Suitable Instruments For Planning
Dominant Visualization Mode	High Realistic Visualizing Capabilities	Schematic Visualizing Capabilities
Analytic Strengths	Few Analytic Capabilities	Analytic Functions for Modelling Systems
Dominant Content	Physical Form	Natural and Socio-Economic Phenomena
Dominant	High Virtual	Thematic

Presentation Capabilities	Reality Capabilities	Representation Capabilities
Number of Alternatives	Increase in Number of Alternatives	Increase in Number of Alternatives/Scenarios
Automated Modelling	Operator-Demanding Modelling	Semi-Automated Modelling
Accuracy	High Accuracy Due to Geometric Base	Limited Accuracy
3D Visualization	Workable 3D Environment	Mainly 2D, limited 3D

This is now however something of the past. The two families are moving closer over time. This converging attitude is actually manifested in new products of the pioneer firms within the two categories e.g. Revit by Autodesk and 3D Analyst by ESRI. Besides, a closer interaction with the Internet and a variety of web-based products and functionalities can be monitored in both groups.

Innovative technological features such as VRML (in the past) and initiatives of pioneer companies e.g. Autodesk, ESRI and Google (quite recently) have been substantial to this scenario of integration. Widespread use of Google Sketchup and Google Earth by public and planners for creating a shared digital globe is an articulate example. Digital models of the buildings can now be created in Sketchup, located on their exact place on Google Earth and linked to their corresponding web-pages. This is nevertheless more appropriate for visual representation of already existing built features rather than planning practices. Some recent efforts have been done to use the same routine for planning purposes as well such as *City Planner* initiative by *Agency 9* [Age10]. Geometric models of Sketchup are nonetheless not constructed according to informative hierarchical patterns. This hampers linking the models to databases; something which is required for integrated planning purposes.

#### 4. Aims, objectives and scope of the research

This study is a search for a conceptual framework for an integrated web-based participatory planning tool. Based on the literature, it is hypothesized that provision of agile, distributed and astute routines for visualization is the key to a better communication with stakeholders during planning period. The sought-after integrated visualization tool is primarily aimed to provide solutions at urban scale.

This study, in particular, examines the capacities of available visualization tools and techniques to be deployed for maintaining a collaborative planning procedure. This has been realized through a thorough search for theories and literature on use of visualization in planning, a comprehensive survey over a set of state-of-the-art visualiza-

tion applications followed by evaluation and analysis of the findings. Finally, generalities of a back-casted visualization interface are presented.

#### 5. Background activities and institutional frameworks

The point of departure for this study was the project *KTH Classroom Search Engine & 3D KTH Virtual Campus* initiated by the *Division of Geo-informatics* in *School of Architecture and the Built Environment of KTH* in 2009. Within the project, digital exterior and interior models of the buildings throughout KTH main campus were constructed through footprint extrusion and enhanced with photorealistic mapping of the façades using Google SketchUp. Challenges confronted during presentation of digital models of the buildings in the ensuing seminar partly inspired the idea behind this study. Later on, getting in touch with ViSuCity (*Visual Sustainable City*) project helped to consolidate the subject as an interdisciplinary master thesis and, at the same time, a part of working package 8 (WP8) of the *ViSuCity* project [Ban11].

#### 6. Methodology

Current study is a qualitative research initiating with a descriptive and exploratory survey followed by an evaluative phase and a brief prescriptive supplement at the end. Within the first phase, the overall design of the research was formulated and narrowed down to its most essential components.

Interviews and discussions with experts of visualizations helped developing an overall insight to the complicated and multi-disciplinary area of visualization. Choice of experts within the focus group (professionals in relevant fields) was based on their being competent and well-acknowledged within their fields of expertise and their availability. Utmost effort was also made to select people with various backgrounds to cover diverse aspects. At this stage, generalities of the field were discussed through face-to-face meetings and without any questionnaire or detailed agenda. The intention was to facilitate the exploratory approach of the initial phase and help discovering new areas of concern which were deemed necessary for developing a holistic insight.

Online search was carried on in two different ways: searching through websites, weblogs and web-catalogues of companies active in visualization and planning authorities as well as acquiring *Google Alerts*. The latter is a service which is activated in Gmail and periodically sends a set of relevant links to user's inbox based on the keywords provided. *Visualization* and *planning* were the main keywords used which were over time combined with other words and phrases such as *participatory* and *urban planning* so as to enhance the results. Proposed web pages were regularly monitored and filtered based on their relevance and importance and findings were incorporated into

the research process. This approach helped access the state-of-the-art actors, activities, findings, trends and knowledge in the field which were later on used for choosing case studies.

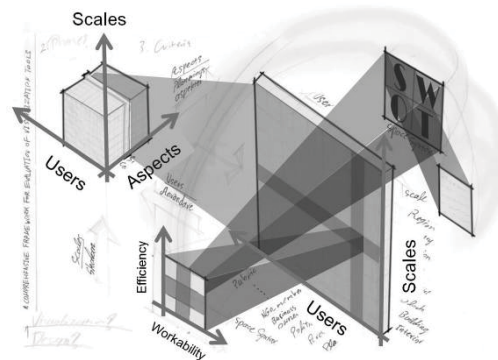
Study of bibliographical resources helped discover history and basics of visualization in planning and also introduce a set of relevant disciplines e.g. collaborative planning, city modelling, virtual reality, augmented reality, Geographic Information Systems, Public Participatory GIS, Web 2.0, neogeography, e-government and decision support systems. These contributed to a more comprehensive understanding of the context over which the research question was to be examined and provided with a holistic solution.

Simultaneous use of the aforementioned sources of information contributed to accurate delimitation of the problem to be studied. Web-accessibility was also identified as a momentous quality for the looked-after visualization tool. The research question was consequently developed to: ***What are the main characteristics of an integrated web-based visualization tool for enhancing stakeholders' participation in planning procedures?***

In search of the integrated web-based visualization tool and based on the knowledge and insight already gained, an evaluative survey over a set of case studies was then conducted. Case studies were selected through online search. The main criteria for choice of visualization tools were being technically avant-garde and relatively outstanding in capabilities and possibilities. The visualization demonstrator of ViSuCity, Neo4 UrbanPlanner, was also considered as one of case studies. Examples were intended to possess favoured characteristics discovered through previous phase of study. Selected visualization tools were studied and generally acknowledged through a survey over their websites, weblogs, catalogues, manuals, user feedbacks, demo versions and available literature also contacts with developers and marketing agents through e-mail, phone call, net-meeting and meeting sessions.

An evaluation cube was then developed to introduce a method based on five parameters for evaluation of the whole range of visualization tools. The idea of the cube was basically taken from Prof. Ulf Ranhagen's notion (cited in [Ban11]). Here, however, the cube was used in a slightly different sense: as a method for evaluation of existing planning/visualization tools which will, in turn, be used to clearly outline characteristics of the integrated web-based planning tool. This evaluation method demonstrated in Figure 2 is based on locating existing visualization and planning tools onto the units within the cube. Major criteria which have been proposed for evaluation of each package are *efficiency* and *workability*. SWOT analysis method is proposed for a more comprehensive survey over each case (strengths, weaknesses, opportunities and threats). The three factors of *user groups*, *planning aspects and planning scales* and criteria such as *efficiency*

and *workability* which had been proposed within the cubic model were then expanded to a set of dual criteria aimed at better elaboration of the optimal tool. Functioning in 2D or 3D environments, determining an integrated or specific approach, being user-friendly or expert-oriented, more interactive or more informative, suitable for planning or mere visualizing purposes, possessing visual or information-rich architecture, being workable or resource-demanding, participatory or excluding, using realistic or schematic representations and being interoperable or self-sufficient were the criteria set for further evaluation of case studies.



**Figure 2:** *The evaluation cube.*

A number of prominent visualization applications were then selected, studied, categorized and examined against dual criteria. Eventually, findings were applied to devise a back-casted proposal as a concrete example of an integrated web-based visualization tool for participatory planning.

## 7. Case studies

Selected case studies to be examined against dual criteria are: City Engine, City Maker, City Planner, Urban Circus, Neo4 UrbanPlanner and Symbiocity Scenarios.

*City Maker*<sup>TM</sup> is a multidisciplinary 3D visualization platform which is used in variety of fields including urban planning, management, administration, surveying, architecture, transportation, emergency, power and utilities. The product operates in close relationship with GIS applications and exchanges a variety of file formats such as DXF and DWG with planning packages. Mass data processing, delicate visual effects and interoperability are the most prominent features of City Maker. It has nonetheless an expert-oriented configuration and is not workable and user-friendly enough so as to be efficiently used by lay users. CityMaker has been developed jointly by Digital City Research Center of Beijing Tsinghua Urban Planning & Design Institute and Gvitech Technologies. [GV10].



*City Engine* operates in real-time and possesses an interactive interface [Cie10]. Using *procedural* methods for rapid creation of urban fabric ruled by generic geometry-creation grammars is the main principle in *City Engine* [PM01]. This real-time creation of photorealistic representations of a fictive city or district based on a set of parameters which are set by users can be efficiently used in web-based visualization of the future. Nevertheless, *City Engine* is primarily focused on physical manifestation of built environment and should also be linked to dynamics of the city to be developed into a visualization tool for planning. Moreover, it is currently a stand-alone application. *City Engine* is the flagship product of the Zurich-based company, *Procedural Inc.*

*City Planner* is a user-friendly, web-based visualization tool for creating, sharing and communicating future urban plans. Inputs to the program are 3D models of urban entities constructed in SketchUp, Maya or 3D Studio Max. Digital models of planning proposals are placed into their global coordinate space and made available online for being observed, visually analyzed and evaluated by stakeholders. The product provides the infrastructure required for adding geo-referenced feedback to a developing urban plan [Cip10]. The tool is however mainly intended for visualization of planning alternatives rather than actual urban planning practice and does not generally include analytic functions. *City Planner* is developed by *Agency 9 AB* [Age10].

Among available interactive visualization products, *Neo4 Urban Planner* is one of the pioneers in creating realistic, static and animated outputs integrated with analytic planning tools. The product supports a variety file formats such as COLLADA, CityGML and those of ESRI ArcGIS. *Neo4 Urban Planner* is developed by *Sightline Vision AB*, Stockholm-based company which has been founded in 2000. It has undergone some modifications over time so as to expand its area of functionality e.g. in order to also perform social visualization [Sig10]. More web-based functionalities have been recently added to the product e.g. interactive multi-criteria evaluation for planning. Models have been linked to Google Maps and it has been made possible to add comments and sketches to the model and get feedback in real-time. *Neo4 Urban Planner* is one part of the *demonstrator* of the ViSuCity project.

*Symbiocity* is not basically a planning product but a trademark bringing together thousands of Swedish companies so as to provide a multidisciplinary and framework for marketing Swedish sustainable planning products and services around the globe. *Symbiocity* was established in 2008 and is administered by *Swedish Trade Council*. *Symbiocity Scenarios* is an online game within *Symbiocity* website which visualizes consequences of a set of planning strategies on a virtual city in real-time. The principals behind the user-friendly interface of the application can be deployed for developing a professional planning package with a participatory approach [Sym10]. In other words, *SymbioCity's* most impressive features are

realistic representation of urban features and dynamics and availability through the Internet which facilitates collaboration and offers a fairly interactive and workable interface.

*Urban Circus* visualizes planning proposals with lots of realistic details in real-time and within a four-dimensional environment. It covers a variety of planning issues in different phases and is highly interoperable. Nonetheless, *Urban Circus* is not very participatory and its interactivity is mostly limited to navigation tools and presentation modes rather than decision-making and alteration possibilities. This visualization software takes input from 3DSMax, Maya and ArchiCAD among all. Outputs range from 2D rendered scenes, 3D panoramic view, 3D videos, 4D planning environments and interactive web pages. *Urban Circus Company* is based in Brisbane, Australia and has been founded by an urban planner, Dr. Ben Guy in 2004 [Urb10].

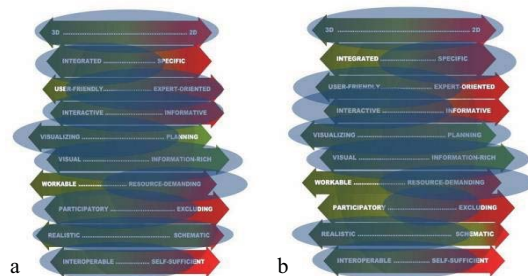


Figure 3: (a) *City Maker*, (b) *City Engine*.

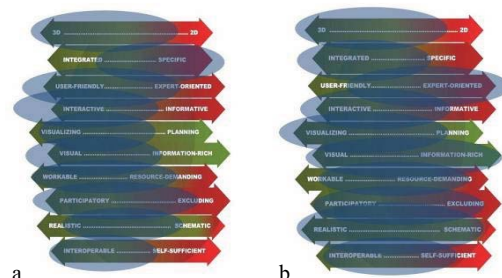


Figure 4: (a) *City Planner*, (b) *Neo4 Urban Planner*.

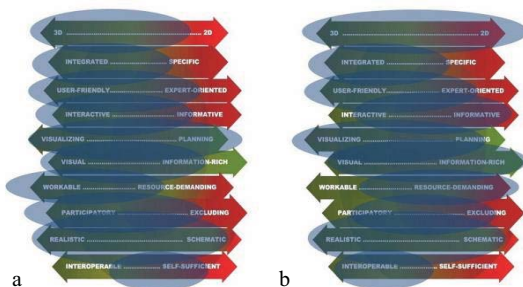


Figure 5: (a) *Symbiocity Scenarios*, (b) *Urban Circus*.

Figures 3-5 depict a summary of evaluation of the six case studies against dual criteria developed earlier within this research. Blue spots and their proximity to one end of each pair of dualities represent that the product possesses those characteristics. Hence, most-favored situations are where green areas and blue spots coincide the most.

## 8. Conclusion

The purpose of the evaluation phase described above is not ranking or categorization of the cases. Judgments are carried out in an approximate way and based on available sources of information. Diagrams convey merits and pitfalls of selected packages in a clear and concise visual setting. Findings through this approach are complementary to specifications for the integrated visualization tool acquired previously through literature review and online search.

Based on evaluation diagrams the following conclusions can be drawn:

- All studied cases possess three-dimensional visual interfaces which are deemed necessary for visualization tools.
- Almost all case studies provide realistic visualizations and they often also use schematic representations in combination for specific purposes.
- A majority of selected products are fairly interoperable and interactive. Only SymbioCity Scenarios is not efficient at exchanging inputs and outputs with other packages which is not a deficiency in essence since it has not been design as a planning tool.
- Most cases are user-friendly and information-rich. This is in line with the fact that the to-be-developed web-based visualization tool of tomorrow should be easy-to-use and also better connected to databases so that it fulfills the requirements for an integrated visualization media.

It goes without saying that there will still be a need for sophisticated expert-oriented visualization tools with numerous menus, functions and parameters to be accurately set by experts of relevant disciplines; but these will no more contribute to the participatory approach which has been of the main focus for this study. The same argument holds regarding an integrated approach towards web-based visualization tools: there will still be a need for specific visualization tools in the fields of e. g. lighting, noise, landscape, infrastructure, transportation, security, safety, circulation, line of sight, pollution, energy efficiency, etc. Whilst the communicative visualization tool should be capable of providing a holistic insight to lay users and offer an integrated yet workable solution.

Workability is the quality that a few examples possess. Even though technological developments enhance workability of digital tools on a daily basis, it is still quite necessary for the integrated tool to avoid resource-

demanding solutions so as not to dampen the collaborative attitude by triggering digital divide [Bra09]. The evaluation cube, dual criteria, evaluation diagrams and this concluding part altogether envision the overall structure of the conceptual framework for the integrated web-based visualization tool. In the following, a further step is taken to provide a concrete back-casted example of the realized visualization tool which could satisfy requirements of the already-developed conceptual framework.

## 9. Proposal for the Integrated Web-Based Visualization Tool



**Figure 6:** Back-casted interface of the proposed integrated web-based visualization tool.

Figure 6 features the back-casted interface on a normal PC or laptop screen. The consequences of the changes made by the user to planning parameters through adjustment bars on the right side can be viewed within the window on the left side in real-time. The user can navigate freely throughout the scene to examine the outcome from different points of view. The change in values is only allowed within specific ranges. Figure 7 demonstrates the output of moving the *Green Area* slider to the right. New green areas are optimally located in various spots around the district.



**Figure 7:** Real-time visualization of a change in the parameter *Green Area* by the user.

Change of a parameter by the user can evidently be visualized in numerous ways. The optimal alternative should thus be produced and presented by the tool through pre-designed algorithms which are in turn based on local planning regulations and routines and implications of available spatial data. When all values are set, the visual consequences are carefully studied and examined from various points of view and the optimal configuration is envisioned, the user can publish her/his planning alternative by pressing the *Vote* button. **All users are thus free to compose their own planning alternatives through an intelligent and fully customized visualization/planning tool instead of choosing among a limited set of planning alternatives.** Based on the area of responsibility and scientific qualification of the user, a Multi-Criteria Evaluation (MCE) tool which is incorporated in the system assigns corresponding weights to each category of voters before putting the results together and developing an overall alternative or a set of collaborative choices.

Customization to different user groups and planning scales is an essential quality for a visualization tool. Adjust controls for planning within district level, for instance, will be totally different from those in the case of planning procedure of an urban block. Besides, the degree of realistic visualization should correspond to the planning stage. This example should only be considered as one of numerous possibilities for the integrated web-based visualization tool provided as a complement to theoretical findings.

## 10. Discussion

A major challenge in this study was the perpetual risk of using outdated data (literature, reports, software tutorials, technical recommendations, etc). New technological features in the realm of computer graphics in general, and web-based visualization tools in particular, are being developed and immediately presented to planners and public on a daily basis. Reliable scientific materials of a couple of months ago can thus easily be part of the history at the time being. Low band-width of the Internet, for example, was once considered as a serious impediment to transfer of photorealistic visualizations to the public [SDD98] which is no longer pertinent in the field of web infrastructure. Of the four types of virtual cities that Smith, Dodge, and Doyle introduce and describe (Web Listing Virtual Cities, Flat Virtual Cities, 3D Virtual Cities and True Virtual Cities) only True Virtual Cities can now be considered as a pertinent case within urban modelling discourse [SDD98]. The three other definitions refer to some abstract or symbolic models which do not comply with contemporary virtual environments' requirements. Nevertheless, utmost care has been taken to recognize and eliminate outdated materials based on findings of the complementary online part of the study.

Another area of uncertainty was differentiating between visualization, planning, presentation, drafting and

enhancement tools. According to definitions of the term *visualization* the concept is closely intertwined with data representation and thus goes far beyond the mechanical act of virtual construction of an urban element in a schematic or realistic manner [BAS00][SDD98][OHD99]. On the other hand, a visualization tool is a medium which visually interprets planning ideas and also helps examine, alter and introduce planning proposals; but it should not necessarily act as the core of planning procedure. The interrelationship between the two concepts of planning and visualization makes it difficult to define the boundaries of the research and seems to cause problems particularly in choice of examples of visualization tools. To better comply with the definitions of the term, however, ubiquitous tools such as Auto Cad, Micro Station, Revit, 3D Studio Max, Maya and Rhyno were not selected as case studies.

Another challenging ground was avoiding contradictions when defining criteria for an efficient visualization tool. A fully integrated package, for example, which has taken a variety of disciplines into account, normally becomes so complicated that can no longer be realized and used by non-expert stakeholders. The fact that there is always a limit to the extent drastically diverse requirements can be met by the sought-after visualization tool should always be taken into account.

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