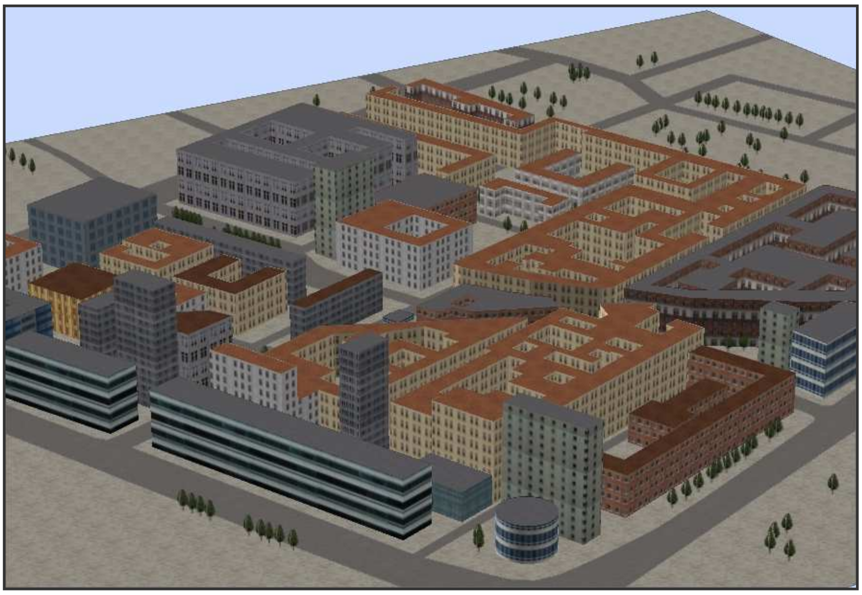
Centre for Geo-Information

Thesis Report GIRS-2006-29

USABILITY OF 3D GEO-VISUALIZATION IN PARTICIPATORY SPATIAL PLANNING

Spatial orientation in 3D geo-visualization

Malgorzata Milosz



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PSPE Participatory Spatial Planning in Europe

Usability of 3D geo-visualization in participatory spatial planning

Spatial orientation in 3D geo-visualization

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Foreword

Writing my MSc thesis was a very challenging work. During this time I had to overcome many difficulties and struggles. Now when I look back I appreciate a lot new things I have learned and the experience I have gained. However, finishing this thesis work would not have been possible without help of many people. Hence, in this place I would like to express my gratitude.

At the beginning, I would like to thank Willy ten Haaf, without whom it would not be possible for me to continue the MSc programme in Geo-Information Science after finishing the Socrates Erasmus exchange period.

I am especially grateful to my supervisors, Ron van Lammeren and Tessa Hoogerwerf. I appreciate a lot the inspiring discussions we had and their valuable comments on my work. I was impressed by the enthusiasm of Ron van Lammeren and his ability of making arrangements in order to support my research activities. Tessa Hoogerwerf was always ready to give me a helping hand and support me in difficult situations. Her remarks and comments helped me to improve the quality of my work.

I would like to give my thanks also to Aldo Bergsma for the work he did to improve my questionnaire application and make it working properly.

Furthermore, I would like to thank all people involved in organizing my public inquiry in Warsaw, in Poland: employees of the Palace of Culture and Science in Warsaw for a warm welcome and to Maria Andrzejewska and Monika Rusztecka (UNEP Grid in Warsaw) for helping me with the preparations.

I am very grateful to my family and Michal, who was always there in case of any problems to lift my spirits and motivate for further work.

My special thanks to other students of the MGI programme. We spent a long hours working together in a one room, sharing concerns and doubts about the progress of our work.

I am very grateful to all of you.

Abstract

This MSc thesis is a part of the PSPE project (Participatory Spatial Planning in Europe), which focuses on improving the spatial information exchange in participatory spatial planning through renewed interactive approaches that make use of a geo-visualization.

The thesis proposes a method to evaluate 3D geo-visualization in participatory spatial planning. First, the lessons learned and best practices for geo-visualizations design - main results of the literature review - were addressed during the expert study (interviews with professionals). Results of interviews confirm the importance of including 3D geo-visualizations in the spatial planning process to support public participation and were helpful in creating 3D geo-visualizations, which was later on used in the usability evaluation.

A web-based questionnaire was developed for performing the usability evaluation of constructed 3D geo-visualizations. This questionnaire is focused on the spatial orientation. Two 3D geo-visualizations were used in the evaluation: one with and one without street names. The usability evaluation was done using the three usability criteria - efficiency, effectiveness and satisfaction and the four assignments testing spatial orientation. These four assignments were based on the comparison of 3D geo-visualizations and 2D maps.

The questionnaire was delivered to the wider audience during the public inquiry which was organised in the Palace of Culture and Science in Warsaw (Poland) and afterwards was available on the internet. In total 218 people filled the questionnaire in. Only responses from the public inquiry were analysed (140 responses).

The questionnaire results show that including street names in the 3D geo-visualization supported people's orientation in a 3D geo-visualization. However, it appeared that people had serious difficulties with solving the orientation assignments - only 46% of responses were correct.

1. Introduction

In this chapter the problem background and problem definition are introduced. It presents the research objective and research questions. It also includes the report outline.

1.1. Context and background

A geo-visualization (visualization of geographic information) itself can be understand as a mean of making the spatial problems and contexts visible by using visualization methods and visual abilities of people (Kwan, et al. 2003 after MacEachren 1999). A geo-visualization in participatory spatial planning can be seen as an important tool for better understanding via improved communication of future planning initiatives and changes.

Nowadays geo-visualization systems are developing very fast (Yun, et al. 2004). Web GIS, mobile GIS, and virtual reality are giving new opportunities for many fields of application, including participatory spatial planning. Geo-visualization tools are becoming more accessible to the public than previously, when these tools were mostly reserved for experts and specialists (Yun, et al. 2004).

Current research topics associated with the use of geo-visualizations for spatial planning include mainly the technology aspects related to the software and the architecture development, e.g. Serpa 2004; Perrin, et al. 2001; Pullar, et al. 2001. Other, e.g. Al-Kodmany (1999), Tress, et al. (2003), Lovett, et al. (2002), Hoogerwerf (2003), consider the geo-visualization methods used in the participatory spatial planning process (Bloemmen, et al. 2005).

However, a big gap still remains between the design and the functionalities of geo-visualizations and the way geo-visualizations are understood and perceived by target groups. For instance, Robinson (2005) underlines the lack of sufficient assurance that geo-visualization tools are applicable for a certain decision situations. Further, Yun, et al. (2004) state that geo-visualizations are not designed in the way that these can serve and support the public involvement. The need for research on interpretation possibilities of geo-visualizations is also raised by Lovett, et al. (2002), Slocum, et al. (2001). Bishop (2005) highlights that such aspects of visualization like the perceptual and societal are left out from research. Hence, the ability of understanding and learning from a geo-visualization appears to be more important than its technological excellence (Castro, et al. 2003).

In this context usability of a geo-visualization is a very challenging issue. Andrienko, et al. (2001) underline that the usability is not only connected with the visualized geodata, but it has a wider context, which is related to the specification of the task which is going to be performed and the problem to be solved by the users. The cultural and personal differences in interpreting and understanding visualizations should also get a more attention when considering the use of geo-visualizations (Ahonen-Rainio 2003).

1.2. Problem definition

Spatial planning is shifting into a more interactive and participatory approach (Geertman 2002 after Stillwell, et al. 1999; Pleizier, et al. 2004; Hofschreuder 2004). Participatory spatial planning involves many different groups of stakeholders. In general we can distinguish two kinds of participants: professionals and non-professionals. The efficient flow of information, discussion and communication between these two main groups could be supported by a new means, methods and techniques. Even some authors underline the need of assuring this support e.g. Bloemmen, et al. (2005) after Adler, et al. (1997), Bishop, et al. (2005) after Appleton, et al. (2001) and Krause (2001). Geo-visualization can be seen as a one of means supporting communication between stakeholders in participatory spatial planning.

Many researches believe that the ability of non-professionals, also called lay people, to read and understand a 2D geo-visualization is rather limited (Hoogerwerf 2005 after Orland 1994, Verbree, et al. 1999; Yun, et al. 2004). The chance for improvement of this situation is seen in visualizing geodata by means of 3D as it is giving greater similarity with the real world and is easier to recognize for non-professional users (Hoogerwerf 2005 after DiBiase 1990; Geertman 2002).

Within this scope, the aim of this thesis is to evaluate the usability of a 3D geo-visualization in participatory spatial planning. In particular, the attention is paid to the understanding of geo-visualizations by non-professional users. As a study area the centre part of Warsaw is used, therefore a usability evaluation is performed in a relation to the Polish spatial planning system.

1.3. Research objectives and research questions

This MSc thesis concentrates on the relation between the design of 3D geo-visualizations for the purpose of participatory spatial planning and its understanding by the potential stakeholders. The main objective of this work is to evaluate the usability of 3D geo-visualization in participatory spatial planning.

Above-mentioned objective can be translated into the following research questions:

1. What are existing lessons learned and best practices about a geo-visualization design for participatory spatial planning?
2. What are possible methods for evaluating usability according to the literature review?
3. How to define usability evaluation of a geo-visualization for the purpose of this research?
4. What is the usability of 3D geo-visualizations created according to the best practices and lessons learned?

1.4. Thesis report outline

This MSc thesis is divided into following chapters:

- Chapter 1. Introduces the problem background and problem definition. Presents the research objective and related research questions.
- Chapter 2. Concentrates on the subjects related to a 3D geo-visualization design in participatory spatial planning and the existing guidelines for designing geo-visualizations. The guidelines are defined by two terms: best practices and lessons learned. In the last subchapter (2.4) expert study (interviews with professionals) is described. Interviews addressed issues about a 3D geo-visualization design for participatory spatial planning, the context of geo-visualizations' use as well as the opinions of planners about best practices and lessons learned. Chapter 2 answers research question number 1.
- Chapter 3. Introduces the reader to the items of usability evaluation. The second subchapter (3.2) explains the method (a questionnaire) used in this MSc thesis for the usability evaluation of 3D geo-visualizations. Questionnaire gives a more practical approach to the usability evaluation, where respondents are asked to solve particular tasks related to 3D geo-visualizations; these tasks concerns the users' spatial orientation. This chapter answers research question number 2 and 3.
- Chapter 4. Shows the results obtained from the questionnaire. This chapter brings the answer to the research question number 4.
- Chapter 5. Consists of the conclusions, discussion of results and recommendations for a geo-visualization and the usability evaluation.

2. Geo-visualization in participatory spatial planning

In this chapter, one can read about the definition of a geo-visualization, participatory spatial planning and the existing lessons learned and best practices for geo-visualizations design - terms which are used in this MSc research for describing the design guidelines. This part answers the first research question. In the last subchapter (2.4) theory from previous subchapters is addressed in the expert study - interviews with professionals.

2.1. Geo-visualization

As it was mentioned in the introductory chapter a geo-visualization can be defined as a visualization of geographic data, which consists of many transformations in order to make the information displayable and understandable by the human perceptual system (Kraak 2003 after Visvalingram 1994).

"Geovisualization can be considered to mean 'making visible' in two ways. Firstly, it refers to making geodata visible by creating graphic or – from a human perspective- external representations in a particular context of use: visual exploration" *Blok 2005*
"…geovisualization grows out of research issues concerning the representation of and interaction with large amounts of complex data, though in its case, the data are specifically geospatial (referenced to the earth's surface)." *Edsall 2003*
"A geo-visualization is defined as a three-dimensional visual representation of data, which has a geographic reference" *Hoogerwerf 2005*
"Geovisualization (visualization of geographic information), …, is the use of concrete visual representations and human visual abilities to make spatial contexts and problems visible" *Kwan 2003 after MacEachren 1999*
"Geovisualization is more than the creation of alternative visual representation of the data (after Fairbairn et al. 2001). It also concerns the geocomputational methods and techniques behind processing the images, the environment in which the images are used (i.e., the interface) and the question ''does it work?'' (i.e., cognitive aspects)" "Geo-visualization - the use of visual geospatial displays to explore data and through that exploration to generate hypotheses, develop problem solutions and construct knowledge" *Kraak 2003*
"Geovisualization can be described as a loosely bounded domain that addresses the visual exploration, analysis, synthesis and presentation of geospatial data by integrating approaches from cartography with those from other information representation and analysis disciplines, including scientific visualization, image analysis, information visualization, exploratory data analysis and GIScience" *Kraak 2005 after Dykes, et al., 2005*
"Through involving the geographical dimension in the visualization process, geovisualization greatly facilitates the identification and interpretation of spatial patterns and relationships in complex data in the geographical context of a particular study area" *Kwan 2003*
"Geographic visualization - the use of concrete visual representations - whether on paper or through computer displays or other media- to make spatial contexts and problems visible, so as to engage the most powerful human information-processing abilities, those associated with vision" *MacEachren, 1992*

Figure 1. Definitions of a geo-visualization.

A geo-visualization has a wider meaning as it is supposed to make the spatial problems and contexts visible by using particular visualizations and people abilities of perceiving these visualizations (Kwan 2003 after MacEachren 1999). A geo-visualization is also supposed to support the geodata exploration in order to develop a new knowledge and problems' solutions by the potential users (Kraak 2003). In the literature, many other definitions of a geo-visualization can be found; see table above (Figure 1).

From the definitions mentioned above it can be concluded that a geo-visualization is a visual representation of geographic data but also includes the process needed to design it. During this process many decisions needs to be made, e.g.; which data to use, which spatial relations to show, what is the context of a geo-visualization, or who will use it.

Representing data by means of 3D underlines the relation of a geo-visualization with virtual reality. A virtual reality is seen as a 3D, computer generated environment that gives the user a sense of being in the real world (Roo 2005 after Masum 2003). Two elements of virtual reality can be distinguished: virtual environment (digitally modelled 3D scene with objects and features giving atmospheric impression) and the 3D scene viewer; as it was introduced with so called 'peep-box metaphor' (Lammeren, et al. 2003).

Within this MSc thesis, a geo-visualization is seen as a visualization of spatial data, which is supposed to support public participation effectively in the spatial planning process. The type of geo-visualizations that is being considered is a geo-visualization that makes use of a third dimension (3D geo-visualization), is computer–generated and is screen displayable. The screen is used as a window through which the user can experience a 3D geo-visualization (desktop geo-visualization/ Window on a World) (Hoogerwerf 2003 after Schneiderman 1998 and Kjeldskov unknown). Both aspects of a 3D geo-visualization are considered; the decision process which needs to take place in order to come up with the final result - spatial representation related to the specific context of use and problem situation.

In this MSc thesis the term 3D geo-visualization very often appears in collocation with 'use' and 'design'. Hence, in this place it is wise to explain briefly what is meant by the geo-visualization use and the geo-visualization design. Design is the ability to combine existing knowledge, methods, resources and the needs, which results in developing new artefact as a solution of a particular problem (Preece 1994). Use of geo-visualizations is related to the final result and is practical application in the specific context of use (in this case the participatory spatial planning process).

This research work focuses on the usability evaluation of designed 3D geo-visualizations that later on can be used in participatory spatial planning, to support public involvement and to solve spatial planning problems. So, the design of 3D geo-visualizations is getting bigger attention.

2.2. Participatory spatial planning

Participatory spatial planning is the spatial planning process, in which governmental bodies in close cooperation with citizens develop new spatial plans (Hoogerwerf 2003 after Kluskens 2000). Spatial plans include agreements about the common space and functions it should have in the future. The allocation of functions should satisfy existing development needs of society by finding the balance between needs and the protection of the environment (The EU compendium of spatial planning system and policies). Among the main advantages of including public participation following can be listed: the stronger sense of commitment and better acceptance, higher satisfaction of citizens, building trust and creating realistic expectations about future planning initiatives (Al-Kodmany 1999).

The main reason to use 3D geo-visualizations in participatory spatial planning is the fact that a geo-visualization should improve the communication between many different stakeholders of participatory spatial planning process. It should help to understand and visualize the future changes of a specific area to all involved people, having different levels of experience and familiarity with a graphical representation of reality.

When we consider the use of 3D geo-visualizations for participatory spatial planning it is important to keep in mind the functions it may have. These functions include: motivating; demonstrating the idea or phenomena; creating and putting information in a spatial context (Schroth, et al. 2005 after Dransch 2000):

- Motivating function is related to stimulating user’s attention and interest.
- Demonstrating the idea means using a specific media for communicating spatial information by giving a realistic picture.
- Creating is linked to construction of mental models of spatial elements and relations between these.
- Putting into context - by this function users should be able to relate information to the bigger context.

Moreover, other constraints exist that also should be taken into account when considering 3D geo-visualizations design for the participatory spatial planning process; which moment in the planning process (planning phases) and what kind of participation

(participation levels) should be supported by a 3D geo-visualization. Among the planning phases we can mention: inventory, analysis, design and presentation; and among the participation levels: informing, consulting, advising, co-producing and co-deciding (Hoogerwerf 2003).

However, the function of geo-visualizations as well as participation level and planning phase that is supposed to be supported may vary in the relation to the specific spatial planning system. Each country develops its own procedures and conditions how public participation is included within the spatial planning process. Hence, as the study area considered in this research is located in Poland, the next paragraph briefly introduces the Polish system of spatial planning and regulations assuring the public involvement.

2.2.1. System of spatial planning in Poland

The framework of the Polish spatial planning system is described by the Spatial Planning and Management Act (Ustawa z dnia 27 marca 2003 roku o planowaniu i zagospodarowaniu przestrzennym - Dz. U. Nr 80, poz. 717).

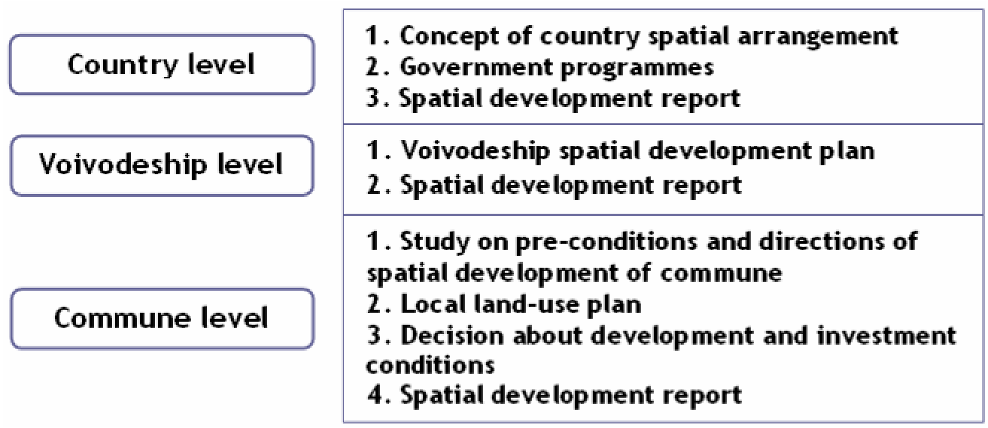

Figure 2. Polish spatial planning system - levels and documents.

The spatial planning system in Poland consists of three levels: national (country), regional (voivodeship) and local (commune). Each of those levels has its own competences and responsibilities related to the spatial planning and management of the area which result in specific planning documents (Figure 2). Spatial planning documents are related to each other, this is mainly a top-down relation. Documents from higher levels need to be included in lower ones.

Among all spatial planning levels, commune has the highest competences in the space management. It owns the substantial planning responsibility and through its planning documents it has the biggest privileges to influence and shape the public space. Local land-use plans and the decisions about development and investment conditions have a regulatory character, and are protecting a specific type of the space development. The rest of the documents have a more strategic character, these documents describe the general direction of the development for a particular unit: country, voivodeship or commune.

The planning procedure in the Polish system could be divided in five main phases: collection of suggestions to the documents, document elaboration, collection of remarks and comments, verification and finally declaration (Wiszniewska 2004).

In the Polish spatial planning system, public participation is also assured in the planning procedure. Basically it concerns:

- informing the citizens that the procedure of drawing up spatial planning documents (Study on pre-conditions and directions of spatial development of commune, Local land-use plan, Voivodeship spatial development plan) is started,
- the possibility of putting forward proposals to the documents mentioned above,
- public presentation of the main planning documents (Figure 3) and the public discussion (mainly local level),
- the possibility of reporting remarks and comments to the documents (only local level).

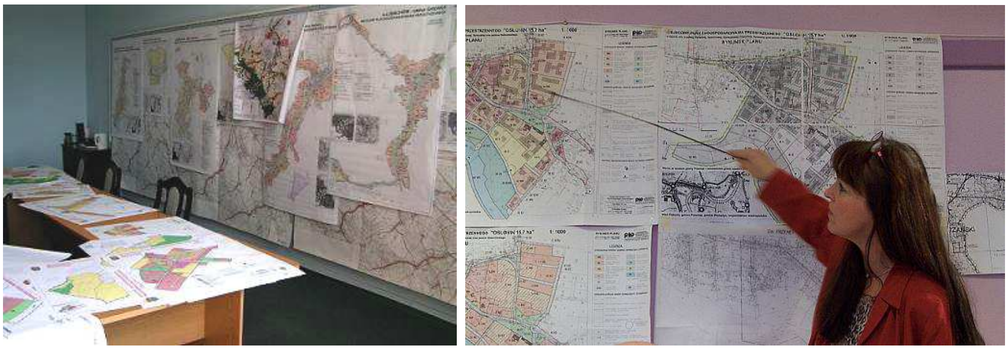

Figure 3. Public presentation of planning documents (url_2, url_3).

2.2.2. Conclusions

Regarding the participation that is assured in the Polish spatial planning system, it is the strongest on the local level. Any instruments to guarantee public involvement at the national level are mentioned in the legal act. Society has the biggest right for participating in planning process on the commune level. However, in the relation to the levels of participation mentioned in the previous sub-chapter the participation mechanism in the commune is related mainly to informing and consulting.

Hence, in this MSc thesis a 3D geo-visualization is supposed to support spatial planning on the commune level, local spatial planning problems and the planning phase: collection of remarks and comments to the plan, which is related to the public presentation of documents to the society. Currently, it is mainly done by presenting 2D maps in the public places e.g. commune office, city hall (Figure 3), but also it is becoming more often available via the internet.

2.3. Lessons learned and best practices

This subchapter is written in order to answer the following research question: what are existing lessons learned and best practices about a geo-visualization design for participatory spatial planning? For this purpose two terms are introduced: lessons learned and best practices and the answer to the question is based on the literature retrieval.

The introduced terms are not directly used in the relation with a geo-visualization, thus classification of the solutions will be based on the definitions explained below and will result in an attempt of creating a list of lessons learned and best practices.

For describing existing guidelines of the 3D geo-visualization design the terms lessons learned and best practices may be used. These terms are used in many fields of application, for defining activities, exercises or solutions which are seen as effective for a particular use. Lessons learned are seen as solutions in the specific application field, but are not evaluated so strictly as best practices. However, lessons learned and best practices still give advices and ideas on what may work best in a given situation, or what does not (url_4). Best practices should be: innovative by giving an answers to the niggling questions; should make a difference, which means improving the current state of knowledge and practice; and have a potential for replication that can be applied to the other initiatives and finally should be evaluated in the relation to a specific context of use (url_5).

Adjusting this general definition to a geo-visualization is related with a few important remarks and considerations. Lessons learned for geo-visualizations show the theoretical framework for designing geo-visualizations; concepts, methods, approaches. And what is important, rationality of lessons learned is not proven by the research in the specific field of application. Best practices for geo-visualizations give practical advices how to design geo-visualizations. Best practices are taken from existing researches, within which geo-visualizations were tested in a specific situation. Here, the most attention is paid to geo-visualizations designed for spatial planning purposes, where the participation of different stakeholders is included. Hence, best practices include findings and conclusion coming out from the case studies; what has been proven to be useful in a specific situation.

To summarise the definitions:

- Lessons learned for geo-visualizations design - ideas and theoretical framework, which can be helpful for designing geo-visualizations, not proven, so can not be regarded as best practices.
- Best practices for geo-visualizations design - ideas and practical solutions on how to design geo-visualizations, approved by research, resulting from the existing case studies related to geo-visualizations designed for solving the spatial planning related problems.

2.3.1. Lessons learned

From a literature review, six examples were derived in order to show the current lessons learned about how to design geo-visualizations. These lessons learned are related to the theoretical frameworks proposed by Yun, Sheppard, Wilkens, Wachowicz, Lammeren and Momot (Figure 4).

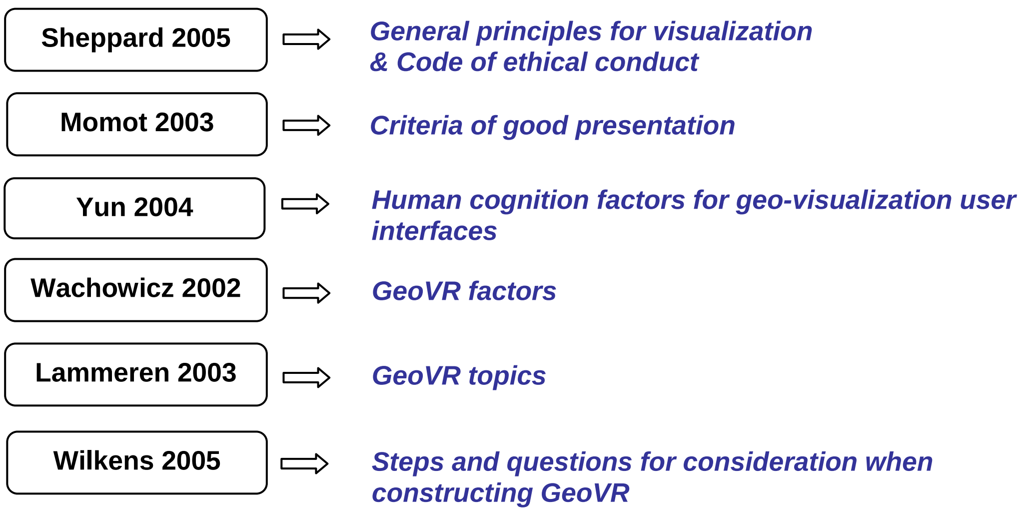

Figure 4. Lessons learned.

<u>General principles for visualization (Sheppard 2005 after Sheppard 2001)</u>

The general principles for visualization introduced by Sheppard were proposed in order to provide an understanding of visualization, avoid the bias and give the credibility of visualizations. These consist of six principles: accuracy, representativeness, visual clarity, interest, legitimacy and access to visual information.

1. Accuracy of visualizations underlines the need of showing elements and objects in relation to these actual or expected appearances.
2. Visualization should represent different range of views and conditions important for the phenomena that is visualized.
3. Visual clarity refers to communicating in clear way all elements, details and general content of the visualization.
4. Interest means that visualizations should bring the attention of the potential users to the important issues without causing distraction or confusion.
5. Legitimacy underlines that tracking of decisions made according to the visualization process should be possible.
6. Access to the visualization should be supported by the diverse means, formats and communication channels.

Besides above principles Sheppard suggested the code of ethical conduct, a list of considerations that translate the general principles into more practical approach. By this code he underlines that:

- appropriate tools and media, appropriate level of realism should be chosen according to the visualization purpose,
- attention should be paid to the data that will be included in the visualization, and this should also be related to the opinion and suggestion of community what issues should be addressed by the visualization,
- visualization should not be used in order to manipulate respondents, to get a favourable feedback,
- when designing and using visualization all taken decision, assumption made should be documented, this is also important for recording feedback from respondents and remarks related to the data and visualization itself quality.

Criteria of good presentation (Momot 2003)

Momot based the criteria of a good presentation on three characteristics: understandable, easy to use and informative. Understandable presentations should make it possible to interpret visualizations easily by showing the terrain in a realistic way, and if it is not possible, then the more abstract visualization should be explained to avoid confusing users. Further, the visualisation should be simple as possible, and include standard colours and symbols. Easy to use is related to the way any user can play with the visualization; the function of buttons, structure of menu and legend should be clear. The navigation of the model should show the high similarity with the real world movements. Overall composition of the model should be geographically balanced, that user can easily focus on the main topic of the visualization. Informative visualization should help user to understand at one glance the structure of information, the aim of the visualization and find appropriate information in the relatively short time.

Human cognition factors for geo-visualization user interfaces (Yun 2004)

Geo-visualization user interfaces are seen as a window on virtual reality, as a 3D viewer, which was mentioned in the previous subchapter. Yun (2004) pays a lot of attention to this issue, and the importance of including the human cognition factors in the design process. He defines five points that require consideration:

1. Concision of user interface; tools and menus of user interface should give the possibility of making choices about viewing possibilities, so that users can adjust these viewing preferences to their personal preferences.
2. Colour harmony in the user interface; harmonic colours should be used to make interfaces look good and to avoid user distraction.
3. Effective use of display space; place to show important information within the viewer should be considered carefully.
4. Three principles of visual information combination; during interface design three principles should be included: neighbourhood combination law, similarity combination law and closes combination law.
5. Visual attention and visual search law; should be used to focus the user's attention to the moving objects by using contrast or changing colours.

GeoVR factors (Wachowicz 2002)

GeoVR factors are derived from I-factors introduced by Heim (1998) and MacEachren, et al. (1999). These four factors should be taken in the account when designing geo-visualizations. The factors are: immersion, interactivity, information intensity, and intelligence of objects, where:

1. Immersion can be characterized as a feeling of being within the virtual world and perceiving it.
2. Interactivity enable user to play with the visualization by changing the viewpoints, layers, setting parameters, making queries, etc..
3. Information intensity refers to the level of detail offered within visualization.

4. Intelligence of objects helps in interpreting visualization by adding specific functions to objects.

This list was translated by Wachowicz (2002) into more specific terms: selection, object behaviour, augmented reality and autonomous agents, which together with four previously explained factors were assigned to two categories: GeoVR construction (selection, immersion, information intensity, autonomous agents) and GeoVR use (interactivity, augmented reality, object behaviour, autonomous agents). Selection gives the possibility of choosing data, models, scales, etc.. Autonomous agents have the possibility of acting and reacting to the changes in the virtual reality. Object behaviour is related to the continuous change of objects. And the last factor, augmented reality brings the additional information to the real world that is visualized.

GeoVR topics (Lammeren 2003)

GeoVR topics combine the specification of I-factors (Heim 1998, MacEachren, et al. 999) and GeoVR factors introduced by Wachowicz. GeoVR factors are assigned to three groups:

- factors, which may be included in the virtual reality (construction factors: control tools, experience tools, feedback, simulation, scene representation, information intensity, object preparation, geodata fusion),
- factors, which influence the content (control factors: experience modes, VR accessories, reference mode, scene immersion, geodata extent, objects types, scene selection),
- and third group of factors, which are related to the experiencing the virtual world (experience factors: manipulation, elaboration, explanation, selection, orientation, navigation movement).

Steps and questions for consideration when constructing GeoVR (Wilkens 2005)

Wilkens presented a conceptual model with questions that should be considered when constructing virtual reality (Figure 5). This approach starts with the defining the purpose of visualization and data, which needs to fulfil the visualization requirements. Then he suggests considering the type of viewpoints for exploring visualization and underlines the need to give the facilities for defining orientation and position of the viewer. Another consideration that Wilkens addressed is the need of interaction (if it is required and by which tools should it be eventually assured) and the availability of additional information. The final question is related to the way scene should be visualized and how realistic it should be. This conceptual process should be helpful for the designer to get good understanding of the elements and functionalities that should be included in the visualization in order to serve the particular purposes.

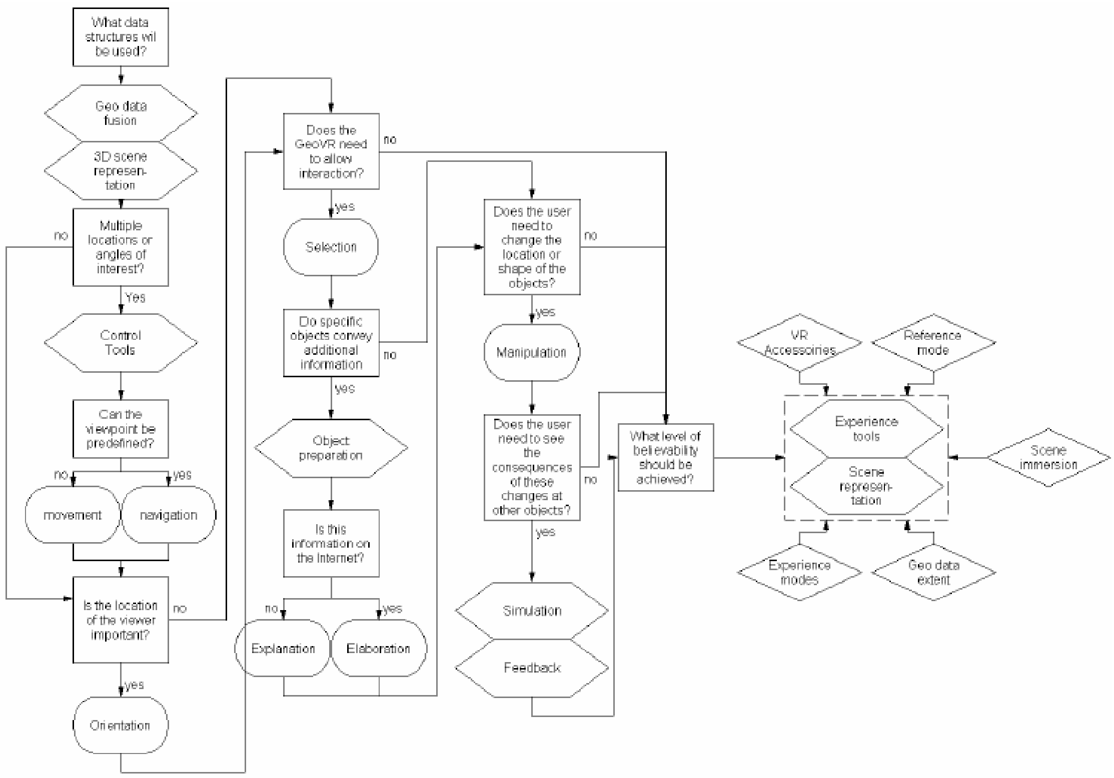

Figure 5. Steps and questions for consideration when constructing GeoVR (Wilkens 2005).

2.3.2. Best practices

Based on the literature retrieval, six case studies were chosen in order to describe the existing best practices for geo-visualizations (Figure 6). These six examples are described by means of the following characteristics: source, type of research, case study, visualization type (method of visualization, data and software), and results - best practices (see Appendix 1).

Best practices resulting from the literature retrieval can be grouped according to the topics these practices cover. The following topics can be distinguished: level of realism/ level of detail, manipulation, viewpoints, providing information, orientation, and dynamism.

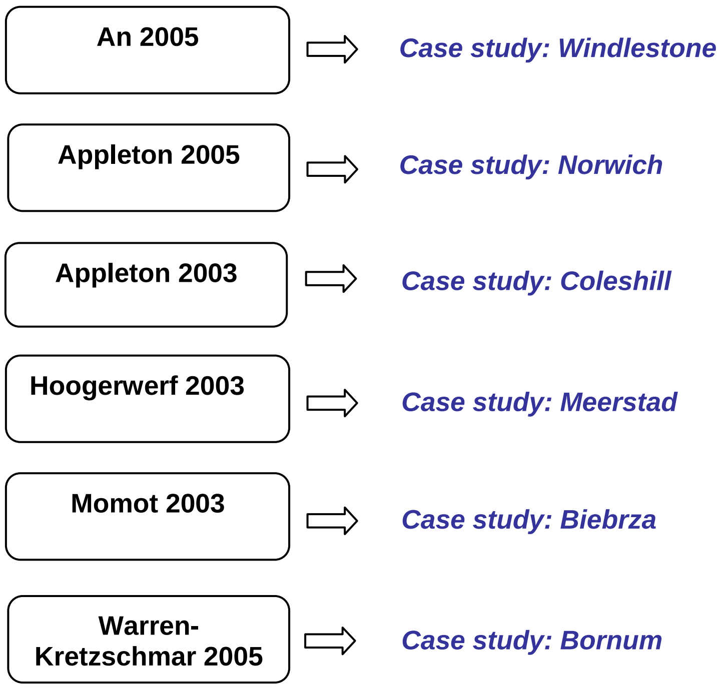

Figure 6. Six case studies chosen for defining best practices.

In following points best practices coming from above mentioned case studies will be explained in detail:

- Level of realism / level of detail. In the considered case studies level of realism and level of detail get a lot of attention. Each example results in the consideration on this subject. Momot (2003) states that geo-visualizations should be realistic, which agrees with Appleton(2003) that the higher level of detail make it easier for people to relate geo-visualizations to the landscape that is being shown, later Appleton (2005) underlines advantages of high realism - preserving clearness of the image and avoiding confusion. However, not all elements of the 3D geo-visualization are seen as of equal importance; ground with vegetation elements, especially in the foreground should be presented in the most realistic way (Appleton 2005, Appleton 2003). Further, Appleton (2005) underlines the need of keeping correct representation of the visualized elements. On the other hand, Appleton (2005) and Warren-Kretzschmar (2005) pay attention to the fact, that high level of detail within geo-visualizations may cause negative effects, like the bias and misunderstanding. Other remarks on realism, according to An (2005) are related to the familiarity of potential users with the visualized landscape. In this case, realism is seen as not significant any more. He also states that assuring the geometrical correctness of objects is more important that providing geo-visualizations with the high level of realism. A different approach to the level of realism comes from the case study of Hoogerwerf (2003), where the appropriate level of realism is related to the planning phases and the participation levels. Realistic type of the visualization is the most appropriate for inventory and presentation stage; and consulting and co-deciding levels of participation; abstract and semi-realistic for stages of analysis and design; and advising and co-producing.

- Orientation. Three case studies: Appleton (2005), Momot (2003) and Warren-Kretzschmar (2005) underline the importance of including orientation possibilities within geo-visualizations. Appleton (2005) proposes - as an example - a map with the location and direction of the viewpoints, Momot (2003) using the local names in geo-visualizations itself and Warren-Kretzschmar (2005) adding 2D maps or photos with landmarks to the visualization.

- Viewpoints. Issues about viewpoints are mentioned by Appleton (2005), Momot (2003) and Warren- Kretzschmar (2005). Warren-Kretzschmar (2005) states that the possibility to view the different perspectives needs to be included within geo-visualizations. On the other hand, Momot (2003) relates the type of viewpoint to the scale of presentation; view of human position is suggested for a bigger scale, for smaller fly over. Appleton (2005) underlines that the choice of viewpoints and the use of techniques to direct attention are two areas of potential misuse due to their ability to hide the undesirable aspects of a particular development.

- Manipulation. The interactivity and manipulation is seen by Momot (2003) and Warren-Kretzschmar (2005) as essential when designing geo-visualizations. Both of them underline the need for assuring possibility of changing layers of visible information. Warren-Kretzschmar (2005) highlights also that tools for editing and adding objects such as panning and zooming are required.

- Providing information. Within the case studies the informative role of geo-visualizations is also stressed. Appleton (2005) states that geo-visualizations should never stand alone, but always include additional information presented by other visualization techniques: text, sound, etc. Warren-Kretzschmar (2005) shares this opinion. He says that a combination of different visualization methods is required in order to satisfy diverse needs of potential users. He also underlines the need to compare different scenarios, and planning initiatives in time (future and current).

- Dynamism. Only one case study mentions the dynamism of geo-visualizations. Warren-Kretzschmar (2005) concludes his research with the statement that static 3D is more appropriate, as rapid and dynamic navigations are difficult to follow.

2.3.3. Conclusions

In this chapter the lessons learned and best practices were presented about the geo-visualization design. Lessons learned show the wide range of topics that should be taken into account during the design process. We can notice, that some of these topics have its reflection in the best practices: level of realism/ level of detail, orientation, viewpoints, manipulation, providing information and dynamism. However, some of topics got a bigger attention (e.g. level of realism) than the other (dynamism). This is related to the specific character of each of the case studies which were chosen to illustrate the best practices (Appendix 1).

One important conclusion coming from the presented lessons learned is the need of documenting decisions made about the design of geo-visualizations, which was proposed by Sheppard (2005). This also agrees with the approach of conceptual model presented by Wilkens (2005). This conceptual model summarizes most of the issues considered by other authors and underlines the way how the design of geo-visualizations may be approached. If we assume that designing geo-visualizations is case specific, then it gives a good idea how to design geo-visualizations. Geo-visualizations should not only be considered as representing geodata in understandable way, but also should be seen as a process that is needed to make it useful. This dual approach of a geo-visualization is already mentioned in the previous subchapter (2.1).

However, having in mind the presented best practices and lessons learned, it become more clear which topics should be addressed during the design processes of 3D geo-visualizations in participatory spatial planning.

Designing 3D geo-visualizations should start with defining its function and the main purpose of use. These two points should be related to the planning phases as well as the participation levels (introduced in subchapter 2.2). This information can be used for further exploration of geo-visualizations characteristics and requirements. Considerations related to the geodata fusion rise following questions: how many layers of information will be provided within 3D geo-visualizations, are some information of greater importance than other, and should be some additional information (besides spatial information) provided within geo-visualizations. Next group of topics is linked to the requirements of interactivity of 3D geo-visualizations. In particular, the important aspects of interaction include: simulation, queries, feedback, selection and manipulation. The next group of topics consist of immersion considerations: how immersive a 3D geo-visualization should be. Immersion is also related to the kind of manipulation: how similar to the real movements it is; and information intensity; how detailed and how realistic should geo-visualizations be. Level of detail is related to the number and the type of elements that are shown, level or realism more to the precision with which the real world is presented. Another topic is related to the media by which geo-visualizations will be delivered to the users, and according to that what kind of support should be provided to users; using mediators, a geo-visualization viewer or autonomous agents. Using a 3D geo-visualization viewer includes such issues as orientation tools and viewpoints direction e.g. should the focus of potential user be directed by means of particularly defined points of views.

2.4. Expert study

In this subchapter an expert study is presented (interviews with professionals). This part is corresponding with the theoretical framework presented in the previous subchapters (2.1, 2.2 and 2.3). Interviews were performed in order to address the main topics that resulted from the presented lessons learned and best practices, define context of use and find out what are the expectations on how a 3D geo-visualization should be designed for the participatory purposes within the Polish spatial planning system.

2.4.1. Interviews set-up

Respondents who took part in the interviews are planners and architects who do have experience in spatial planning management. They are employees of the official governmental units, research institute and university. In total six people were interviewed. During the interviews the set of eight questions (few consists of sub-questions) was followed (Figure 7). Questions were prepared in response to the geo-visualization topics proposed in the paragraph number 2.3.3.

1. **Do you think that geo-visualizations should be used for the Polish spatial planning for participatory purposes?**
2. **What kind of function geo-visualizations should have? Which level of participation geo-visualizations should support? What kind of interaction functionalities are required: queries, simulation, feedback, selection, manipulation?**
3. **For which planning level/ what scale of problems geo-visualizations should be used?**
4. **On which phase of planning process a geo-visualization should be presented to the citizens? By use of what kind o media?**
5. **Do you think that using these geo-visualizations for lay people would be easy? Should users be supported in the geo-visualization exploration?**
6. **What kind of information (layers of information) should be included in geo-visualizations?**
7. **Should some additional information be addressed e.g. photos, movies, text files?**
8. **How detailed and realistic geo-visualizations should be?**

Figure 7. Set of questions prepared for interviews.

Questions had an open character, without fixed possible answers, what gave the possibility of exploring other subjects, which occurred spontaneously during meetings. The interviews were recorded during the meetings using laptop, microphone and Audacity software (free, open source software for recording sounds).

Additionally to give the examples of 3D geo-visualizations which are considered within this research, demos were shown to the interviewed people (example of Biebrza done with TerraExplorer, Texel with CortonaViewer and VRML, Meerstad with Virtual Landscape and a Google Earth application - Figure 8).

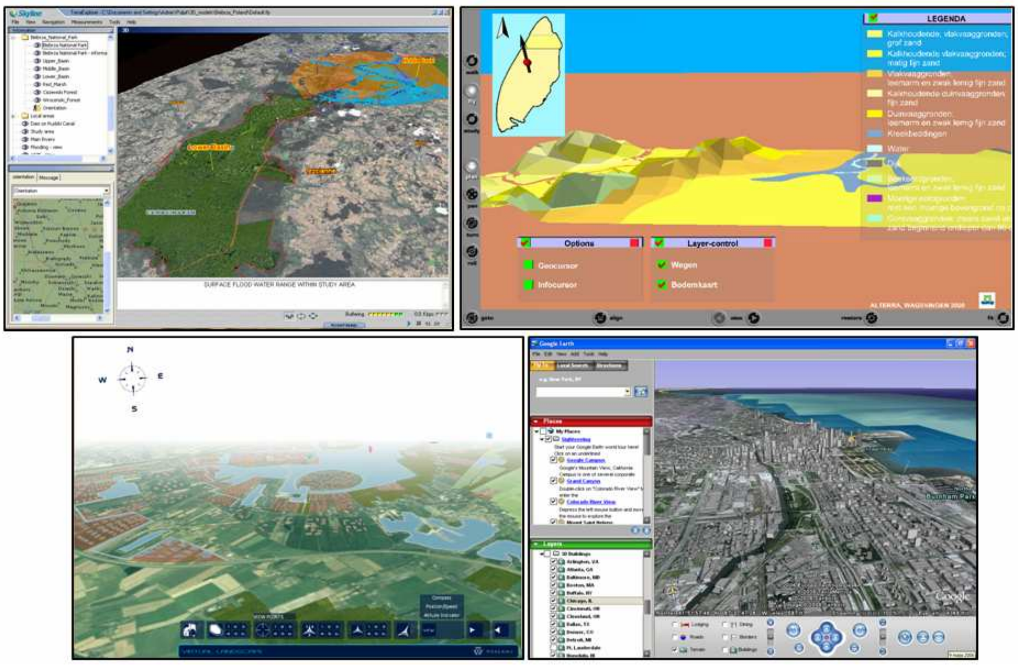

Figure 8. Geo-visualizations used for interviews.

2.4.2. Interviews' responses

Interviews were conducted with the professionals in spatial planning, and as a result qualitative data was obtained. The interviews were recorded and latter on written down in the form of a table (Appendix 2). In total six people were interviewed, but only 5 interviews were recorded.

During interviews following questions were asked:

1. *Do you think that geo-visualizations should be used for Polish spatial planning for participatory purposes?*

All of the respondents agreed that a geo-visualization should be used in the spatial planning process in order to support and enhance public participation.

2. *What kind of function geo-visualizations should have? Which level of participation geo-visualizations should support? What kind of interaction functionalities are required: queries, simulation, feedback, selection, manipulation?*

Respondents mentioned mainly the informing function of geo-visualizations in order to make people understand and aware of the planning initiatives. However, two people addressed the constant consulting possibilities. These answers stayed in line with the legal act, as consultations are one of the ways used to support public participation in the spatial planning procedure practiced in Poland. It was also underlined that a number of functionalities included within geo-visualizations may be extended so these functionalities can support the higher level of public involvement. The possible extra functionalities which were not included in the presented demos consist of additional analysis - economical and environmental, and feedback windows.

3. *For which planning level/ what scale of problems geo-visualizations should be used?*

All of the respondents agreed that this kind of graphical presentation should be used for a smaller scale, local problems e.g. points causing conflicts. However, each level of spatial planning can make use of a geo-visualization for its own purposes.

4. *On which phase of planning process a geo-visualization should be presented to the citizens? By use of what kind o media?*

Presentation of proposal was in the opinion of respondents the planning phase during which a geo-visualization should be presented to the participants. However, three of them saw the possibility of using geo-visualizations for collecting and presenting suggestions, which citizens can make to the planning documents.

Internet was seen as the most convenient way of presenting geo-visualizations to the public. Two people mentioned a debate with the mediator who walk through the 3D geo-visualization, and one person - standing alone computers placed in the public place e.g. municipality office.

5. *Do you think that using these geo-visualizations for lay people would be easy? Should users be supported in the geo-visualization exploration?*

It was underlined in the interviews that it might be difficult to use a geo-visualization by lay people, especially for the older people or those who are not very familiar with using computers and the internet. Three respondents mentioned that people lack good spatial orientation and that presenting data by means of 3D should help people to understand the spatial plans. The 3D geo-visualization for this moment should be kept as simple as possible, not to confuse users, also a short manual or help assistant is essential.

6. *What kind of information (layers of information) should be included in geo-visualizations?*

The content of the 3D geo-visualization should include the specific information as land use. Aerial or satellite images were seen as a useful for orientation within the area by showing the neighbourhood. Two people mentioned including the possibility of comparing future and current state. Only one, the high need of using DEM for geo-visualizations, however all of them seen a big advantage in presenting e.g. buildings by third dimension.

7. *Should some additional information be addressed e.g. photos, movies, text files?*

In general all additional information was seen as precious in order to give a better explanation of the planning initiatives, but what is important according to the respondents, the overload of information should be avoid. Information should be structured in this way, that user can explore and find information that is needed. However, the range of additional information mentioned was very a lot: from a simple photos and text to the environmental and economical impact analysis.

8. *How detailed and realistic geo-visualizations should be?*

The 3D objects should be kept as realistic as possible, but must be in the line with the legal decisions. So, if a detailed design is not included, any unrealistic should be shown as it is difficult to keep people aware that it is only an example how the public space may look. So called intellectual symbols (e.g. lines, dots) should be avoided, instead of this the designer should operate with blocks and shapes.

2.4.3. Conclusions

Responses of interviews confirm that a 3D geo-visualization should be used in participatory spatial planning and it is seen as a useful tool for improving public involvement in the planning process. Geo-visualizations are appropriate mainly for a small scale and local problems and for the presentation phase of the spatial planning process. Internet was seen as the most convenient media for presenting 3D geo-visualizations to the society.

Based on the interviews responses directives can be proposed for constructing a 3D geo-visualization:

- A 3D geo-visualization should be simple. Respondents underlined that using the 3D viewers as showed in the demos, may be far too difficult for people. Furthermore, the overload of the information should be avoided.
- The 3D objects need to be as realistic as possible. So called intellectual symbols (e.g. lines, dots) should be avoided. Instead of these the designer should operate with blocks and shapes, elements that has higher similarity with the real world.
- Aerial or satellite images should be used to give the context to the geo-visualization by showing the neighbourhood.

2.5. Conclusions

In this chapter following issues based on the literature review were addressed: explaining the definition of a geo-visualization, introducing the Polish spatial planning system, describing lessons learned and best practices for geo-visualization design. Afterwards above mentioned issues were confronted with the opinions of experts - planning professionals.

Best practices and lessons learned show the big variety of topics, which seems to be important when designing geo-visualizations. In the next part of this MSc work - the usability evaluation of a 3D geo-visualization - it would be difficult to include all issues related to the geo-visualization design.

One of the topics coming out from the lessons learned and best practices is the spatial orientation. Spatial orientation can be understood as the ability to imagine how an object will appear from different perspectives. A person needs to imagine being in a different location, and make a judgment about the situation and the spatial relations (Contreras, et. al 2001 after Lohman 1979). According to the lessons learned and best practices the support of orientation in geo-visualizations may include: an extra map with location and direction of viewpoints (Appleton 2005), the local names in geo-visualizations (Momot 2003), additional 2D maps or photos with landmarks as part of visualization (Warren-Kretzschmar 2005). However, other functionalities can be proposed as well: using street names, using the reference system, using orientation according to the world directions, or using a compass. However, still it is not known how these functionalities of a geo-visualization improve users' spatial orientation.

In relation to spatial planning the user ability to orientate in geo-visualizations is very interesting as well: if people really understand what is presented in geo-visualizations, is the geo-visualization only an eye-catcher or it has a bigger meaning. We can easily imagine how different reaction a 3D geo-visualization may cause when people who take part in the spatial planning process will understand that this newly proposed highway will run in front of their dwelling. So, does the person know where he is, what is he/she looking at, where is his/her parcel, in which direction is the proposed highway, etc., those are the questions that the person should be able to answer. Furthermore the users' spatial orientation appeared in the interviews' responses as an important consideration of visualizing data by 3D. Hence, in this MSc thesis the usability evaluation of a 3D geo-visualization will be performed in relation to the functionalities supporting spatial orientation.

3. Usability evaluation of geo-visualization

This chapter answer the research question number 2 and 3. Firstly, based on literature retrieval issues related to the usability evaluation are introduced: the usability definition and the existing usability evaluation methods. Secondly the definition and method of usability evaluation of 3D geo-visualization in participatory spatial planning is described.

3.1. Usability evaluation

The main goal of this subchapter is to get a basic insight into the usability issues. Describing all aspects of the usability evaluation would cost place and time, therefore the usability evaluation issues are not described in a big detail. Based on the knowledge gained about the usability evaluation two research question are answered: what are possible methods for evaluating usability according to the literature review and how to define usability evaluation of a geo-visualization for the purpose of this research?

3.1.1. Defining usability

The term of usability is very popular in the industry, production or computer and software design. Usability according to the one of ISO standards (ISO 9241-11) can be defined as “extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (Jokela 2003). In other words, any product that is designed to serve people should be easy to learn and remember, useful, which means it should provide the functions and possibilities that potential users really need and finally be easy and pleasant to use (Preece 1994 after Gould, et al. 1985).

Other terms related to the usability, which should be shortly explained in this place are: usability engineering, user centred approach, usability evaluation, usability evaluation methods, criteria of usability.

Usability engineering is an umbrella term for all aspects related to the user interaction development activities; context of use, users, task analysis and methods for evaluating usability (Bowman 2002). It should be based on the following elements: knowing the potential user beforehand designing and constructing the specific product, iterative design process and evaluation of the product with representative users (Blok 2005). Usability engineering evolves around the user centred approach of designing products (Blok 2005). This approach assumes that the potential user and his/ her expectations and requirements are included in the whole design process, even in the very early stage (Figure 9). It aims at getting users really involved (putting users in the centre of design process) by collecting their remarks and suggestions in order to improve the design of a specific product (Preece 1994).

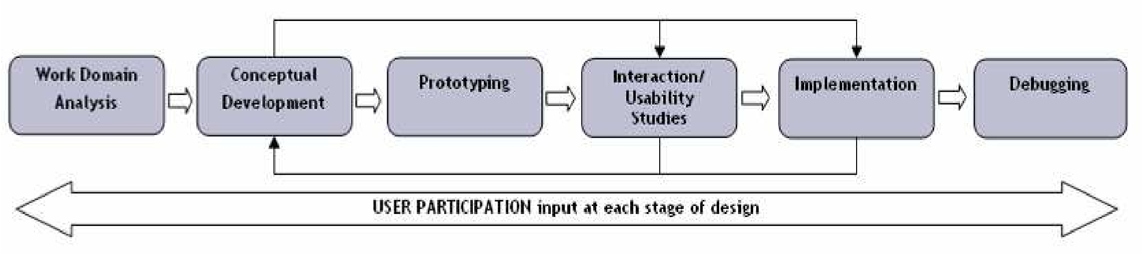

Figure 9. User centred design process (after Robinson 2005).

From the usability definitions presented above three basic criteria for defining usability come out: effectiveness, efficiency and satisfaction. Effectiveness refers to the accuracy and correctness, efficiency to completeness and time requirements with which certain tasks is performed, and resources that are expended according to this. Satisfaction is positive attitude to the certain product and freedom from discomfort (Jokela 2003).

Other sets criteria for defining usability that can be found include:

- learnability, efficiency, memorability, low error rate and satisfaction (Holzinger 2005);
- learnability (time and effort needed to obtain the specified level of use), throughput (speed and error occurrence related to performing certain task), flexibility (extent to which system can adapt to the new task) and attitude (general positive user opinion about product) (Preece 1994);
- learnability, speed and accuracy of user task performance, user error rate, and subjective user satisfaction (Bowman 2002 after Hix, et al. 1993).

3.1.2. Usability evaluation methods

Usability evaluation is the assessment of particular product, system or service conducted for the purpose of determining actual or probable usability (Bowman 2002).

There are many different methods that might be used for the usability evaluation, often described by the different terms. All of these methods originate from the traditional usability evaluation methods. According to Holzinger (2005), who did research about methods for assessing usability of software and user interfaces, existing methods for usability evaluation can be divided into two groups: inspection and test methods (Holzinger 2005).

Usability inspection methods are based on the comparison of an application design with the existing standards and norms that should be included within this process (Holzinger 2005). Usability inspectors might be e.g. usability experts, software developers or specialists with specific knowledge about use context of particular product (Nielsen 1994).

Among this methods we can distinguish (based on Holzinger 2005, Nielsen 1994):

- heuristic evaluation – which include an individual evaluation done by few (3-5) specialists in regard to previously defined usability principles (heuristics) and then the general discussion to define usability problems and issues,
- cognitive walkthrough – is a task-oriented method, in which specialists follow the user possible behaviour in order to evaluate system functionalities,
- action analysis method – focus on actions that the potential user need to take in order to perform the task, it is more precise than the cognitive walkthrough method, as it also include time measurements,
- guideline review – during which the characteristics of the product/ application are checked for the conformance with a complete list of the usability guidelines,
- pluralistic walkthrough – is a method, which includes different participants: representative users, product developers and professionals,
- consistency inspection – aims at comparing product with the whole group of products,
- standards inspection – is done by confronting a specific system with the opinion of inspector who has the expertise in this class of products.

Usability test/ testing methods give as a result information how people use a particular application and what kind of problems they face. Methods in this group consist of:

- thinking aloud – involves users that during using particular system are asked to give all comments and opinions loudly in order to define how the potential users would like to use system and which elements cause misunderstandings and problems,
- field observation – is related to the observation of person who is using specific application in the situation for which this application is designed, this observation should be undisturbed by observer presence,

- questionnaires – consists of the set of questions delivered to the users in order to collect a subjective opinion and satisfaction level determination about application and its elements.

In general, when comparing both groups of methods, inspection methods are seen as not able to address as wide range of evaluation issues, problems and objectives as usability testing methods (Nielsen 1994). The available literature shows that current inspection methods do not generally facilitate the generation of recommendations for change as compared to the usability testing. Inspection methods unlike testing methods may not provide data that are possible to quantify. Inspection data are regarded as an opinion data, when data coming out from usability testing as a fact data. Another remark is that the inspection methods are not appropriate for using in the early stage of the product design and for assessing the overall usability; these do not provide the effective evaluation. However, the required amount of human factors involvement is much smaller for conducting inspection methods (Nielsen 1994).

More details about the particular method from both groups of methods (based on Holzinger 2005 and Axup 2002) are enclosed in the Appendix 3. The characteristics used for this comparison consist of: required time, required evaluators, needed users, required equipment, required expertise, advantages and disadvantages.

3.1.3. Conclusions

In this MSc thesis for evaluating a 3D geo-visualization in participatory spatial planning the definition of usability proposed by the ISO standard is used. The usability of 3D geo-visualization is seen as an extent to which a 3D geo-visualization can be used by actors in spatial planning process to achieve specified goals with effectiveness, efficiency and satisfaction.

In this subchapter many different methods for assessing usability were presented. Two main groups can be distinguished; usability inspection and usability testing methods. The main difference between these two groups lay in the level of the expertise of people, who evaluate the usability. In the usability inspection method evaluation is done by the usability or product experts, when in the usability testing methods by the end users of a designed product or system. This is the reason why the usability testing methods are considered in this MSc thesis. These methods can be used to evaluate 3D geo-visualizations in participatory spatial planning, where a geo-visualization is used in order to improve the understanding of the spatial planning proposals by non-professional users (as it was mentioned in subchapter 1.2). Furthermore, the usability testing methods are more in line with the user centred approach of design introduced in the subchapter 3.1.1, which underlines the need of getting users involved in the design process.

Based on the comparison of the usability testing methods (see Appendix 3) a questionnaire will be used to evaluate the usability of a 3D geo-visualization. This method is thought to require low time, equipment and expertise (Holzinger 2005), which makes it very applicable for this thesis work. It gives the possibility of getting quantifiable results, but needs to be delivered to a lot of people (at least 30 for one usability test), which improves the reliability of results. Two other methods: field observation and thinking aloud methods require more time, equipment and expertise. Beside this reasons, in a field observation method specific situation for which the product is designed needs to be assured. In this thesis this specific situation would be the spatial planning process, hence this method might be difficult to perform.

In this context, the next chapter describes a questionnaire that was developed in order to evaluate the usability evaluation method of a 3D geo-visualization in participatory spatial planning in relation to the users' spatial orientation.

3.2. Questionnaire

The usability evaluation of a 3D geo-visualization for participatory spatial planning in this thesis work is based on a questionnaire, which concentrates on the spatial orientation. This usability evaluation method was chosen to evaluate a 3D geo-visualization with the society; no selection of respondents was made in advance. In a questionnaire three criteria were used to evaluate usability: effectiveness (number of correct answers), efficiency (time spent to accomplish task) and satisfaction (opinions of respondents).

The questionnaire consists of four assignments that need to be solved by the respondents, for each assignment the time spent on solving it was counted for. Each assignment has only one correct solution.

3.2.1. Questionnaire construction

Questionnaire developed for this research is a web-based application, available on a PC. The big advantage of using computer based questionnaire was the fact that it was possible to link the web pages (*.asp) with the database (*.mdb), so responses were automatically written down. For building this application Microsoft FrontPage, Microsoft Access and Windows component: Internet Information Systems (IIS) were used.

In the questionnaire for the usability evaluation, only one of the topics coming from lessons learned and best practices was chosen. The questionnaire tests the users' spatial orientation related to a 3D geo-visualization. Spatial orientation, as it was mentioned in subchapter 2.5, is ability to imagine how an object will appear from different perspectives (Contreras, et. al 2001 after Lohman 1979).

In order to define the spatial orientation assignments the comparison of 2D maps with stills of a 3D geo-visualization of the same area was used (all assignments can be seen in Appendix 4). In total respondents had to solve four assignments, in which they were asked to:

1. Indicate which part of the map was presented by the still - respondent has to relate the 2D map with its 3D representation and imagine from which place on the map, she /he can see the objects presented in the still.
2. Orientate the still on the map and indicate on the still direction, in which letters were (letters were on the map) - respondent has to find on the map place, which is presented by 3D in the still, and then find the directions of the letters.
3. After seeing a short animation of the 3D geo-visualization, they have to select the navigation path of the animation on the map - respondent has to relate the animation of 3D scene to the map, and indicate the path, which was followed by the camera in the animation.
4. To answer free short question about the elements that were showed in the animation (types of street lights, street names, and how many times path of animation turn left or right) - respondents has to recall elements that was presented in the animation and answer three questions.

On the last page of the questionnaire, remarks could be written down (remarks about maps and stills, assignments and other remarks).

3.2.2. Geo-visualizations construction

For questionnaire two types of geo-visualizations were used: 3D geo-visualization without street names (3DNN) and a 3D geo-visualization with street names (3DSN) (Figure 10). Finally there where two questionnaires: one dedicated to the 3DNN and one to 3DSN. These two types of orientation possibilities where chosen according to the lessons learned and best practices. Although more possibilities were identified for supporting orientation in a geo-visualization, having in mind the time available only one was chosen.

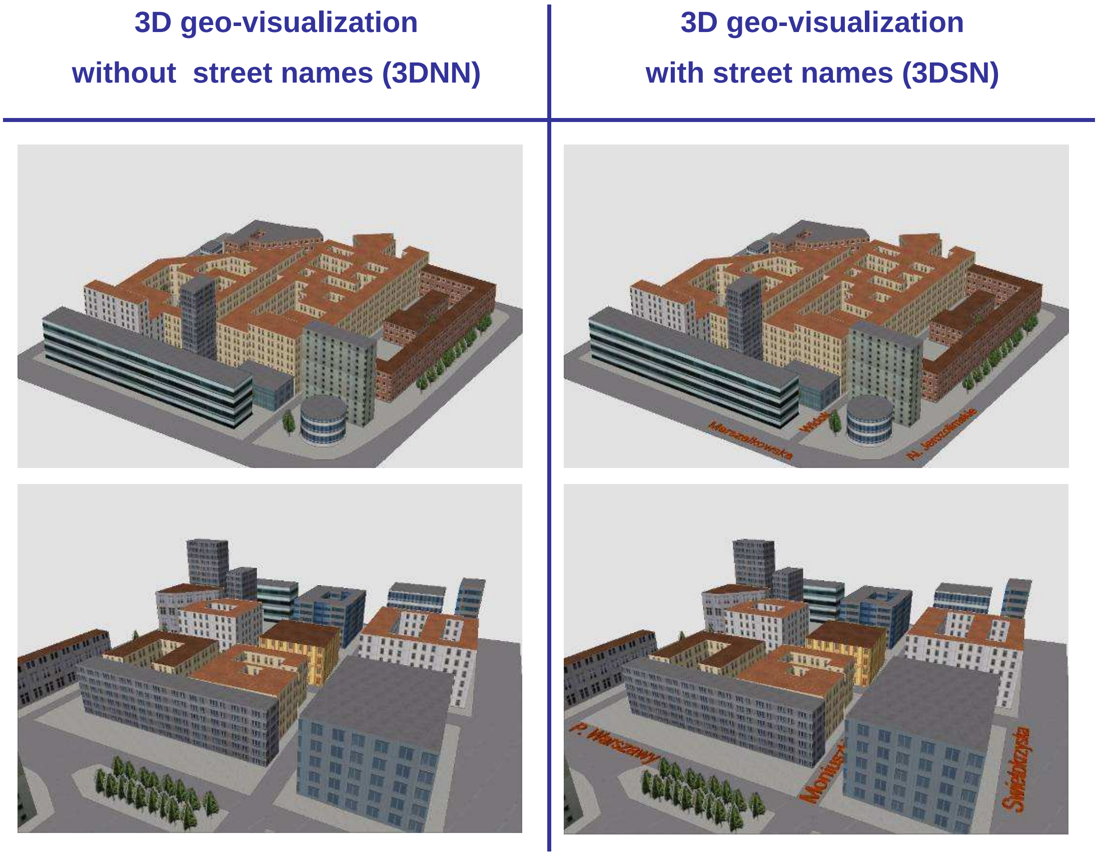

Figure 10. Geo-visualizations used in the questionnaire (3DNN and 3DSN).

According to the interviews' responses (subchapter 2.4) the constructed geo-visualization consisted of considerably low amount of information. Only following layers of information were included: buildings, roads, pavements, loans and trees and for animation street lights and benches were added. In geo-visualizations symbols (blocks and shapes) are used in order to represents the current situation. From 3D symbols: extruded buildings with textures dropped on these were used (unfortunately no information about the buildings heights were available), and simple street symbols: trees, street light and benches (taken from the ArcScene library). Regarding the time available, higher realism and similarity with the study area could not have been assured. During the expert study it appeared that using 3D viewers may be too difficult for people, hence only 2D maps, stills and the animation of 3D geo-visualizations were used.

Data used for geo-visualizations consists of the topographic data (VMapL2-Vector Map Level 2), last update year 2002, which was complemented according to the aerial photo available at the Google Earth. Geo-visualizations were constructed with ArcScene (ArcGIS 9.1), SketchUp 5 and SketchUp 5 ArcGIS Plug-in.

Study area used for the questionnaire was the centre part of Warsaw (Figure 11). At the beginning few options were taken into account, but as some of those were lacking sufficient data, other required more time for data preparation, or did not meet with the approval and willingness for cooperation from the Warsaw authorities, thus finally existing situation (part of Warsaw centre) was the only option to chose.

Using the existing area is still in line with the considered context of use as in spatial planning an existing area is transformed to the new allocation of functions. Hence, when considering 3D geo-visualizations design for spatial planning, first step is check how participants perceive a geo-visualization in general, here based upon current state, which already is known to them.

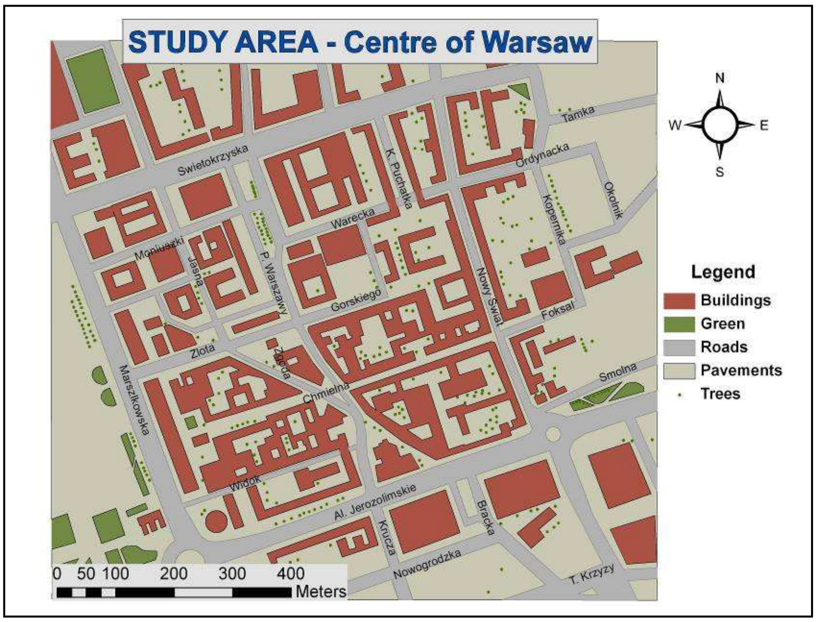

Figure 11. Study area.

3.2.3. Questionnaire testing

Before the public inquiry started questionnaire was tested with the supervisors and a few PhD students (Wageningen University) as well as a group of students in Poland. This test was done to improve the questionnaire design and the way assignments were formulated in order to make these clear and easy to understand. Remarks and suggestions were used for the final improvements.

3.2.4. Questionnaire delivery

To address high number of people with the questionnaire, the Palace of Culture and Science in Warsaw was chosen. Main reasons to select this place were: localization in the centre of the city, accessibility for people (citizens as well tourists) localization of the planning offices, the public presentation of study on pre-conditions and directions of spatial development for Warsaw (which took place March - April 2006) and the willingness of the Board to cooperate.

Questionnaire was available to people during five days (April 4th - April 8th) for eight hours per day. The small stand (Figure 12) was organized in the hall near the main entrance to the building. To attract people two large aerial images were used (each 3x3 meters; one showing the Old Town, second the Palace of Culture and Science). These were covering the floor, where the stand was localized.
The stand consisted of a table, chairs, one laptop and the poster explaining the initiative (Appendix 5).

Figure 12. Questionnaire set-up.

The questionnaire organised in the Palace of Culture and Science brought attention of media. A short news item was broadcasted in the edition of regional news, there was article in the local newspaper, a note in the internet - Polish geo-portal and afterwards a short note was published in the geo-information magazine (Appendix 6).

After the questionnaire was available in the Palace of Culture and Science, it was put on the website of the Palace, as well as on the Polish geo-portal, that still people might fill this in.

4. Results of questionnaire

In this chapter the results of the performed usability evaluation of geo-visualizations are presented in order to answer the fourth research question: what is the usability of 3D geo-visualizations created according to the best practices and lessons learned?

The questionnaires were available in the Place of Culture and Science in Warsaw, and were filled in by 146 people. During the time the questionnaires were available via the internet, 72 people took part (during period from 20th of April to 22nd of May). So, in total 218 people took part in this part of the evaluation.

For results analysis 140 responses were taken to assure an equal number for each questionnaire: one including 3DNN and 3DSN.

The analyses of quantitative results (related to the effectiveness and efficiency) were done in Microsoft Excel and are presented by using the percentage of responses as a measurement of effectiveness and seconds as a measurement of efficiency.

For the result description, questionnaire 1 is used for the questionnaire that included the geo-visualization without street names (3DNN), questionnaire 2 for the questionnaire that included the second type of geo-visualization – with the street names (3DSN).

4.1. Users characteristics

The first part of the questionnaire included questions about personal details of respondents (in the appendix 7 graphs illustrating this part of analysis are enclosed). Respondents were described with following characteristics:

1. ***Gender***

   In general more men (83 people – 59 %) than women (57 – 41 %) took part in the research. For the questionnaire 1 (these include the geo-visualization without street names – 3DNN) it was 43 (61 %) men and 27 (39 %) women, for the questionnaire 2 (the geo-visualization with street names – 3DSN) respectively 30 (43 %) and 40 (57 %).

2. ***Age***

   The largest age group that took part in the research consist of people 19-24 years old (72 people – 51 %). Then group of 25 – 34 years old people (30 – 21 %), group 35 – 44 and 45 -54 years equally (12 – 9 %), 16 – 18 (6 - 4 %), and 55 – 64 as well as 65 and older than 65 equally (4 - 3 %).

3. Education level

Most of the people who fill in the questionnaires have a secondary education (69 – 49 %), then higher (61 – 44 %) and the least primary (10 – 7%). This relation is similar as well for the questionnaire 1 as for the questionnaire 2.

4. Internet

Internet is used by the majority of people (130 – 93 %). For the questionnaire 1 this number was a bit smaller (62 – 89 %) than for the questionnaire 2 (68 – 97 %).

Among those respondents who use the internet most of them use it every day (100 people – 77 %). In questionnaire 2 more people (12 – 18 %) than in questionnaire 1 (6 – 10 %) use the internet few times a week.

5. Computer games

Playing computer games is not very common among people who took part in questionnaires. It is popular for 51 respondents (36 %). This number is a bit higher for the questionnaire 1 (30 – 43 %) than for the questionnaire 2 (21 – 30 %).

6. GIS and CAD software

Most of respondent neither use GIS or CAD software (106 people – 76 %). This proportion is similar for both of questionnaires (questionnaire 1: 52 - 74% and questionnaire 2: 54 – 77 %).

7. Visiting centre of Warsaw

90 % of respondents (121) replayed that they visit often the centre of Warsaw; for the questionnaire 1 (63 – 90 %) more than for the questionnaire 2 (58 – 83 %).

Among those who often visit the centre of Warsaw, most of the respondents selected that they visit Warsaw every day (75 - 62 %). In questionnaire 1 (45 - 71 %) more people admitted visiting the centre of Warsaw daily than in questionnaire 2 (30 - 52 %).

8. Willingness for participating is spatial planning

In total most of respondents (82 – 59 %) said that they would like to participate in the spatial planning process related to the construction of the spatial plan for Warsaw Metropolitan Area. More responses of questionnaire 2 (14 – 20 %) were against this idea than of questionnaire 1 (7 – 10 %).

For a number of people it was difficult to decide, in total 37 people (26 %). More for people who filled in the questionnaire 1(22 people).than for questionnaire 2.

4.2. Usability criteria

The main part of questionnaire consists of four assignments (see Appendix 4):

- In the assignment 1 respondents were asked to indicate which part of the 2D map was presented in the still of 3D scene. This assignment consisted of three tasks.
- In the assignment 2 respondents were supposed to locate in the still of 3D geo-visualization letters that were shown on the 2D map. This assignment consisted of 4 tasks.
- In the assignment 3, after seeing the short animation, the path that was presented was supposed to be chosen in the 2D map.
- In the assignment 4 respondents were asked about elements they saw in the animation. This assignment consisted of three tasks.

In total, the respondents were asked to solve 11 tasks. These tasks were used for describing effectiveness and efficiency. The high number of correct answers gives the high effectiveness. Short time spent on the assignment means high efficiency. Satisfaction is based on the opinions collected during the public inquiry; these could be written down by respondents in the last part of the questionnaire. High satisfaction is related to the positive opinions.

The usability of 3D geo-visualizations is based on the comparison of the results of two questionnaire types: one including the 3D geo-visualization without (3DNN) and the second with street names (3DSN).

Effectiveness

When comparing the number of correct responses for particular task: more correct answers were chosen for the questionnaire 2 than for the questionnaire 1 (Figure 13). The biggest differences appeared for the task 1.2, 2.2 and 4.3. These differences may be due to the fact that in the task 1.2 text was more readable than in the tasks 1.1 and 1.3 for the questionnaire 2, in the task 2.2 street names were located near the letter, so it was easier to choose the correct one. In task 4.3 people were asked about the street names. Simply it was easier for respondents of the questionnaire 2 it was easier, as they had street names included in the geo-visualization.

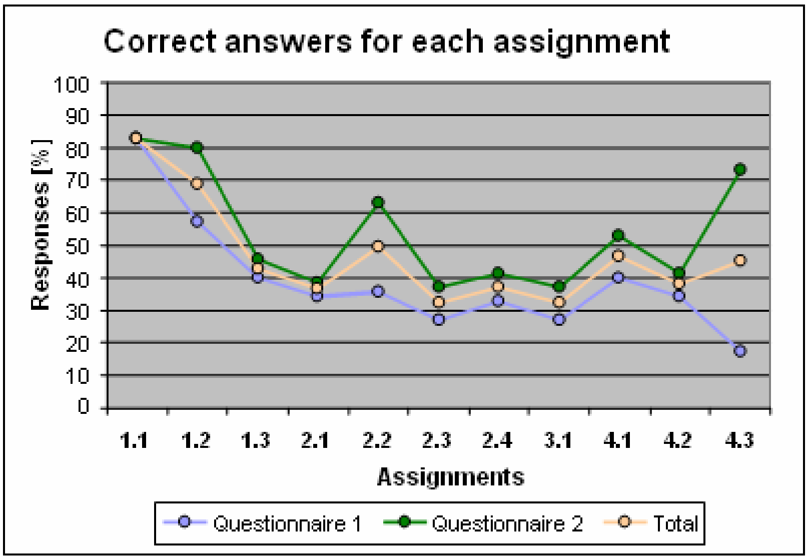

Figure 13. Number of correct answers per assignment [%].

In general there was 46 % of correct responses. Only 6 respondents solved all assignments correctly; for the questionnaire 1 – 1 person and for the questionnaire 2 – 5 people. The minority of people (56 – 40 %) solved more than 5 tasks correctly. The number of people who solved more than 5 tasks correctly was higher for the questionnaire 2 (35 people – 50 %) than for the questionnaire 1 (21 people – 30 %) (Table 1).

Table 1. Number of correct answers and number of respondents.

No. of correct responses	Questionnaire 1		Questionnaire 2		Total	
	No.	[%]	No.	[%]	No.	[%]
1	7	10	0	0	7	5
2	12	17	4	6	16	11
3	13	19	11	16	24	17
4	12	17	10	14	22	16
5	5	7	10	14	15	11
6	5	7	9	13	14	10
7	8	11	8	11	16	11
8	4	6	3	4	7	5
9	2	3	5	7	7	5
10	1	1	5	7	6	4
11	1	1	5	7	6	4
Sum	70	100	70	100	140	100

Efficiency

Analyzing the time spent by respondents to solve a particular assignment in the questionnaire 1 and in the questionnaire 2, it appeared that the assignments of questionnaire 1 took more time than in the questionnaire 2. There was one exception, which is assignment 1 (Figure 14), because in this case questionnaire 1 required less time. In this assignment respondents were asked to indicate which part of the map was presented in the picture of 3D geo-visualization. For respondents of the questionnaire 2 it might have taken more time, as they needed to consider the additional textual information. In addition in the case of task 1.1 and 1.3 text might be not so readable.

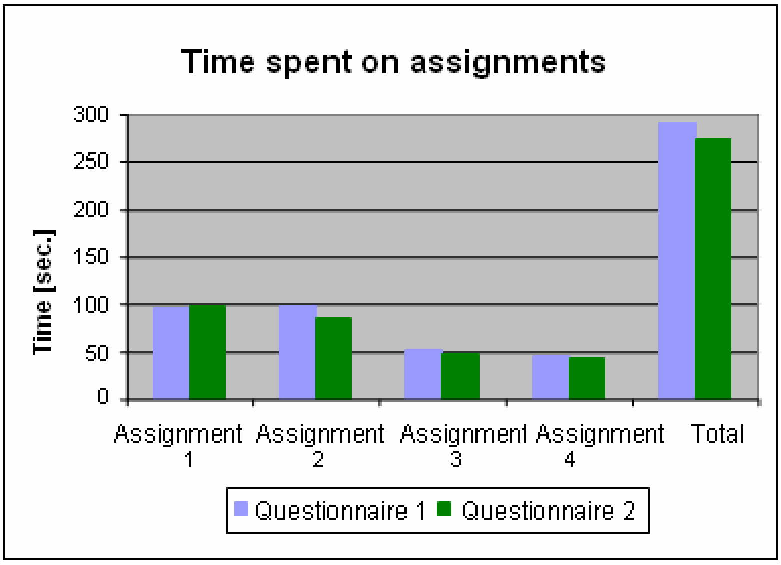

Figure 14. Time spent on assignments.

Satisfaction

26 people filled in the last part of the questionnaire, where remarks could have been written down. These comments were related mainly to:

- the maps and pictures used in the questionnaires; respondents expressed a positive attitude towards maps and pictures describing these as “superb”, “legible”, “done correctly”, “nice”, “very good”, “readable and precise”. However, there were also few comments related to the realism of geo-visualizations: “in the reality buildings in the area are different, not so modern”, “the ‘Warsaw’ hotel is missing in the pictures”, “it was difficult for me to recognize the buildings”, and “the shape of trees is odd”.
- the assignments; assignments were seen as *“complicated”* and *“difficult”*, but *“interesting”* and *“explained clearly”*.

People could give their opinions about the public inquiry in general via the item ‘others’. These opinions show that the assignments were seen as *“excellent idea”* and *“good fun”*.

4.3. Additional results

Regarding the two groups of results these groups are not equal in the sense of personal details of respondents e.g. more men than women took part in the questionnaire, more young people. Hence, more in depth result analysis were done in order to check the relation between the users' characteristics and two usability criteria.

Effectiveness

During result analysis the relations were found between the personal details of respondents and the correctness of responses (graphical illustration of these relations can be seen in the appendix 8). Task were solved more correctly by people who:

- are familiar with GIS and CAD software,
- play computer games,
- use internet,
- are male,
- have higher education than those, who have primary or secondary,
- visit often the centre of Warsaw than those who do not ,
- who are willing to participate in the spatial planning processes than those who do not.

Efficiency

Also relations between the time and the personal details could be seen from the result analysis. The time of solving assignments is growing with the age of respondents, older the person was the more time to solve assignments was needed (Figure 15).

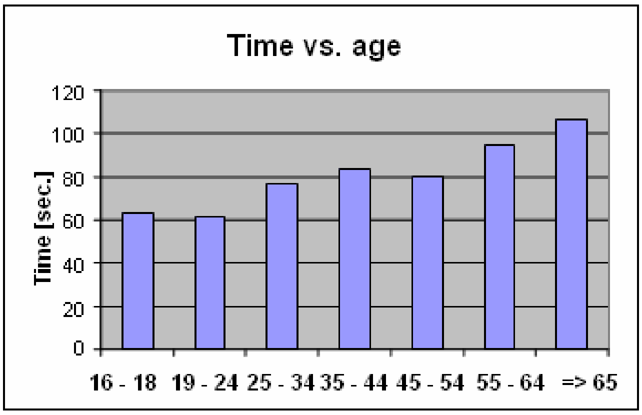

Figure 15. Time vs. age of respondents.

Additionally, more time for solving questionnaire required:

- women (294 seconds) than men (275 seconds);
- people with higher education (310 seconds) than secondary (264 seconds) and primary (231 seconds);
- people using internet (304 seconds) than not using internet (281 seconds);
- people not playing computer games (297 seconds) than those who plays (260 seconds);
- people using GIS and CAD software (289 seconds), than those not using (280 seconds);
- people who visit the centre of Warsaw often (284 seconds) than those who do not (272 seconds);
- people willing participate in the spatial planning process (291 seconds) than those not willing (281 seconds) as well as those who do not know (270 seconds).

Elements of geo-visualizations

In general respondents paid mostly the attention to the street network the most (53 % of responses), then to the street names (28 %) and at least to the 3D elements (20%) (Figure 16). The main difference between two questionnaires is regarding the street names; in the questionnaire 1 none paid attention to this element.

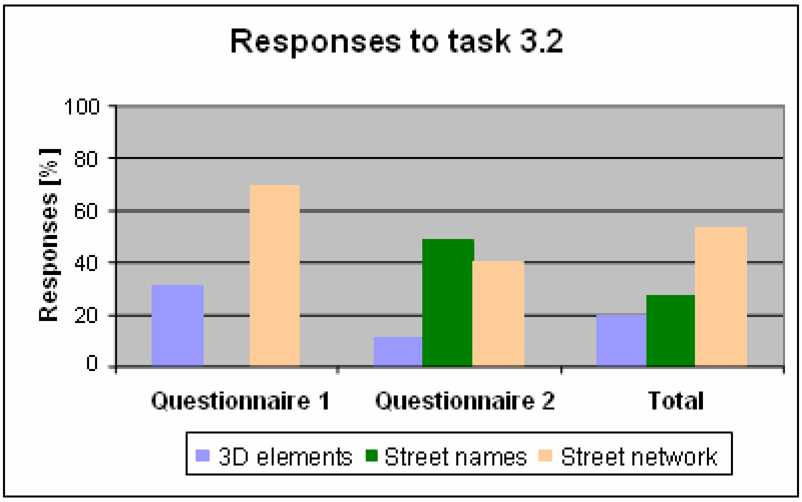

Figure 16. Responses to task 3.2 [%].

In the assignment 3, there was one additional question in which respondents were asked to indicate to which elements (3D elements, street names, and street network) they paid the attention when they were seeing animation of the 3D geo-visualization. In assignment 4, they were asked to choose the correct element from above mentioned elements that were shown in the animation.

In general respondents who looked at the 3D elements, solved smaller number of tasks in the assignment 4 correctly (Table 2).

Table 2. Geo-visualizations elements (assignment 3) vs. number of correct responses (assignment 4).

	3d elements			
	Yes		No	
	No.	[%]	No.	[%]
Questionnaire 1	10	43	18	38
Questionnaire 2	4	36	33	56
Total	14	40	51	47
	Street names			
	Yes		No	
	No.	[%]	No.	[%]
Questionnaire 1	0	0	12	17
Questionnaire 2	39	81	12	55
Total	39	41	24	36
	Street network			
	Yes		No	
	No.	[%]	No.	[%]
Questionnaire 1	21	40	3	17
Questionnaire 2	21	53	8	27
Total	42	46	11	22

However in the questionnaire 1, there were more correct responses for people, who paid attention to the 3D elements than for those who did not. Probably as they were not considering more elements as respondents of the questionnaire 2 did, who had the additional text presenting the street names.

People, who paid attention to the street names, got more correct responses in the assignment 4, where they were asked to choose which streets were shown in the animation.

Also respondents who choose the street network got more correct answers than those who did not.

5. Conclusions, discussion and recommendation

In this chapter the following issues are addresses: conclusions about the research, discussion of the evaluation method and the results, and finally the recommendations about 3D geo-visualizations and usability evaluation.

5.1. Conclusions

The objective of this MSc thesis is to evaluate the usability of 3D geo-visualizations in participatory spatial planning. This objective was achieved by developing of the web-based questionnaire, which was delivered to the wide audience during the public inquiry. In the questionnaire the usability of two 3D geo-visualizations - one without (3DNN) and one with street names (3DSN) - was evaluated in relation to the users' spatial orientation.

The analysis of the results brings to the light difficulties people may have with understanding and interpreting 3D geo-visualizations. The geo-visualization which includes the street names (3DSN) was easier in the sense of spatial orientation to the users than the one that does not include the street names (3DNN). Nevertheless as the differences in the responses were not very high, spatial orientation in geo-visualizations still brings a serious problems to the users. It was found that orientating in 3D geo-visualization is related to similarity, with which the area is presented, how well it serve people's imagination.

It addition it appeared that the better understanding of a 3D geo-visualization is characteristic for people who have higher information literacy (use of the internet, computer games, GIS ad CAD software). Hence, the results of this thesis show the importance of promoting new technologies. Then, such tool as geo-visualizations can increase its potential in participatory spatial planning.

5.2. Discussion

In this subchapter, firstly the method used to evaluate 3D geo-visualization in participatory spatial planning is discussed. After that the results of the questionnaire which are linked to the existing knowledge about 3D geo-visualization design and the spatial orientation are described.

5.2.1. Discussion of evaluation method

In this MSC thesis the usability evaluation is defined according to the *ISO 9241-11 standard* as an extent to which geo-visualizations can be used by the actors in the spatial planning process to achieve specified goals with effectiveness, efficiency and satisfaction. Many different methods for evaluating usability can be found in the literature (see subchapter 3.1. For usability evaluation of 3D geo-visualization in participatory spatial planning the *usability testing methods* were considered, which seems to be more applicable as these methods support the user oriented design.

To evaluate the usability of 3D geovisualization a *questionnaire* was used. Designing the questionnaire brought many problems, which were mainly related to defining spatial orientation assignments, preparing questions and formulating tasks. Many people addressed that the assignments included in the questionnaire were difficult and required a lot of attention. It is hard to judge if the level of difficulty was too high or too low. However, the difficulty of the assignments differs, from the easy one to the more complex, and still the trend of effectiveness for both questionnaires is comparable.

The questionnaire was delivered to the society in the public place. Including potential users in an evaluation is seen as one of the conditions for fulfilling the *validation* requirements (Ahonen-Rainio 2003). Also the number of respondents (70 per each questionnaire) who took part in the research agrees with the numbers proposed in the literature for the usability evaluation (Holzinger 2005).

The questionnaire evaluates the usability of 3D geo-visualizations in relation to the spatial orientation. For these purpose two 3D geo-visualizations were constructed: one without (3DNN) and one with street names (3DSN). Orientation resulted as one of the topics related to the *lessons learned and best practices* presented (see subchapter 2.5). In this research best practices are focused on the design of a geo-visualization, so elements that a geo-visualization should include in order to make geo-visualizations useful in participatory spatial planning. No criteria were chosen in order to support this selection of the lessons learned and best practices. This selection was done mainly due to the subjective opinion of author.

For evaluating the usability of 3D geo-visualizations *three usability criteria* were used; efficiency (time spent on assignments), effectiveness (number of correct answers) and satisfaction (opinions of respondents). It appeared that the time is not only the measurement of efficiency, it also showed the interest of people. For instance people familiar with GIS was wondering how the geo-visualization was made. Another interesting aspect is that people living in Warsaw were looking for similarities with the area they know.

The opinions of respondents were used as a qualitative data for describing satisfaction. However, on the basis of those results it was difficult to compare satisfaction related to the 3D geo-visualization without (3DNN) and with street names (3DSN). Giving opinions was a free choice of respondents. The structure of the form gave the possibility of writing down the very general comments, which afterwards were difficult to analyze.

Besides filling in the questionnaire people showed a great *interest* in the initiative organised in the Palace of Culture and Science. Their questions and remarks were another valuable source of information for this thesis work. However, these results were not documented in any way as it occurred unexpectedly and very enthusiastically.

5.2.2. Discussion of results

Results of the questionnaire give the impression about the usability of created 3D geo-visualizations in relation to the users' spatial orientation. Questionnaire was based on the three criteria: effectiveness, efficiency and satisfaction.

At the beginning of this thesis report it was underlined that the ability of non-professionals to read and understand a 2D geo-visualization is rather limited (Hoogerwerf 2005 after Orland 1994, Verbree, et al. 1999; Yun, et al. 2004). Furthermore, it was mentioned that visualizing geodata by means of 3D, as it is giving greater similarity with the real world, is easier to recognize and understand for non-professional users (Hoogerwerf 2005 after DiBiase 1990; Geertman 2002).

The results do not prove that it is easier to understand and recognise 3D geo-visualizations in comparison with 2D, but underline that people may have a serious difficulties also with understanding 3D geo-visualizations. The result analysis showed that only the minority of people can easily orientate in 3D geo-visualizations. As mentioned previously, few authors underlined the need of including extra elements in order to support the users' spatial orientation (Appleton 2005, Momot 2003 and Warren-Kretzschmar 2005). Having in mind two criteria: effectiveness and efficiency it came out that for respondents who had the questionnaire where the 3DSN geo-visualization was included, it was easier to solve assignments about the spatial orientation (this questionnaire brought more correct responses and required less time). However, the differences in the number of correct responses and time were not so significant between two 3D geo-visualizations. This small disparity matches up with the results of interviews, which underlined the problems that people may have when using 3D geo-visualizations. Although including street names in the geo-visualization makes it easier for people to orientate, this was still difficult for respondents. This underlines the need of participants' training and experience, when analysing users' capabilities to understand visual representation of the landscape (Lewis, et al. 2005). Better understanding of 3D geo-visualizations requires more time to make it popular and widely used. More pilot projects should be organised in order to train people how to relate geo-visualizations to their mental imaginations and expectations. Consequently, 3D geo-visualizations must be used more often, not only in the theory, but also in practice. Here it can be brought up the critics about one of the ongoing spatial planning processes in Warsaw. It was mentioned that the 'virtual projects' get a lot of attention, but when it comes to the reality, people (stakeholders of the spatial planning process) have to deal with the piles of maps and not understandable information. The core synthesis of the spatial planning problems by means of a geo-visualization is missing (url_6).

By the questionnaire also elements of 3D geo-visualizations that might be helpful in orientating were evaluated. These elements included 3D elements, street names and street network. It appeared that people use more 2D elements to orientate themselves in the area than 3D elements. Reponses of people, who chose street names and street network, were more correct. It shows that people do not pay big attention to 3D elements as long as they are forced to do so, in this case by excluding street names. The spatial orientation is based upon looking for similarity of the street names, then to the street network, and finally to the 3D elements. The fact that 3D elements are seen as less helpful in orientating in the 3D geo-visualization may be related to the level of realism that was used in geo-visualizations, especially textures. From the satisfaction of users related to the geo-visualizations it occurred that respondents were expecting to see the geo-visualization that resembles area very precisely and gives a very realistic impression (this comes to e.g. An 2005, Appleton 2003, Appleton 2005). For instance people commented: inaccuracies in the textures, heights of buildings, the lack of some elements recognisable for them, or they expected to see the shop windows or logos of companies. The fact that people paid attention to such details shows the way people orientate themselves and how they build their imagination about the area that is visualised. This can be explained in bigger detail by the Lynch's five elements of city imageability (Al-Kodmany 2001 after Lynch 1960). In the Lynch’s theory imageable city helps people to orientate themselves more easily by constructing visual representations of the area. According to Lynch five elements of imageability consist of paths (e.g. transport channels, street), nodes (junctions, squares, centres of public services), edges (boundaries of districts or of different functions, streets), districts (large section of the city), and landmarks (recognisable psychical elements e.g. high buildings, viewpoints). This theory presents the way people perceive and remember the area. It underlines that in designing geo-visualizations also people mental maps should be included. This has also reflection in the results of this thesis research.

5.3. Recommendations

Spatial orientation in 3D was related in this thesis to the existing knowledge about a geo-visualization. It emerged that the orientation is related not only to the elements of the 3D geo-visualization that support orientation, but also to the people’s individual characteristics and their mental map of the area. Hence, further research should also include cognitive aspects and knowledge from other fields of science e.g. psychology.

In this thesis the lessons learned and best practices for a 3D geo-visualization were presented. These can be used as a starting point for creating a database, which could be updated with a new examples and ideas about geo-visualizations. However, more strict criteria and precise distinction between lessons learned and best practices should be proposed.

More practical approach to the results shows the need of the reformulation of spatial policy in order to support using in the planning procedure new technologies such as geo-visualizations. Changing policy framework, could result in using geo-visualizations in wider extent.

In the thesis the evaluation was done in relation to two geo-visualizations: one with and another without street names. Hence, in the further research more methods of supporting orientation e.g. landmarks, the reference system should be included.

Another recommendation is to evaluate geo-visualizations in the real situation e.g. public debate. As the questionnaire was based on the current situation it might be adapted that it also includes future situation proposed by the planning initiative.

The usability evaluation in this thesis brought to the light that understanding geo-visualization is related to such users characteristic like familiarity with GIS or the internet. The questionnaire was conducted in Poland. Hence the comparison study between different countries may be of a great value for the further research.

A lot of result was obtained from the questionnaire. However, only a simple statistic analysis were performed (univariate). The results should be explored in the details and more correlations should be addressed to improve our knowledge about a 3D geo-visualization.

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url_1 http://www.pspe.net

url_2 http://www.przemet.pl/start/foto/20listopada2b.jpg

url_3 http://www.gmina.swidnica.pl/images/stories/2005_09_07_plan_ zagospodarowania_przestrzennego_II.JPG

url_4 http://www.infoforhealth.org/practices.shtml

url_5 http://www.unesco.org/most/bphome.htm#1

url_6 http://serwisy.gazeta.pl/wyborcza/1,68586,3296154.html#dalej

List of figures

List of tables

Appendixes

Appendix 1. Best practices for geo-visualization design.

Lp.	Source	Research type	Study area	Visualization type			Results - best practices for designing geo-visualizations
				Method	Data	Software	
1.	An 2005	Research on usage of real- time visualization in planning	Windlestone	3D models, 2D photographic images	DTM, high resolution aerial photography, land cover data	Shockwave, Lingo language, CAD software, Director,	1. Realism is not a critical issue, as far as geometrical correctness is assured
							2. Realism does not play a big role to users who already know the area
2.	Appleton 2005	Research on aspects of computer visualization which may have a significant effect on the viewer	Norwich	3D models, 2D photographic images	LandLine and Profile data, Cities Revealed georeferenced aerial imagery	Visual Nature Studio (3DNature), ArcView, 3D CAD	1. Realism needs to be high to make images clear and avoid confusing or misleading the audience
							1.1. Foreground areas need to be as detailed as possible for the identity of the various elements to be clear
							2. Existing elements must be shown correctly if (local) viewers are to trust the images
							3. There is a definite need for a map of the location and direction of viewpoints
							4. Visualizations cannot and should not stand alone-extra information is always needed
							5. Choice of viewpoints, and the use of techniques to direct attention are two areas of potential misuse due to their ability to hide undesirable aspects of a particular development
							6. Increases in detail should be tied to real-world data and used only to meet a specific need

Lp.	Source	Research type	Study area	Visualization type			Results - best practices for designing geo-visualizations
				Method	Data	Software	
3.	Appleton, Lovett 2003	Research conducted in order to answer question: to what extent do user feel that the style and content of image allow imagination of the future landscape that is being considered?”	Coleshill	3D models, 2D photographic images	LandLine data for rural areas (1:2500), Landform Profile digital elevation (resolution: 10 m), Cities Revealed georeferenced aerial imagery (res.: 25 m)	VRML, ArcInfo, ArcView, Visual Nature Studio (3DNature),	1. Higher levels of detail help people to relate to a visualization and imagine for themselves the landscape that is being presented 2. Not all elements of a scene are of equal importance in helping viewers to imagine the landscape being portrayed, and that effort may be best directed towards improving the realism of the ground, including vegetation, and especially in the foreground
4.	Hoogerwerf 2003	Research on realism requirements for particular level of participation and planning phase	Meerstad	3D models	Topographic data (1: 10 000), land use plan, photographs	ArcView, 3D StudioMax, Photoshop, Adobe, PixMaker Pro (PixAround), VRML	1. According to planning phases: realistic type of visualization is the most appropriate for inventory and presentation stage; abstract and semi-realistic for analysis and design 2. According to participation levels: realistic visualization is the most suitable for consulting and co-deciding; abstract and semi-realistic for informing, advising and co-producing
5.	Mamot 2003	Research about creating understandable, easy to use and informative presentation of the hydrologic data	Biebrza	3D model	DEM, aerial photo, satellite image, orthophoto, land cover data, topographic map	Terra Explore Pro (Skyline tools), ArcInfo, ArcView	1. Visualization should be realistic 2. Depending on scale of presentation, view of standing position is suggested for bigger scale, for smaller fly over 3. Using local names for better orientation is essential 4. Visualization should be interactive and give possibility of choosing layers, and adding new one

Lp.	Source	Research type	Study area	Visualization type			Results - best practices for designing geo-visualizations
				Method	Data	Software	
6.	Warren-Kretzschmar 2005	Research on role of visualization in communication with citizens/ Visual support for the discussion of planning alternatives	Bornum	Sketches, digital photomontage, 3D renderings with VNS, interactive 3D model with	Artistic sketches, DEM, GIS habitat data, land use map, high resolution aerial photos	Visual Nature Studio (3DNature), Photoshop, LaVisTo,	1. Possibility to view different perspectives of the landscape should be assured
							2. Tools for editing and adding objects and posting massages should be included
							3. Manipulation tools e.g. pan, zoom in/ out are essential
							4. Possibility of changing layers is needed
							5. Comparison of current and future state as well as different scenarios is required
							6. Orientation capabilities, e.g. 2D maps, photos with landmarks need to be part of visualization
							7. Static 3D are more preferable in comparison with VR representations, rapid navigation in 3D is difficult to follow
							8. Level of detail should be used, which show planning initiatives, but also do not cause bias and misunderstanding among participants
							9. Participants shows very diverse expectations that can be met only with combination of visualization methods

Appendix 2. Interviews' responses.

Questions	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
1. Do you think that geo-visualizations should be used for Polish spatial planning for participatory purposes?	For sure.	For sure it's needed.	Yes.	Yes. Each level has it one specification, but may make use of this kind of geo-visualization.	Yes it should be used. Mainly local level was discussed.
2. What kind of function geo-visualizations should have? Which level of participation geo-visualizations should support? What kind of interaction functionalities are required: queries, simulation, feedback, selection, manipulation?	Inform but also consult.	Inform. Analysis e.g. economical influence on the property value. Layers of information should be switch able - possibility of choosing layers.	Inform, and bring awareness of spatial changes. Animation (movie).	Depends on how far we want to involve people. Inform and explain the planning initiatives. This seems to be universal and flexible tool, so might be used n order to get higher public participation.	Inform, in order to make people aware and understand planning problems and construct they ones point of view, make remarks
3. On which phase of planning process a geo-visualization should be presented to the citizens?	When planning intention is started (which is not defined by law).	Presentation of proposals of plans. It would be difficult to include geo-vis on stage when collecting suggestion. Maybe this should be change to show directly interested people their suggestion.	Public presentation of plan, debate, but it may be possible before when collecting suggestions.	On each, but it should be used as illustration to the proposal.	During public presentation or public debate
By use of what kind o media?	Internet. Both media: during public meeting with support of specialists.	Internet.	Internet.	Internet.	Computer presentation/ computers in the municipality office, during public debate with mediator
4. For what scale of problems geo-visualizations should be used?	Not for bigger scale as it will be too abstract. May be, if precise description should be included. More info is available the more efficient geo-vis will be..	Geo-visualization should be design for the each case specifically. It can be used on many scales, but then it requires	More for local scale problems.	Problems of local scale, related to the architectural design of space.	Not for the big areas, the whole land use plan, better more sensible for problematic points

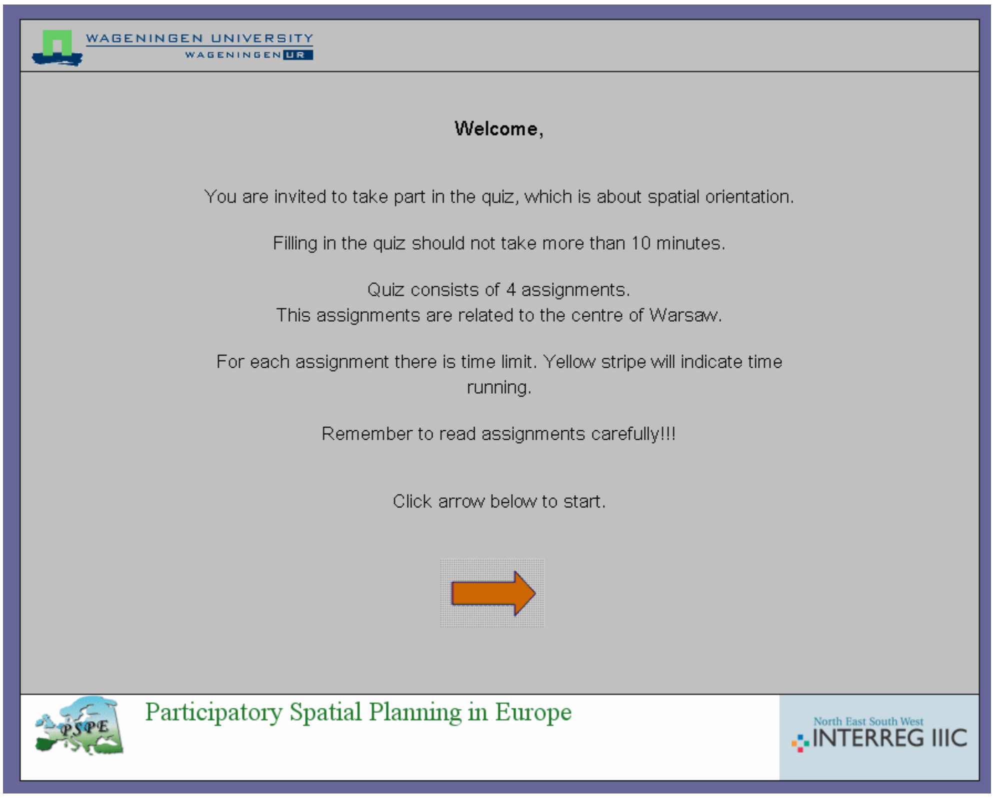
Questions	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
5. Do you think that using these geo-visualizations for lay people would be easy? Should users be supported in the geo-visualization exploration?	It may cause problems. It should be kept the simplest as possible. Guidelines/ manual should be included.		More time is needed that every one can use, that this tool can be used widely. But pilot projects should be included.		It may cause problems, especially in rural communes
6. What kind of information (layers of information) should be included in geo-visualizations?	Photos. Land use functions.	Land use, functions, the relation of old and new space arrangement, DEM	Changes, showing existing and future state.	Photos. Land use functions.	Land use functions, photo for orientation
7. Should some additional information be addressed e.g. photos, movies, text files?	All other information are precious. It's important not to overload with information. Levels of information should be included, as far as it is needed the user will go. Description e.g. environmental impact, cost, transport network.	All other information if available are precious, but also economical and environmental influences (analysis)	All other information if available are precious.	Depends on the function of geo-vis. If constant consultation tool, all extra info should be included e.g. parameters of buildings, abstracts of legal documents.	Link with the municipality website, description of development conditions
8. How detailed and realistic geo-visualizations should be?	Geo-vis should be kept realistic as possible, especially or society, but must be in line with statements from planning documents.	Geo-vis should be kept realistic as possible, but in line with statements from planning documents.	Abstract form are not easy to understand for every one. Geo-vis should be kept realistic as possible, but in line with statements from planning documents.	Symbols should be related to the reality. So called intellectual symbols (e.g. lines, dots) should be avoid. Realism depends on the scale - local land use plan should be kept very simple (demos might be to complex for lay people to understand).	Operating with blocks and shapes, if information available e.g. front elevation of buildings

	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
Comments	It might be more and more popular, if financial and technical condition would be improved. Knows examples from other countries, but not aware of any Polish example.	Geo-visualization should be design for the each case specifically. Geo-vis enhance possibility of creating opinion by bigger imagination Geo-vis should replace the spatial imagination of lay people to enhance communication process. The people are interested about the financial aspects of planning. The economic information should be included.	Most of people lack of spatial orientation, 3D geo-vis should help to understand the planning initiative. Knows examples of presenting plans by internet by only 3D.	Problem of keeping geo-vis actual. If all analysis should be available to the public? What and when planning decision should be shown to the pubic not to cause misunderstanding? Not everyone can read map, this geo-vis can help to see as it has higher similarity with reality. Geo-vis may be use as a language to communicate between the specialists with lay people. Mentions 3D visualization of the city centres of biggest cities in Poland.	Not everyone can read map, this geo-vis can help to see like a mock-up It is a good initiative, interesting presentation of planning initiatives may attract more people to give their own opinion. Knows only 3D visualization from abroad.

Appendix 3. Usability evaluation methods (after Holzinger 2005, Axup 2002).

Method		Required time	Required evaluators	Needed users	Required equipment	Required expertise	Advantages	Disadvantages
Inspection methods	Heuristic evaluation	low	3 +	none	low	medium	The application of recognized and accepted principles; intuitiveness; usability early in the development process; effective identification of major and minor problems. It is easy, fast and considerably cheap.	Separation from end users; inability to identify or allow for unknown users' and unreliable domain-specific problem identification. Does not necessarily evaluate the complete design, since here is no mechanism to ensure the entire design is explored.
	Cognitive walkthrough	medium	3 +	none	low	high	Independence from end users and a fully functioning prototype, helping designers to take on a potential user's perspective, effective identification of problems arising from interaction with the system	Possible the danger of an inherent bias due to improper task selection, emphasis on low-level details, and non-involvement of the end user.
	Action analysis	high	1.2	none	low	high	Precise prediction of how long a task will take, and a deep insight into users' behaviour.	It is very time-consuming and requires high expertise.
Test methods	Thinking aloud	high	1	3+	high	medium	Provides a close approximation to how individuals use the system in practice; provision of a wealth of data, which can be collected from a fairly small number of users; user comments of often contain vivid and explicit quotes; preference and performance information can be collected simultaneously.	Is often perceived as unnatural, distracting, and strenuous by the users; non-analytical learners generally feel inhibited; and this method is time-consuming since briefing the end users is a necessary part of the preparation.
	Field observation	medium	1 +	20+	medium	high	The simplest of all methods.	Noise and disturbance can also lead to false results; normal working conditions should be ensured.
	Questionnaires	low	1	30+	low	low	Subjective user preferences, satisfaction, and possible anxieties can be easily identified; and questionnaires can be used to compile statistics.	This method needs sufficient responses to be significant (we are of the opinion that 30 users is the lower limit for a study); and it identifies fewer problems than the other methods.

Appendix 4. Questionnaire



Part I
Please, at first give your personal details. This will be used latter on for result analysis.

1. What is your gender?
Female Male
2. How old are you?
Please, type in:
3. What is your education level?
4. Do you use Internet?
Yes, How often? No
5. Do you play in computer games?
Yes, How often? No
6. Do you use any of CAD, GIS software?
Yes, How often? No

7. Are you often visiting centre of Warsaw? No
8. Would you like to participate in the planning process of constructing Warsaw Metropolitan Area? Yes No I don't know

Assignment 1

On your left you see map and on your right three pictures.
Map is divided by blue lines into 4 parts (boxes A - D).
For each picture please indicate (by choosing appropriate letter below pictures) which part of map it shows. Parts can be shown more than once.

You have time limit of 3 minutes.

Assignment 2

On your left you see a map, on your right a picture. Picture is presenting part of the area showed in the map. Imaging that picture is the view that you are looking at.

Can you please indicate on picture:
In which direction is letter A?
In which direction is letter B?
In which direction is letter C?
In which direction is letter D?

You have time limit of 3 minutes.

Assignment 3

On map below you can see blue, red and green path that the animation might have followed.

Chose which path was showed by the animation. Then, please answer one additional question.

You have time limit of 2 minutes.
In the window below you will see short (40 seconds) animation of 3D geo-visualization. Press bottom below to start.
When film finishes new page will be displayed.

Assignment 4

Some time ago, you have seen short animation. Please, answer now few questions about what you have just seen.

You have time limit of 2 minutes.
1. Which type of street lights have you seen in the animation?
2. How many turns of camera did you noticed during animation?
3. Which street have you noticed?

Additional remarks

If you have any additional remarks, please type these here.
If not, press arrow to finish the quiz.

Remarks about:

1. Maps and pictures

2. Assignments

3. Other

Appendix 5. Poster ‘Visualization in spatial planning

Appendix 6. Media about the public inquiry

Spójrz na miasto z lotu ptaka

Do piątku w Pałacu Kultury i Nauki (wejście od Marszałkowskiej) można obejrzeć fotografie centrum stolicy z lotu ptaka i wziąć udział w ciekawym badaniu naukowym. Prowadzi je Małgorzata Miłosz (24 l.), studentka uniwersytetu w Wagenigen w Holandii.

– Zapraszamy wszystkich, którzy mogą poświęcić 10 minut na rozwiązanie multimedialnego quizu. Na ekranie komputera pokazujemy trójwymiarowy model części Warszawy. Trzeba rozwiązać kilka zadań na orientację w przestrzeni. Można sprawdzić umiejętność czytania map – zachęca Małgosia. Badanie to część europejskiego projektu – wprowadzenia nowoczesnych technologii do planowania przestrzennego miast.

AMG

Małgosia Miłosz i jej miasto

Super Express, 5.04.2006

Aktualności
Temat z okładki
Artykuły
Nowości techniczne
Listy i polemiki
Zobacz też
Porównania sprzętu
Fotogaleria
Kalendarium
Archiwum
Kontakt
Napisz do nas
Prenumerata
Reklama
O nas
Informator
Instytucje
Organizacje
Edukacja
Prawo
Po godzinach...
Perełki
Linki
Do ściągnięcia
Tapety
Dodano na stronie

| 2006-04-05 | Z kraju

Quiz przestrzenny w Pałacu Kultury i Nauki

Do piątku 7 kwietnia wszyscy miłośnicy geoinformacji przebywający w Warszawie będą mieli okazję wziąć udział w króciutkim teście komputerowym na orientację przestrzenną. Wystarczy jedynie udać się do Pałacu Kultury i Nauki.

Jednym z etapów quizu jest np. dopasowanie trójwymiarowego modelu części miasta do odpowiadającego mu fragmentu "płaskiej" mapy. Po "przelocie" ulicami centrum Warszawy komputer pyta, jakiego rodzaju były lampy oświetlające, ile razy skręciliśmy w lewo lub prawo, albo jak przebiega trasa po przeniesieniu jej na mapę.
Wyniki tego eksperymentu posłużą Małgorzacie Miłosz (młodej absolwentce wydziału planowania przestrzennego SGGW, a obecnie studentce Centrum Geoinformacji Uniwersytetu w Wegeningen) do oceny przydatności nowoczesnych technologii komputerowych w planowaniu przestrzennym. Poszczególne etapy quizu mają dać odpowiedź na pytanie, czy systemy informacji geograficznej, modelowanie trójwymiarowe i wizualizacja mogą zwiększyć udział społeczeństwa w podejmowaniu decyzji w procesie zagospodarowywania terenu. Dodatkowo test ma sprawdzić, czy mieszkańcy miasta potrafią poprawnie "odczytywać" model 3D, a co za tym idzie, czy można go używać np. do interaktywnej prezentacji pomysłów miejskich architektów.
Badania prowadzone w Warszawie są częścią większego projektu Unii Europejskiej pt. Participatory Spatial Planning in Europe. W imieniu pani Małgorzaty zapraszam do licznego udziału w teście. Im więcej uczestników, tym ciekawsze wyniki. Stanowisko komputerowe znajduje się w PKiN (wejście od ul. Marszałkowskiej) na poziomie -1, przy windach.

http://www.geoforum.pl

Kurier Warszawski, 5.04.2006

GEOKRAJ

TRÓJWYMIAROWY EKSPERYMENT

Na początku kwietnia 2006 w Pałacu Kultury i Nauki w Warszawie przeprowadziłam quiz naukowy „Wizualizacja w planowaniu przestrzennym". Jest on elementem pracy naukowej oceniającej przydatność wizualizacji (w szczególności trójwymiarowych modeli) w konsultacjach społecznych, jako jednego ze sposobów prezentacji zagadnień i problemów związanych z planowaniem przestrzennym.

MAŁGORZATA MIŁOSZ

Quiz sprawdzający orientację w przestrzeni składał się z czterech zadań bazujących na porównaniu trójwymiarowych modeli z tradycyjnymi dwuwymiarowymi mapami. Respondenci proszeni byli m.in. o zorientowanie modelu na mapie, określenie miejsca, w którym stoją, kierunku, w którym patrzą, a także wskazanie, którą część mapy pokazuje model. Ponadto testowana była ich spostrzegawczość, ile są w stanie zapamiętać z krótkiej animacji i na jakie elementy zwracają uwagę.

W ciągu pięciu dni w badaniu wzięło udział 150 osób, z czego do analizy wykorzystano 140 odpowiedzi, po 70 dla każdego z dwóch typów quizów. Połowa osób rozwiązywała zadanie z ułatwiającymi orientację nazwami ulic. Wstępne wyniki pokazują, że orientacja w przestrzeni, a nawet czytanie dwuwymiarowej mapy stanowi duży problem. W pierwszej grupie respondentów tylko jednej osobie, a w drugiej pięciu udało się poprawnie rozwiązać wszystkie zadania. Ogólny procent poprawnie rozwiązanych zadań wynosi 41%.

Ze względu na duże zainteresowanie, quiz został udostępniony na stronach internetowych www.pkin.pl oraz www.geoforum.pl.

Przedsięwzięcie zorganizowane w PKiN jest wynikiem współpracy między Uniwersytetem Wageningen, Pałacem Kultury i Nauki, Centrum UNEP/Grid – Warszawa, firmą ARCADIS Polska (ARCADIS Ekokonrem, ARCADIS Grabowska i Grabowski, Profil) oraz firmą MGGP Aero w Tarnowie. Sponsorowane było ze środków Unii Europejskiej jako część projektu PSPE (*Participatory Spatial Planning in Europe*), projektu, którego głównym celem jest propagowanie wykorzystania nowych metod w planowaniu przestrzennym, m.in. wirtualnej rzeczywistości, trójwymiarowej wizualizacji, technologii informatycznych oraz internetu.

Autorka jest absolwentką gospodarki przestrzennej w SGGW, a obecnie studiuje na Wydziale Nauki o Geo-Informacji na Uniwersytecie Wageningen w Holandii

Geodeta 5 (123) May 2006

Appendix 7. Personal details of respondents

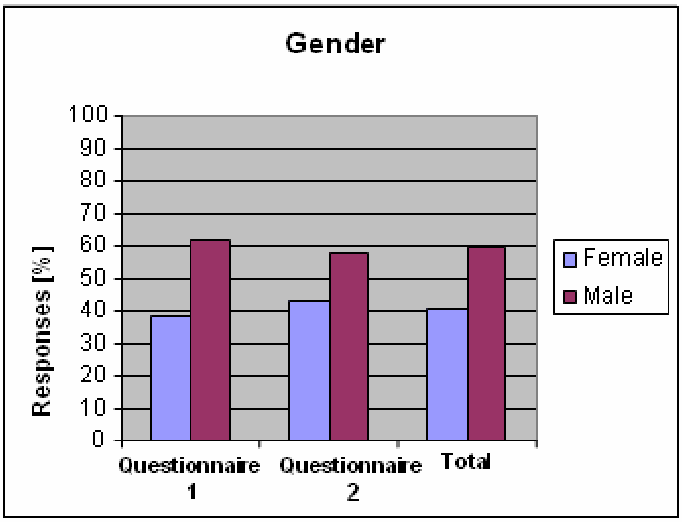


Figure 1. Gender of respondents [%].

Table 1. Age of respondents [%].

Age group	Questionnaire 1		Questionnaire 2		Total	
	No.	[%]	No.	[%]	No.	[%]
16 - 18	3	4	3	4	6	4
19 - 24	35	50	37	53	72	51
25 - 34	14	20	16	23	30	21
35 - 44	5	7	7	10	12	9
45 - 54	6	9	6	9	12	9
55 - 64	3	4	1	1	4	3
>= 65	4	6	0	0	4	3
Sum	70	100	70	100	140	100

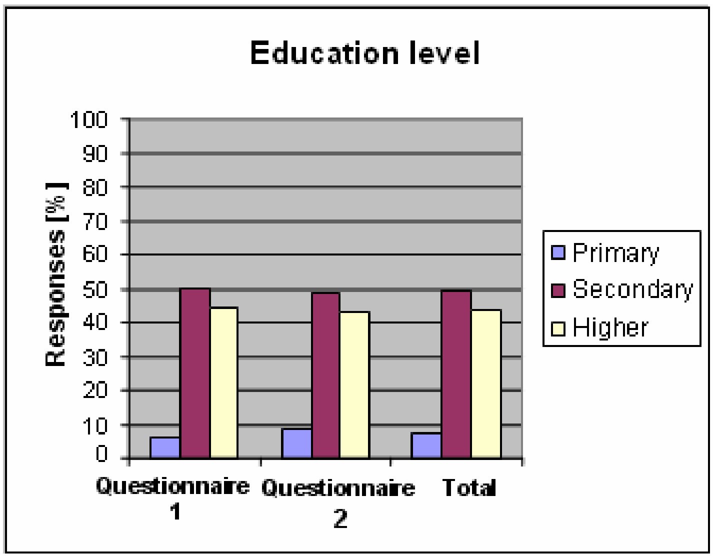


Figure 2. Education level of respondents [%].

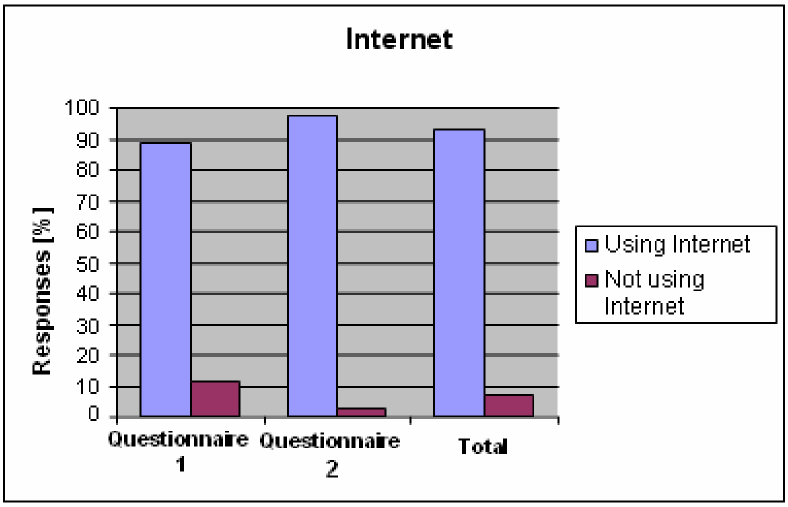


Figure 3. Respondents using and not using Internet [%].

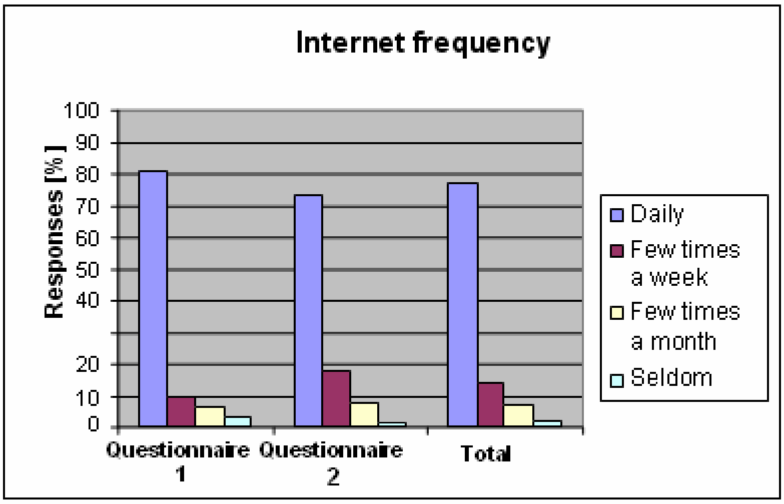


Figure 4. Frequency of using Internet [%].

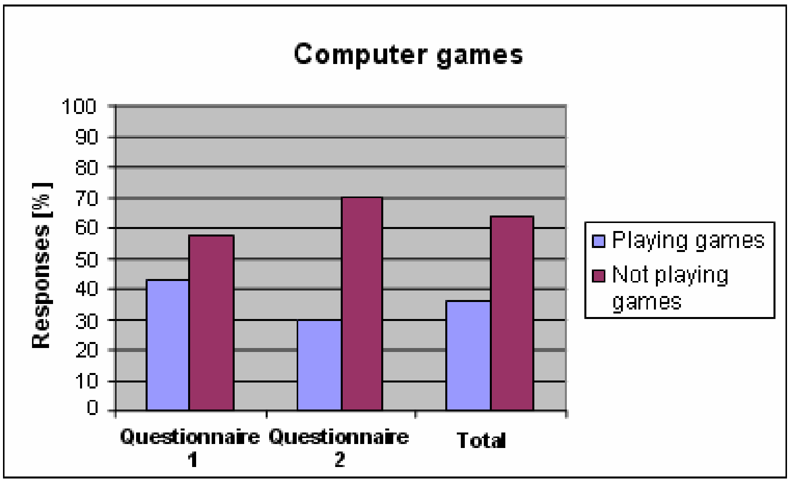


Figure 5. Respondents playing and not playing computer games [%].

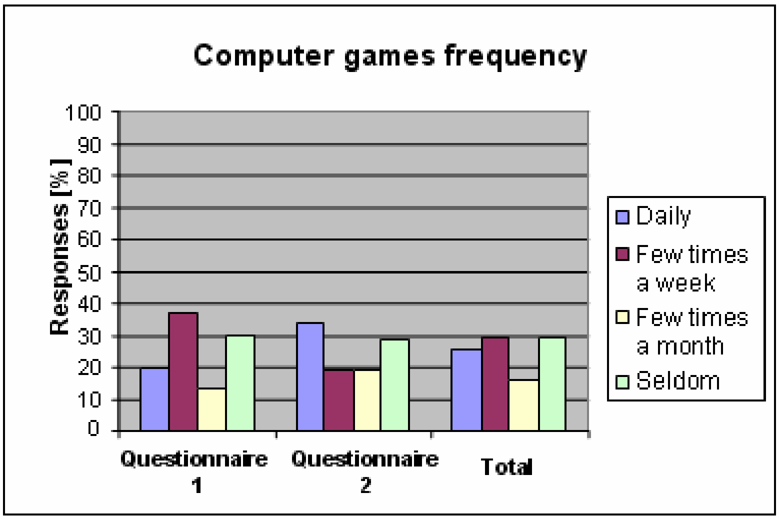


Figure 6. Frequency of playing computer games [%].

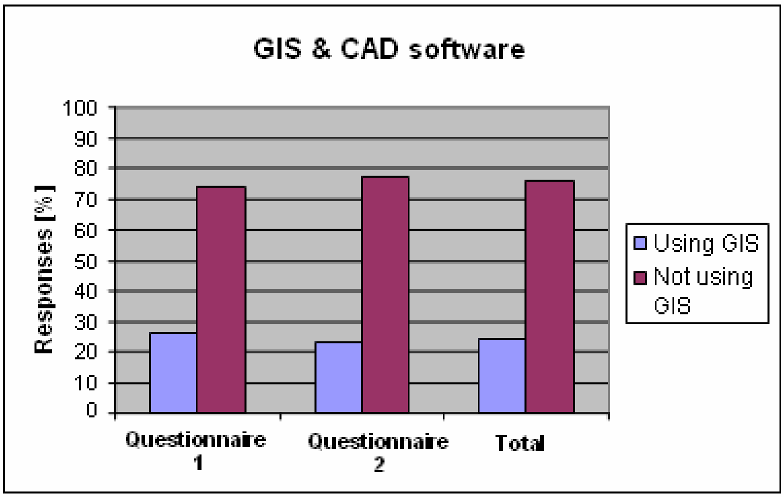


Figure 7. Respondents using and not using GIS and CAD software [%].

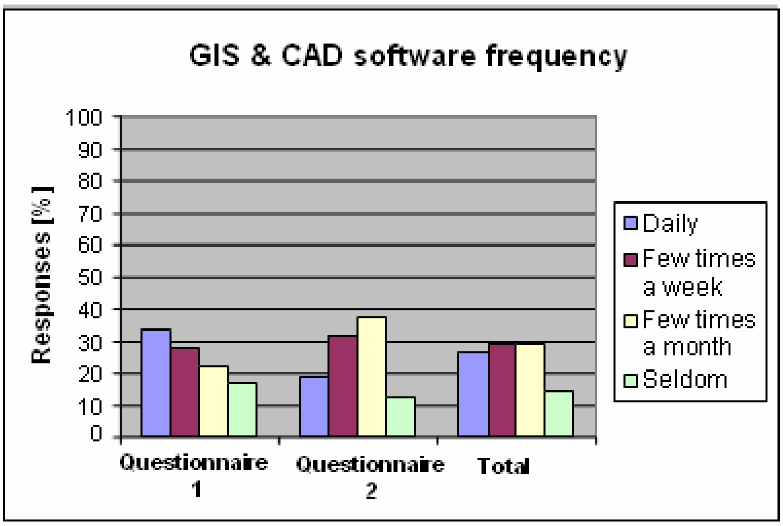


Figure 8. Frequency of using GIS and CAD [%].

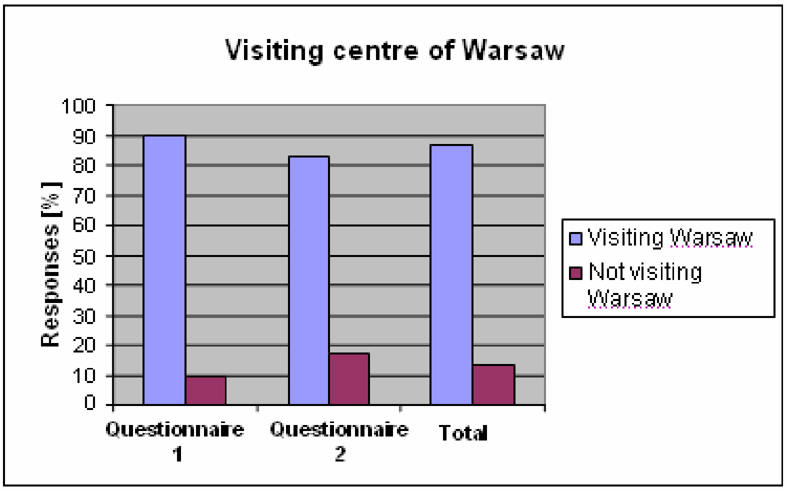


Figure 9. Respondents often visiting and not visiting Warsaw [%].

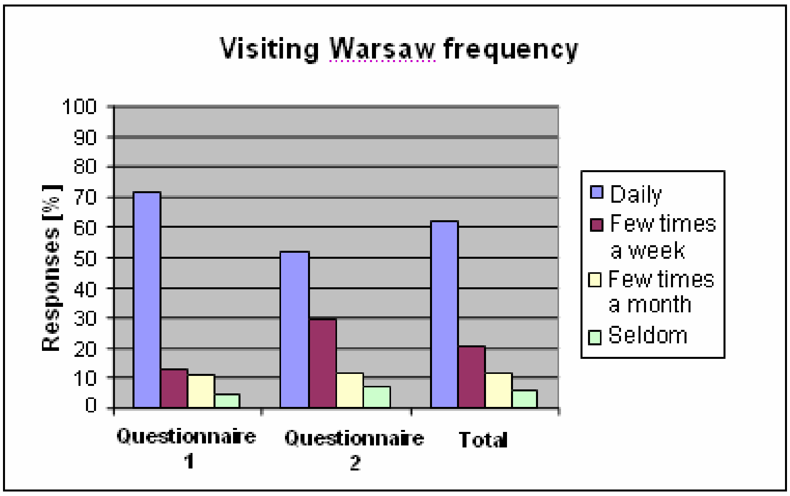


Figure 10. Frequency of visiting Warsaw [%].

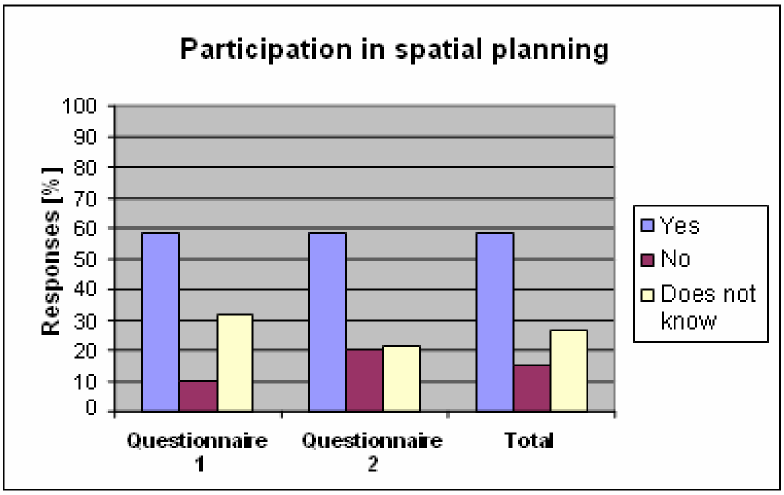


Figure 11. Willingness of participation in spatial planning [%].

Appendix 8. Users' characteristics vs. number of correct responses

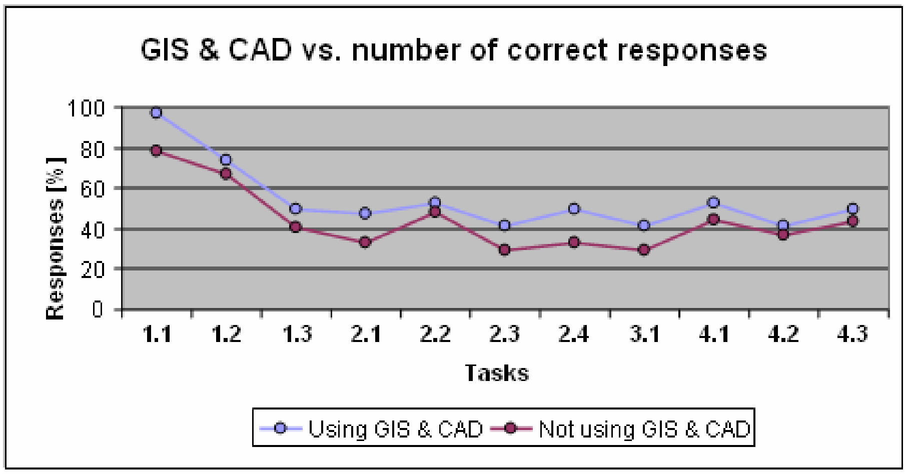


Figure 1. Using CAD & GIS software vs. number of correct responses [%].

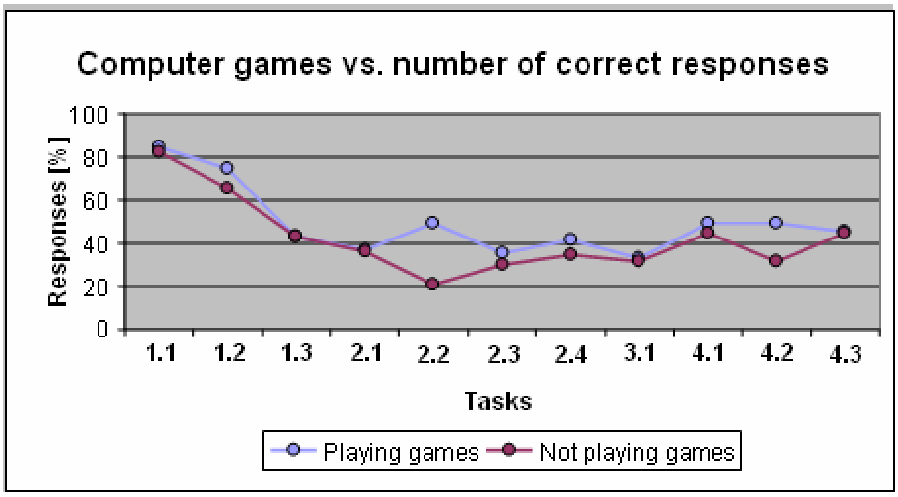


Figure 2. Computer games vs. number of correct responses [%].

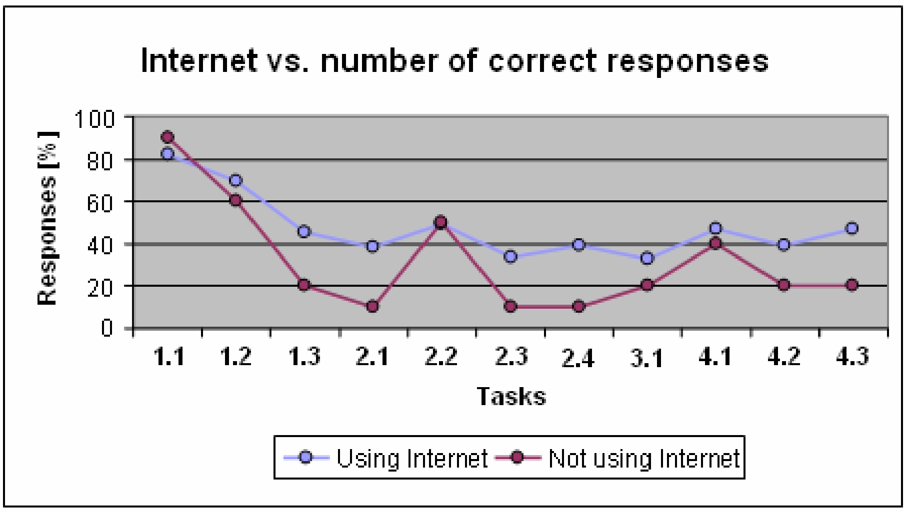


Figure 3. Internet vs. number of correct responses [%].

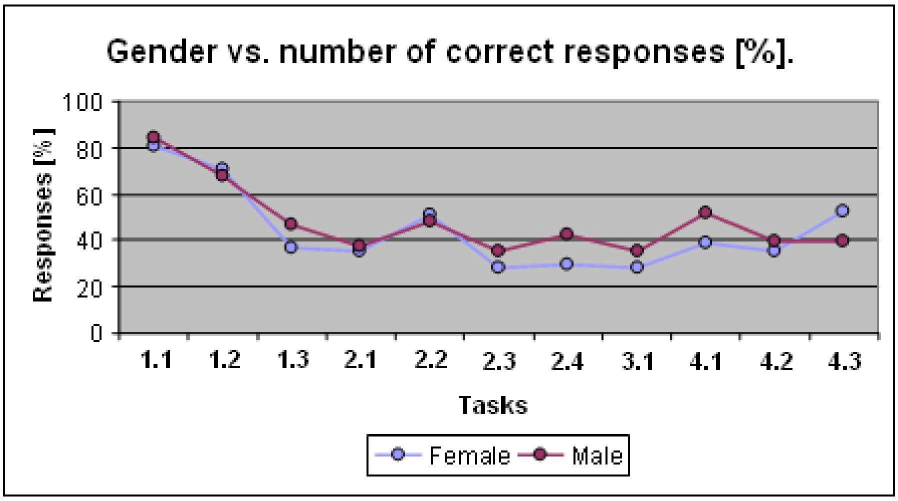


Figure 4. Gender vs. number of correct responses [%].

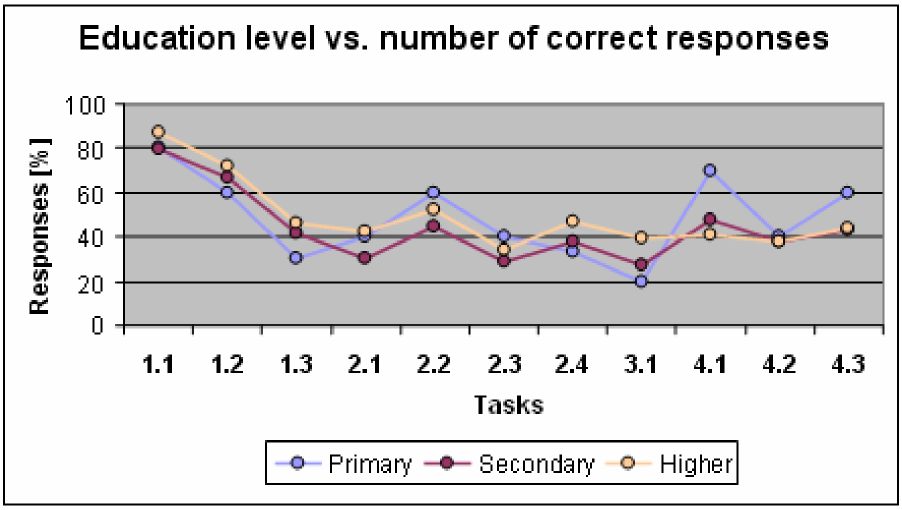


Figure 5. Gender vs. number of correct responses [%].

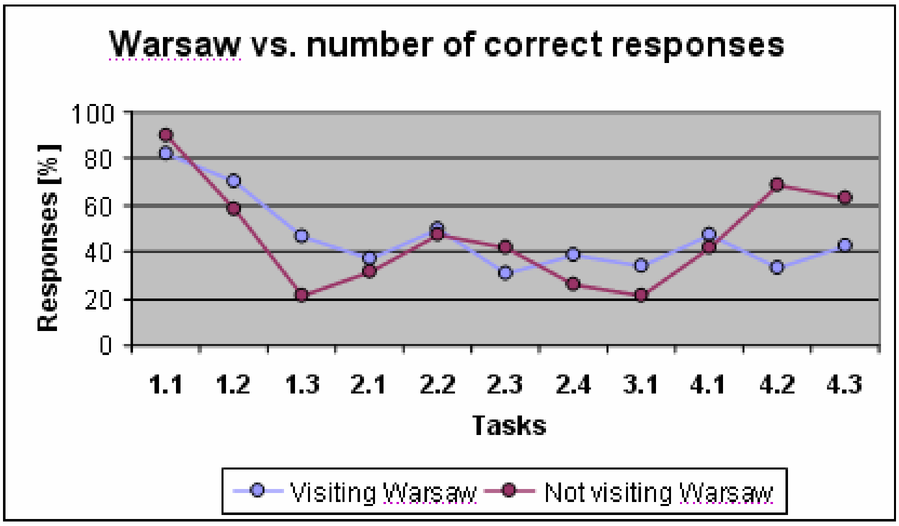


Figure 6. Warsaw vs. number of correct responses [%].

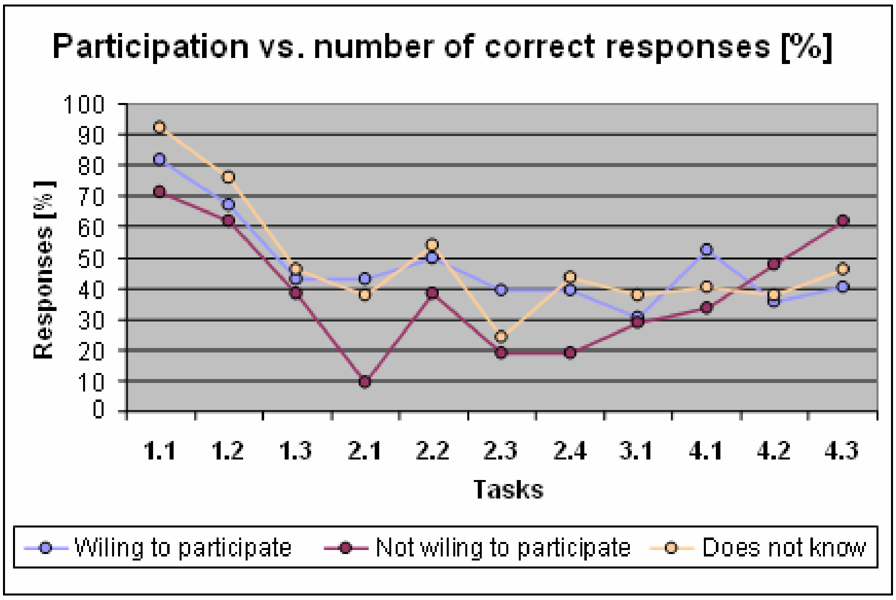


Figure 7. Willingness of participation vs. number of number of correct responses [%