A FRAMEWORK FOR VISUALIZATION OF INFORMATION IN 3D VIRTUAL CITY ENVIRONMENT FOR DISASTER MANAGEMENT

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ABSTRACT

A FRAMEWORK FOR VISUALIZATION OF INFORMATION IN 3D VIRTUAL CITY ENVIRONMENT FOR DISASTER MANAGEMENT

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In recent years, new developments in technology have brought about novel methods and platforms that have provided innovative visualization of geo-spatial information. Among the possible platforms, 3D virtual platforms are increasingly preferred as they not only depict the real world phenomena but also convey additional information. The creation of 3D geo-spatial information visualization in the conducted studies is mainly technology-driven and not standardized. Moreover, perception of the user, user experience and cognitive processes are not considered profoundly. 3D geo-spatial information visualization has widespread usage in Disaster Management as it allows decision makers a better understanding of the disaster phenomena. The aim of the study is to build a framework that follows a user-centered approach and to propose steps to design effective visualizations for Disaster Management specialists. The framework is enhanced with theories and concepts from the disciplines of cartography, human computer interaction and cognitive science. The proposed framework provides guidance for creating visualizations of information in Disaster Management. In this thesis, guidelines are proposed for visualization of disaster risk in order to help decision makers take accurate and rapid decisions.

Keywords: Geovisualization, Disaster Management, User-Centered Approach, Decision Making Process

ÖZ

AFET YÖNETİMİNDE BİLGİNİN 3B SANAL KENTSEL ORTAMLARDA GÖRSELLENMESİ İÇİN BİR ÇERÇEVE GELİŞTİRİLMESİ

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Son yıllarda, gelişen teknolojilerle beraber coğrafi-mekânsal bilginin, yeni metotlar ve platformlar kullanılarak inovatif olarak görselleştirilmesi mümkündür. Bu platformlardan biri olan 3B sanal platformlar artan derecede tercih edilmektedirler çünkü bu ortamlar gerçek dünyayı tasvir ettiği gibi coğrafi- mekânsal bilgiyi de iletebilmektedirler. Hâlihazırdaki 3B coğrafi ortamda yapılan bilgi görsellemeleri teknoloji odaklı olup, standardize edilmemişlerdir. Ayrıca, kullanıcı algısı, deneyimi ve bilişsel süreçler yeterince değerlendirilmemektedir. 3B coğrafi ortamda bilginin görselleştirilmesi, karar vericilerin afet fenomenini daha iyi anlamasını sağlaması sebebiyle, Afet Yönetimi'nde yaygın olarak kullanılmaktadır. Bu tez çalışmasının amacı Afet Yönetimi'nde karar vericiler için efektif görsellerin hazırlanabilmesi için adımlar öneren ve kullanıcı odaklı bir süreci takip eden bir çerçeve oluşturmaktır. Bu çerçeve kartografya, insan bilgisayar etkileşimi ve bilişsel bilimler disiplinlerinde yer alan kavram ve teorilerle desteklenmiştir. Bu tez çalışması sonucunda oluşturulacak çerçevenin, Afet Yönetimi'nin birçok aşamasında bilginin nasıl görsellenmesi gerektiği ile ilgili bir kılavuz görevi görmesi amaçlanmaktadır. Bu tez kapsamında afet riskinin görsellenmesine yönelik karar vericilerin hızlı ve doğru kararlar almasına yardım eden öneriler sunulmuştur.

Anahtar Kelimeler: Coğrafi Görselleştirme, Afet Yönetimi, Kullanıcı Odaklı Yaklaşım, Karar Verme Süreci

To My Twin Sisters

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
BIM	Building Information Modeling
CAD	Computer Aided Design
City GML	City Geography Markup Language
DM	Disaster Management
ERF	Emergency Response Framework
ERM	Emergency Response Management
GIS	Geographic Information System
HCI	Human Computer Interaction
IFC	Industry Foundation Classes
KML	Keyhole Markup Language
LoD	Level of Detail
NPR	Non-Realistic Rendering Technique
OGC	Open Geospatial Consortium
UBM	Unified Building Level
XML	Extensible Markup Language
VRML	Virtual Reality Modeling Language

CHAPTER 1

INTRODUCTION

1.1 Motivation

It is a well-known definition in Information Systems that data when processed computationally, becomes information; when information is cognitively processed and interpreted by the user, it becomes knowledge. During the construction of knowledge, visualization can be seen as a tool which is responsible for both envisioning and interpreting data. As it is perfectly stated by McCormick et al. (1987, p.3), “It offers a method for seeing the unseen”. The visualization enables users to observe their analysis effectively and efficiently. It embraces both image understanding and its synthesis (McCormick et al., 1987). Similarly, Brodlie et al. (1992) define the goal of visualization as being the promoter of a deeper interpretation of data and the bringer of new insight into the process, relying on human’s natural ability of visualization.

In Geographic Information System (GIS), large amounts of data are stored, manipulated, analyzed, and displayed. Many disciplines use GIS such as urban planning, geodesy, geology, oceanography, agriculture, mining, environmental science, disaster management, etc. GIS serves for a systematic compilation of geospatial information and its users’ interaction to support spatial decision, management and operations. In this data-rich system, users need to access relevant information in a timely manner, interpret them easily, do effective exploration and analysis and at last present the results meaningfully. This whole process may include different types of users and their interactions.

The visualization of geospatial information is a key issue for effective decision-making (Kemeç and Düzgün, 2006). Decision makers in GIS are users that may simply act as audiences to the presented geospatial data. However, more often they are the ones who perform visualization, exploration and analysis of data with the help of proper software program(s) to make more refined decisions. Decision makers should be able to be well introduced to the problem by effective visualization of information so that they can generate applicable strategies (Godschalk et al., 2006). Therefore, Andrienko et al. (2007) state that visualization of geospatial information, which is defined simply as geovisualization, is an emerging discipline that creates synergy between computational techniques and human capabilities.

Over the past few years, new developments in technology have brought about novel methods and platforms that enable innovative visualization of geospatial information. Among the possible platforms, 3D virtual environments are increasingly preferred as they not only depict the real world phenomena but also convey additional information. 3D geovisualization is employed in an increasing number of applications from the areas of city planning, city marketing, tourism, and facility management (Altmaier and Kolbe, 2003). MacEachren and Kraak (1999) express that 3D virtual environments are "super" environments since they enable users to experience not only the visible but also the invisible.

In the meantime, virtual 3D city models are rapidly increasing with explicit semantics, topology, and thematic information (Döllner, 2009). They become essential computational tools as they allow 3D analysis, simulation, navigation, communication and management (Döllner, 2009; Baig and Rahman, 2011). Examples for the uses of 3D city models include city walk-throughs or fly-throughs showing how a new building would look like in situ, whether a view or light will be blocked by a new structure, flood inundation and signal modelling (Ellul, and Joubran, 2012). According to Petzold and Matthias (2011), 3D city models are generally more useful if they include additional data which can be analyzed with 3D representation of real world phenomena.

Numerous standards have been proposed for 3D city models. The most well-known ones that can be adapted during their visualization are 3D visualization standards for online visualization such as the Extensible Markup Language (XML), the Keyhole Markup Language (KML), the Virtual Reality Modeling Language (VRML) and the standards for building objects and sites for 3D city models such as the Industry Foundation Classes (IFC), the Unified Building Model (UBM) and the City Geography Markup Language (City GML). Among them, the City GML, which is proposed by the Open Geospatial Consortium (OGC), is comprehensive because it defines 3D city models not only as geometrical and graphical models but also with their thematic, topological and semantic aspects (OGC, 2012). Although the City GML supports standards broadly for city objects, it is limited in terms of defining the attributes of specific domains.

Although 3D virtual environments for visualizing geospatial information are increasingly used and various standards are created for them, they mostly focus on technology and 3D model construction. According to Bleisch (2012), 3D geovisualization is often technology-driven and misses solid theories. Most of the research focuses on the aspects of technology and process; usefulness or cognitive outcomes are rarely evaluated (Bleisch, 2012). For several aspects involved in 3D geovisualization, the guidelines for theory and design have not been well established and suitable evaluation methods are needed (Slocum et al., 2001). Comprehensive user-centered studies are limited. Efficiency and effectiveness or measuring task completion time and success /error rates are typically used as usability evaluation measures (Bleisch, 2012). User individual differences such as cognitive abilities, socio-demographic profiles, individual knowledge bases and understandings of the underlying phenomena are not systematically examined for geovisualization design process (Slocum et al., 2001).

The 3D geovisualization has not involved a comprehensive theoretical background yet. What has been constituted had its origins in other disciplines such as information visualization, scientific visualization, human-computer interaction and cartography (MacEachren, 1995; Dix et al., 1998; Card et al. 1999; Chen, 1999; Ware, 2000). Therefore, although the guidelines for theory and design for 3D geovisualization are still not well-developed, considerations can be based on these disciplines (Slocum et al., 2001). As it is underlined in the definition of geovisualization by MacEachren and Kraak (2001, p.3), geovisualization is “the integration of visualization in scientific computing, cartography, image analysis, information visualization, exploratory data analysis and GIS, which all together can provide theory, methods and tools for visual exploration, analysis, synthesis and presentation of geospatial data”

3D geovisualization is a new research area for Disaster Management (DM). The right and fast user interpretation of information is very critical in DM. Decision-making processes in each DM phase play an important role and differs from each other. Each DM phase includes different user *profiles* and *roles,* different types of *scenarios* for pre-disaster or post-disaster. The attributes to be visualized differs with the DM phases and scenarios studied by the users in these phases. Although 3D city models are increasingly used in DM, comprehensive user-centered studies that suggest theoretical approaches and guidelines for visualization criteria are limited. As a matter of fact, the advantages and disadvantages of the usage of 3D geovisualization in DM are not properly evaluated with real visualization experts and real decision makers.

1.2 Aim and Scope

In this thesis study, it is aimed at developing a 3D visualization framework for interpreting DM-related information based on a user-centered approach. The main target users of the framework are the designers/experts that perform visualizations for DM, the GIS vendors that build specific tools for DM, the researchers who study geovisualization and finally the end users that are the decision makers of DM, who interact with the visual outcomes of the framework.

The framework is built upon the methodologies and theories from the disciplines of cartography, human computer interaction (HCI) and cognitive science. It is based on a comprehensive overview of the fundamental methodologies and theories of these disciplines. Although the proposed framework serves for DM, it can be adapted to other domains with appropriate modifications. The framework incorporates a theoretical background from the disciplines mentioned above but with the performances of the decision makers of DM and as well as the judgments of visualization experts.

The framework includes five main steps. The details of each step are explained in separate chapters. A specific visualization of an attribute in a DM phase is aimed to be conducted in a 3D city model. In the framework the purpose is to explore the "Visual Variables", "Data Measurement Scale" and "Level of Details (LoD)" of the City GML for modeling through a "Visual Taxonomy" for 3D environment. 2D visual variables that have been defined in cartographic theories are reidentified according to 3D environments since they are originally proposed only for the visualization of 2D maps.

The main consideration of the framework is to follow a user-centered approach. Hence, it starts with the step "Exploration of User Requirements", which suggests generating user *profiles* and *roles* and users' needs during the decision-making processes. The context of the information that is visualized in DM is defined according to the analysis of user requirements. Visualization alternatives are generated after a specific phase, scenario, and city objects and an attribute is selected. During the "Validation Process", the generated visualizations are evaluated with the visualization experts and the end users. The framework suggests an iterative approach that keeps the user-centered approach in the core in order to create effective and efficient visualizations to embrace the end users' decision-making processes.

1.3 Research Questions

This research is aimed to answer the following questions:

- What would be the main steps of a framework that would help creating visualizations to increase the effectiveness and efficiency of the decision-making process of DM specialists? What would be the advantages and disadvantages of each proposed step when the results are considered?
- What would be the negative and positive feedbacks of the users and experts about visualizations in a 3D city model?

- Could there be a systematic approach in defining the visualization of an attribute throughout taxonomy? What would be the dimensions of this taxonomy?
- What kind of design mechanisms should be considered when 2D visual variables are adapted to the 3D environment?
- Which visual variable(s) should be considered for visualizing information utilizing which Level of Detail of the model?

1.4 Organization of the Thesis

The thesis includes ten chapters that cover the corresponding subjects in an organized manner. A brief description of each chapter is as follows:

Chapter 1 introduces the motivation section, which includes the explanation of general gaps in the literature as well as the state of the art, the outcomes and the research questions. It also includes the organizational information. Chapter 2, which is an overview of studies for geovisualization, includes theories and concepts from cartography, HCI and cognitive science. The studies for geovisualization for DM are also discussed in this chapter. Chapter 3 briefly describes the DM cycle and the phases of DM. Chapter 4 describes the proposed framework. The target users and each step of the framework are described. Chapter 5 explains the methods used in the framework. Chapters 6 to 10 explain each step of the proposed framework in detail. Chapter 6 provides what is performed in the first step of the framework, which is “Exploration of User Requirements”. Chapter 7 describes the second step of the framework, which is “Defining the Visualization Context”. Chapter 8 explains the third step of the framework, which is “Creation of the Visualizations according to the Visual Taxonomy”. Chapter 9 is about the fourth step of the framework, which is “Validation Process”. This chapter includes the studies of pilot user tests, the expert evaluation, the final user tests and summary of all. In Chapter 10, which is the last step of the framework, “Guidelines for the Final Visualizations” are given. Chapter 11 provides the conclusions related to the proposed framework and includes suggestions for future work.

CHAPTER 2

OVERVIEW OF RELATED GEOVISUALIZATION CONCEPTS

An interdisciplinary approach is required for this thesis study, because it aims to suggest a solid and useful framework for visualization of information for 3D geospatial environment. Hence, innovative strategies and methods from the disciplines of cartography, human computer interaction (HCI), and cognitive science are overviewed. The reason for considering cartography is that it is an old discipline and closely integrated with Geographic Information Systems (GIS). In cartography solid theories exist and they can be considered for maintaining fundamental bases for current geovisualization concepts. HCI and cognitive science are directly used in user-centered studies and they are essential disciplines for creating effective information visualization. This chapter consists of three main parts. In the first part, main cartographic theories for geovisualization are summarized. In the second part, important concepts from HCI and cognitive science are discussed for effective geovisualization. In the last part, the studies related to geovisualization for Disaster Management (DM) are expressed and the gaps are stated.

2.1 Cartographic Theories for Geovisualization

It constitutes many theoretical and practical foundations of GIS. It is traditionally defined as the art and science of creating maps, but in reality it can be best defined as a craft combining knowledge from graphic design and mathematics (Muehlenhaus, 2010). In order to develop information spaces, many methods can be inspired from old cartographic processes such as generalization, simplification, map projection and map scale generations. Information visualization can benefit from cartography, because information spaces are based on spatial metaphors such as location, distance, region, scale, etc. (Fabrikant and Skupin, 2005).

The cartography cube created by MacEachren (1994) is a simple structure conceptualizing the level of user interaction, the type of environment and the aim of the interaction considered in the visualization (Figure 2-1). This cube, which was proposed in 1994, considers the user interaction with 2D map and it also still gives us a clear understanding of the user's interaction with geospatial information. In this cube, *human-map interaction* is the degree to which the user can manipulate a map; *presenting unknowns* and *revealing unknowns* are related to the goal of the user, which means presenting and discovering respectively; *public* and *private* are the degrees of the presentation to a specialized audience. According to MacEachren (1994), *visualization* is visual thinking and *communication* is visual communication. Therefore, MacEachren (1994) argues that cartographic visualization is a *private* activity in which unknown facts are revealed in a highly interactive environment. In contrast, cartographic communication is a *public* activity in which known facts are presented in a non-interactive environment

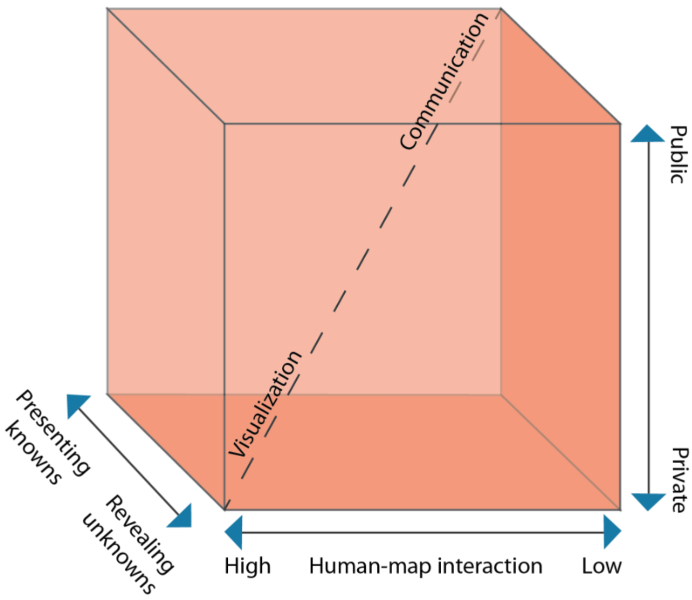


Figure 2-1: Cartography Cube, MacEachren (1994)

Bertin (1967/1983) is the first cartographer that sets off fundamental visual variables for visualizing spatial information. The variables he proposes are **size**, **value (brightness)**, **color**, **position** (dimensions on the plane), **orientation**, **texture** and **shape**. He defines **position** as *planar variable* and the others as *retinal variables*. "Bertin's Variables", which is covered in his book of "Semiology of Graphics", is one of the focus points of this thesis. His theory, which is related to visual variables, is one of the most known and discussed theories by cartographers, cognitive scientists and researchers of information science. It is a flexible and expandable theory that all the disciplines considered for this study can connect well.

According to Bertin (1983), visual variables have five characteristics, which are being *associative*, *selective*, *quantitative*, *ordered* and the *length* of the variable. He introduces **shape**, **orientation**, **texture**, **hue** and **position** as *associative* visual variables (Bertin, 1983). According to Bertin (1983), a visual variable is *associative* if marks that are unlike can be grouped according to a change in an *associative* variable. **Size** and **value** are *dissociative*. A visual variable is *selective* if a mark changed in this variable becomes easier to select than the other marks. All the variables except for **shape** are *selective* (Bertin, 1983). A visual variable is *quantitative* if the relation between two marks differing can be seen numerically. The variables of **position** and **size** are *quantitative*. A visual variable is *ordered* if changes of this variable can be seen in an *ordered* manner (Bertin, 1983). **Position**, **size** and **value** are said to be ordered. The *length* of a visual variable is the number of changes that is supportable (Bertin, 1983). For example, **shape** is the longest and can have an infinite variety. However, **orientation** is the shortest because confusion may occur if more than four levels are used (Electronic Visualization Laboratory, 2012). Bertin defines mark as point, line, area, surface or volume (Bertin, 1983). Visualization in geospatial terms, the implantations of Bertin's variables as point, line and area can be seen in Figure 2-2. As 3D visualizations are not considered by him, volume is disregarded.

Although Bertin (1983) has strict definitions about categorizing these variables, some authors criticize that there is no enough empirical evidence to support or ground his theory. For instance, Filippakopoulou et al. (1999) state that the dichotomy of visual response to a visual variable (eg. variable's being *selective* or *non-selective*) is strict. Their tests reveal that there is a continuum between two ends. They state that cognitive research must be examined with real maps and real cartographic tasks.

Bertin creates the syntactics that each variable is defined as *acceptable* or *unacceptable* according to the visualization of the measurement scale of data where they are categorized as *numerical*, *ordinal* and *nominal*. The syntactics related to the level of measurement for the graphic variable can be seen in Figure 2-3. According to this syntactics, for *numerical* data, **location** and **size** are *acceptable*, whereas **value**, **texture**, **color**, **orientation** and **shape** are *unacceptable*. For *ordinal* data, **location**, **size**, **value**, **texture** and **orientation** are *acceptable*, while **color** and **shape** are *unacceptable.* For *nominal* data, **location**, **color** and **shape** are *acceptable*, but **size**, **value**, **texture** and **orientation** are *unacceptable.*

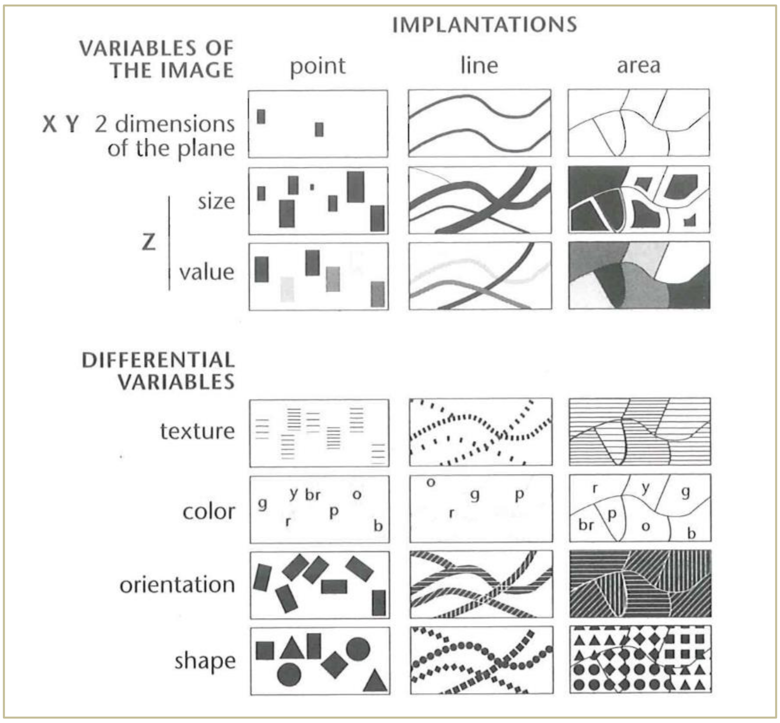


Figure 2-2: Bertin's Variables (In MacEachren, 1995, p.271)

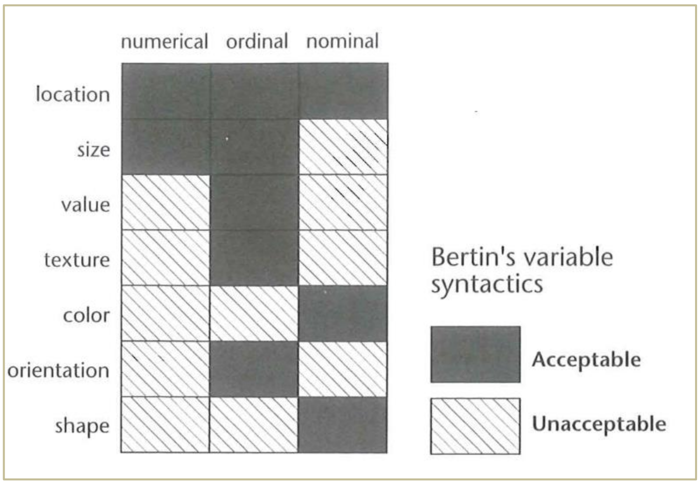


Figure 2-3: Bertin's variable syntactics related to level of measurement to graphic variables (In MacEachren, 1995, p.272)

Bertin does not mention **saturation**, although he proposes **value** and **color (hue)**. Morrison (1974) proposes nine visual variables and includes **saturation** because computer visual technologies allow three of them. Morrison's syntactics related to the level of measurement for graphic variables can be seen in Figure 2-4. He does not specify syntactics for the variable of **location**. Morrison (1974) uses the terms *useable* and *impossible* instead of *acceptable* and *unacceptable*. He also coins an intermediate term which is *possible*. He offers using **color** separately in the format of **hue**, **saturation** and **value**. Instead of **location,** he uses the variables of **arrangement** and **orientation**. According to the syntactics that he creates for the effective visualization of *ordinal* data, **size**, **color value**, **color saturation**, **texture** are *useable*, **color hue**, **pattern arrangement** and **pattern orientation** are possible; however, **shape** is *impossible*. Although **size**, **color value**, **color saturation** are *impossible*, **pattern texture** is *possible* and **shape**, **color hue**, **pattern arrangement** and **orientation** are *useable*.

Other examples of visual variables studied are **structure** or **pattern arrangement** (Muehrcke and Muehrcke, 1992), **abstract sound variables** (Krygier, 2004) and **focus** (effect of fading, blurring or fuzziness) (MacEachren, 1992). MacEachren (1992) adds three variables, namely **crispness**, **resolution** and **transparency**. **Crispness** and **resolution** together form the term **focus**. **Crispness** deals with the sharpness of detail in the spatial information, and **resolution** deals with the spatial precision change. The syntactics related to them can be seen in Figure 2-5. He defines the levels of effectiveness as *good*, *marginal* and *poor*. According to him, **resolution**, **crispness**, **transparency** and **arrangement** are *poor* for visualizing *interval/ratio* data. However, **resolution**, **crispness**, **transparency** are *good* for visualizing *ordinal* data. **Arrangement** is *poor* for visualizing *ordinal* data. Similarly, **resolution** and **crispness** are *poor* for visualizing *nominal* data. **Transparency** and **arrangement** are *marginal* for visualizing *nominal* data. Slocum et al. (2001) add **spacing** and **perspective height.**

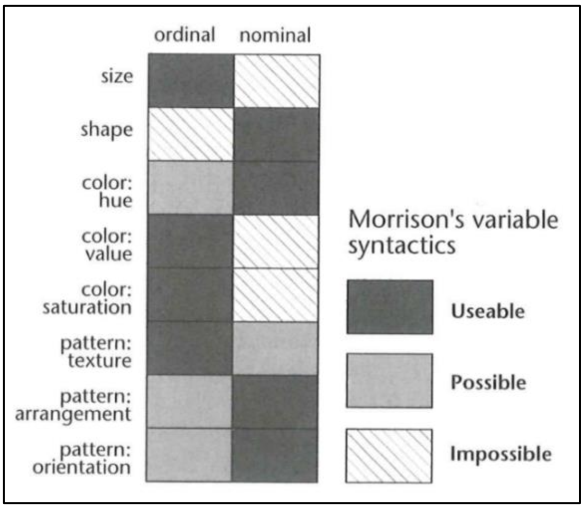


Figure 2-4: Morrison’s Variable Syntactics Related to Level of Measurement to Graphic Variables (In MacEachren, 1995, p.275)

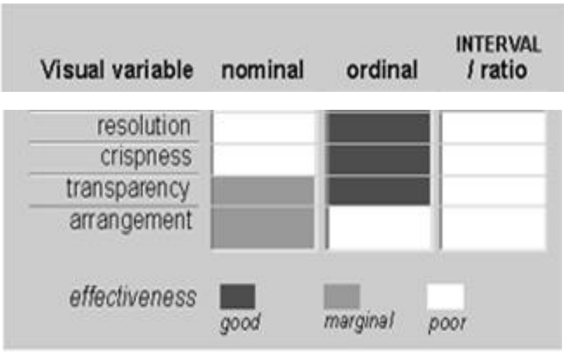


Figure 2-5: Syntactics Related to Level of Measurement to Graphic Variables (In MacEachren, 1995, p.288)

Bertin (1967) has a negative approach to *dynamic* maps as he states that movement is dominant and distracts all attention from the other variables. However, some researchers are against this statement. DiBiase et al. (1992) found that movement would reinforce the traditional graphical variables. DiBiase and MacEachren (1992) introduced the *dynamic* variables, which are **duration**, **frequency**, **display time**, **order** and **rate of change** and **synchronization**.

There are many recent examples related to the "Bertin's Variables" as well. For instance, Fabrikant and Skupin (2005) focus on a cognitively plausible strategy for data generalization which is composed of *semantic generalization* and *geometric generalization* and they use visual variables. According to Swienty et al. (2006), GIS vendors need to incorporate more graphical and map making tools and consider the variables; **transparency**, **motion** and **focus**. Jobst et al. (2008) explore new potential methods for representing 3D city models and discuss the incorporation of design mechanisms for 3D by using Bertin's theory of graphics. They present a method of rendering, which shows a close relation with variables. They emphasize the need for usability evaluations for extended semiotic structures for 3D applications in GIS. Robinson (2009) presents a range of possible approaches to *color highlighting* in geospatial visualization, beginning with examples of available variables and moving beyond options. Garlandini and Fabrikant (2009) evaluate the efficiency and effectiveness of four commonly used variables, which are **size**, **color value**, **color hue** and **orientation** for designing 2D maps. Similarly, Dong et al. (2012) evaluate the efficiency and effectiveness of *dynamic* map symbols. Halik (2012) analyzes visual variables to use in the cartographic design of point symbols for mobile Augmented Reality applications.

In addition, variables are ranked according to their attention guidance by Wolfe and Horowitz (2004). The variables **color**, **orientation**, **size**, **luminance** and **shape** are rated as *undoubted* and *probable* attributes (Figure 2-6). **Color** and **orientation** are *undoubted* attributes since they attract attention more and processed pre-attentively (less than 10ms). They define **shape** and **luminance** as *probable* attributes. However, they exclude **motion** because it is detected faster when compared to **static** attributes.

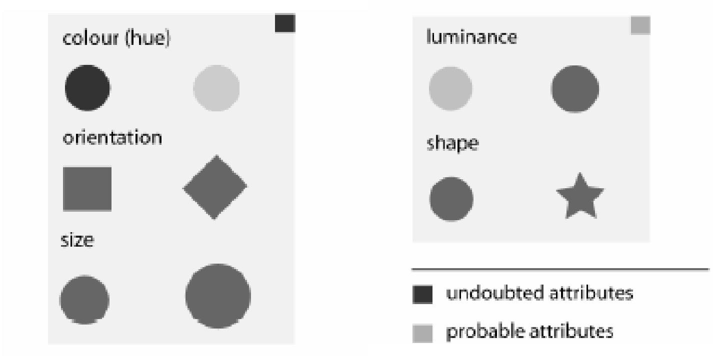


Figure 2-6: Undoubted and Probable Attributes (in Swienty et al., 2006)

In this section, visual variables in fundamental theories are listed in the form of 2D by cartographers in the literature. The design mechanisms in the form of 3D are discussed in Chapter 8.

2.2 Human Computer Interaction and Cognitive Science Concepts for Geovisualization

The increasing usage of possible computer and mobile tools let the discipline of Human Computer Interaction (HCI) be considered during the design process of geovisual environments and their interfaces. User-centered techniques are utilized and evaluated in many researches in the context of geovisualization. However, in the case of geovisualization, user goals are general and there is a high level interaction with information. The typical usage is hard to define (Marsh, 2007). The users of GIS interact with the information that is gathered from different disciplines. In this thesis study, the target user's manner of interaction with the visualization of information may be a deep exploration, analysis and discovery, or it can just be a simple visual presentation of the information.

Creating a successful user-centered design encircles the principles of HCI and goes further to include project management, user research, usability evaluation, information architecture, user interface design, interaction design, visual design, content strategy, accessibility and web analytics (usability.gov, 2015). User-centered design is a design process in which the needs, limitations and requirements of end-users are taken in to account to shape the design of the product. User-centered design approach can include a variety of user research methods such as usability testing, focus groups, field studies, contextual inquiries, interviews, questionnaires etc. in order to understand the needs of the users. Also, it includes broad design methods for generating new ideas with users. This is called participatory design (co-creation), which uses tools such as time-line activities, diary studies, brainstorming, card sorting, collaging, role playing etc.

The term of user-centered design originated in the 1980s by Donald Norman and it was widely used afterwards. Norman (1988) defines it as "a philosophy based on the needs and interest of the user, with an emphasis on making products usable and understandable" (p.188). He offers four basic suggestions as to how a design should be:

- Make it easy to determine what actions are possible at any moment.
- Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions.
- Make it easy to evaluate the current state of the system.
- Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state. (Norman, 1988, p.188).

These suggestions place the user at the center of the design. More suggestions are given by other experts as well. For instance, Shniederman (1987) proposes similar eight golden rules. Later Nielsen (1993) creates ten general heuristics for usability engineering.

1. Visibility of system status: The system should always keep users informed about what is going on through appropriate feedback within a reasonable period of time.

2. Match between system and the real world: The system should speak the users' language with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

4. Consistency and standards: Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. Error prevention: Even better than that, good error messages are a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6. Recognition rather than recall: Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. Flexibility and efficiency of use accelerators: Unseen by the novice user - may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. Aesthetic and minimalist design: Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. Help users recognize, diagnose, and recover from errors: Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. Help and documentation: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

According to Travis (2011), ISO 9241-210 (formerly ISO 13407) defines 6 key principles for user-centered design:

- The design is based upon an explicit understanding of users, tasks and environments.
- Users are involved throughout design and development.
- The design is driven and refined by user-centered evaluation.
- The process is iterative.
- The design addresses the whole user experience.
- The design team includes multidisciplinary skills and perspectives.

The successful design of a product must take into account the wide range of users of the product (Abras et al., 2004). Therefore the users should be well defined. Once they are identified by researching the needs of them, designers can create solutions to their problems (Abras et al., 2004). There are users other than the end users who finally use the product. These are the users who are affected in some way. Eason (1987) identifies three types of users: *primary*, *secondary*, and *tertiary*. *Primary* users are the end users who actually use the product. *Secondary* users are those who infrequently use the product or use it through an intermediary. *Tertiary* users are those users who are affected by the use of the product or make decisions about its purchase.

User-centered design concepts in geovisualization have been developed for the last decade. The usability evaluations of GIS are the main applications. They are linked with the integration of approaches of HCI, information science and cognitive science fields, but in few applications (MacEachren and Kraak 2001; Haklay and Tobon 2003; Koua and Kraak 2004; Fuhrmann et al., 2005). In recent years, user-centered studies that comprehensively consider the end user needs have received considerable attention. These studies include the research for the needs of the users like the usage of geovisualization tools, decision support systems and web cartography (Tsou, 2011; Kumar et al., 2013; Koua et al., 2006). Traditional usability metrics, namely satisfaction, efficiency and effectiveness are used in some studies. For instance, Coltekin et al. (2009) evaluate the interactive map interfaces using traditional usability metrics and analyze the cognitive processing of users by examining their eye movements. Similarly, Brychtova and Coltekin (2014) analyze color distance and font size in map readability using traditional usability metrics in combination with eye tracker metrics such as fixation frequency, fixation duration, and scan path speed and they also perform the area of interest analysis.

Slocum et al. (2001) propose that cognitive research and usability engineering approaches should be considered in the context of six major research themes: 1) geospatial virtual environments (GeoVEs); 2) dynamic representations (including animated and interactive maps); 3) metaphors and schemata in user interface design; 4) individual and group differences; 5) collaborative geovisualization; and 6) evaluating the effectiveness of geovisualization methods. They underline that the traditional theories for static 2D maps may not be applicable to interactive three dimensional immersive and dynamic representations (Slocum et al., 2001).

Cognitive Science deals with human perception, memory, reasoning, problem-solving, communication and visualization (Montello, 2005). Information Visualization and HCI are highly interacted with Cognitive Science. Furthermore, some cartographers built their research on cognitive theories such as Gibson's active perception, Gestalt theories and knowledge structures (MacEachren, 1995). It is known that GIS tasks include analysis, decision-making and problem solving. Researchers address the relation between geospatial information and cognition through questions such as "how geospatial information is learned and how this learning varies as a function of the medium through which it occurs (direct experience, maps, descriptions, virtual systems, etc.)", "what the most effective ways of designing interface for GIS are", "how people understand geospatial concepts", "how complex geospatial information can be depicted to promote comprehension and effective decision-making, whether through maps, models, graphs, or animations" etc. (Montella, 2005, p.79).

What types or which ways of visualization create minimum cognitive effort is a critical question. According to Kolbe et al. (2005), 3D graphical representations significantly improve the workflow and efficiency of the decision-making process. Moreover, virtual reality techniques provide better perception and comprehension of complex 3D structures (Beck, 2003). "Meanwhile, there is a further trend towards 3D virtual GIS. These systems can represent and handle complex 3D objects like buildings and allow for real-time visualization applications. The rapid developments in the field of computer graphics have also supported the use of 3D virtual components within standard GIS" (Haala, 2005, p.285). It can be deduced that 2D traditional usage of spatial information is not sufficient for 3D environments.

Visualization cannot be properly performed without understanding the visual perception. Cognitive scientists define the act of perception by two kinds of processes, which are *bottom-up* and *top-down* processes. During a *bottom-up* process, visual information (the pattern of the light falling on the retina) driven wave passes the information to the back of the brain. During a *top-down* process, the wave sweeps back to the fore brain to reinforce the most relevant information (Ware, 2008). For instance, attention guiding visualization is a *bottom-up* oriented process. *Bottom-up* processes are driven by information from the outside world. One of the strongest articulations of the *bottom-up* process is given by Gibson (2002), who proposes a theory of *direct perception*. He states that the outside world provides sufficient contextual information for our visual systems to directly perceive what is there and it is not influenced by higher cognitive processes. However, visual exploration requires existing knowledge, current goals and prospects; therefore, it can be regarded as a top-down process (Swienty et al., 2006). In other words, with top-down process perception of information is guided by people's prior knowledge, goals and expectations.

Bottom-up and *top down* processes are also defined as *stimulus-driven* and *goal-directed.* As explained by Corbetta and Shulman (2002), different attentional functions occur in different part of the brain areas. According to them, in *goal-directed* one, the intraparietal cortex and the superior frontal cortex are involved. In *stimulus-driven* one the temporoparietal cortex and the inferior frontal cortex are included and this system is largely localized to the right hemisphere. This localization is not involved in *goal-directed* selection. This system is related with the detection of relevant stimuli, particularly when they are salient. In this thesis, during the preparation of user tests and the analysis of saliency maps and eye tracker heat maps, *bottom-up* and *top-down* processes are considered (Chapter 9).

2.3 Visualization for Disaster Management

Natural disasters have caused deaths of millions of people and huge economic losses over the history. Effective DM strategies are needed in order to minimize the losses especially in vulnerable areas. Today, cities in the world are growing at a fast pace and naturally the vulnerabilities increase due to the growing complexity of the urban processes. Therefore, natural disaster risks in urban areas have become higher as the elements at risk in urban areas and their interaction in urban processes are growing steadily.

In order to assist the DM, researchers propose many frameworks using GIS-based technologies. Uitto (1998) proposes a framework, which uses GIS for DM considering the Disaster Vulnerability concept. In the proposed framework, urban vulnerabilities are calculated especially for megacities. The study is one of the pioneers for natural hazard *risk assessment* with a consideration of social vulnerability. Herold et al. (2005) outline a framework for establishing an online Web-based Spatial Disaster Support System (SDSS). The reason for developing the SDSS is that real-time disaster data could be accessed and shared easily, inexpensively and in a straightforward manner during various stages of a disaster life cycle.

Zlatanova and Holweg (2004) provide an overview of Emergency Response Management (ERM) and outline different types of end users which are the decision makers of ERM system/products who can use the system mobile, using web/desktop and virtual environment. Further, Zlatanova et al. (2007) suggest an Emergency Response Framework (ERF). A 3D spatial information perspective is used to evaluate the technical necessities of multi-risk emergency response systems. The suggested architecture covers data management and communication subjects of problem areas. Similarly, Friedmannová et al. (2006) outline the heterogonous user groups of DM. Different groups vary according to their roles, skills and knowledge. Each group can be described by ontology, the list of tasks, the spatial extend of authority and the place of operation. Therefore, they suggest that adaptive cartography can be considered for DM to make proper visualization according to situation, purpose and users' background.

Geographic visualization with the usage of information technology enhances the decision-making process by clarifying the realities of a disaster more clearly and help the DM specialists formulate better decisions quickly (NRC, 2007). In recent years, new developments in geographic information technologies provide new methods and platforms that enable innovative visualization of geospatial information. Among the possible platforms, 3D virtual environments are increasingly preferred. 3D visualization has a great potential for being an effective tool for communicating disaster risk at each phase of the decision-making process in DM (Marincioni, 2007).

There are several studies on the use of 3D geographic information in modeling urban environment. In Gouin et al. (2002), a survey of visualization techniques and approaches that are applied to various domains is conducted. The survey is conducted using a three dimensional framework, which is named the Reference Model framework for the application of Visualization Approaches. The Domain Context, Descriptive Aspects and Visualization Approach constitute the three axis of the proposed framework. Sapaz and Isler (2006) put three transportation visualization examples to the reference model of Gouin et al. (2002). An organizational and theoretical gap is distinguished through the approach of Gouin et al (2002).

Isikdag and Zlatanova (2009) propose a framework for automatic generation of buildings in the City GML using Building Information Modeling (BIM). The framework defines the procedure of automatic building generation in a three-stage flow. In the first stage, the rules for generation are defined for semantic mapping of BIM classes to the City GML. The second stage includes geometric simplification rules, and in the third stage, the rules for the transformation of attribute information are defined. Hizaji et al. (2010) propose a framework for integrating the 3D BIM utilities network data into a GIS-based system of water utilities maintenance operations and management. Like the proposed framework, this study also utilizes the City GML as a base model to provide an integrated ontology covering the BIM and GIS model concepts.

Most current GIS-based DM systems for different types of disasters have been developed by 2D GIS with 3D visualization systems (Lee and Zlatanova, 2008). Studies that specifically contributed a method or framework for 3D Visualization in DM are limited. Meijers et al. (2005) propose a semantic model for interior spaces in 3D model that aims to calculate available evacuation routes. Similarly, Lee and Zlatanova (2008) focus on developing a 3D data model to represent urban-built environments including the interior structures of the buildings and on 3D spatial analysis functions used for emergency responses such as 3D navigation and 3D buffering. Kemec et al. (2009) propose a rule-based approach that derives the relation between the hazard type and the urban 3D model. Eight attributes are used within the proposed decision rule to establish a link between the hazard type and the spatial detail level of 3D urban model for the visualization of vulnerabilities in DM. Shen et al. (2010) create a method for extracting the building attributes of a disaster area from high-resolution remote sensing images. 3D visualization of the buildings they created is feasible, reliable and advantageous to show the damage area and the damage grades of the buildings for decision-making. A study that proposes a framework for 3D visualization using the City GML standards was conducted for DM by Kemeç et al. (2010). Based on the disaster type, the needed Level of Detail (LoD) for a 3D model is derived, which is then linked to the time needed to process the data and obtain the required LoD. The LoD is compliant with the 3D international standard of the City GML. The framework is designed to serve risk managers and to help them make a better selection for 3D model representations. These studies use the technological advances and propose theoretical framework accordingly. However, they lack in considering the user requirements and incorporating them into designs.

CHAPTER 3

BASIC CONCEPTS OF DISASTER MANAGEMENT

"Disaster Management (DM) can be defined as the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies in particular *preparedness*, *response* and *recovery* in order to lessen the impact of disasters" (IFRC, n. d., #2). World Health Organization (WHO/EHA/EHTP) (1998a) classified disasters as natural and man-made/technological disasters. Natural disasters can be meteorological such as hurricanes, tornados, floods, drought; topographical such as landslides, avalanches; tectonic and telluric such as earthquakes and volcanic eruptions; biological such as epidemics and infestations. Man-made or technological disasters can be industrial disasters, nuclear or chemical accidents, wars, structural failures and fire (WHO/EHA/EHTP, 1998a). No matter what type the disaster is, its management involves certain general principles according to the phases of the disaster. Hence, in this chapter, the concepts of Disaster Management are briefly explained.

3.1 Disaster Management Cycle

The phases of DM can be grouped under two main headings. These are "Ex-Ante Strategies", which are conducted pre-disaster, and "Ex-Post Strategies", which are conducted post-disaster (Government of Japan, World Bank and GFDRR, 2012; Gutmann, 2011). The phases of DM are tightly connected to each other. Therefore, actions or decisions made in one phase are expected to affect another phase. They cannot be defined as separate phases happening in sequence. Hence, they should be considered as parts of a cycle which occur in different temporal phases in an overlapping manner.

Ex-Ante Strategies cover pre-disaster phases which are *risk assessment*, *risk avoidance*, *mitigation*, *risk transfer* and *preparedness* and *warning and evacuation*. Ex-Post Strategies include post-disaster phases which are *response*, *recovery* and *reconstruction* (Figure 3-1).

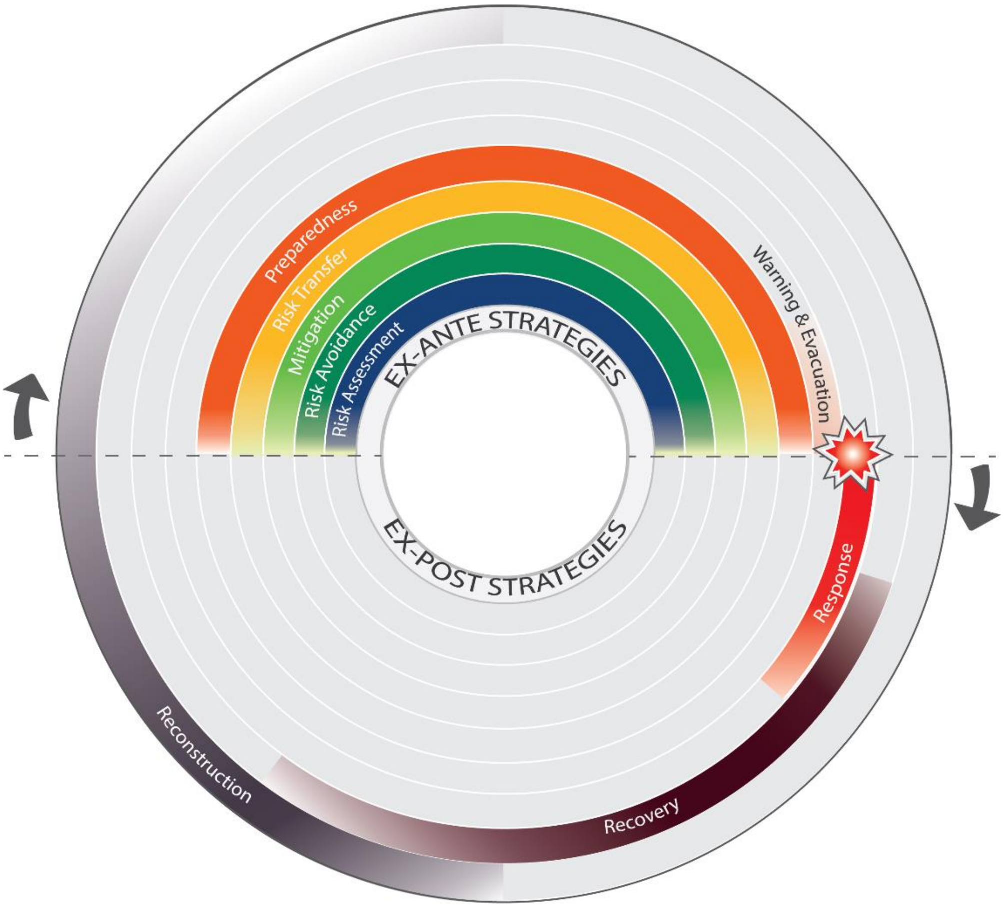


Figure 3-1: Disaster Management Cycle

3.2 Disaster Management Phases

Ex-Ante Strategies, which are pre-disaster phases, cover *risk assessment*, *risk avoidance*, *mitigation*, *risk transfer*, *preparedness* and *warning and evacuation*. *Risk assessment* is the first phase in an effective DM process. *Risk* in DM is defined as the expected losses such as deaths, physiological injuries, psychological traumas, and property loss caused by a specific hazard in a specific location for a specific time period. “Objective of r*isk assessment* is to quantify potential damages and losses due to the future earthquakes (consequences) and their probabilities of occurrence in a given period (likelihood)” (OPUS, 2005, p.3). *Risk* is derived from the variables *hazard*, *exposure* and *vulnerability* (WHO/EHA/EHTP, 1998b; WMO, 2002; ADRC, 2005; Government of Japan, World Bank and GFDRR, 2012).

Hazard assessment involves defining the nature, intensity, location and probability of the occurrence of hazard(s) (likelihood) in a specific area for a given period of time (UNDP, 2010). For example, hazard analysis for earthquake includes the identification of earthquake sources, modelling of earthquakes occurrences from these sources, the estimation of the attenuation of earthquake motions, the evaluation of the side effects of soil amplification, liquefaction, landslide and surface fault rupture (OPUS, 2005). *Exposure assessment* is used to understand the elements at risk. It refers to the inventory of population and assets in a given area in which hazardous events may occur (UNDP, 2010). *Vulnerability assessment* is to define the capacity of elements at risk for given hazard scenarios (UNDP, 2010). These three variables form the main triangle of r*isk assessment* (Figure 2). Then, *damage estimation* is performed to understand the impact of the disaster on the community. During this step, the estimation of damage in elements at risk from earthquake motion or post-earthquake fires is calculated. (OPUS, 2005). The next step covers *loss estimation* and analysis in order to find potential direct losses of exposed population, property, services, livelihoods and environment, and to assess their indirect impacts on society (UNDP, 2010). Afterwards, risk profiles are generated and evaluated. Once the current and acceptable levels of risk are determined, disaster risk reduction plans and strategies could be revised or developed (Figure 3-2) (UNDP, 2010).

A comprehensive *risk assessment* not only covers the steps from *hazard assessment* to *loss assessment* but also provides a full understanding of the causes and the impact of those losses (UNDP, 2010). Thus, the process of *risk assessment* includes the technical features of hazards and probability as well as an analysis of physical, social, economic and environmental dimensions of *vulnerability* and *exposur*e

(ISDR, 2004). Therefore, *risk assessment* is one of the key elements of a Disaster Management strategy and provides decision makers with information that is useful for all the stages of the DM cycle. *Risk assessment* seeks for the computed risk being acceptable or not, what objects or areas are at risk, what the capacities and resources are, and how the risk could be mitigated or reduced (Kemeç, 2011). *Risk assessment* is the most fundamental step and thus it affects all the decision making processes in DM.

Figure 3-2: Steps of Risk Assessment

If the evaluated *risk* is too high and unacceptable, even with a partial reduction in likelihood, total avoidance is the only solution. This phase is called *risk avoidance* (Coppola, 2007). An example of a *risk avoidance* strategy can be moving people and assets out of *high risk* areas. The phase of *risk mitigation* covers long term strategies for minimizing or reducing the harmful effects of disasters and their impacts (Herrmann, 2007 and UNISDR, 2004). For example, improvements of building practices, upgrading bridges and other lifelines, education of homeowners are typical *risk mitigation* strategies. *Risk transfer* is the phase in which the reduced *risk* is accepted but the consequences of *risk* can be transferred. The financial consequences of *risk* is generally transferred from one party to another since household, community, enterprise or state authorities obtain resources from the other party after the disasters occur. The second party benefits from ongoing or compensatory social or financial supplies (UNISDR, 2004). This way the consequences of *risk* are diluted to a larger group of people that handles an average consequence (Coppola, 2007). A well-known example of *risk transfer* is insurance. The phase of *preparedness* includes plans or arrangements to enhance disaster *response* operations and to prepare organizations and individuals to respond (ODPEM, 2008). It involves equipping people with tools to increase their chance of survival or help those impacted minimize their losses (Coppola, 2007). Although there is no known and applicable *warning and evacuation* system for earthquakes, this phase involves the provision of timely and effective information for individuals who are exposed to hazard so that they can take necessary precautions (ISDR, 2004).

Ex-Post Strategies deals with post-disaster phases, which involve *response*, *recovery* and *reconstruction*. In the phase of *response*, actions are carried out to reduce or eliminate the impact of disasters such as saving life, prevent suffering, reducing financial losses etc. (Coppola, 2007). *Recovery* phase focuses on the stabilization and return of the exposed community to its pre-impact status (Herrmann, 2007). Lastly, *reconstruction* phase involves an in-depth assessment and prevention of new risks, and measures for local communities to get back on their feet (European Commission, 2010).

In this thesis study, the disaster type to be studied is chosen as the “Earthquake”. The main reason for this choice is that earthquake is the most powerful natural disaster that has caused loss of life and property in Turkey (Ergünay et al., 2013). Therefore, DM projects in Turkey are mainly related to earthquake. Moreover, it is known that earthquakes affect large populations in the urban areas in the world. “In the past decade, earthquakes caused more than 780,000 deaths - almost 60% of all disaster-related mortality” (BBC News, 2011, #6). Therefore, effective 3D visualization can provide decision makers with better decision support.

CHAPTER 4

THE PROPOSED FRAMEWORK

The framework is the main output of this thesis study for guiding to create effective DM-related information visualization in 3D Environment based on a user-centered approach. The framework is developed for four types of target users. These are *designers*, who perform visualizations for Disaster Management (DM), *researchers*, who study geovisualization, *GIS vendors*, who provide tools and modules for geovisualization in GIS software, and the *end users*, who are *DM decision makers.*

The proposed framework serves the *designers*, who aim to develop a comprehensive approach about creating effective and efficient visualizations for DM decision makers. These visualizations are generally performed by researchers in research institutions and DM specialists in governmental and private organizations who are mainly earth scientists, engineers, GIS experts and mapping specialists. The systematic approach in the framework can give insights to *researchers* of geovisualization. The framework can be adaptable to any other domains that include decision making processes. Specifically, the researchers who study user experience design for geovisualization can use the guidelines and follow the steps of the framework. The *GIS vendors*, who decide to build a specific module for Disaster Management in their GIS software, can create tools according to the given guidelines in the framework. This module can be prepared separately or be imported to the software as well. The module can be named as DM tools.

The most important target users are the *end users*, who are the decision makers in DM. They are the users who interact with the final visualizations generated according to the proposed framework. Two types of decision makers are taken into account; these are executive level decision makers who are mainly administrative staff that develop strategies, and DM specialists and researchers who mainly explore, analyze and present information to the executive level decision makers. With this framework, it is expected to obtain an increase in the effectiveness and efficiency of DM decision-making processes. In the framework, end users are active both in the step “Exploration of User Requirements” and the step “Validation Process”.

The proposed framework consists of five main steps, namely “Exploration of User Requirements”, “Defining the Context to be Visualized”, “Creation of the Visualizations according to the Visual Taxonomy”, “Validation Process” and “Guidelines for the Final Visualizations” (Figure 4-1).

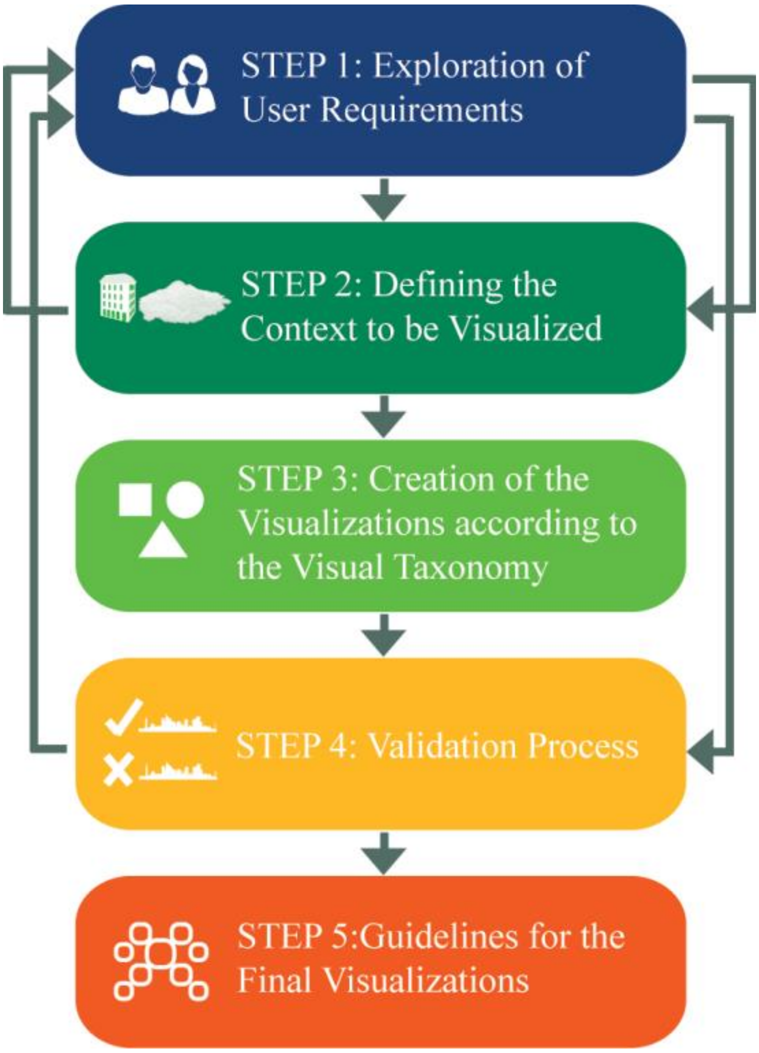


Figure 4-1: The Steps of the Framework

The first step in the proposed framework is “Exploration of User Requirements” (Figure 4-1). This step involves interviews of various end users from different phases of DM and different organizations such as academia, civil society organizations, governmental organizations and financial institutions. For this purpose, an interview method is used and 20 end users are interviewed at their places. One interview takes approximately 45 minutes. With the help of the interview questions, the users’ *profiles* are identified, including data on their profession, job title, team workers (if any), experience and foundation. Also, their scope, main decision processes, and the scenarios considered, the city objects and attributes visualized and the visualization tools used are generated. What kind of problems they encounter during their analyses as to the visualizations, what they expect from the visualization of geospatial information in a 3D city model, and what kind of tools they need are questioned as well. The details of this step can be seen in Chapter 6.

The second step is “Defining the Context to be Visualized” (Figure 4-1). In this step, the scenarios, city objects and the attributes of scenarios they work are analyzed. Highlighted scenarios, city objects and attributes are defined. The statements of the users related to standardization and 3D city modeling are analyzed. According to users’ explanations, a Hierarchical Task Analysis is carried out and the hierarchical structure between the phases and their tasks are described. According to this analysis, as the phases change, their scenarios differ as well. Therefore, the objects and attributes on which they focus differ. In other words, for each scenario, the city objects, possible attributes of the objects and the decision makers become different. According to Hierarchical Task Analyses, the fundamental phase is considered as *risk assessment*. All the Ex-Ante (pre-disaster) phases of DM, which are *risk assessment*, *risk avoidance*, *mitigation*, *risk transfer* and *preparedness*, are connected to this phase. Therefore, a scenario used in *risk assessment* is decided to be tested in this thesis study. The scenario that is used in the case study is decided to be earthquake *Risk Prioritization,* which is *risk* scoring of the Buildings according to certain criteria. Therefore, the main city object is decided to be Building and the attribute to be visualized is selected as *total earthquake risk* of the Building. Further details can be seen in Chapter 7.

The third step in the framework is “Creation of the Visualizations according to the Visual Taxonomy” (Figure 4-1). A Visual Taxonomy is generated in this way. The Visual Taxonomy has three dimensions, which are Measurement Scale, Visual Variable and Level of Detail (LoD). Each visualization of an attribute of a city can be defined as a point placed in this taxonomy. In this step, different alternative visualizations of *risk* on the buildings are prepared. The *risk* is visualized as *ordinal* data (*low, medium* and *high risk*). While doing this, the suggestions of Bertin, MacEachren and Morrison on visualizing *ordinal* data with visual variables are considered. However, 3D mechanisms differ from 2D as they include global properties such as lighting, shadows, shading, background and atmospheric properties and view properties such as camera and projection properties. Therefore, these are analyzed in a systematic manner. The global properties are set fixed for alternative visualizations created during the thesis study. The viewing angle is also fixed. However, zooming levels are differed according to LoD of the visualizations.

The fourth step is “Validation Process”, where the visual alternatives are evaluated. Based on the Visual Taxonomy, the *risk* attribute is visualized on the city object building in three different LoDs using the effective 2D visual variables suggested by the cartographers for *ordinal* data. The alternative visualizations are evaluated by the pilot user tests and expert evaluation in a workshop. Then, some alternatives are eliminated and new ones are generated. After the elimination, the new visualizations are tested with real users through a test procedure that considers *short-time* and *long-time* response to the visualizations as human perception differs with time (Chapter 9). Saliency maps that are generated upon the Itti-Koch Model are compared with eye tracker heat maps of the final user tests. This comparison is suggested to be a comparison of the usage of the variables when *bottom-up* (with saliency maps) and *top-down* (with heat maps) decision-making processes are in progress. All the results are analyzed and are discussed.

The last step involves “Guidelines for the Final Visualizations”, where the most effective, efficient and usable set of *risk* visualizations of the buildings in 3D city model is determined. The final visualizations are generated and the guidelines referencing the Visual Taxonomy are given (Chapter 10).

CHAPTER 5

METHODS CONDUCTED WITH THE END USERS AND VISUALIZATION EXPERTS

This chapter introduces briefly the methods conducted with the end users and visualization experts. Three main methods are used which are interview, user tests and expert evaluation. The reason to use both qualitative and quantitative methods is that they are complimentary methods. User tests are the most comprehensive as they include both quantitative and quantitative methods. Participant number is 30 or over 30 in user tests to statistically infer meaningful results. Why each method is used is explained in this chapter.

5.1 Interview (In Step 1)

During the first step which is “Exploration of the User Requirements” a structured interview method is conducted. The questions of the interview are planned before the interview sessions and same questions are asked to each participant (Appendix A). The main aim is to learn deeply about profiles and roles of the participants, decision making processes in Disaster Management (DM) and their first impressions about visualization of DM related information. Interview method is a qualitative method and advantageous for the researcher who is not experienced in the topic of DM. It provides deep knowledge about structures in DM and the end users in detail. Questionnaires are given after each interview to quickly collect the visualization context they consider during their decision making processes. The participants are observed throughout the day at their premises when they are visited.

5.1.1 Participants

Participants of the interview sessions are the end users who are the decision makers of DM. 20 participants are interviewed at their premises. The reason to select end users for this method is to understand their needs and requirements as the final visualizations created according to the framework are used by them during their decision making processes. The participants are aware of the 3D visualization for DM, but they are not experienced enough as they mainly use 2D visualizations during their routine work. The details of the participants are given in Chapter 6.

5.1.2 Materials

During the interview, the recordings are made using iPhone 5. Also, the answers are noted to the sheets. The simulation shown to the participants is generated in Windows Media Player in laptop. The questionnaires are given to the participants as paper sheet format.

5.1.3 Procedure

Each interview takes approximately 45 minutes. Each interview is composed of two parts (Appendix A). In each interview, a simulation of 3D model is presented to the participants and their positive and negative comments are recorded. After each interview, two questionnaire sheets are given to the participants to learn about their requirements related with the visualization context they consider during their own decision making process. These are obtained under the headings of city objects and their attributes. The details are given in Chapter 6.

5.2 Pilot User Test (In Step 4)

User tests are conducted both with the experts and end users. User tests are conducted after the alternative visualizations are created. This test method is quantitative and conducted in controlled manner. Pilot user tests are conducted with visualization experts. The experts are mainly deal with visualization especially geovisualization. Pilot tests are conducted for two main reasons. First reason is to gain positive and negative feedback from the experts who perform geovisualization. The results of these tests which are response time and accuracy are considered in Step 4 which is “Validation Process”. In pilot user tests low level of cognitive processing is considered as the participants are asked to response as soon as they decide and they are informed that the images will change every five seconds. Therefore, their decision mode is intuitive. The second reason is that as these user tests are pilot tests and if problems occur better test procedure in the final user tests which are done with end users can be created. For instance, in this thesis study, the user tests are extended to include a second part in the final user tests.

5.2.1 Participants

30 visualization experts participate to the tests. Half of the test sessions are conducted with the experts who deal with risk and uncertainty visualization who are the participants of Vienne at Risk and Uncertainty Visualization Workshop, held in 23 September, 2014. The other half of the sessions is conducted in Ankara, in October 2014 with Turkish visualization experts.

5.2.2 Materials

The visualizations are created in 3Ds max and rendered in jpeg format. The visual variables in the pilot user test visualizations are **saturation**, **brightness**, **pattern**, **transparency**, **blur**, **size** (of an **abstract object**), **hue**, **self-illumination** (for LoD 2). 28 images are embedded to Open Sesame program which is a behavioral analysis program. In each visualization, three buildings in three different Level of Details are given. Each visualization risk is visualized with one visual variable. No legend is used in order to understand participant instinctual decision. The participants used keyboard to press their decisions. In each visualization, global properties are fixed. Further details are written in Chapter 9.

5.2.3 Procedure

The pilot test procedure is very similar to the first part of the final user test procedure The only difference is the three buildings presented in the pilot tests are different.

However, the ones in the final tests are the same. Before the tests start participants perform a demo test to get used to the keyboard. Each visualization is presented to the participants for five seconds. The participants are asked to click the number of the building which they think has the highest risk from the keyboard. Response time and accuracy according to the prepared ground truths before the test are collected in Open Sesame in excel format. They are saved with the participant number. The details are given in Chapter 9.

5.3 Expert Evaluation

Expert Evaluation is done to get a broader and deeper feedback from the visualization experts. Because, the pilot user tests with the experts provide quantitative results. Expert evaluation is performed in a workshop format. The reason is that in the sessions, there is a discussion part where the presented alternative visualizations are evaluated. There is a creative activity that experts are asked to create their own ideas for risk visualization. Different materials are provided. In the workshop the participants have the chance to discuss their ideas. Therefore, topic can be deeply evaluated and new designs can be generated.

5.3.1 Participants

Five experts who deal with geovisualization in their work in practice or academic way are invited to the workshop. All of them are familiar to 3D visualization. Two of them can perform 3D visualization. The further details of the participants are given in Chapter 9.

5.3.2 Materials

In the first session, laptops are provided to the participants and the visualizations are prepared in the folders on their desktop. Sheets are given to the participants for to evaluate the effectiveness of the visualizations. The sheets are in A3 format because all of the participants' sheets are hanged on the board after they evaluate them for the discussion. In the second session, Legos, drawing pencils, papers, printouts of abstract objects are given. All of the sessions are recorded with video. Participants are asked to sign a consent form before the sessions that indicated that the study is confidential and their personal information will not be shared. Eleven types of visual variables for the expert evaluation are defined for 3D environment. The list includes **hue**, **saturation**, **brightness**, **self-illumination** usage with **hue**, **saturation** and **value**, **transparency, pattern**, **pattern** usage with **transparency**, **blur, size** usage with **abstract object** and **size** and **hue** usage with **abstract object**. Why these variables are selected is explained in Chapter 9 in detail.

5.3.3 Procedure

At the beginning, a brief explanation about the thesis topic and what has been done up to that time is presented. Afterwards, the participants are asked to introduce themselves. The first session is related to the evaluation of the alternatives. It takes approximately 70 minutes with the discussions. Alternatives are presented in different zooming views in their laptops. The experts are asked to evaluate them according to seven scales of effectiveness. During the second session, the experts are asked to create their own alternatives using Legos, drawing pencils, papers, printouts of abstract objects. This session also takes about 70 minutes with the discussions. Photographs from the workshop can be seen in Appendix E.

5.4 Final User Test

The final user tests are held in the Test Lab of User Testing and Research Lab (UTRLAB), which is located in the Middle East Technical University. This is the final step of the validation as the eliminated visual variables are presented to the participants. It is a controlled study that aims to collect both qualitative and quantitative data. Qualitative data is collected during the discussion part conducted after each session. The reason for to conduct these tests with the end users is that they are the users who interact with the visualizations during the decision making processes. Therefore, the way they percept the visualizations is important.

5.4.1 Participants

Final User Test is conducted with 35 end users who are the decision makers of DM. The users are selected to be from different range of foundations. The users are separated into two groups according to the level of decision making; executive level decision makers and DM specialists and researchers. Also they are defined according to their profession and the DM phases they work for. The details are given Chapter 9.

5.4.2 Materials

During the tests, a desktop computer and Tobii X120 eye tracker are used. The sessions are recorded using the software Morea Recorder 3.0. Also a USB camera is used. The users are asked to sign a consent form before the tests. The visualizations are again prepared in Open Sesame Program; however Open Sesame files are embedded in Tobii eye tracker software. In the first part, the images of three same buildings and fixation dot are embedded into the software and shown to the participants every five seconds. Each image has the dimension of 640x480 pixels. In each image, *risk* visualization is created using different variables. Eight types of variables are used during the first and second parts which are **brightness**, **saturation**, **hue**, **transparency**, **blur**, **contour**, **self-illumination-hue** and **abstract object-hue**. **Brightness** and **saturation** are used with both *blue* and *red*. Two different types of background are used, which are satellite view and map view in the second part.

5.4.3 Procedure

Each test is performed individually and each session takes approximately 40 minutes. At the beginning of the test sessions, participants are asked to perform a demo test. The main reason behind this is to make the participants get used to the keyboard keys and mouse clicking while they are making their choice. Therefore, the content of the demo test differs from the content of the tests. An explanation document is provided to the participants with details about the test.

The tests are composed of two parts and 10 minutes discussion part. In the first part of the final user tests, 19 images are shown (see Appendix G). Participants are asked to click on the number of the building that they think has the *highest risk* according to the image. The participants are asked to press the key immediately after they make their decision. There is no map legend given on the images. This part of the test comprises a low level of cognitive processing. The decision mode is intuitive. The participant makes a quick and unconscious response.

In the second part of the final user tests, 38 images are used (see Appendix H). In this part, the Cumhuriye district is shown. Some of the buildings on that district is visualized as having *high risk*, some of them *medium risk* and some of them *low risk*. The participants are informed that each visualization is prepared according to an artificial data, no real calculations are considered for determining each *risk* level Participants are asked to click on any building which they think is from the *highest risk* range. There is no time limit in this part; therefore, there is a slower thinking process. This part of the test comprises a high level of cognitive processing. The decision mode is deliberate. The participant makes a slow and conscious response.

After these test sessions, the images used in the second part are shown to the participants who are grouped together according to LoD and background image. Their opinions about the visualizations are asked. This part takes more than 10 minutes and it is more like a discussion part

CHAPTER 6

EXPLORATION OF THE USER REQUIREMENTS (STEP 1)

This chapter is about the first step of the framework. The aim of this step is to understand the end user's general opinion about visualization in 3D environment and what they need to visualize in this environment using of which scenario and phase. It starts with explaining the procedure for analyzing end users' requirements. This step can be considered as the starting point. The second step is "Defining the Context to be Visualized" in the designed 3D city model and comes after this step. Therefore, this step can be considered as a basement for providing the definitions of the scenario, city objects and attributes to be visualized. As it is stated in the previous chapter, the end users are the decision makers of Disaster Management (DM). In the beginning, there is no specific scenario of a DM phase that is considered to be studied for the thesis study. Therefore, all types of users from DM phases that deal with different scenarios are considered as users. However, to underline for the researchers who follows this framework, it would be possible to study with the users with a defined scenario.

The interview and questionnaire methods are used in this step. *Profiles* and *roles* of the end users are investigated through these methods. The *profile* is the user's job title, experience (in years), foundation, profession and co-workers. The *role* is his/her scope, DM phases that he/she studies, main decision processes, the tools he/she uses, scenarios he/she studies, city objects and attributes that he/she wants to see in the 3D city model visualization. At the end of each interview, a short simulation of a 3D city model is presented.

6.1 The Procedure of User Requirements Exploration

User requirements are established under two main headings; *profile* and *role*. *Profile* of each user is examined by defining user's job title, profession, experience in Disaster Management, department and foundation worked and coworkers. *Roles* of the users are specified by defining the scope of user's study/work, in which the users are active in DM phases, main decision processes gone through, the tools used, the highlighted scenarios studied, city objects and attributes considered in the decision processes.

Interview method is used to understand the needs of users. 20 users are visited at their premises. The average time which the users are allocated for the interview is about 45 minutes. During the interviews, the aim of the thesis study and a general description about the interview is conveyed to the users. Beside the interviews, users' working routines, working environments and conditions are observed and noted. The interview questions are composed of three parts (Appendix A). The first part includes general questions in order to understand the *profiles* of the users and their working routines. The second part is about the *roles* of the users, decision processes in detail, phases and the steps considered in DM, analyses, tools and visualizations required during decision processes. The second part is of great importance in order to understand the required tools and visualization methods. In the last part, a perspective animation of a 3D city model is presented. The city model includes textured buildings, transportation, terrain and vegetation. However, the model is not a finished product. Therefore, it is explained to the users that the model is a prototype and still in the design process. With the questions in this part, it is aimed to understand whether the users can take advantage of 3D Environment during the decision process. Which city objects and attribute/information are needed to be seen in the environment is discovered by conducting evaluation surveys (Appendix A). One of the surveys includes the list of possible city objects to be visualized in a 3D model. During the preparation of the list, the City GML objects are the main reference. The users are asked to choose the city objects that they want to see in the model and state how *important (high, mid, low)* the objects are to them. Also, they are asked to add the objects that are not in the list. The second survey is to identify the list of object attributes considered (Appendix A). The users' answers to the questions are gathered under the headings specified in the first step of the methodology. These specifications can be found in Appendix B and Appendix C. The city objects preferred in the model are described according to the main scenarios analyzed during the decision process. Main decision processes and scenarios of the users are listed in Appendix C. With the help of the evaluation surveys, the level of importance for each object is obtained.

6.2 Exploration of the User Profiles and Roles

The users actively work in different phases of DM. The user *profile* is composed of users from all phases of Disaster Management, from *risk assessment* to *reconstruction*. Mainly they are active in more than one phase. For instance, user 11 is active in both *preparedness* phase and *response* phase. Similarly, user 16 is active in both *risk avoidance* phase and *reconstruction* phase. As seen more clearly from Figure 6-1, most of the users are the decision makers of Ex-Ante Strategies and most of them are active in *risk assessment* phase. For example, while user 4 is only responsible for *risk assessment*, user 13 is active in *risk assessment* and also active in further phases such as *mitigation*, *response* and *recovery*. As it can be understood from the interview results, the users do not often work individually. They perform group projects and generally make decisions collaboratively.

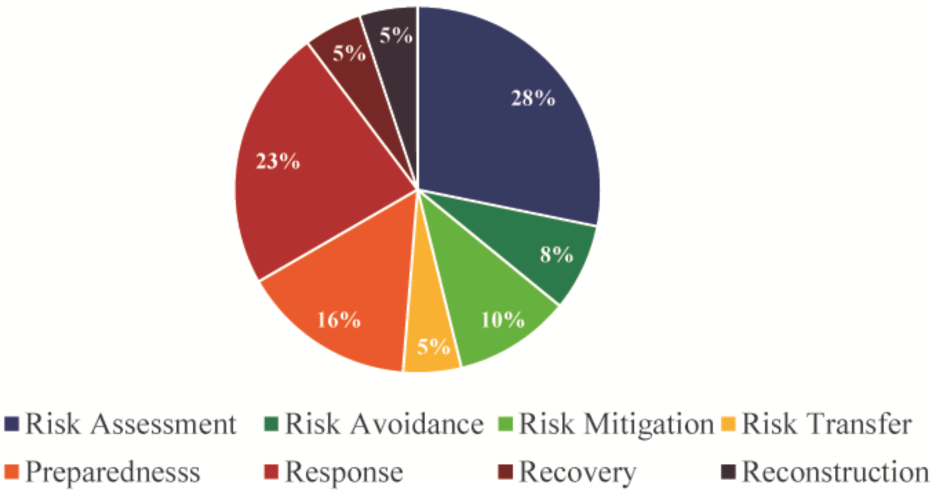


Figure 6-1: Users according to Phases

The end users are grouped under two titles according to the level of decision making; executive level decision makers and DM specialists and researchers (Figure 6-2). Six users are executive level decision makers, 10 users are DM specialists and finally four users are DM researchers. 5 users of the DM specialists and researchers deal with visualizing their exploration and analysis.

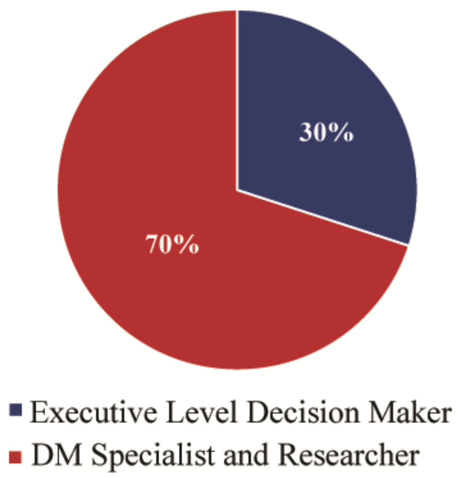


Figure 6-2: Users according to Level of Decision Making

Users are selected to be from different range of backgrounds. Although most of them work at governmental organizations such as the Prime Ministry Disaster and Emergency Management Presidency (AFAD), the Ministry of Environment and Urban Planning, some work at Non-Governmental Organizations such as AKUT Search and Rescue Association, Turkish Red Crescent; academia and financial institutions (Figure 6-3). Their distribution according to the background can be seen in Figure 6-4. 13 out of 20 users are engineers (Figure 6-4). The others are urban and regional planners, statisticians, economists and political science and public administrators. The mean experience of the users in Disaster Management is 17.15 years. There are experienced users, such as the user 13, who has been specialized in DM for 50 years, but also not-experienced ones like the user 10, who has been working for DM for two years. Appendix B gives the details of each user (Profession, Department/ Foundation, Job Title, Co-workers, Experience).

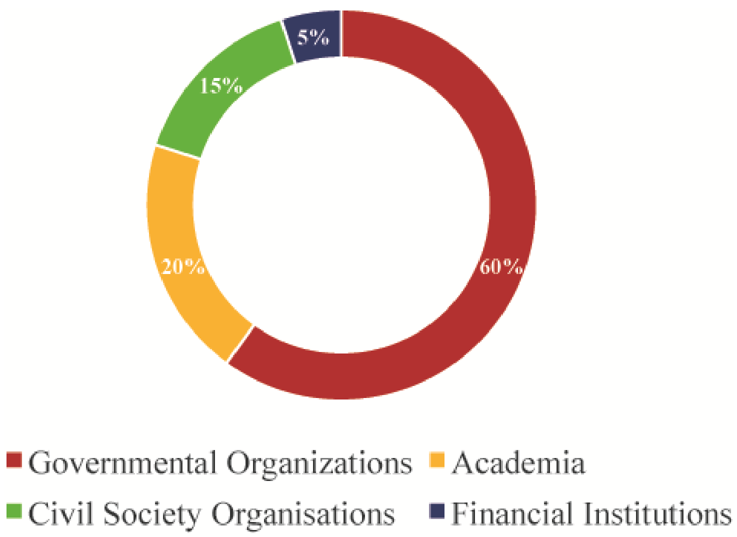


Figure 6-3: Users according to Foundations

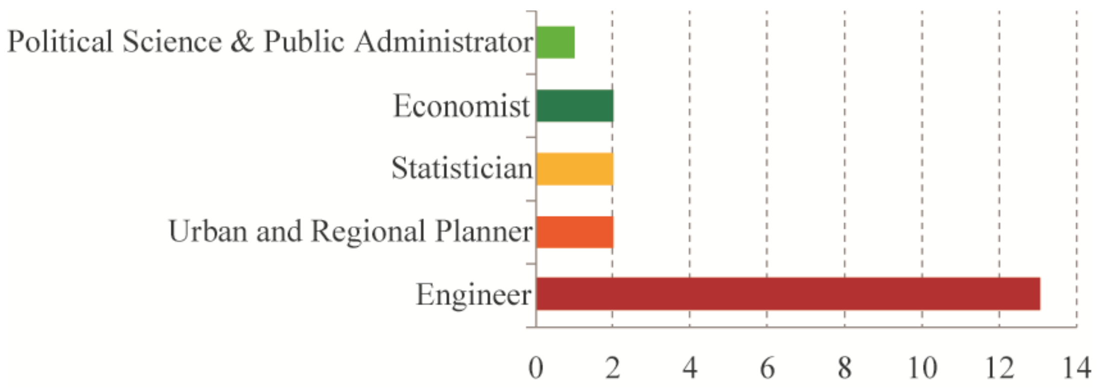


Figure 6-4: Users according to Professions

The second part is about the *roles* of the users, decision processes in detail, phases and the steps considered in DM, the analyses, tools and visualizations required during the decision processes. The second part is significant to understand the required tools and visualization methods as well. The scenarios, objects and attributes specified by the users directly affect the second step, which comprises the selection of main scenarios and the attributes needed for 3D model visualizations. These specifications of each user according to these parameters are provided in Appendix C.

CHAPTER 7

DEFINING THE VISUALIZATION CONTEXT (STEP 2)

This chapter describes the definition of visualization context based on step 1. It has a systematic approach for identifying the highlighted scenarios, city objects and attributes expressed by the users according to the involved Disaster Management (DM) phases. A Hierarchical Task Analysis method is used to understand the relationships between the phases, the tasks (scenarios) used, and main city objects and the attributes to be visualized are explained schematically in a hierarchical manner. Lastly, a scenario used in a DM phase is considered for the case study that the visualizations to be prepared accordingly.

During the interviews, most of the end users indicate that there is no standardization of visualization of the information they use, therefore most of the visualizations are complicated and not understandable. The tools they use do not have user friendly interfaces; hence few people can use them efficiently. Although as stated by Kolbe (2005), 3D visualization require extra costs such as human resources, hardware and software usage, it can be deduced that the users think that visualization in 3D Virtual has advantages more than disadvantages. Especially, they think that these environments are effective to visualize in 3D when vertical axis is considered, such as describing damage assessment/estimation, epicenter, geomorphological and geological properties. Likewise, neighborhood relations changing with the model scale can be understood better with 3D. According to Nielsen (1998) and Sebrechts et al. (1999). 2D information visualization is better perceived than in 3D and searching for information is difficult in 3D environment. However, several users state that the perspective view increases their perception as they can see the whole environment. However, some of the users indicate that 2D view is also necessary and can be supportive to 3D visualization. They state that there are conditions for 2D view to be sufficient and effective (eg. visualizing land use from top view in small scale). In the study the focus on information visualization is decided to be for pre-disaster phases since the interview results show the 3D city model can be advantageous for mainly pre-disaster phases.

7.1 Identification of the Highlighted Scenarios, City Objects and Attributes

As inferred from the users' feedback, the model can be effective mostly for Ex-Ante Strategies (pre-disaster). For Ex-Post Strategies (post-disaster), the real-time data input to the model is necessary. Ex-Ante Strategies cover the phases *risk assessment, risk avoidance*, *risk mitigation*, *risk transfer* and *preparedness*.

As it is understood from the results of the interviews and questionnaires, users together or individually perform the same type of analysis or follow the same decision process. Therefore, the same scenario can be studied by different types of users. Hence, it is better to define users not individually but within a group (Table 7-1). The groups can be arranged according to the phase in which they are actively working. Once the scenario is decided for the user group, common objects selected from the City GML standards and additional objects that the users request become the objects of the model (Table 7-2). The attributes differ according to the scenario and the user group. The detailed analyses of selected scenarios, objects and attributes for each user group are given in Table 7-1 and 7-2. As it can be seen from Table 7-1, the user groups are distributed according to the phases. The objects and attributes of each user group differ from each other. The objects and attributes are selected according to common answers and priorities defined. When the Table 7.1 and 7.2 are explicated, an obvious hierarchy between the phases, their objects and attributes can be seen. For instance, only after *risk assessment* and visualization of *risk* (the main attribute of *risk assessment*), many analysis can be performed within other DM phases. Also, steps within each phase are in a hierarchical manner. For example, *risk assessment* can only be carried out after the steps of *hazard* and *vulnerability assessment, damage* and *loss estimation* in which different objects and sub-attributes are considered. The detailed analysis of the hierarchical structure of scenarios, objects and attributes are explained in the next section.

Table 7-1: Users and Highlighted Scenarios for Each Phase

PHASES	USERS	HIGHLIGHTED SCENARIOS
RISK ASSESSMENT	U2,U3,U4,U5,U7,U9, U13, U19	* Preparation of earthquake risk map of a specific place
	U1,U15,U19	* Preparation of earthquake risk map of city objects in a specific place
H Hazard — V Vulnerability	U1,U2,U3,U4,U5,U7,U9, U13,U18	* Preparation of seismic hazard map of a specific place with integrating ground properties (H)
E Exposure	U1	* Defining vulnerability for city objects of a specific place. (V)
	U8	* Defining social vulnerability for an earthquake in a specific place (V)
D Damage Estimation	U1,U2,U3,U4,U5,U7 U9,U13,U19	* Estimation of damage when earthquake with __ parameters occurs (In which provinces,districts etc. damage would occur? How many city objects (building, lifelines etc.) would be damaged?) (D)
L Loss Estimation	U1,U2,U3,U4,U5,U7 U9,U13,U19	* Estimation of loss when earthquake with __ parameters occurs (How many people would die or get injured? What would be their loss of property) (L)
RISK AVOIDANCE	U15, U16,U17	* Urban Renewal (First strategy: in place) considering social and economic conditions (Can the renewal be in place or residents should be moved to low-risk areas? Where should new buildings be located? What are the proposed social and economic conditions?etc.)
MITIGATION	U1, U6, U8, U13	* Preparation of roadmaps for minimizing loss if an earthquake with __ paramaters occurs?
RISK TRANSFER	U19, U20	* Preparation of strategies for shifting risk from placeholders to insurers
PREPAREDNESS	U11, U12, U13, U14, U18,U20	* If an earthquake with __ parameters occurs in a specific place what should be the response plan? (How much food supply should be sent? Where shoud be the shelters located, how should be the heath service?etc.)

Table 7-2: Objects and Attributes for Each Scenario

HIGHLIGHTED SCENARIOS	HIGHLIGHTED OBJECTS	HIGLIGHTED ATTRIBUTES
• Preparation of earthquake risk map of a specific place	Terrain, Land Use, **E**	Risk
• Preparation of earthquake risk map of city objects in a specific place	Building, Lifelines, Transportation, **E**	Risk
• Preparation of seismic hazard map of a specific place with integrating ground properties **H**	Terrain **E**	Earthquake Hazard Potential
• Defining vulnerability for city objects of a specific place. **V**	Building, Terrain, Lifelines Transportation **E**	Physical Vulnerability
• Defining social vulnerability for an earthquake in a specific place **V**	Building, Land Use,Terrain **E**	Social Vulnerability
• Estimation of damage when earthquake with __ parameters occurs (In which provinces,districts etc. damage would occur? How many city objects (building, lifelines etc.) would be damaged?) **D**	Building, Transportation, Lifelines, Terrain **E**	Damage Estimation
• Estimation of loss when earthquake with __ parameters occurs (How many people would die or get injured? What would be their loss of property) **L**	Building, Lifelines, Transportation, Land Use, Terrain **E**	Loss Estimation
• Urban Renewal (First strategy: in place) considering social and economic conditions (Can the renewal be in place or residents should be moved to low-risk areas? Where should new buildings be located? What are the proposed social and economic conditions?etc.)	Building, Lifelines, Transportation, Land Use, Terrain	**Terrain/Land Use:** Risk, Loss Est. **Building/ Land Use:** Economic, educational, social, ownership, neighbourhood profiles, Damage Estimation **Transportation/ Lifelines:** Types, Damage Estimation
• Preparation of roadmaps for minimizing loss if an earthquake with __ paramaters occurs?	Building, Lifelines, Transportation, Land Use, Terrain	**Terrain/Land Use:** Risk, Loss Est. **Building / Land Use:** Demographic, social, educational and economic profile, Damage Estimation **Transportation/ Lifelines:** Types, Damage Estimation
• Preparation of strategies for shifting risk from placeholders to insurers	Building, Land Use	**Building:** Risk,number of floors, year of construction, number of occupants, material, type, surface area of apartment **Land Use:** Population, Loss Estimation, Cumulative Risk-portfolio
• If an earthquake with __ parameters occurs in a specific place what should be the response plan? (How much food supply should be sent? Where shoud be the shelters located, how should be the heath service?etc.)	Building, Lifelines, Transportation, Land Use, Terrain	**Building:** Occupants' profile, Risk Damage Est., type **Terrain:** Slope, ground properties **Land Use:** Vacancy, Risk, Loss Estimation **Transportation/ Lifelines :** Type, Damage Est., Availability

According to the results of the questionnaire, the most *important* city objects for users of all phases are found to be Building, Terrain, Transportation, Land Use and Lifelines (Figure 7-1). However, their preference changes according to the phase (Table 7.2). Vegetation and City Furniture are described as the objects that have the *lowest importance*. Waterbody is found to be *important* for five of the users; however, seven users even do not consider it as an object to be visualized in the 3D model. Users suggest adding objects such as infrastructure, city cameras and stations. The positional information of all the objects is the most preferred attribute to be seen in the model. In addition, according to most of the users, information about population should be visualized. The related object of population attribute differs according to the phase of the user. For instance, the users of *mitigation* consider the population of a region, but the users of *risk transfer* considers the population in a building (the number of occupants) to be visualized. Furthermore, demographic, economic, social, and neighborhood profiles of the population should be specified according to the users of *risk mitigation and risk avoidance* (Table 7-2). All of the attributes preferred by the users of each scenario of the phases can be seen in Table 7-2.

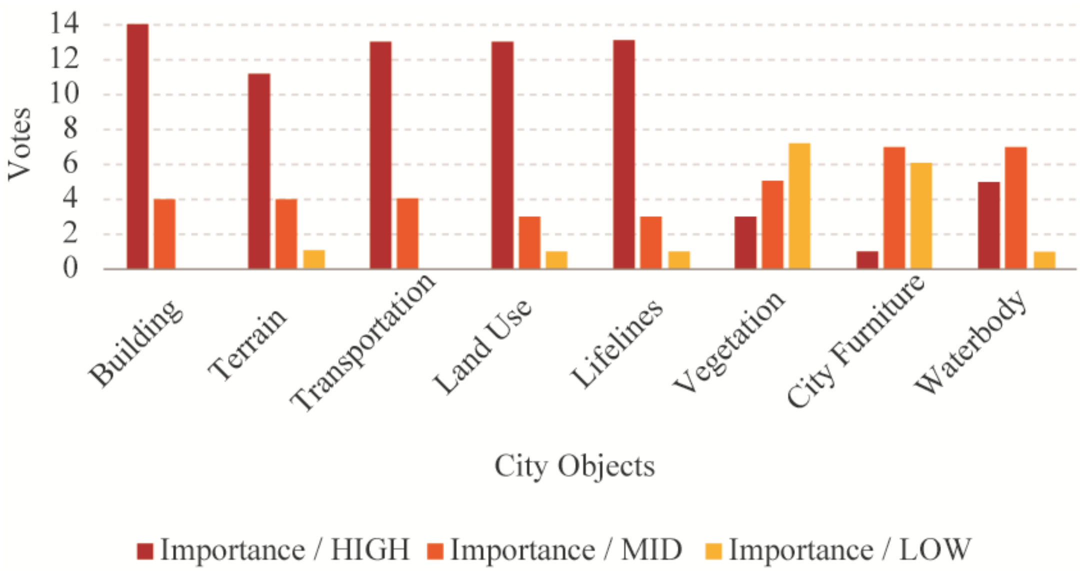


Figure 7-1: Highlighted City Objects by all Users

7.2 Methodology for Defining the Visualization Context

In pre-disaster phases, decision makers need to establish certain scenarios to achieve various goals. The scenarios include tasks that decisions makers perform in different DM phases. Moreover, these tasks can be divided into multiple levels of sub-tasks. From User Experience perspective, the Hierarchical Task Analysis method can serve this type of organization. Once the Hierarchical Task Analysis is carried out, it can serve as an effective form of the overall system, enabling designers or developers to rapidly understand and analyze how users interact with the system. The Hierarchical Task Analysis requires a detailed understanding of users' tasks. This can be achieved by identifying users' primary goals, detailing the steps that users must perform to accomplish their goals and optimizing these procedures (UX Matters, 2010).

The Hierarchical Task Analysis method allows the comparison of different approaches to supporting the same task by different users. Furthermore, it is effective for designers to understand how a system works. Therefore, multiple implementations of a design pattern can be captured (UX Matters, 2010). The Hierarchical Task Analysis of the phases is given in Figure 7-2. Here, target users and five DM phases are examined. The parent task, which is Task 1, under *risk assessment,* is "Preparation of earthquake risk map of a specific place/city object". The sub-tasks are broken down under Task 1, because they are the steps required to complete Task 1. These sub-tasks are Task 1.1 "Preparation of seismic hazard map of the place", Task 1.2.1 "Defining vulnerability of city objects in the place", Task 1.2.2 "Defining social vulnerability of the place", Task 1.3 "Estimation of damage when earthquake with __ parameters occurs in the place", and Task 1.4 "Estimation of loss when earthquake with __ parameters occurs in the place". Each sub-task may act as parents of sub-sub tasks but they are not specified yet. Task 2 under *risk avoidance* is "Creating an urban renewal strategy of a high-risk place". This is a task following Task 1 because in order to create a strategy for a high-risk place, the *risk assessment* of the place should be performed and high risk areas should be specified. Task 3 under *mitigation* is "Preparation of a roadmap for minimizing loss of the place". Task 4 under *risk transfer* is "Preparation of a strategy for shifting the risk from placeholders to insurers". Task 5 under *preparedness* is "Preparation of a *response* plan if an earthquake occurs in the place". Task 3, 4, and 5 are also the tasks that should be conducted after Task 1 as well. Although the strategies of each phase affect each other, in terms of parent-child task relationship, there is no significant relationship between Tasks 2, 3, 4 and 5. The users of each task differ. Therefore, objects to be visualized differ according to each task. Each task has main objects and attributes to be visualized (Figure 7-2 and 7-3). In addition, tasks have sub-tasks considering the visualizations of sub-attributes. For example, for Task 2, which is

“Creating an urban renewal strategy of a high risk place”, the city objects needed to be visualized are Building, Transportation, Lifelines, Terrain and Land Use. The main attributes that should be visualized are *risk* (main attribute of Task1/*risk assessment*, *damage estimation*, *loss estimation*, and *vulnerabilities* (sub-attributes of Task1/*risk assessment*). The sub-attributes to be visualized are Economic, Educational, Social, Ownership and Neighborhood Profiles, Transportation and Lifelines Types. These attributes can be planned to be used under sub-tasks. For instance, “Analysis of social and economic profiles of the population during the renewal of high risk area to low risk area” can be a sub-task. Sub-tasks are specified by the users from each phase and confirmed by them before the preparation of visualizations. This analysis can be expandable and even sub-sub tasks can be detailed.

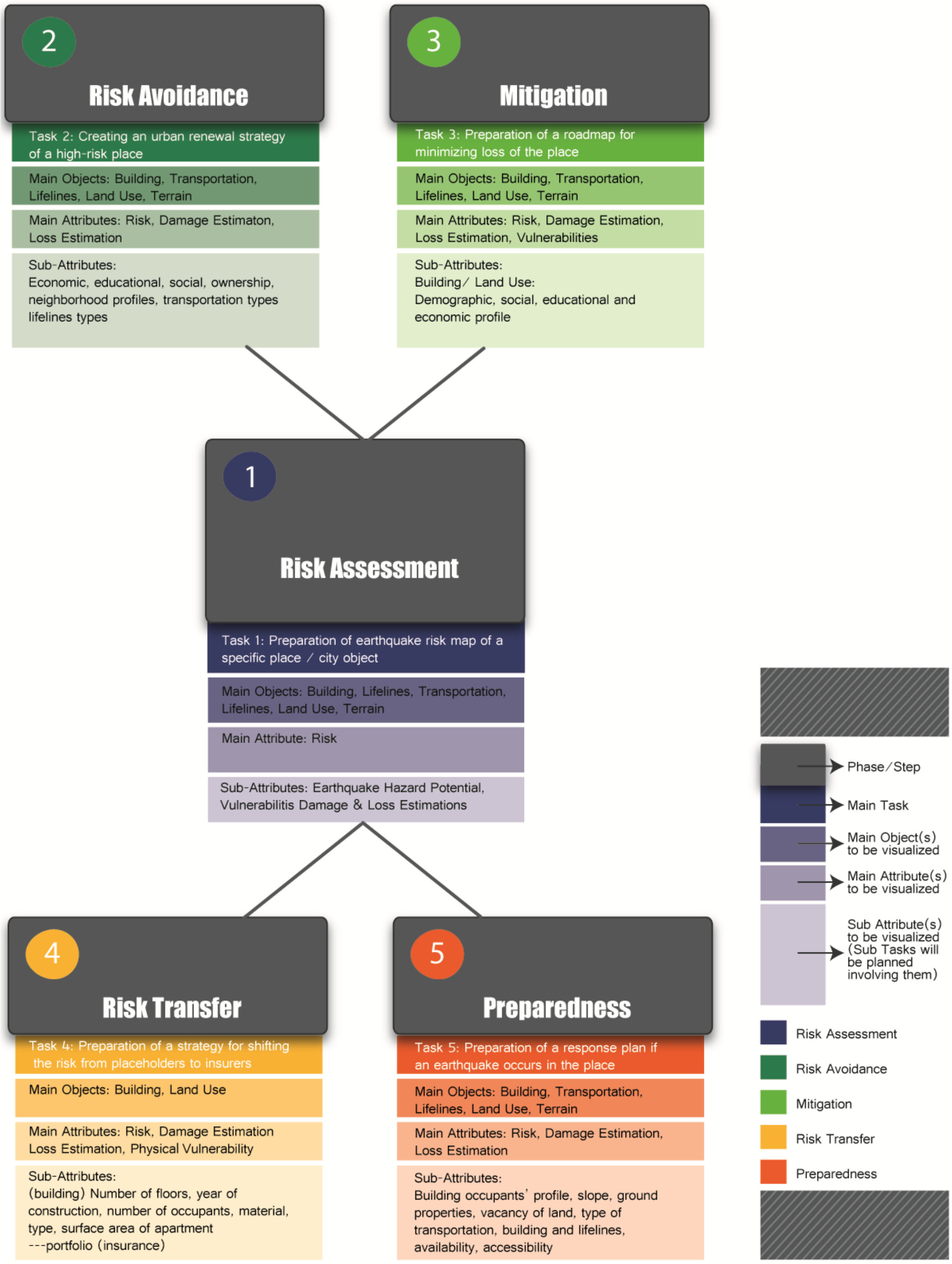


Figure 7-2: Hierarchical Task Analysis for Pre-Disaster Phases

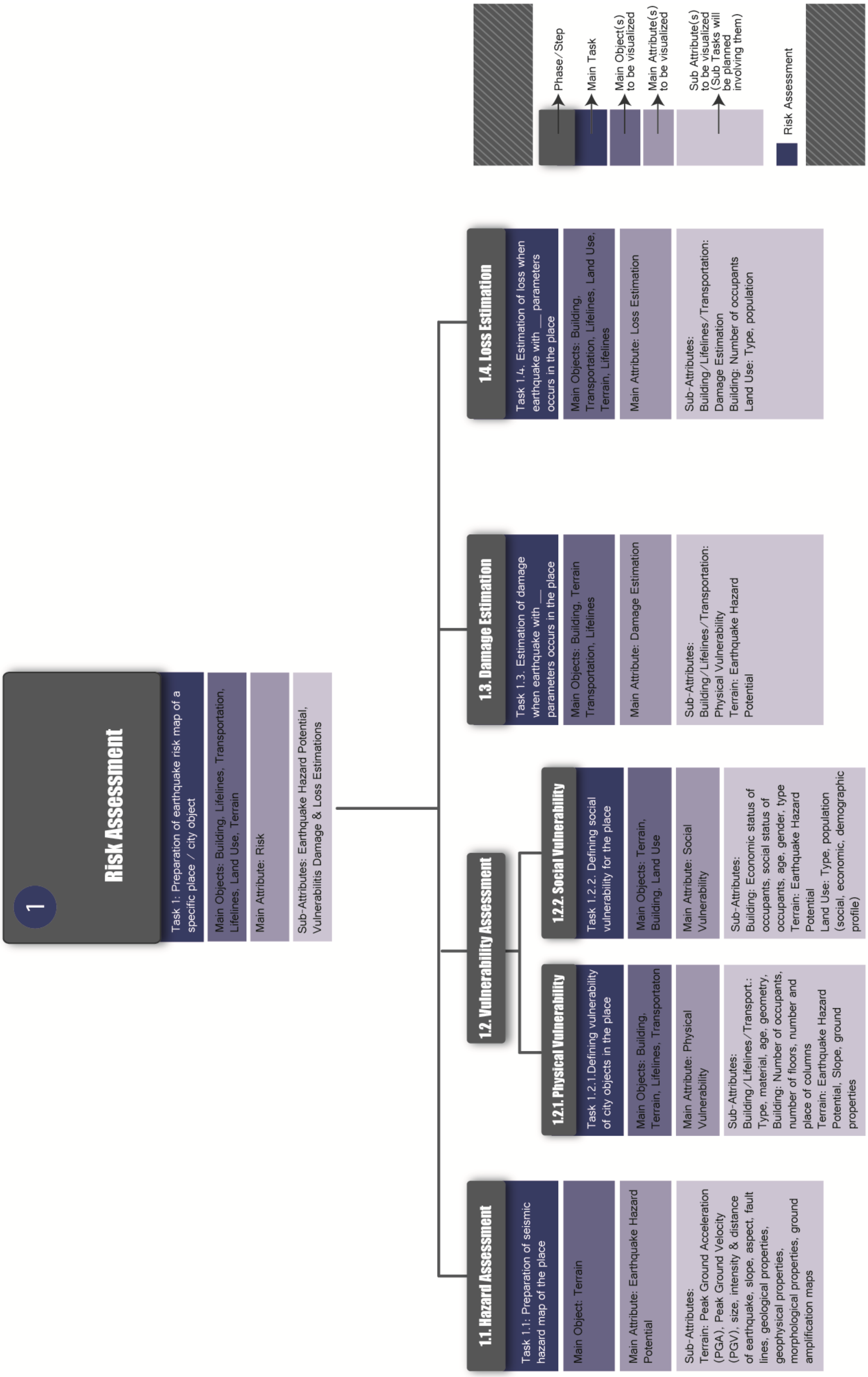


Figure 7-3: Hierarchical Task Analysis for Risk Assessment Phase

7.3 Visualization Context of the Case Study

A case study is designed by considering a scenario from *risk assessment* phase. The reason for this choice is that according to the Hierarchical Task Analysis, *risk assessment* phase is the fundamental phase that all other pre-disaster phases are connected to. Therefore, it can be considered as the starting point of DM where different types of users interact with *risk assessment*. According to the case study, the *risk assessment* of the buildings is assumed to be visualized by scoring the building according to the criteria of accessibility during disaster, the structured features of the building, and the number of residents. This step, which is called prioritization, is a part of *risk assessment*. Fake scores are conducted for each building and each score is turned to *ordinal* data which depicts *low*, *medium* and *high risk.*

CHAPTER 8

CREATION OF THE VISUALIZATIONS ACCORDING TO THE VISUAL TAXONOMY (STEP 3)

This chapters starts with the definition of the Visual Taxonomy proposed in the thesis. This taxonomy is created for designers to help them systematically create and define their visualizations. This taxonomy can be used not only for Disaster Management (DM), but also for the disciplines which include decision making process and visualization generation for the decision makers. In this chapter, the proposed dimensions of the taxonomy are described. Any attribute to be visualized can be defined on these dimensions. These are informed in the first part. The definition of 2D visual variables in 3D environment is also explained in this part. In the second part, the case study for visualization is described. In the last part, the visualization platform and visual variables created on the city object building used are explained.

8.1 The Visual Taxonomy

Three dimensions are considered for establishing the Visual Taxonomy (Figure 8-1). These are Measurement Scale (*Level of Measurement: nominal, ordinal, interval/ ratio*), Level of Detail (*LoDs specified by City GML standards*) and Visual Variables *(size, color, texture etc...).* The dimensions of the taxonomy are illustrated in an example (Figure 8-2).

The first dimension is the Measurement Scale. As it is discrete, it is defined as an axe. This dimension defines the measurement scale of the attribute. Three types of measurement scale are defined, which are *nominal* and *ordinal* data for categorical level and *interval/ratio* data for continuous level (Figure 8-1). Data which is measurable and quantitative is categorized as *interval/ ratio*. The distinction between *interval* and *ratio* is ignored and they are combined as one category. In this thesis study, the attributes that should be visualized are categorized according to these data measurement scales. For instance, type of a building is a *nominal* data, where the building can be a hospital, a school or a residence. On the other hand, the number of floors is an *interval/ ratio* data like 1, 2…18…etc. Although *risk* can be expressed as *ordinal* data, e.g. *low risk*, *medium risk* and *high risk*, it can also be expressed as *interval/ ratio* data. The measurement scale is directly related to visualization because the measurement scale gives clues for visualizing the city objects and attributes in the virtual model.

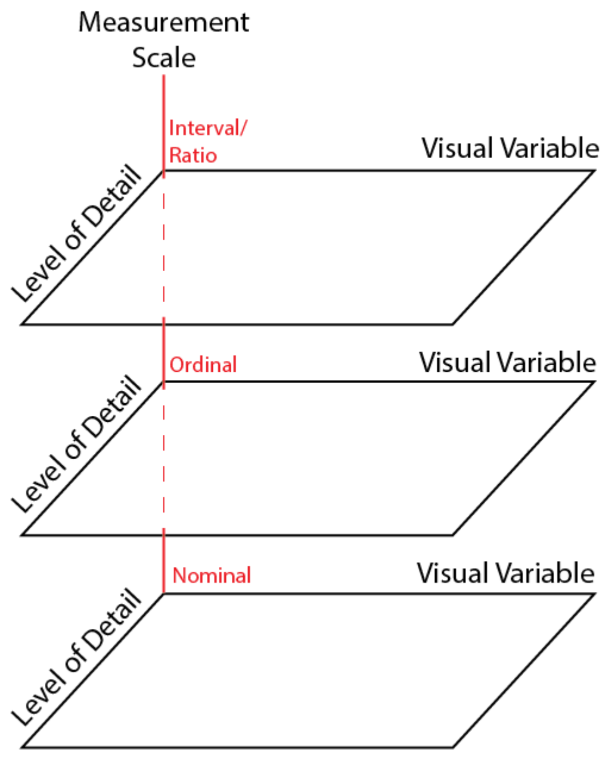


Figure 8-1: The Dimensions of the Visual Taxonomy

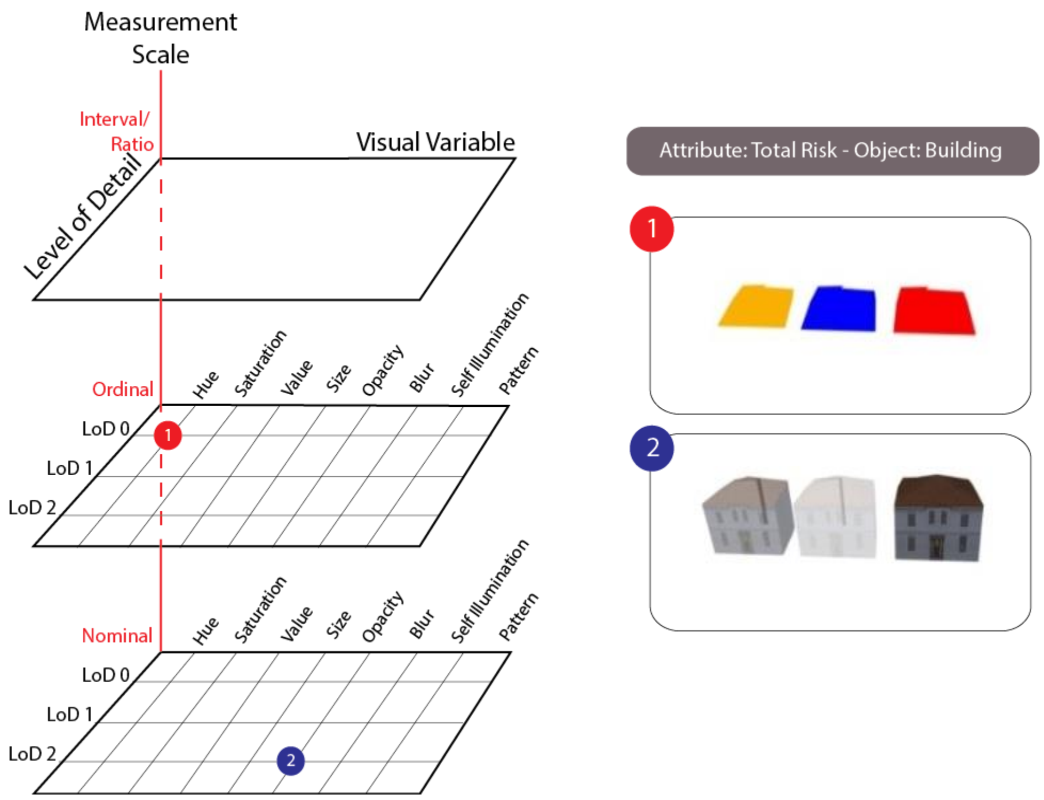


Figure 8-2: The Dimensions of the Visual Taxonomy with an Example

The second dimension is the Level of Detail (LoD), which defines the geometric detail of the city object that is going to be modeled. It is therefore directly related to visualization. The abstraction which is converted into visible representations is called LoD (Kemeç, 2011). LoD can directly be related to the resolution, hence the identification of city objects in 3D modeling (Kemeç, 2011). The City GML introduces LoDs for many objects. The one developed for buildings can be seen in Figure 8-3. Also, there is a LoD definition of the City GML which covers the whole city model (Figure 8-3). This taxonomy defines the attribute that is expressible with the City GML definitions. The LoD of each city object can be defined according to the City GML standards (Gröger et al., 2012). Therefore, the election affects the visualization of the city objects and the attribute. This dimension is not discrete as different Level of Details can be added.

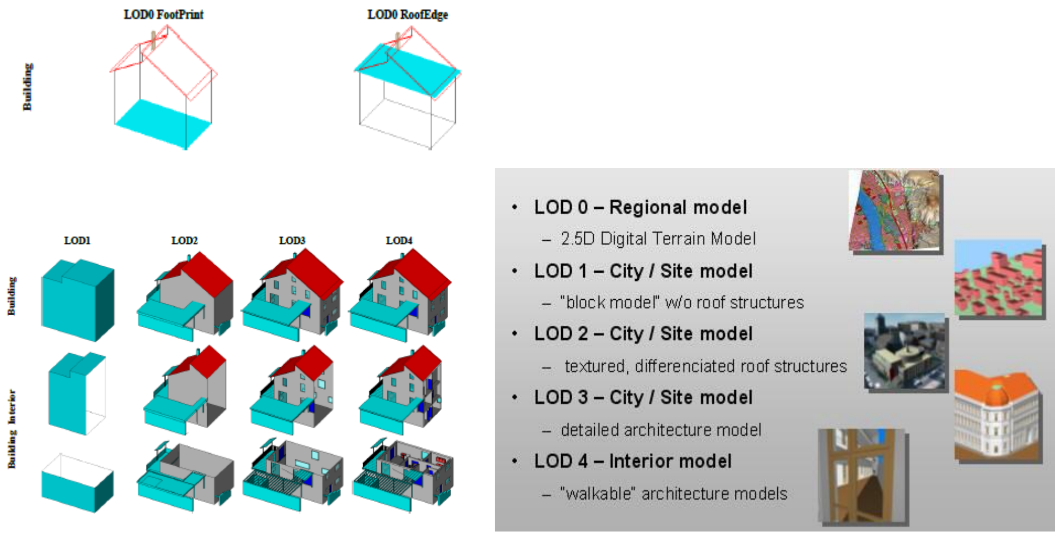


Figure 8-3: Building Model in LoD 0 - LoD 4 in the City GML (Groeger et al., 2012)

The third dimension is the Visual Variable. The dimension of variables is continuous and defined on the plane. The visual variables are determined based on Bertin's variables as well as other variables which are suitable for 3D visualizations. The visual variables can be listed as **size**, **shape**, **hue**, **saturation**, **orientation**, **texture**, **lightness**, **location**, **arrangement**, **focus**, **resolution**, **spacing**, **transparency** and **perspective height** (Halik, 2012) (Figure 8-4). Visualization for different measurement scales with different visual variables is discussed by Morrison (1974), Bertin (1983) and MacEachren (1995). They create syntactics, which suggests *acceptable/unacceptable*, *usable/possible/impossible*, *good/marginal/poor* visualizations in charts (Chapter 2).

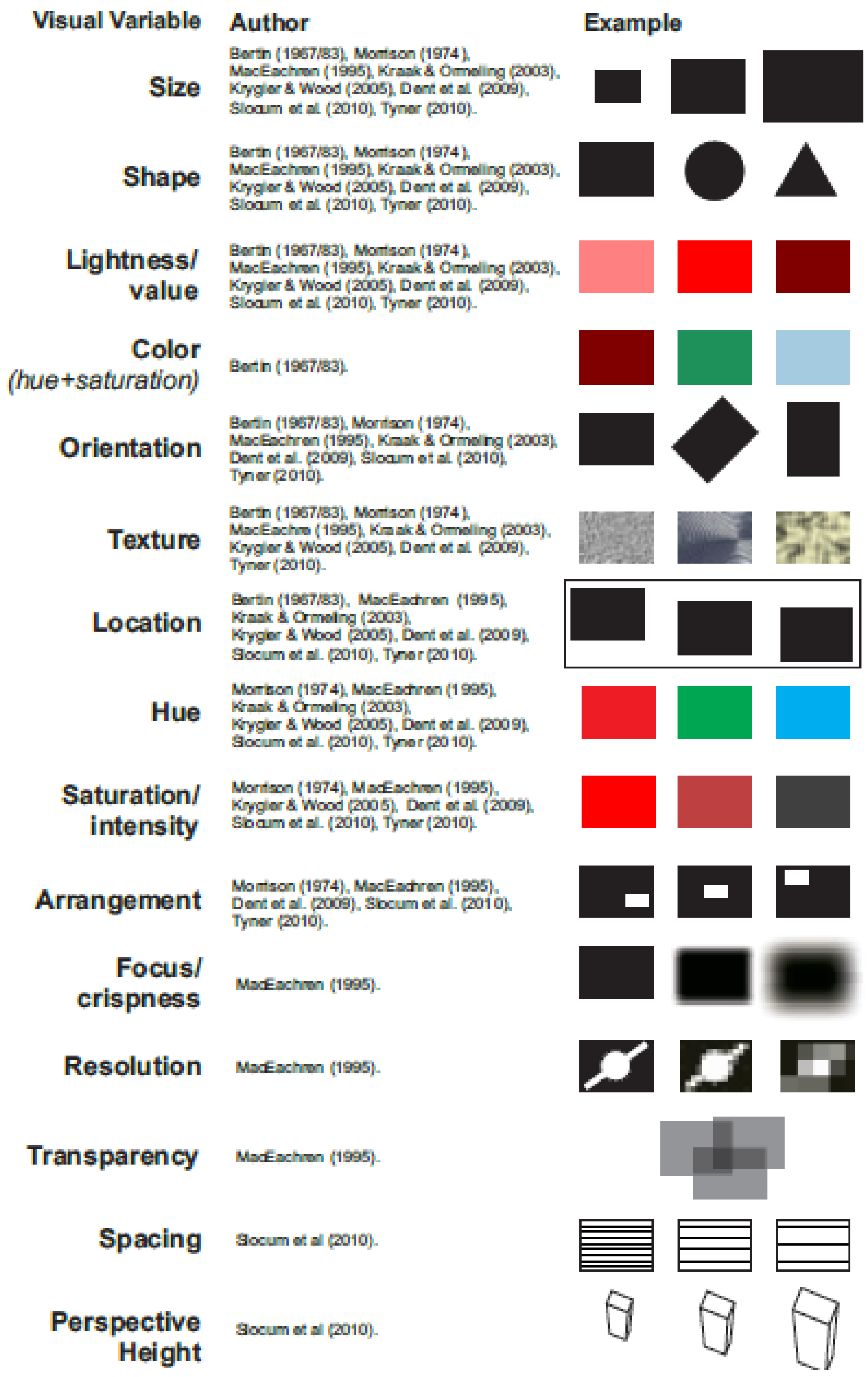


Figure 8-4: The Static Visual Variables (In Halik, 2012)

Although many authors study how to convey data effectively and efficiently with visual variables in 2D environment, few studies focus on their extended structure with design mechanisms in 3D environments. In fact, the perception of basic visual variables in 2D environment differs in many aspects when compared to their perception in 3D environment. In 3D environment, global mechanisms can be created in a scene where lighting, shading, shadowing, exposure, background and environmental properties can be defined. Moreover, change in viewport affects the perception. Perspective views enable depth of field. Therefore, expressions of visual variables are tightly linked with global and viewing design mechanisms. Furthermore, as it can be seen in many 3D modelling software (Unity, 3Ds Max, Rhinoceros, x3D), any object is visualized by changing the components of material and texture/map properties in 3D environment. A visual variable can be defined in a more complex manner. For example, **color** is defined as **diffuse color**, **emissive color** and **specular color**. **Texture** can be visualized by UVW mapping properties which are mathematical texture mapping techniques for coordinate mapping of an object (UVW Coordinates (2014).

Jobst et al. (2008) explore new potential methods for representing 3D city models and discuss the incorporation of design mechanisms of 3D with Bertin's theory of graphics. They emphasize the need for usability evaluations for extended semiotic structures for 3D applications in GIS. They also emphasize the conflicts that appear when visual variables are presented with 3D design mechanisms. Jobst et al. (2008) focus on five visual variables, which are **form (shape)**, **size**, **color**, **brightness** and **pattern**. According to them, lighting influences **color** and **brightness**. The reaction of an object's surface with lighting and the combination of lighting color with an object's surface bring about different impacts. When lighting increases, the object is seen brighter and **color** becomes more unsaturated. Shading influences **color** as **brightness** and **saturation** are changed. Shading influences **textures** because of the shadows. Shading also affects an object's **form**. If shading is hard, it is impossible to differentiate between the object's **form** and its shadow. Atmospheric property affects the **brightness;** therefore it affects the **color** that is perceived. The depth of field affects the perception of the **size** of the object. Besides changing these parameters, changes in object's material, texture, transparency and orientation affect the perception of five basic graphical variables (Jobst et al., 2008). In order to reduce these effects, they propose a non-realistic rendering technique (NPR). This is a kind of cartoon-like visualization which creates a controlled environment that directly uses graphical variables and design mechanisms in cartography (Jobst et al., 2008).

Fosse et al. (2013) test different types of shading on 3D model objects which are visualized in different colors. By using different light sources such as headlight, directional light, point light, and spot light, and without a light source, they present shading variations of the model. They conclude that more research should be conducted to better define color for each object and to better control the type of light source and the location to depict the thematic characteristics of geographic phenomena. In another research project in the Institute of Cartography, ETH Zurich, design variables for 3D maps, such as viewing distance, sky structure, lighting direction, haze density, atmospheric affects and natural phenomenon, are evaluated by experts and 19 guidelines are listed (Haeberling, 2004a). Haeberling (2004b) again studies design aspects and graphical variables specifically for 3D mountain maps. The shape of point and line objects (the aspect of object abstraction), the size of point and line objects (the aspect of object dimension), viewing inclination (the aspect of camera), zoom grades (the aspect of camera), illumination azimuth (the aspect of lighting), sky structure (the aspect of atmospheric effects) and haze gradient (the aspect of atmospheric effects) are evaluated.

Apart from global mechanisms, viewing mechanisms of 3D environment are also discussed. The expression of perspective views depends on camera properties for the viewport. These parameters are field of view, camera distance, and view angle within the scenery (Döllner and Buchloz, 2005). According to Haeberling (2004a), an inclination angle of 45^o in average is preferable to look at a 3D cartographic landscape. Jobst and Döllner (2008) investigate viewing alternatives for conveying information effectively in 3D virtual city visualization. According to them, the modification of standard perspectives with the techniques of progressive and degressive perspective reduces dead values on the information interface.

Although some authors study cartographic design issues in 3D environments, 3D cartographic design principles are still in their preliminary stages. There is still not enough knowledge about the user's requirements of 3D cartographic design (Pegg, 2012). The 2D static variables should be redefined for 3D environment. By examining three well-known 3D CAD programs, which are Autodesk 3Ds Max, Rhinoceros and Unity, the adaptation of visual variables is defined for this thesis. As it can be seen in Table 8-1, in 3D environment the **shape** of the object can be **point**, **line**, **area** or **3D element**. **Size**, **location** and **orientation** are defined according to the x, y, z coordinate system. The **resolution** of objects in 3D environment can be defined if the scene is rendered as a 2D image, which is out of the scope of this thesis study. Besides these, objects can be defined by *material* and *texture*, which is the main definition held by 3D CAD programs and the City GML appearance model. If the objects do not have **texture**, they are defined by **ambient color**, **diffusive color**, **emissive color**, **specular color**, **smoothness**, **transparency**, **shininess**, **reflectivity**, **refractivity** and some post effects such as **focal blur**, **self-glow (self-illumination) etc.** Objects can have **texture**. Simply they can have an image as textured and bump image as textured which makes the object more realistic. The texture wrapping properties of objects which can be done by UVW mapping in modern CAD programs define the pattern on the objects, or in other words how a 2D map is wrapped on a 3D object (Table 8-6).

Table 8-1: Adaptation Schema of Static Visual Variables for 3D Environment

2D Static Variables	Adaption of Visual Variables for 3D environment	
* Color Value * Color Hue * Color Saturation * Shape * Size * Texture * Location * Focus (Crispness) * Transparency * Resolution * Orientation	* Shape > Point, line, area, 3D element * Size > Size in x, y, z * Location > Coordinates in x, y, z * Orientation > Rotation in x, y, z * Resolution > Resolution	
	Material	**Texture**
	* Color > Ambient Color - Value, Hue, Saturation Diffuse Color - Value, Hue, Saturation Emissive Color - Value, Hue, Saturation Specular Color - Value, Hue, Saturation * Focus > Focal blur / Gaussian blur(post effect) * Transparency > Opacity <u>Additional Variables:</u> * Smooth/ Soften * Reflectivity * Refractivity * Gloss Finish/ Shininess * Glow / Self Glow/ Illumination (post effect)	* Map- Image * Bump Map- Image * Wrap mode / UVW properties

During the visualizations of the attributes of the case study, 3D design mechanisms are considered (Table 8-2). These mechanisms are adapted visual variables, view properties, and global properties. View properties include camera properties and projection properties. Global properties include lighting, shadows, background, shading and atmospheric properties. For this study, global properties are set fixed. The spot lighting with the intensity of 0.7 multiplier in 3Ds Max is used and it is placed slightly from a head which is based on the guidelines given by Haeberling (2004a). For the shadow type, ray traced shadow with 0.1 density is used. Also, a skylight is placed with the intensity of 0.4 multiplier in the environment. The render of each image is done when active shade mode is used in 3Ds Max.

Table 8-2: Design Mechanisms for the 3D City Model

Adapted Visual Variables	View Properties	Global Properties
* Material properties * Texture properties	* Camera properties (position, focal length, viewing direction) * Projection properties (perspective)	* Lighting (type and position) * Shadows * Background * Shading * Atmospheric Properties

8.2 The Case Study

Cumhuriye district in Eskişehir, Turkey is modeled as the case study. The reason to select this area is related with the availability of data. The main attribute is the *total risk* score of the building, which is visualized as *nominal* data, as *low risk*, *medium risk* and *high risk*. This *risk* score is gathered from a prioritization process where criteria such as accessibility during a disaster, the structural vulnerability of the building and the socio-economic vulnerability of the dwellings. The total scores are obtained weighing the scores of each criterion. Instead of using original scores, fake total scores are used. The buildings' *risk* scores have three categories as *high risk*, *medium risk* and *low risk*. Therefore, the measurement scale in the first dimension of the Visual Taxonomy is *ordinal*. The model is prepared in three different LoDs, which are LoD 0, LoD 1 and LoD 2 (Figure 8-5).

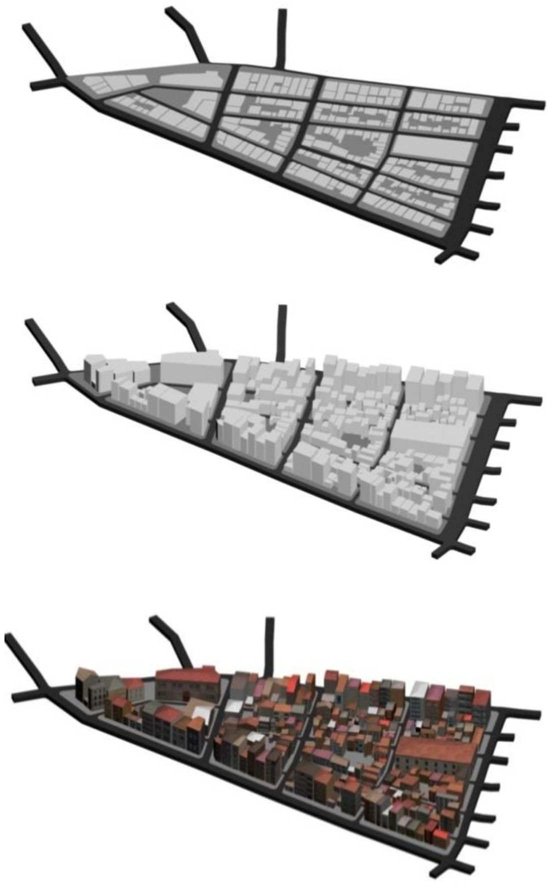


Figure 8-5: The City Model in Three Different Level of Details (LoDs)

8.3 The Visualization Platform

The visualization platform which is used for the study is Autodesk 3Ds Max, as it has basic 3D CAD modeling functions. In this platform, global and viewport properties can be changed. Also, visual variables can be adapted to 3D environment. Post effects can be created to the materials which are textured or not.

The buildings are textured according to unwrap UVW mapping property. Whole faces of the building are flattened as a 2D map. UVW map is rendered as a template. The template is imported to the Photoshop. Textures are prepared which are suitable for each face and a single image containing all the face textures which are obtained by using Photoshop. Then the image is imported to 3Ds Max. The prepared map is assigned to the building (Figure 8-6).

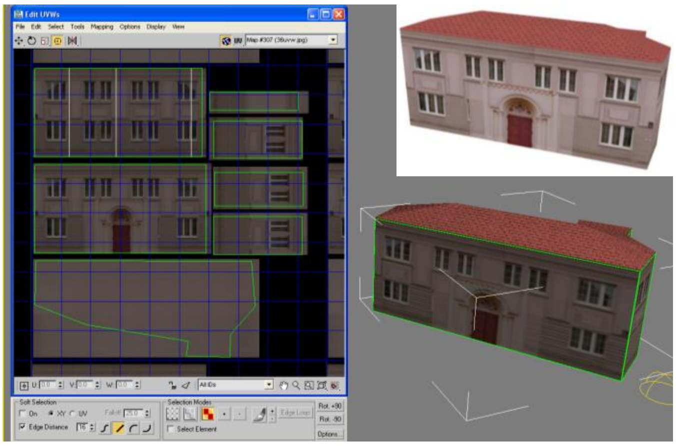


Figure 8-6: Wrapping Textures to the Buildings

As it is decided to visualize *risk* as *ordinal* data in the visualizations of the thesis study, the syntactics according to Morrison (1974), Bertin (1983) and MacEachren (1995) for *ordinal* data is analyzed again. With respect to these syntactics, *ordinal* data can be effectively visualized with **size**, **value**, **saturation**, **pattern/texture**, **orientation**, **location**, **resolution**, **crispness** and **transparency**. In this thesis, whether these variables can be effective in 3D environment or not is investigated. Moreover, it is also questioned whether other visual variables that are thought not to be effective for 2D can actually be effective in 3D environment or not. However, **location** and **orientation,** which directly affect the position properties, are disregarded. Also **resolution, which** cannot easily be created in 3D environment, is not considered. In this thesis, it is suggested that the variables **hue** and **self-illumination** can be effective as well as for visualizing *risk* as *ordinal* data and added to the list to be considered during this thesis study (see Table 8-3 for the list).

Another categorization of visual variables is studied by Bertin (1983). In this categorization, visual variables are classified according to whether changes in a given variable enable the performance of a particular task. This is called the characteristic of Bertin's list of visual variables. The details of this categorization are explained in Chapter 2. According to this approach, a visual variable is *ordered* if changes of this variable can be seen in an *ordered* manner (Bertin, 1983). **Position**, **size** and **value (brightness)** are ordered. However, **shape**, **hue**, **orientation**, **texture** are not ordered (Carpendale, 2003).

The focus in this thesis is on *ordinal* data. **Hue** is not considered to be effective for visual interpretation of *order*. Similarly, **texture** is thought to be an ineffective property to be *ordered*; however, it is found to be effective by Bertin (1983) and Morrison (1974). From the given perspectives, the definitions of **pattern** and **texture** are not consistent within the cartographers' approaches. However, **size**, **saturation** and **value (brightness)** are thought to be effective according to Bertin (1983) and Morrison (1974). **Location** is only defined as acceptable by Bertin (1983). **Resolution**, **transparency** and **crispness** are found to be effective by MacEachren (1995). The suggestions of these cartographers are taken into consideration for the visualizations prepared in this thesis study. Before each step of the validation process, which visual variables are tested with the users and experts are given (Chapter 8).

CHAPTER 9

VALIDATION PROCESS (STEP 4)

The "Validation Process" is composed of literature review, pilot user tests, expert evaluation and final user tests (Figure 9-1). As it can be seen in Figure 9-1, two eliminations occur between these steps. The details of each step are explained in this chapter. The pilot tests and expert evaluation were conducted by visualization experts. On the other hand, final user tests were conducted by end users who are DM decision makers.

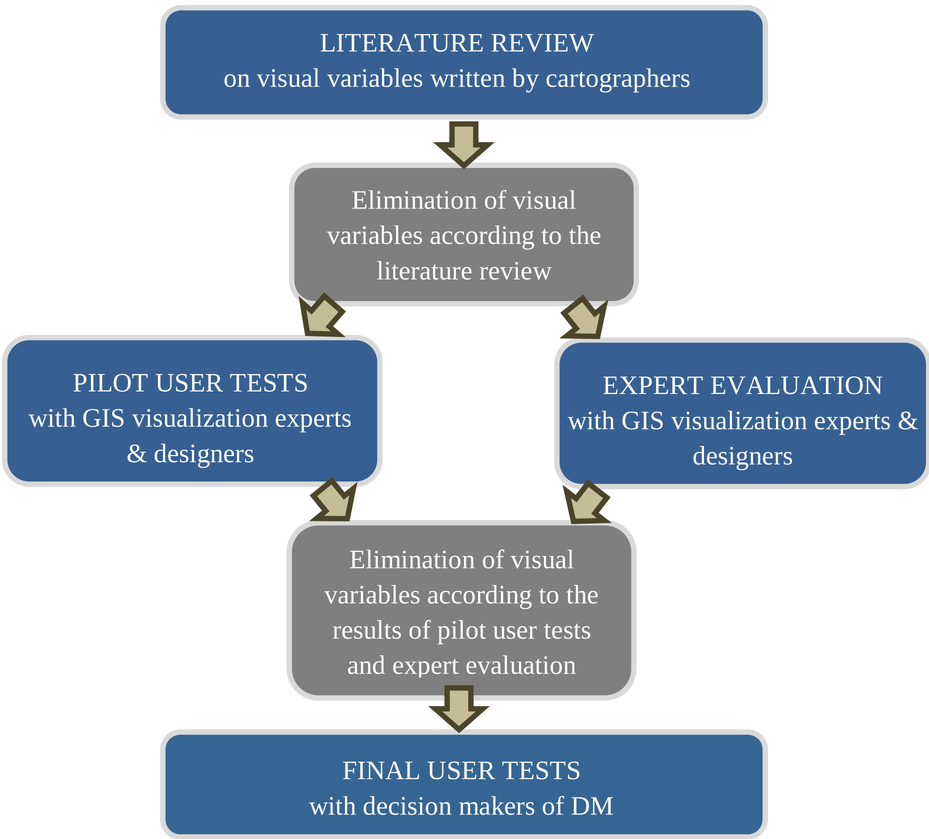


Figure 9-1: Flowchart of the Validation Process

9.1 The Pilot User Tests

Before starting the pilot user tests, the visual variables that could be effective for visualizing *risk* are decided. For this decision, the theories from the literature related to effective visualization for *ordinal* data visualization are considered (Figure 9-2). According to Morrison (1974), Bertin (1983) and MacEachren (1995), some visual variables are effective while some are not for visualizing *ordinal* data. Their common suggestions are **saturation**, **size**, and **brightness (value),** which are found to be effective for visualization. According to all of them, **hue** is not good for representing *ordinal* data. MacEachren (1995) adds **transparency** and **crispness (blur)** for good visualization of *ordinal* data.

After analyzing the suggestions of these cartographers, it is decided to use variables **saturation**, **brightness**, **pattern**, **transparency**, **blur**, **size** (not the size of a city object but an abstract object related to the city object) and **hue** in the pilot user test visualizations. Although **hue** is not found to be effective in the literature, it is considered to be effective for Disaster Management (DM) and hence is included in the list.

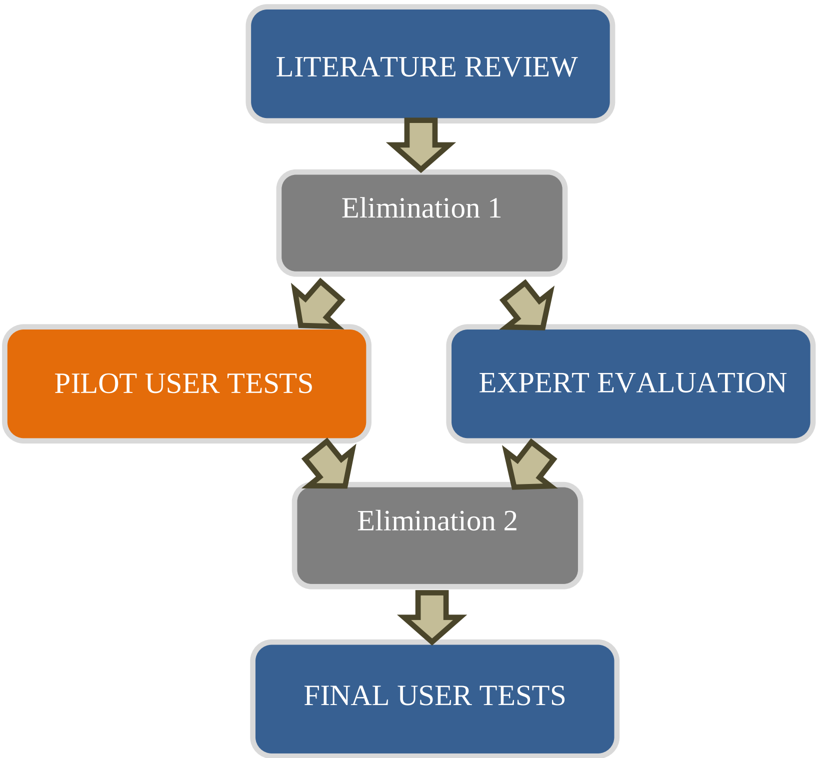


Figure 9-2: Pilot User Tests Highlighted in the Flowchart

The visualizations are conducted for three buildings using these variables. All of the visualizations used in the pilot user tests can be seen in Appendix D.

9.1.1 The Procedure of the Pilot User Tests

Each test takes around five minutes. During the test alternative visualizations of *risk* on three buildings are presented to the participants. Each visualization is presented for five seconds. The participants are asked to select the building which they think has the *highest risk*. The main aim here is to collect the reactions of the participants in terms of response time and accuracy in a very short time. This test comprises a low level of cognitive processing. The decision mode is intuitive. The participant makes a quick and unconscious response. The pilot user tests were held in September 2014 with 30 visualization experts. Half of the test sessions are conducted in Vienne at Risk and Uncertainty Visualization Workshop, held in 23 September, 2014. The other half of the sessions is conducted in Ankara, in October 2014.

The test procedure was designed in Open Sesame Behavioral Analysis Program, which is freeware (Figure 9-3). The images of three buildings and fixation dots are embedded into the software. In each image, *risk* visualization is created using different variables. Seven variables are used, which are **brightness**, **saturation**, **hue**, **pattern**, **transparency**, **blur** and the **size** of an **abstract object** *(a pyramid).* For LoD 2 **saturation**, **brightness** and **hue** are given using **self-illumination, because** the buildings have textures in LoD 2. These variables are used for various LoDs which are LoD 0 with a camera angle of 45^o, LoD 1 with an angle of 45^o, LoD 2 with an angle of 45^o and LoD 2 with a camera angle 60$^{o.}$ The angle 45^o is suggested in the guidelines given by Haeberling (2004a) for 3D maps. The angle 60^o is given as an alternative. Therefore, 28 images are shown to the participants (Appendix D). They are asked to press the number of one of the three buildings shown in the image that they think has the *highest risk.*

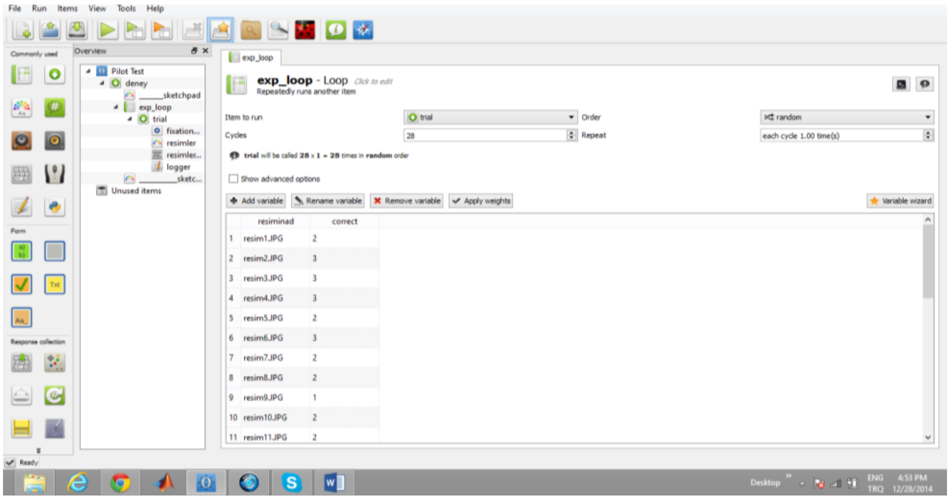


Figure 9-3: Screenshot from the Software Open Sesame

9.1.2 The Analysis of the Pilot User Tests

As an output of the pilot user tests, *response time* and *accuracy* are collected. The results of the response time and accuracy of each participant are analyzed in the SPSS software. First, the variables used are compared according to the response time for each LoD. The comparison of the difference in camera angle is not analyzed. The same is performed for the accuracy results. The parametric one-way ANOVA test is used to compare the means of response time for each variable used for each LoD. The non-parametric test of Kruskal Wallis is used to analyze if there is a significant difference between the groups in terms of accuracy. The analysis is again performed for each LoD.

The one-way ANOVA test is used to compare the results of the response time of the pilot user tests. However, according to the tests of normality (Kolmogorov-Smirnov), the data is not normally distributed within groups; D (30) =0.190, $p<0.05$ in **abstract object-size** / LoD 0 data, D (30) =0.100, $P<0.05$ in **hue** / LoD 1 data, D (30) =0.05, $p<0.05$ in **blur** / LoD 2 data when outliers are eliminated and the data distribution fits to the normal distribution for each LoD (Table 9-1, Table 9-2 and Table 9-3).

Table 9-1: Test of Normality for LoD 0

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BrightnessLoD0	.146	26	.161	.932	26	.088
SaturationLoD0	.169	26	.055	.874	26	.004
HueLoD0	.140	26	.200*	.915	26	.034
TransparencyLoD0	.144	26	.175	.923	26	.054
BlurLoD0	.158	26	.092	.930	26	.079
AbstractObjectsizeLoD0	.171	26	.049	.937	26	.113
PatternLoD0	.155	26	.111	.907	26	.022

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

Table 9-2: Test of Normality for LoD 1

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BrightnessLoD1	.143	27	.163	.936	27	.095
SaturationLoD1	.143	27	.165	.921	27	.042
HueLoD1	.165	27	.057	.916	27	.031
TransparencyLoD1	.165	27	.057	.923	27	.047
BlurLoD1	.127	27	.200*	.926	27	.057
AbstractObjectSizeLoD1	.161	27	.071	.921	27	.041
PatternLoD1	.121	27	.200*	.947	27	.185

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

Table 9-3: Test of Normality for LoD 2

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BrightnessLoD2	.132	26	.200*	.918	26	.039
SaturationLoD2	.099	26	.200*	.957	26	.332
HueLoD2	.124	26	.200*	.940	26	.136
TransparencyLoD2	.122	26	.200*	.945	26	.178
BlurLoD2	.154	26	.112	.954	26	.281
AbstractObjectSizeLoD2	.170	26	.051	.846	26	.001

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

According to ANOVA test results for LoD 0 in the pilot user tests, the means are significantly different with a 95% confidence level (Table 9-5). When the mean plot and Tukey multiple comparisons are analyzed, it is seen that **pattern** is statistically significant with **saturation**, **blur** and **abstract object-size** (Table 9-6 and Figure 9-4). The mean response time is the lowest when **saturation** and **abstract object-size** are used. It is the highest when **pattern** is used.

Table 9-4: ANOVA Test Results for Response Time - LoD 0 - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
BrightnessLoD0	26	2413.27	1351.449	265.041	1867.41	2959.13	533	5000
SaturationLoD0	26	1937.65	1304.629	255.859	1410.70	2464.61	473	5000
HueLoD0	26	2523.81	1360.079	266.734	1974.46	3073.16	637	5000
TransparencyLoD0	26	2612.42	1284.471	251.905	2093.61	3131.23	824	5000
BlurLoD0	26	2239.31	1044.842	204.910	1817.29	2661.33	779	5000
AbstractObjectsizeLoD0	26	1913.31	917.057	179.850	1542.90	2283.72	86	3655
PatternLoD0	26	3308.65	1306.785	256.282	2780.83	3836.48	724	5000
Total	182	2421.20	1291.841	95.758	2232.26	2610.15	86	5000

Table 9-5: ANOVA Test Results for Response Time - LoD 0

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	35349291.132	6	5891548.522	3.866	.001
Within Groups	266713210.346	175	1524075.488		
Total	302062501.478	181			

Table 9-6: Post Hoc Tests - Multiple Comparisons – LoD 0

	(I) Variable	(J) Variable	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Games-Howell	BrightnessLoD0	SaturationLoD0	475.615	368.389	.853	-655.94	1607.17
		HueLoD0	-110.538	376.023	1.000	-1265.48	1044.41
		TransparencyLoD0	-199.154	365.654	.998	-1322.37	924.06
		BlurLoD0	173.962	335.015	.998	-857.70	1205.63
		AbsObjectsizeLoD0	499.962	320.301	.707	-489.35	1489.27
		PatternLoD0	-895.385	368.683	.209	-2027.83	237.06
	SaturationLoD0	BrightnessLoD0	-475.615	368.389	.853	-1607.17	655.94
		HueLoD0	-586.154	369.609	.692	-1721.47	549.17
		TransparencyLoD0	-674.769	359.054	.503	-1777.60	428.06
		BlurLoD0	-301.654	327.799	.967	-1310.45	707.14
		AbsObjectsizeLoD0	24.346	312.745	1.000	-940.77	989.46
		PatternLoD0	-1371.000*	362.138	.007	-2483.29	-258.71
	HueLoD0	BrightnessLoD0	110.538	376.023	1.000	-1044.41	1265.48
		SaturationLoD0	586.154	369.609	.692	-549.17	1721.47
		TransparencyLoD0	-88.615	366.883	1.000	-1215.63	1038.40
		BlurLoD0	284.500	336.356	.979	-751.42	1320.42
		AbsObjectsizeLoD0	610.500	321.703	.493	-383.31	1604.31
		PatternLoD0	-784.846	369.901	.356	-1921.06	351.37
	TransparencyLoD0	BrightnessLoD0	199.154	365.654	.998	-924.06	1322.37
		SaturationLoD0	674.769	359.054	.503	-428.06	1777.60
		HueLoD0	88.615	366.883	1.000	-1038.40	1215.63
		BlurLoD0	373.115	324.722	.909	-625.95	1372.18
		AbsObjectsizeLoD0	699.115	309.519	.286	-255.68	1653.91
		PatternLoD0	-696.231	359.356	.466	-1799.99	407.53
	BlurLoD0	BrightnessLoD0	-173.962	335.015	.998	-1205.63	857.70
		SaturationLoD0	301.654	327.799	.967	-707.14	1310.45
		HueLoD0	-284.500	336.356	.979	-1320.42	751.42
		TransparencyLoD0	-373.115	324.722	.909	-1372.18	625.95
		AbsObjectsizeLoD0	326.000	272.643	.892	-511.99	1163.99
		PatternLoD0	-1069.346*	328.129	.032	-2079.18	-59.51
	AbsObjectsizeLoD0	BrightnessLoD0	-499.962	320.301	.707	-1489.27	489.35
		SaturationLoD0	-24.346	312.745	1.000	-989.46	940.77
		HueLoD0	-610.500	321.703	.493	-1604.31	383.31
		TransparencyLoD0	-699.115	309.519	.286	-1653.91	255.68
		BlurLoD0	-326.000	272.643	.892	-1163.99	511.99
		PatternLoD0	-1395.346*	313.091	.001	-2361.56	-429.13
	PatternLoD0	BrightnessLoD0	895.385	368.683	.209	-237.06	2027.83
		SaturationLoD0	1371.000*	362.138	.007	258.71	2483.29
		HueLoD0	784.846	369.901	.356	-351.37	1921.06
		TransparencyLoD0	696.231	359.356	.466	-407.53	1799.99
		BlurLoD0	1069.346*	328.129	.032	59.51	2079.18
		AbsObjectsizeLoD0	1395.346*	313.091	.001	429.13	2361.56
Dunnett t (2-sided) b	SaturationLoD0	BrightnessLoD0	-475.615	342.398	.546	-1363.19	411.96
	HueLoD0	BrightnessLoD0	110.538	342.398	.999	-777.04	998.11
	TransparencyLoD0	BrightnessLoD0	199.154	342.398	.982	-688.42	1086.73
	BlurLoD0	BrightnessLoD0	-173.962	342.398	.991	-1061.54	713.61
	Abs.ObjSizeLoD0	BrightnessLoD0	-499.962	342.398	.495	-1387.54	387.61
	PatternLoD0	BrightnessLoD0	895.385*	342.398	.047	7.81	1782.96

*. The mean difference is significant at the 0.05 level.

b. Dunnett t-tests treat one group as a control, and compare all other groups against it.

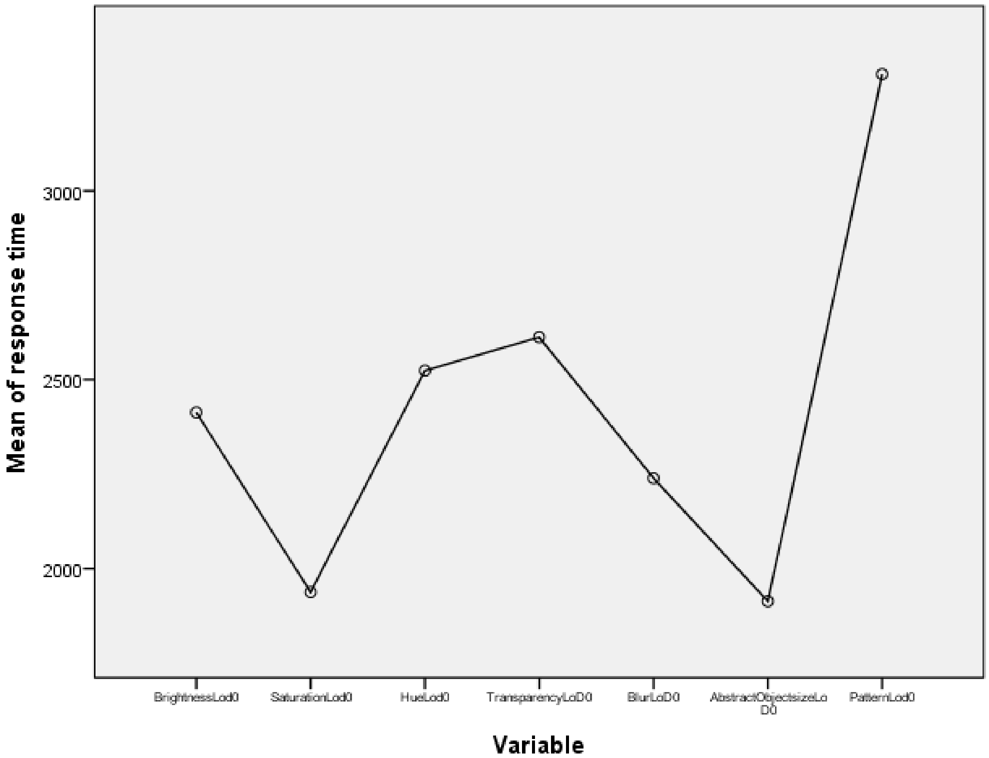


Figure 9-4: Mean Response Time for each Variable for LoD 0

According to the ANOVA test results for LoD 1 in the pilot user tests, the means are significantly different with 95% confidence (Table 9-8). When the mean plot and Tukey multiple comparisons are analyzed, **pattern** is statistically significant with **hue** ($p < 0.05$) (Table 9-9). As seen from the mean plot, the highest mean response time happens when **pattern** is used; the lowest mean response time happens when **hue** is used (Figure 9-5).

Table 9-7: ANOVA Test Results for Response Time - LoD 1 - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
BrightnessLoD1	27	2529.22	1204.708	231.846	2052.66	3005.79	868	5000
SaturationLoD1	27	2213.41	1255.168	241.557	1716.88	2709.94	586	5000
HueLoD1	27	2020.48	1044.508	201.016	1607.29	2433.68	588	4108
TransparencyLoD1	27	2260.44	1175.129	226.154	1795.58	2725.31	700	5000
BlurLoD1	27	2644.56	1248.116	240.200	2150.82	3138.29	865	5000
AbstractObjectsizeLoD1	27	2777.15	1361.382	261.998	2238.60	3315.69	698	5000
PatternLoD1	27	3119.41	1276.855	245.731	2614.30	3624.51	921	5000
Total	189	2509.24	1256.948	91.430	2328.88	2689.60	586	5000

Table 9-8: ANOVA Test Results for Response Time - LoD 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22979421.101	6	3829903.517	2.544	.022
Within Groups	274045369.185	182	1505743.787		
Total	297024790.286	188			

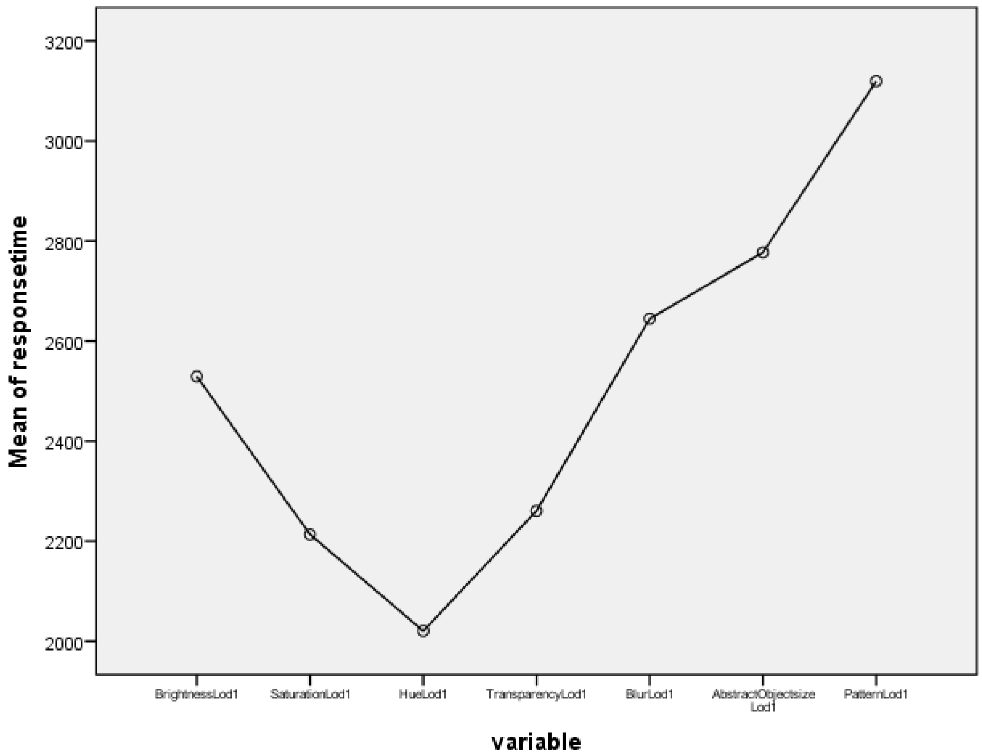


Figure 9-5: Mean Response Time for each Variable for LoD 1

Table 9-9: Post Hoc Tests - Multiple Comparisons – LoD 1

(I) variable	(J) variable	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
BrightnessLoD1	SaturationLoD1	315.815	333.971	.964	-679.96	1311.59
	HueLoD1	508.741	333.971	.731	-487.03	1504.51
	TransparencyLoD1	268.778	333.971	.984	-726.99	1264.55
	BlurLoD1	-115.333	333.971	1.000	-1111.10	880.44
	AbstractObjectsizeLoD1	-247.926	333.971	.990	-1243.70	747.85
	PatternLoD1	-590.185	333.971	.572	-1585.96	405.59
SaturationLoD1	BrightnessLoD1	-315.815	333.971	.964	-1311.59	679.96
	HueLoD1	192.926	333.971	.997	-802.85	1188.70
	TransparencyLoD1	-47.037	333.971	1.000	-1042.81	948.73
	BlurLoD1	-431.148	333.971	.855	-1426.92	564.62
	AbstractObjectsizeLoD1	-563.741	333.971	.625	-1559.51	432.03
	PatternLoD1	-906.000	333.971	.101	-1901.77	89.77
HueLoD1	BrightnessLoD1	-508.741	333.971	.731	-1504.51	487.03
	SaturationLoD1	-192.926	333.971	.997	-1188.70	802.85
	TransparencyLoD1	-239.963	333.971	.991	-1235.73	755.81
	BlurLoD1	-624.074	333.971	.504	-1619.85	371.70
	AbstractObjectsizeLoD1	-756.667	333.971	.267	-1752.44	239.10
	PatternLoD1	-1098.926*	333.971	.020	-2094.70	-103.15
TransparencyLoD1	BrightnessLoD1	-268.778	333.971	.984	-1264.55	726.99
	SaturationLoD1	47.037	333.971	1.000	-948.73	1042.81
	HueLoD1	239.963	333.971	.991	-755.81	1235.73
	BlurLoD1	-384.111	333.971	.911	-1379.88	611.66
	AbstractObjectsizeLoD1	-516.704	333.971	.716	-1512.47	479.07
	PatternLoD1	-858.963	333.971	.141	-1854.73	136.81
BlurLoD1	BrightnessLoD1	115.333	333.971	1.000	-880.44	1111.10
	SaturationLoD1	431.148	333.971	.855	-564.62	1426.92
	HueLoD1	624.074	333.971	.504	-371.70	1619.85
	TransparencyLoD1	384.111	333.971	.911	-611.66	1379.88
	AbstractObjectsizeLoD1	-132.593	333.971	1.000	-1128.36	863.18
	PatternLoD1	-474.852	333.971	.789	-1470.62	520.92
AbstractObjectsizeLoD1	BrightnessLoD1	247.926	333.971	.990	-747.85	1243.70
	SaturationLoD1	563.741	333.971	.625	-432.03	1559.51
	HueLoD1	756.667	333.971	.267	-239.10	1752.44
	TransparencyLoD1	516.704	333.971	.716	-479.07	1512.47
	BlurLoD1	132.593	333.971	1.000	-863.18	1128.36
	PatternLoD1	-342.259	333.971	.948	-1338.03	653.51
PatternLoD1	BrightnessLoD1	590.185	333.971	.572	-405.59	1585.96
	SaturationLoD1	906.000	333.971	.101	-89.77	1901.77
	HueLoD1	1098.926*	333.971	.020	103.15	2094.70
	TransparencyLoD1	858.963	333.971	.141	-136.81	1854.73
	BlurLoD1	474.852	333.971	.789	-520.92	1470.62
	AbstractObjectsizeLoD1	342.259	333.971	.948	-653.51	1338.03

*. The mean difference is significant at the 0.05 level.

According to ANOVA test results for LoD 2 in the pilot user tests, the means are significantly different with a 95% confidence level (Table 9-11). When the mean plot and Tukey multiple comparisons are analyzed, it is seen that there is no significant relationship between the variables (Figure 9-6 and Table 9-12). The lowest response times occur when **saturation** and **blur** are used, whereas the highest response time occurs when **abstract object-size** is used.

Table 9-10: ANOVA Test Results for Response Time - LoD 2 – Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
BrightnessLoD2	26	2952.50	1257.164	246.550	2444.72	3460.28	1181	5000
SaturationLoD2	26	2408.12	1169.867	229.430	1935.60	2880.63	714	5001
HueLoD2	26	2508.69	1235.490	242.300	2009.67	3007.72	770	4695
TransparencyLoD2	26	2737.62	1332.920	261.407	2199.24	3275.99	796	5000
BlurLoD2	26	2391.19	710.983	139.435	2104.02	2678.36	944	3725
Abst.ObjectSizeLoD2	26	3119.88	1607.784	315.312	2470.49	3769.28	976	5000
PatternLoD2	26	2818.88	1189.617	233.303	2338.39	3299.38	1081	5000
Total	182	2705.27	1246.503	92.397	2522.96	2887.58	714	5001

Table 9-11: ANOVA Test Results for Response Time - LoD 2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12286843.615	6	2047807.269	1.332	.245
Within Groups	268945430.192	175	1536831.030		
Total	281232273.808	181			

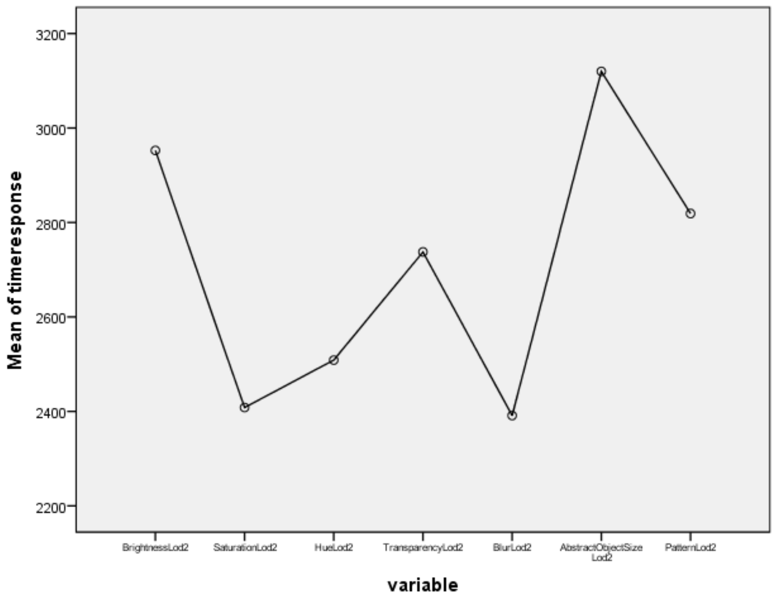


Figure 9-6: Mean Response Time for each Variable for LoD 2

Table 9-12: Post Hoc Tests - Multiple Comparisons – LoD 2

	(I) variable	(J) variable	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	BrightnessLod2	SaturationLod2	544.385	343.828	.693	-481.24	1570.01
		HueLod2	443.808	343.828	.855	-581.81	1469.43
		TransparencyLod2	214.885	343.828	.996	-810.74	1240.51
		BlurLod2	561.308	343.828	.661	-464.31	1586.93
		Abs.ObjectSizeLod2	-167.385	343.828	.999	-1193.01	858.24
		PatternLod2	133.615	343.828	1.000	-892.01	1159.24
	SaturationLod2	BrightnessLod2	-544.385	343.828	.693	-1570.01	481.24
		HueLod2	-100.577	343.828	1.000	-1126.20	925.05
		TransparencyLod2	-329.500	343.828	.962	-1355.12	696.12
		BlurLod2	16.923	343.828	1.000	-1008.70	1042.55
		Abs.ObjectSizeLod2	-711.769	343.828	.375	-1737.39	313.85
		PatternLod2	-410.769	343.828	.895	-1436.39	614.85
	HueLod2	BrightnessLod2	-443.808	343.828	.855	-1469.43	581.81
		SaturationLod2	100.577	343.828	1.000	-925.05	1126.20
		TransparencyLod2	-228.923	343.828	.994	-1254.55	796.70
		BlurLod2	117.500	343.828	1.000	-908.12	1143.12
		Abs.ObjectSizeLod2	-611.192	343.828	.565	-1636.81	414.43
		PatternLod2	-310.192	343.828	.972	-1335.81	715.43
	TransparencyLod2	BrightnessLod2	-214.885	343.828	.996	-1240.51	810.74
		SaturationLod2	329.500	343.828	.962	-696.12	1355.12
		HueLod2	228.923	343.828	.994	-796.70	1254.55
		BlurLod2	346.423	343.828	.952	-679.20	1372.05
		Abs.ObjectSizeLod2	-382.269	343.828	.924	-1407.89	643.35
		PatternLod2	-81.269	343.828	1.000	-1106.89	944.35
	BlurLod2	BrightnessLod2	-561.308	343.828	.661	-1586.93	464.31
		SaturationLod2	-16.923	343.828	1.000	-1042.55	1008.70
		HueLod2	-117.500	343.828	1.000	-1143.12	908.12
		TransparencyLod2	-346.423	343.828	.952	-1372.05	679.20
		Abs.ObjectSizeLod2	-728.692	343.828	.346	-1754.31	296.93
		PatternLod2	-427.692	343.828	.876	-1453.31	597.93
	AbstractObjectSizeLod2	BrightnessLod2	167.385	343.828	.999	-858.24	1193.01
		SaturationLod2	711.769	343.828	.375	-313.85	1737.39
		HueLod2	611.192	343.828	.565	-414.43	1636.81
		TransparencyLod2	382.269	343.828	.924	-643.35	1407.89
		BlurLod2	728.692	343.828	.346	-296.93	1754.31
		PatternLod2	301.000	343.828	.976	-724.62	1326.62
	PatternLod2	BrightnessLod2	-133.615	343.828	1.000	-1159.24	892.01
		SaturationLod2	410.769	343.828	.895	-614.85	1436.39
		HueLod2	310.192	343.828	.972	-715.43	1335.81
		TransparencyLod2	81.269	343.828	1.000	-944.35	1106.89
		BlurLod2	427.692	343.828	.876	-597.93	1453.31
		Abs.ObjectSizeLod2	-301.000	343.828	.976	-1326.62	724.62
Dunnett t (2-sided)[a]	BrightnessLod2	PatternLod2	133.615	343.828	.998	-757.67	1024.90
	SaturationLod2	PatternLod2	-410.769	343.828	.689	-1302.05	480.51
	HueLod2	PatternLod2	-310.192	343.828	.877	-1201.48	581.09
	TransparencyLod2	PatternLod2	-81.269	343.828	1.000	-972.55	810.01
	BlurLod2	PatternLod2	-427.692	343.828	.653	-1318.98	463.59
	AbstractObjectSizeLod2	PatternLod2	301.000	343.828	.890	-590.28	1192.28

In the pilot user tests, accuracy results are considered according to the ground truths proposed for the *highest risk* for each variable that depends on the literature on the expert evaluation. Here is the list:

- Abstract Object Size LoD 0,1,2 : the biggest
- Brightness LoD 0,1,2 : the most bright
- Pattern LoD 0,1,2 : the most repeated pattern
- Hue LoD 0,1,2 : red
- Saturation LoD 0,1,2 : the most saturated
- Transparency LoD 0,1,2 : the least transparent
- Blur LoD 0,1,2 : the least blurred

According to the Kruskal-Wallis Test results for LoD 0 in the pilot user tests, the means are not significantly different with a 95% confidence level (Table 9-15). When the accuracy results are turned into the mean accuracy percentages for each variable and seen from the bar gram, the percentages are not so different from each other. However, it should be stated that accuracy is according to the ground truths proposed for each variable. Especially for **transparency** and **blur (focus),** some participants have decided the *highest risk* just the contrary to the ground truths for them (Figure 9-7).

Table 9-13: Analysis of Accuracy for LoD 0 - Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	210	.59	.494	0	1
variable	210	4.00	2.005	1	7

Table 9-14: Kruskal-Wallis Test – Ranks for LoD 0

	variable	N	Mean Rank
accuracy	BrightnessLoD0	30	114.00
	SaturationLoD0	30	114.00
	HueLoD0	30	107.00
	TransparencyLoD0	30	103.50
	BlurLoD0	30	93.00
	AbstractObjectSizeLoD0	30	114.00
	PatternLoD0	30	93.00
	Total	210	

Table 9-15: Kruskal-Wallis Test – Chi Square for LoD 0

	Accuracy
Chi-Square	5.976
df	6
Asymp. Sig.	.038
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

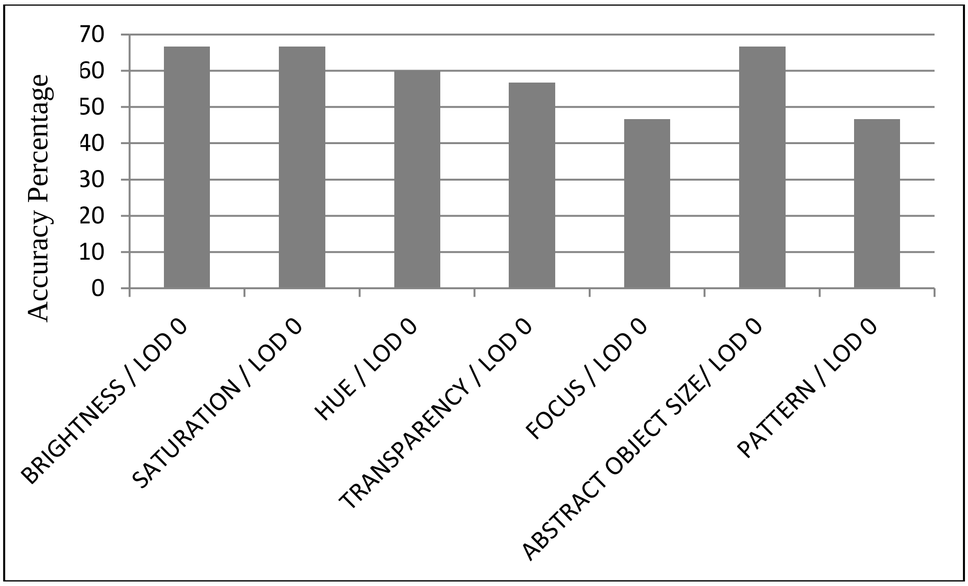


Figure 9-7: Accuracy Percentages for LoD 0 Variables

According to the Kruskal-Wallis Test results for LoD 1 in the pilot user tests, the means are significantly different with a 95% confidence level (Table 9-18). When the accuracy results are turned into the mean accuracy percentages for each variable and seen from the bar gram, the percentages are different from each other. Accuracy is higher when **saturation**, **hue**, **transparency** and **abstract object-size** are used. It is lower when **brightness**, **blur (focus)** and **pattern** are used (Figure 9-8).

Table 9-16: Analysis of Accuracy for LoD 1 – Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	210	.53	.500	0	1
variable	210	4.00	2.005	1	7

Table 9-17: Kruskal-Wallis Test – Ranks for LoD 1

	variable	N	Mean Rank
accuracy	BrightnessLoD1	30	81.50
	SaturationLoD1	30	120.00
	HueLoD1	30	134.00
	TransparencyLoD1	30	123.50
	Focus/BlurLoD1	30	78.00
	AbstractObjectSizeLoD1	30	127.00
	PatternLoD1	30	74.50
	Total	210	

Table 9-18: Kruskal-Wallis Test – Chi Square for LoD 1

	Accuracy
Chi-Square	44.581
df	6
Asymp. Sig.	.000
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

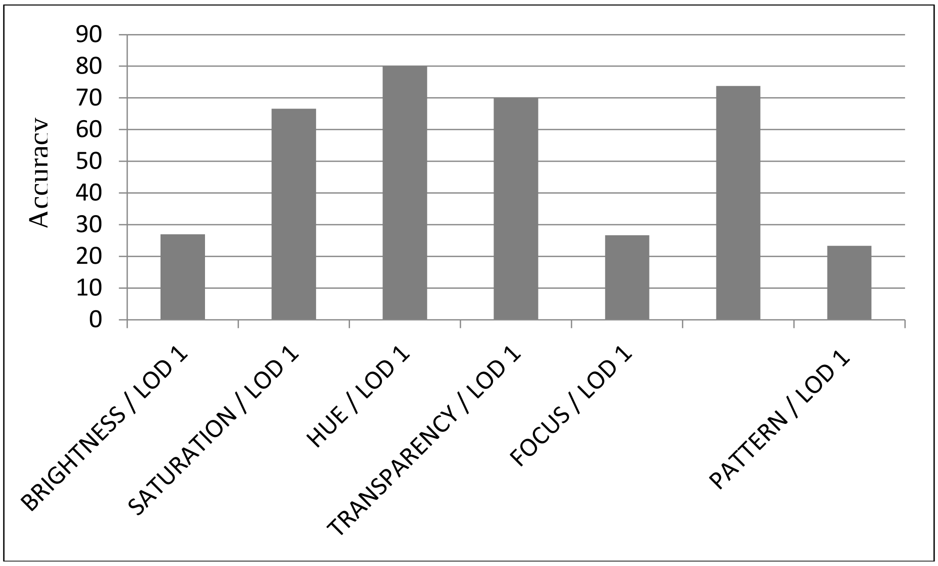


Figure 9-8: Accuracy Percentages for LoD 1 Variables

According to the Kruskal-Wallis Test results for LoD 2 in the pilot user tests, the means are significantly different with a 95% confidence level (Table 9-21). When the accuracy results are turned into the mean accuracy percentages for each variable and seen from the bar gram, the percentages are different from each other. Accuracy is higher when **saturation**, **hue**, **abstract object-size** are used. It is low when **brightness**, **blur (focus), transparency** and **pattern** are used. When compared to LoD 1, the percentage values are higher (Figure 9-9).

Table 9-19: Analysis of Accuracy for LoD 2 – Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	210	.55	.499	0	1
variable	210	4.00	2.005	1	7

Table 9-20: Kruskal-Wallis Test – Ranks for LoD 2

	variable	N	Mean Rank
accuracy	BrightnessLoD2	30	86.50
	SaturationLoD2	30	121.50
	HueLoD2	30	125.00
	TransparencyLoD2	30	100.50
	BlurLoD2	30	100.50
	AbstractObjectSizeLoD2	30	111.00
	PatternLoD2	30	93.50
	Total	210	

Table 9-21: Kruskal-Wallis Test – Chi Square for LoD 2

	Accuracy
Chi-Square	13.353
df	6
Asymp. Sig.	.038
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

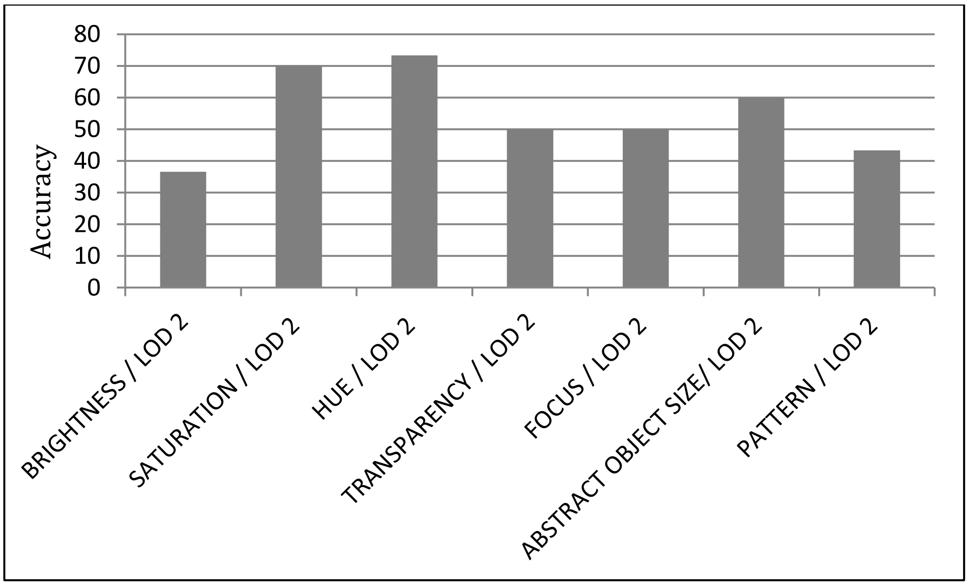


Figure 9-9: Accuracy Percentages for LoD 2 Variables

9.2 The Expert Evaluation

After the pilot user tests, the Expert Evaluation was conducted by five visualization experts in a workshop (Figure 9-10). The date of the workshop performance was 29 November, 2014. The expertise profile of the participants can be seen in Table 9-22. The workshop is planned to take approximately three hours. The workshop is recorded and all of the participants are asked to sign a consent form to imply their voluntariness. At the beginning, a brief explanation about the thesis topic and what has been done up to that time is presented. Afterwards, the participants are asked to introduce themselves.

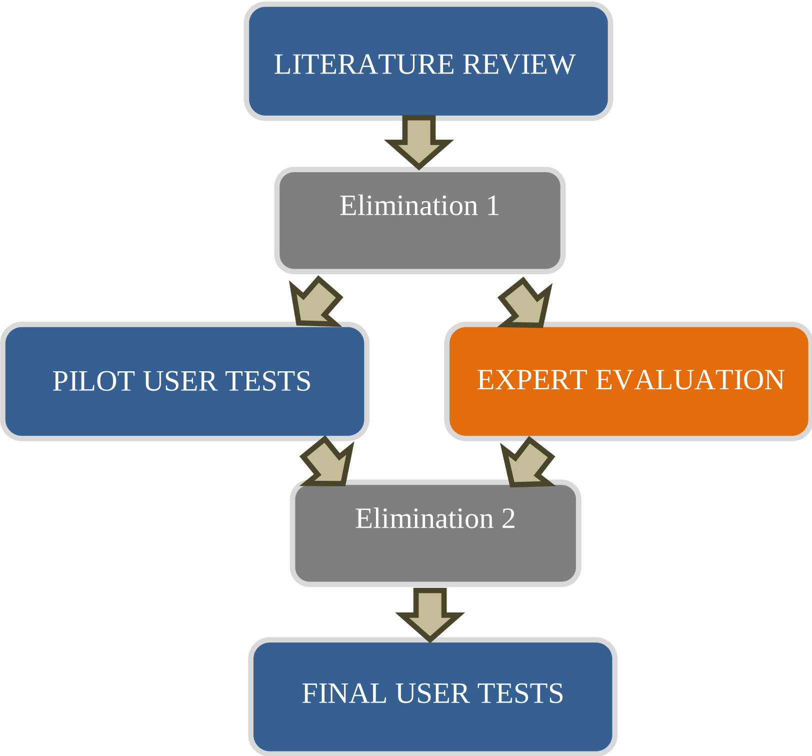


Figure 9-10: Expert Evaluation Highlighted in the Flowchart

Table 9-22: Expertise Profiles

Participant No	Expertise Areas	Years of Expertise	Type of Expertise
Participant 1	Disaster Management	10	Academic
	3D Visualization	10	Academic
	GIS	14	Academic
	Remote Sensing	10	Academic
	Risk Analysis	15	Academic
Participant 2	GIS	17	Practice
	Safety Critical Systems	5	Practice
	Cognitive Systems	10	Academic
	Situational Awareness	10	Academic
Participant 3	Ergonomics	12	Academic+ Practice
	Usability	12	Academic+ Practice
	Interface Design	12	Academic+ Practice
Participant 4	3D Visualization	10	Academic
	Disaster Management	10	Academic
	Remote Sensing	10	Academic
	GIS	10	Academic
Participant 5	Geodesy and Geophysics	5	Academic+ Practice
	Cartography	11	Academic+ Practice
	Photogrammetry	6	Academic+ Practice
	Remote Sensing	6	Academic+ Practice

The first session is related to the evaluation of the alternatives. It takes approximately 70 minutes with the discussions. Alternatives are presented in different zooming views. The screenshots of each visual alternative are prepared with different visual variables and presented to the experts in folders on their laptops. The experts are asked to evaluate them according to seven scales of effectiveness. During the second session, the experts are asked to create their own alternatives using Legos, drawing pencils, papers, printouts of abstract objects. This session also takes about 70 minutes with the discussions. Photographs from the workshop can be seen in Appendix E.

In order to define the visual variables of this study for visualizing the *ordinal risk* information of the buildings, these suggestions are considered. The results of pilot user tests are analyzed and the same variables used in the pilot user tests are used but additional combinations of the variables are created for expert evaluation. Therefore, eleven types of visual variables for the expert evaluation are defined for 3D environment. The list includes **hue**, **saturation**, **value (brightness)**, **self-illumination** usage with **hue**, **saturation** and **value**, **transparency (opacity)**, **pattern**, **pattern** usage with **transparency** and **blur**. Also, some variables are visualized on the *building*s and some on the *abstract objects* referring to *buildings.* The variable **size** is used on the **abstract object** as the dimensions of the buildings should not be changed. Both the **size** and **hue** of the **abstract object** are changed. In one alternative only the **hue** of the **abstract object** is changed. For the study, the **abstract object** is selected to be a *pyramid* in pilot user tests and a *cylinder* in user tests and expert evaluation. Its shape can differ for further studies. All the variables are offered for different LoDs. Table 9-23 summarizes the selected visual variables, their design properties and Level of Details to be used.

Table 9-23: List of the Visual Variables Considered in the Expert Evaluation

VISUALIZATION ON THE OBJECT BUILDING		
Variable	**3D Design Property**	**Level of Details**
HUE (see Example in Fig. 7-7)	Using Diffuse Color property (changing only Hue, Saturation and Value are fixed)	For LoD 0 and LoD 1
SATURATION	Using Diffuse Color property (changing only Saturation, Hue and Value are fixed)	For LoD 0 and LoD 1.
VALUE	Using Diffuse Color property (changing only Value, Hue and Saturation are fixed)	For LoD 0 and LoD 1.
SELF ILLUMINATION+ HUE/SATURATION/VALUE	Using Glow property	For LoD 2
TRANSPARENCY/ OPACITY	Using Opacity property	For all LoDs.
PATTERN	Using UVW Mapping property - changing the size of the texture	For LoD 0 and LoD 1
PATTERN + TRANSPARENCY	Using UVW Mapping property - Using the opacity property	For all LoDs.
BLUR	Using Post Effect property	For all LoDs.
VISUALIZATION ON ABSTRACT OBJ REFERRING TO THE OBJ BUILDING		
Variable	**3D Design Property**	**Level of Details**
SIZE	Changing dimension of the abstract object	For all LoDs
SIZE + HUE	Changing dimension of the abstract object and using Diffuse Color property (changing only Hue, Saturation and Value are fixed)	For all LoDs.
HUE	Using Diffuse Color property (changing only Hue, Saturation and Value are fixed)	For all LoDs.

9.2.1 The First Session: Evaluation of the Visual Alternatives

The visualizations that use the list of variables (Table 9-23) are prepared using 3Ds Max. The Cumhuriye district of Eskişehir is modeled in three Level of Details. The prepared render screenshots of the visualizations are 124 in number. Appendix F can be seen for all of the images. The screenshots are demonstrated in four different folders for each LoD. In the first folder, there are only three building renders and each building is labelled as *low*, *medium* and *high risk*. In the next three folders, there are the whole city renders in three different zoom levels. Different folders are prepared in order to show the effect of the variables better rendered in different zoom angles to the city.

The folders are uploaded to each participant's laptops. In the first session, they are asked to evaluate the visualizations in which each different visual variable are used. They are asked to evaluate each visualization according to seven scales of effectiveness. In this scale, 1 corresponds to *extremely poor*, 2 to *quite poor*, 3 to *slightly poor*, 4 to *marginal*, 5 to *slightly good*, 6 to *quite good* and 7 to *extremely good*. Their answers to each of the variables for three different Level of Details presented can be seen in Table 9-24. The numbers are listed in descending order.

It is found that the visualizations in LoD 0 are quite different from those in LoD 1 and LoD 2. The reason for this is that in LoD 0, the visualization of the city objects are in 2D format (apart from Terrain). Therefore, according to them the perception of *risk* differs in LoD 0. One participant states that many effective alternatives can be created using LoD 0 as it looks simple and 2D, however effective alternatives using LoD 1 and LoD 2 can be limited. Similarly, another participant adds that LoD 1 and LoD 2 have extra one dimension; therefore conveying the information clearly becomes more difficult. They state that 3D elements are used as in LoD 1 and LoD 2, so there is the risk of visibility of information.

Two participants think that instead of using screenshot, navigating in the environment can be offered. One participant states that different levels or multimedia properties can be used to show different information if not only *total risk* is aimed to be shown.

Table 9-24: Effectiveness of the Visual Alternatives referring Visual Variables

Level of Detail 0						
Variable used	**P1**	**P2**	**P3**	**P4**	**P5**	**AVG**
Hue 2	6	4	7	5	4	5,2
Hue 1	7	7	6	4	1	5
Transparency	4	5	7	4	5	5
Saturation	4	2	5	7	5	4,6
Abstract Object + Size	4	2	3	7	7	4,6
Pattern + Transparency	1	3	3	7	5	3,8
Brightness	3	1	1	7	6	3,6
Blur	3	2	2	2	7	3,2
Pattern + Size	2	1	2	7	4	3,2
Abstract Object + Hue + Size	5	2	4	2	2	3
Abstract Object + Hue	4	3	2	3	1	2,6
Level of Detail 1						
Variable used	**P1**	**P2**	**P3**	**P4**	**P5**	**AVG**
Hue 2	6	4	7	4	6	5,4
Transparency	4	6	6	6	5	5,4
Hue 1	7	7	6	3	1	4,8
Saturation	3	3	6	7	4	4,6
Pattern + Transparency	3	5	2	7	6	4,6
Brightness	2	2	5	5	6	4
Pattern + Size	3	2	2	7	5	3,8
Abstract Object + Size	3	2	2	4	7	3,6
Abstract Object + Hue	5	5	5	2	1	3,6
Abstract Object + Hue + Size	5	5	4	1	3	3,6
Blur	2	2	1	4	7	3,2
Level of Detail 2						
Variable used	**P1**	**P2**	**P3**	**P4**	**P5**	**AVG**
Self-Illumination + Hue 1	6	7	6	4	5	5,6
Self-Illumination + Hue 2	5	5	7	5	6	5,6
Transparency	1	4	6	7	7	5
Self-Illumination + Saturation	1	2	4	6	6	3,8
Blur	1	3	1	3	7	3
Self-Illumination + Brightness	1	2	1	5	5	2,8
Abstract Object + Size	1	2	2	3	6	2,8
Abstract Object + Hue + Size	2	3	4	1	3	2,6
Abstract Object + Hue	1	4	3	2	1	2,2

It is found that the visualizations in LoD 0 are quite different from those in LoD 1 and LoD 2. The **abstract object** is found to be useful by some participants. One participant states that **abstract objects** can hide the information. The variables **transparency** and **blur** are found to be effective by some participants. However, high **transparency** or high **blur** conveys the *highest risk* or otherwise are confusing for them. The variable **pattern** is not clear. For them, the type of the **pattern** used can differ the perception.

Hue: For all the LoDs, **hue 1**, which is composed of *blue*, *yellow* and *red*, has the highest effectiveness score. It is used with **self-illumination** in LoD 2. **Hue 2**, which is composed of *green*, *yellow* and *red*, is found to be the most effective one to show *ordinal risk* information for LoD 1 (Figure 9-11).

Figure 9-11: Hue 2 - LoD 1 Visualizations

In this combination the temperature of the colors and its universal cycle are considered. In **hue 1**, as *blue* is a cooler color than *green*, it is used for showing *low risk*. Other colors are the same for both hue types. One participant who is from the Defense Industry states that green can mean *totally safe* and *zero risk.*

Transparency: After **hue**, **transparency** is found to be the second effective variable (Figure 9-12) for all the LoDs. However, transparency is confusing, because the building that has the *lowest risk* is understood as the one that has the *highest risk* by two participants. One participant states that if the data is discrete, **transparency** can be more effective. Three participants think that **transparency** can be very effective if they have the chance to navigate in the environment.

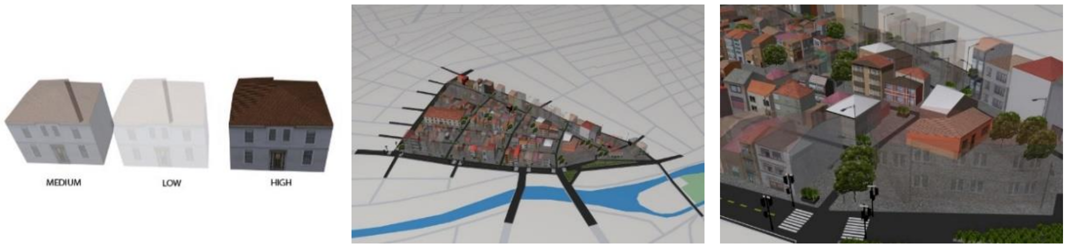


Figure 9-12: Transparency - LoD 2 Visualizations

Saturation: After **transparency**, **saturation** is found to be effective (Figure 9-13). It is found to be effective in all the LoDs. One participant states that **brightness** and **saturation** give the same impression in the sense that darkness implies more *risk*.

Figure 9-13: Saturation - LoD 0 Visualizations

Self- Illumination: Self-illumination is used in LoD2. One participant states that **self-illumination** with *green* is better recognized. **Self-illumination** is found to be the most effective variable for conveying *risk* information in LoD2. Especially its usage with **hue** is found to be very effective (Figure 9-14).

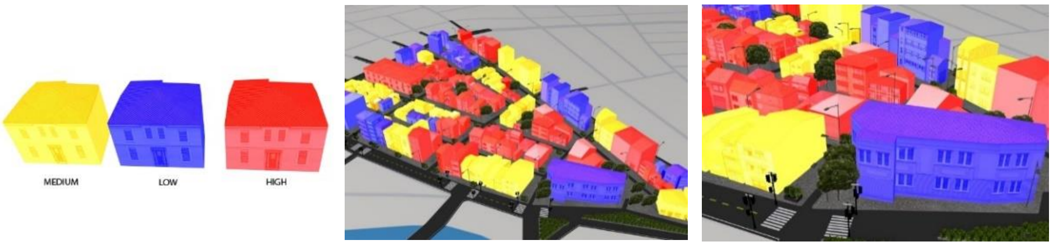


Figure 9-14: Self-Illumination-Hue 1 - LoD 2 Visualizations

Pattern: It is found that the type of the **pattern** is important according to the participants. One participant states that **pattern** is similar to **brightness** since when its **size** changes, it seems like the **brightness** changes, too. She adds that it looks like a combination of light and dark color rather than a **pattern**. She suggests that a **pattern** with dots would be better. One participant states that the **pattern-transparency** is better than its combination with **pattern-size.** He states that if the **size** of the **pattern** is increased it can be understood as the *risk* is increased or vice versa. He adds that the one which is more distinct is the one that has the smallest size and that one conveys the *highest risk* better (Figure 9-15).

Figure 9-15: Pattern - LoD 0 Visualizations

Brightness: When the visualization of LoD 0 and LoD 1 are considered **brightness** is effective. Participants state that it can be more effective if the color *red* is used instead of *blue*. The participants state that **self-illumination-brightness** is not clear in LoD 2. One participant states that **brightness** seems to be effective but he thinks that *low* and *high risk* should be more clearly expressed with lower and higher **brightness** values (Figure 9-16).

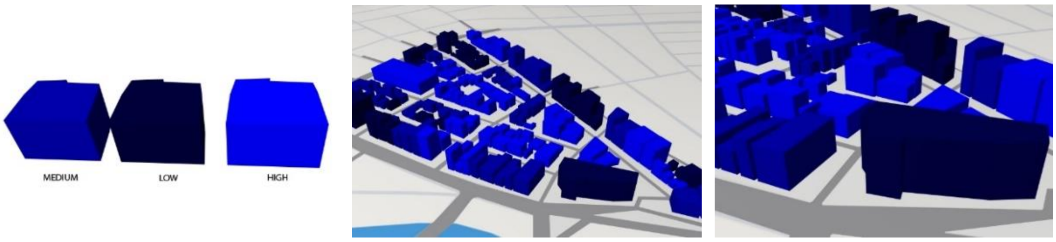


Figure 9-16: Brightness - LoD 1 Visualizations

Blur: Except one participant, **blur** is found to be distracting. The participants state that **blur** should be well-coded because both the building having *high* **blur** and *low* **blur** can refer to *high risk*. One participant states that high **blur** can mean that the image is not downloaded yet (Figure 9-17).

Figure 9-17: Blur - LoD 2 Visualizations

Variables Used with Abstract Object: These variables are found to be the least effective (Figure 9-18). The participants think that it hinders the background information. **Abstract object** with both **size** and **hue** can mean that it conveys two types of information.

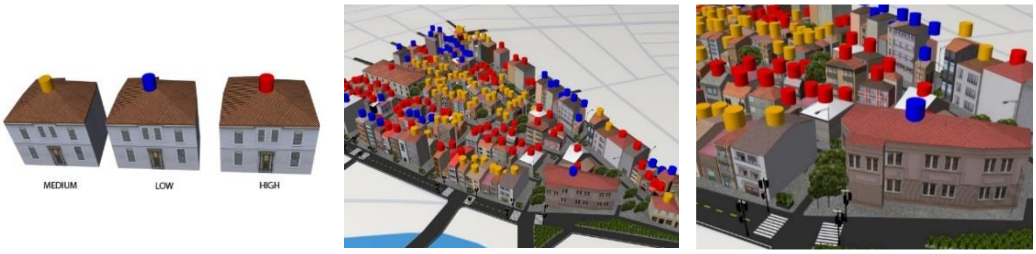


Figure 9-18: Abstract Object - Hue - LoD 2 Visualizations

9.2.2 The Second Session: Suggestion of New Visual Alternatives

In the second session, the participants are asked to create their own design for conveying *ordinal risk* information in different LoDs. This session takes approximately 70 minutes. The participants create their designs using Legos, drawing pencils, papers, print outs without discussing with each other. The photographs of the participants during this session can be seen in Appendix E.

Participant one (P1) and Participant 5 (P5) state that the *total risk* information can be conveyed on the top of the buildings for LoD 1 and LoD 2. They explain that different risk information can be given on different parts of the building, such as on its base and on its floors and they add that the *total risk* information can be given on the roof. They code them using **hue** and **saturation**. Participant 3 (P3) and Participant 5 (P5) state that figure-ground relationship should be well analyzed. P3 expresses that the variables should differ with different backgrounds. He suggests using **transparency** with red **color**. Participant 4 (P4) suggests a 3D cartogram for conveying *risk*. He also suggests a 3D texture on the buildings to convey *risk* in LoD 1 (Figure 9-19).

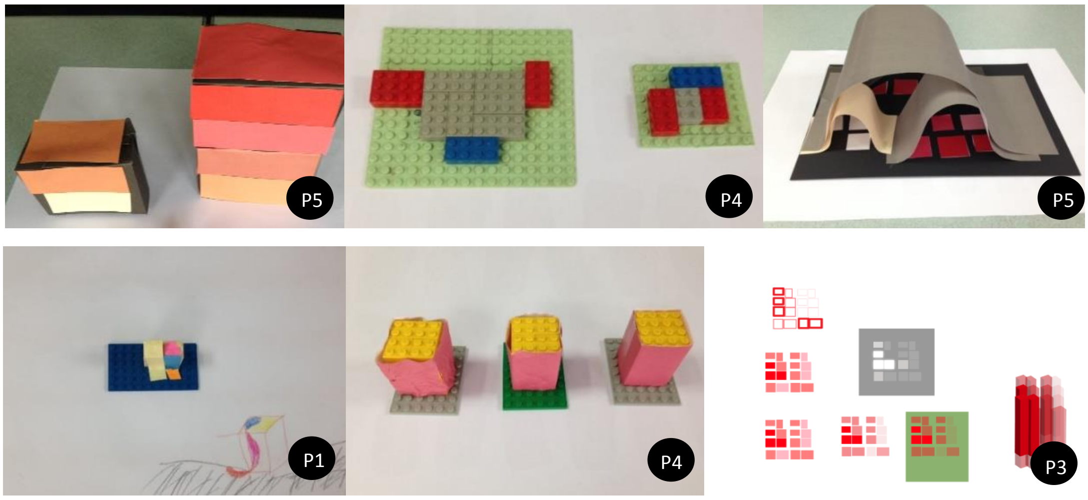


Figure 9-19: Designs of the Participants

9.3 Selection of the Visualizations for the Final User Tests

Texture is found to be confusing by the pilot user test participants and the experts. Therefore, it is eliminated. **Blur** is found to be ineffective for LoD 1 and 2. **Contour** usage is suggested during the expert evaluations. Hence, it is added to the list. Instead of using the **abstract object-size**, **abstract object-hue** is found to be more successful. On the other hand, it is found effective for only LoD 0. Therefore, it is also shifted. **Self-illumination-hue** is considered effective for LoD 2 and added to the list. Therefore, the final selected variables are **hue**, **self-illumination-hue**, **transparency**, **saturation, brightness, contour, abstract object-hue**, and **blur**. Two background alternatives, *map view* and *satellite view*, are selected for the final user tests because not only *map view* but a *satellite view* can also be used in the background of the visualizations, which are mostly used in Disaster Management. The whole process summary up to the final user tests can be seen in Figure 9-20.

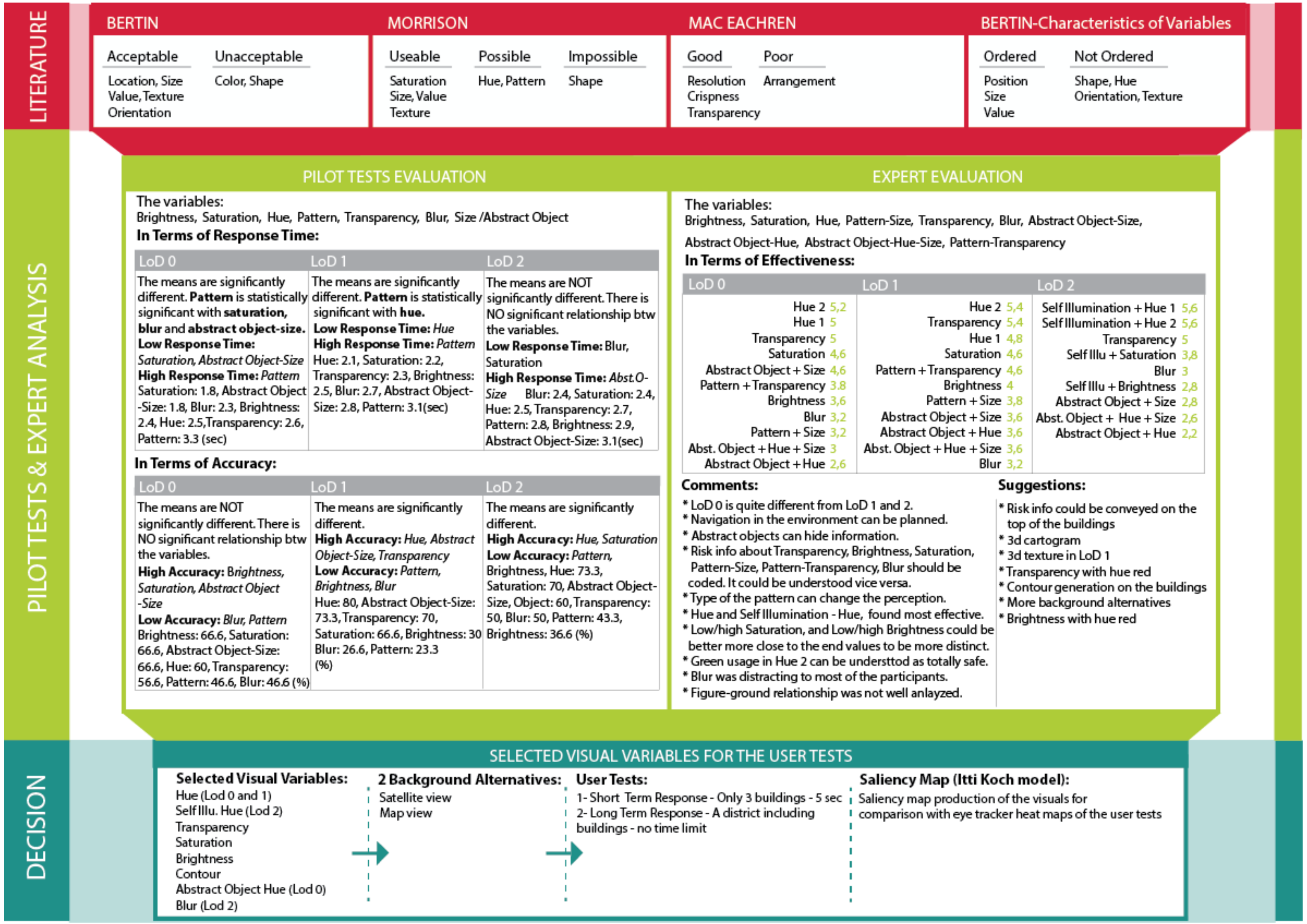


Figure 9-20: Selection of Visual Variables for Final User Tests

9.4 The Final User Tests

The final user tests occur after the elimination of variables is performed according to the pilot tests and expert evaluation results (Figure 9-21. The final user tests are held in the Test Lab of User Testing and Research Lab (UTRLAB), which is located in the Middle East Technical University. The number of DM decision makers (end users) in the user tests is 35. Each test is performed individually and each session takes approximately 40 minutes. The users are specialized in different phases of Disaster Management or Disaster Visualization. During the tests, eye tracker is used and the sessions are recorded using the software Morea Recorder. The users are asked to sign a consent form before the tests.

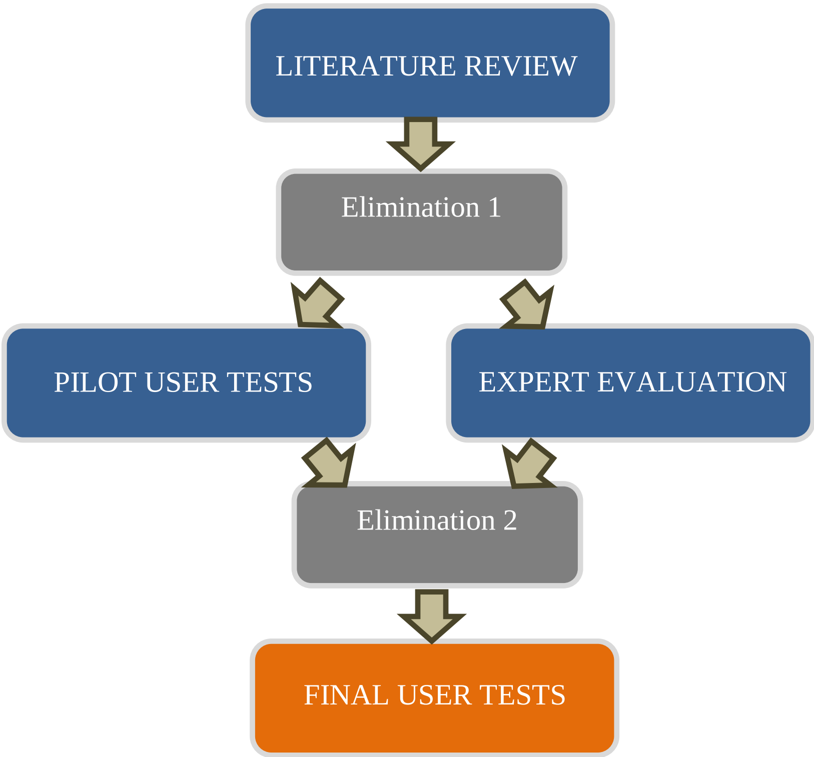


Figure 9-21: Final User Tests Highlighted in the Flowchart

9.4.1 User Profile of the Final User Tests

The users are mainly engineers. Mostly they are geological and geophysical engineers. Apart from the engineers, there are city and regional planners, a sociologist, an economist and a statistician (Figure 9-22).

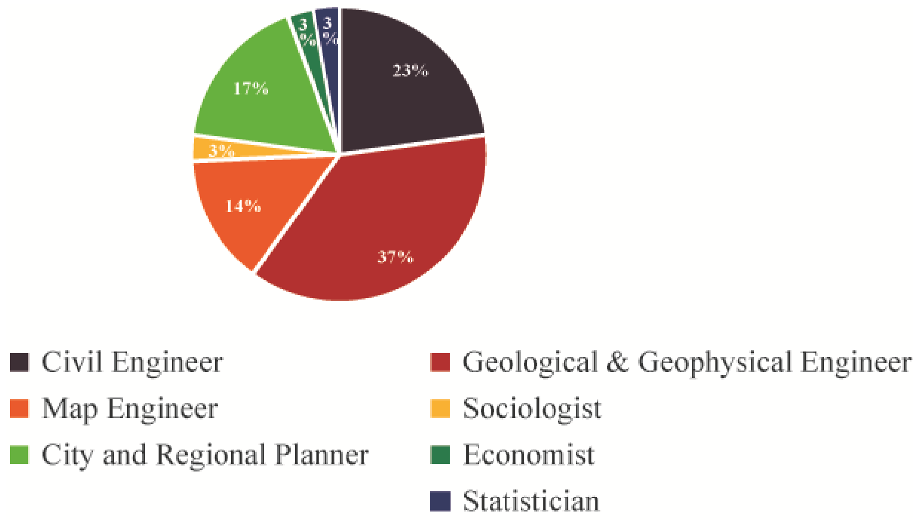


Figure 9-22: Users according to Professions

30 users are from pre-disaster and five users are from post-disaster phases. Nine users are form both pre- and post-disaster (Figure 9-23).

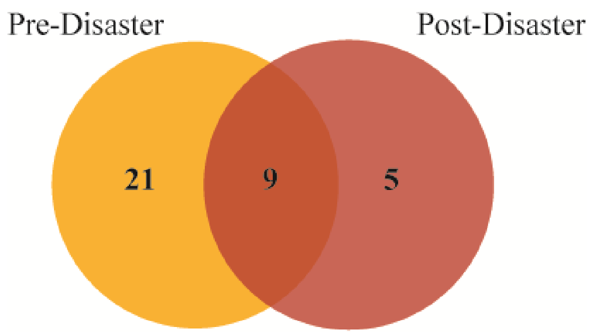


Figure 9-23: Users according to Phases

The users are separated into two groups according to the level of decision making; executive level decision makers and DM specialists and researchers (Figure 9-24). Three users are executive level decision makers. 20 users are DM specialists and 12 users are DM researchers. 15 users of the DM specialists and researchers deal with visualizing their exploration and analysis.

Figure 9-24: Users according to Level of Decision Making

The users are selected to be from different range of foundations. Although most of them (16 users) work at the governmental organization of the Prime Ministry Disaster and Emergency Management Presidency (AFAD), there are academicians who are experts in Disaster Management from the Middle East Technical University (METU), and there are also city and regional planners from the Ministry of Environment and Urbanization, three of whom work at the General Command of Mapping (National Mapping Agency/ HGK) (Figure 9-25).

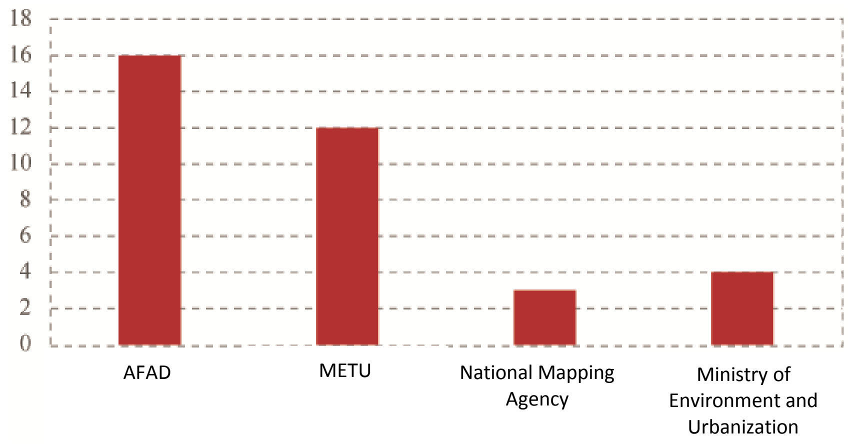


Figure 9-25: Users according to Foundations

9.4.2 The Test Design of the Final User Tests

The final user tests are performed on a Windows workstation on one PC running Tobii Studio software for automatic stimuli display and eye movement recordings, a microphone for voice recordings and Morea Recorder 3.0 software for screen recordings. Eye movements are recorded with a Tobii X120 eye tracker, at a 60Hz sampling resolution.

The final user tests are composed of two parts and each part is designed in Open Sesame but they are imported to Tobii. Open Sesame is the same software that is used in the pilot user tests (Figure 9-26). It is a behavioral analysis program which is freeware and open source. A behavioral experiment can be built using the tools of the program that supports a sequence system into which a response collector, target display, cue display, fixation display and images can be embedded. Any output needed by the researcher can be collected by the logger item and logged to an excel file. External devices can be incorporated such as eye trackers, joysticks, audio input response boxes, parallel ports etc. (Sebastiaan, 2015)

At the beginning of the test sessions, participants are asked to perform a demo test. The main reason behind this is to make the participants get used to the keyboard keys and mouse clicking while they are making their choice. Therefore, the content of the demo test differs from the content of the tests. An explanation document is provided to the participants with details about the test.

In the first part of the final user tests, 19 images are shown (see Appendix G). The images of three same buildings and fixation dot are embedded into the software and shown to the participants every five seconds (Figure 9-27). Each image has the dimension of 640x480 pixels. In each image, *risk* visualization is created using different variables. Eight types of variables are used, which are **brightness**, **saturation**, **hue**, **transparency**, **blur**, **contour**, **self-illumination-hue** and **abstract object-hue**. **Brightness** and **saturation** are used with both *blue* and *red*. These are the variables that are selected according to the results of the pilot user tests and the expert evaluation (Figure 9-20). Participants are asked to click on the number of the building that they think has the *highest risk* according to the image. The participants are asked to press the key immediately after they make their decision. There is no map legend given on the images. The design of the first of the final user tests is very similar to the design of the pilot user tests. The difference is that three same buildings are shown from one viewing angle which is 45^{o} in the first part of the final user tests. This part of the test comprises a low level of cognitive processing. The decision mode is intuitive. The participant makes a quick and unconscious response.

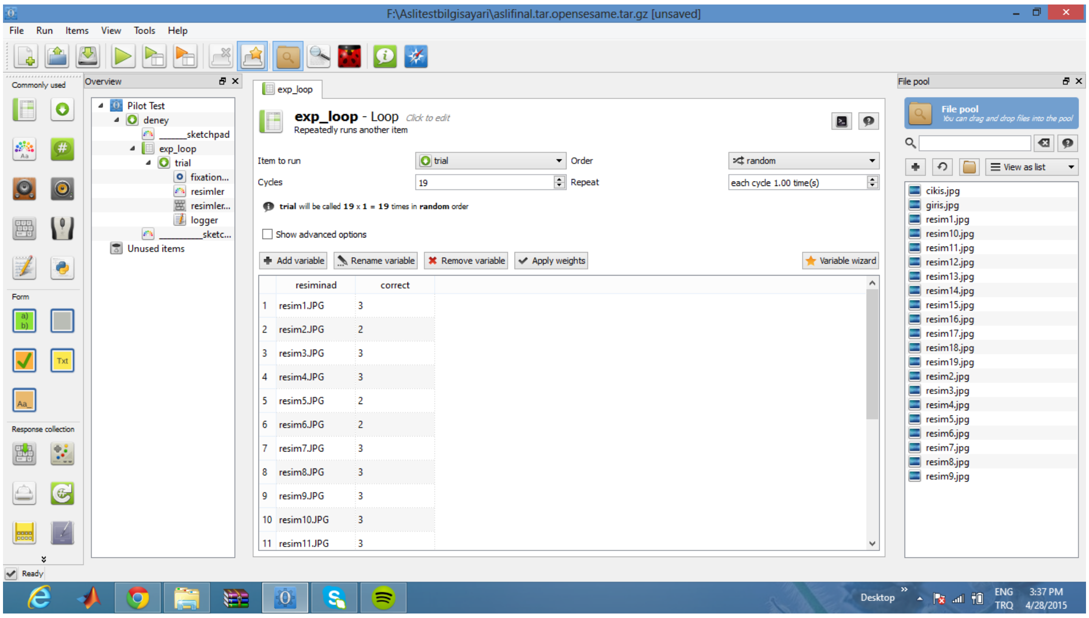


Figure 9-26: Screenshot from Open Sesame Document

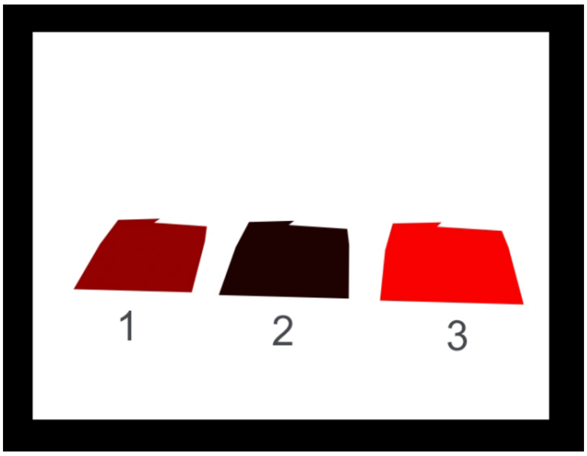


Figure 9-27: One of the Images Shown in the First Part of the Test

In the second part of the final user tests, 38 images are used (see Appendix H). In this part, the Cumhuriye district is shown. Some of the buildings on that district is visualized as having *high risk*, some of them *medium risk* and some of them *low risk* (Figure 9-28). Each visualization is prepared according to an abstract data, no real calculations are considered for determining each *risk* level. The same eight visual variables are used in the images. However, two different types of background are used, which are satellite view and map view. Therefore, the number of the images is twice the number of images in the first part. Participants are asked to click on any building which they think is from the *highest risk* range. There is no time limit in this part; therefore, there is a slower thinking process. This part of the test comprises a high level of cognitive processing. The decision mode is deliberate. The participant makes a slow and conscious response.

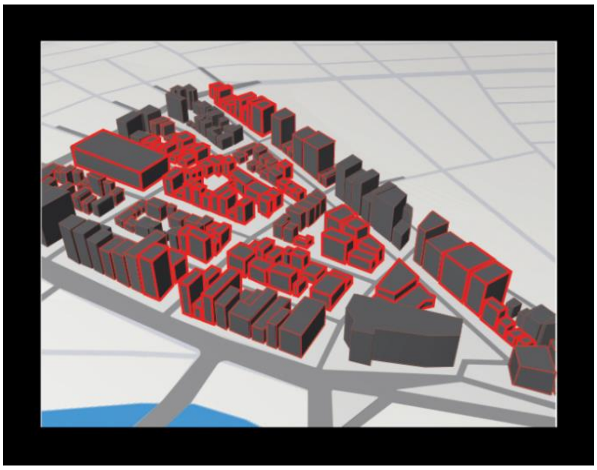


Figure 9-28: One of the Images Shown in the Second Part of the Test

After these test sessions, the images used in the second part are shown to the participants which are grouped together according to LoD and background image. Their opinions about the visualizations are asked. This part takes more than 10 minutes and it is more like a discussion part. The questions asked in this part are:

- Which variable do you think most effectively expresses *ordinal risk* visualization for this Level of Detail?
- What if the range of the *ordinal risk* information is more than three (such as five or more), would your decision be the same?

- Which background usage is effective for expressing the *total risk* information of the buildings in Disaster Management?
- Which Level of Detail is effective for expressing the *total risk* information of the buildings in Disaster Management?
- In which visualization the *highest risk* is easily and quickly seen?

9.4.3 The Usage of Eye Tracker Technology

Eye tracker technology, which is widely used in Human Computer Interaction research and practice, is used to measure people's eye movements, both where a person is looking at any given time and in the sequence which the person's eyes shift from one location to another (Poole and Ball, 2006). The beginning of the usage of eye tracker technology can be dated back to a hundred years ago, when electrooculographical techniques started to be used which relied on electrodes mounted on the skin around the eye that measured the differences in electric potential.

The modern eye tracker technologies are mostly video-based and use the center of the pupil (Goldberg and Wichansky, 2003). These modern eye trackers usually consist of a standard desktop computer with an infrared camera mounted on or next to a monitor, with image processing software to locate and identify the features of the eye movements (Poole and Ball, 2006).

Main measurements that can be made by eye tracker system are *fixations* and *saccades*. From these measurements, gaze and scan path analysis can be made. By the new eye tracker technologies pupil size and blink rate can also be measured (Poole and Ball, 2006). Shortly after defining these terms, fixation occurs when the eye is resting on something. The eye's rapid movements from one fixation to another are called saccades. The retina blurs when the eye moves from one location to another. Therefore, users are effectively blind during a saccade in the tests (Nielsen and Pernice, 2010).

Nielsen and Pernice (2010) exemplify the fixation-derived metrics with references such as number of overall fixations (Goldberg and Kotval, 1999), fixation per area of interest (Poole et al., 2004), fixation per area of interest and adjusted for text length

(Poole et al., 2004), fixation duration (Just and Carpenter, 1976), fixation cycle (gaze) (Mello-Thomas et al., 2004 and Hauland, 2003), fixation spatial density (Cowen et al., 2002), post target fixations (Goldberg and Kotval, 1999), time to first fixation on target (Byrne et al., 1999), the percentage of participants fixating an area of interest (Albert, 2002) and on-target fixations (Goldberg and Kotval, 1999). They also exemplify saccade-derived metrics with references such as number of saccades (Goldberg and Kotval, 1999), saccade amplitude (Goldberg et al., 2002), regressive saccades (Sibert et al., 2000) and saccades revealing marked directional shifts (Cowen et al., 2002).

Gaze is an eye tracking metric which is usually the sum of all fixation durations within a prescribed area. Scan path is a complete sequence of fixations ad interconnecting saccades. Blink rate and pupil size can be measured especially for cognitive workload, stress or detect emotion. Data output can be mainly visualized by creating heat maps and gaze plots. Heat maps are the best known visualization methods where the amount of look is coded with color. In gaze plots, series of dots indicating one fixation are visualized in which the sizes of the dots are defined according to the length of the look.

In cartographic research, eye tracker usage was popular until the 1980s but after that decade the interest seemed to be disappeared (Steinke, 1987; Brodersen et al., 2002; Fabrikant et al., 2008). This might be because of the financial cost of the eye tracker technology and reduced cost-effectiveness in terms of the set up and analysis (Coltekin, Garlandini, Heil and Fabrikant, 2009).

In the thesis study, the reason to use an eye tracker is that the heat maps and number of fixations give clues about how easy it is for the decision maker to make the final decision during the tests. Also, in this thesis, eye tracker heat maps are compared with saliency maps. Saliency maps, which are produced through the Itti-Koch model, refer to *bottom-up* cognitive process. This model is a computational model of focal visual attention which emphasizes the *bottom-up* cognitive process and the image-based control of attentional deployment. However, eye tracker heat maps produced for the images of the second part of the final user tests mainly refer to *top-down* cognitive process as the participants' decision-making processes are affected by their previous experience and background. Their decision processes are not only driven by a simple representation of data, image or stimuli. Therefore, they cannot be considered only as *bottom-up*. To decide the effective visual variable and LoD, both *bottom-up* and *top-down* cognitive processes should be considered. Therefore, the best visualization alternative should show the buildings which are coded in the *highest risk* range to be salient in the saliency maps and as the most focused by the participants in the eye tracker heat maps. The details are explained in section 9.4.5.

9.4.4 The Analysis of the Final User Tests

The response time and the accuracy to the visual variables, the number of clicks/choices for each variable by the participants, the fixation durations and counts to the images, the discussion part of the test, eye-tracker heat maps and their comparison with saliency maps are analyzed.

First of all, the response time and accuracy data are collected from Open Sesame Excel logs. The results of the response time and accuracy of each answer are analyzed in the SPSS. First the variables used are compared according to the response time for each LoD. The same is performed for the accuracy results. The parametric one-way ANOVA test is used to compare the means of response time for each variable used. The analysis is performed for each LoD. The non-parametric test of Kruskal Wallis is used to analyze if there is a significant difference between the groups in terms of accuracy. The analysis is again performed for each LoD.

One-way ANOVA test requires the test of normality (Kolmogorov-Smirnov). The data of LoD 0 is not normally distributed within groups; $D(35) = 0.153$, $p<0.05$ in contour/ LoD 0 data. Therefore, outliers are eliminated and data distribution becomes normal for each LoD (Table 9-25). The data of LoD 1 and LoD 2 are normally distributed (Table 9-26 and 9-27).

Table 9-25: Test of Normality for LoD 0

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AbstractObjectHueLoD0	.098	32	.200*	.962	32	.318
BrightnessRedLoD0	.099	32	.200*	.979	32	.774
BrightnessBlueLoD0	.098	32	.200*	.965	32	.382
ContourLoD0	.155	32	.050	.922	32	.023
HueLoD0	.115	32	.200*	.940	32	.074
SaturationRedLoD0	.122	32	.200*	.960	32	.283
SaturationBlueLoD0	.095	32	.200*	.962	32	.315
TransparencyLoD0	.096	32	.200*	.983	32	.888
*. This is a lower bound of the true significance. a. Lilliefors Significance Correction						

Table 9-26: Test of Normality for LoD 1

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BrightnessRedLoD1	.112	35	.200*	.953	35	.138
BrightnessBlueLoD1	.115	35	.200*	.949	35	.108
ContourLoD1	.110	35	.200*	.965	35	.332
HueLoD1	.106	35	.200*	.951	35	.119
SaturationRedLoD1	.103	35	.200*	.954	35	.149
SaturationBlueLoD1	.078	35	.200*	.968	35	.392
TransparencyLoD1	.108	35	.200*	.972	35	.505
*. This is a lower bound of the true significance. a. Lilliefors Significance Correction						

Table 9-27: Test of Normality for LoD 2

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BlurLoD2	.069	35	.200*	.970	35	.440
ContourLoD2	.079	35	.200*	.976	35	.613
SelfIlluLoD2	.139	35	.086	.956	35	.179
TransparencyLoD2	.143	35	.068	.905	35	.005
*. This is a lower bound of the true significance. a. Lilliefors Significance Correction						

According to the ANOVA test results for LoD 0 in the final user tests, the means are significantly different with a 95% confidence level (Table 9-29). When the mean plot and Tukey multiple comparisons are performed, it can be analyzed that **contour** is statistically significant with **abstract object-hue** (Figure 9-25 and Table 9-30). The least response time occurs when the variable **contour** is used. Then, **saturation-red** follows it (Figure 9-29).

Table 9-28: ANOVA Test Results for Response Time - LoD 0 - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
AbstractobjecthueLoD0	32	2992.22	1236.948	218.664	2546.25	3438.19	453	5000
BrightnessredLoD0	32	2742.34	1175.716	207.839	2318.45	3166.23	378	5000
BrightnessblueLoD0	32	2822.97	1208.268	213.594	2387.34	3258.60	544	5000
ContourLoD0	32	2007.91	1042.363	184.266	1632.09	2383.72	411	4074
HueLoD0	32	2669.09	1129.554	199.679	2261.85	3076.34	1023	5000
SaturationredLoD0	32	2270.53	1008.310	178.246	1907.00	2634.07	569	5000
SaturationblueLoD0	32	2418.81	1271.428	224.759	1960.41	2877.21	106	5000
TransparencyLoD0	32	2432.72	1111.440	196.477	2032.00	2833.44	41	5000
Total	256	2544.57	1174.676	73.417	2399.99	2689.16	41	5000

Table 9-29: ANOVA Test Results for Response Time - LoD 0

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23166296.184	7	3309470.883	2.497	.017
Within Groups	328698802.406	248	1325398.397		
Total	351865098.590	255			

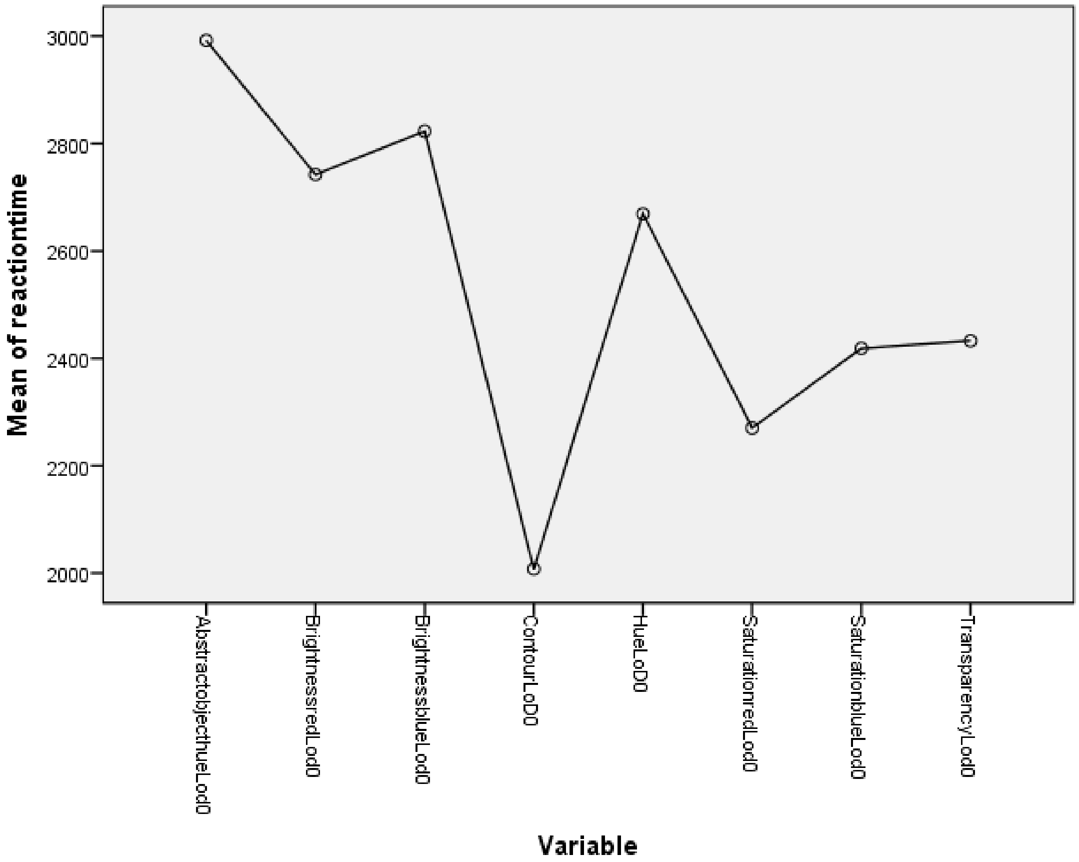


Figure 9-29: Mean Response Time for the Variables for LoD 0

Table 9-30: Post Hoc Tests - Multiple Comparisons – LoD 0

	(I) Variable	(J) Variable	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	AbstractobjecthueLoD0	BrightnessredLoD0	249.875	287.815	.989	-629.98	1129.73
		BrightnessblueLoD0	169.250	287.815	.999	-710.60	1049.10
		ContourLoD0	984.313*	287.815	.017	104.46	1864.16
		HueLoD0	323.125	287.815	.951	-556.73	1202.98
		SaturationredLoD0	721.688	287.815	.197	-158.16	1601.54
		SaturationblueLoD0	573.406	287.815	.489	-306.44	1453.26
		TransparencyLoD0	559.500	287.815	.522	-320.35	1439.35
	BrightnessredLoD0	AbstractobjecthueLoD0	-249.875	287.815	.989	-1129.73	629.98
		BrightnessblueLoD0	-80.625	287.815	1.000	-960.48	799.23
		ContourLoD0	734.438	287.815	.179	-145.41	1614.29
		HueLoD0	73.250	287.815	1.000	-806.60	953.10
		SaturationredLoD0	471.813	287.815	.726	-408.04	1351.66
		SaturationblueLoD0	323.531	287.815	.951	-556.32	1203.38
		TransparencyLoD0	309.625	287.815	.961	-570.23	1189.48
	BrightnessblueLoD0	AbstractobjecthueLoD0	-169.250	287.815	.999	-1049.10	710.60
		BrightnessredLoD0	80.625	287.815	1.000	-799.23	960.48
		ContourLoD0	815.063	287.815	.092	-64.79	1694.91
		HueLoD0	153.875	287.815	.999	-725.98	1033.73
		SaturationredLoD0	552.438	287.815	.539	-327.41	1432.29
		SaturationblueLoD0	404.156	287.815	.855	-475.69	1284.01
		TransparencyLoD0	390.250	287.815	.876	-489.60	1270.10
	ContourLoD0	AbstractobjecthueLoD0	-984.313*	287.815	.017	-1864.16	-104.46
		BrightnessredLoD0	-734.438	287.815	.179	-1614.29	145.41
		BrightnessblueLoD0	-815.063	287.815	.092	-1694.91	64.79
		HueLoD0	-661.188	287.815	.299	-1541.04	218.66
		SaturationredLoD0	-262.625	287.815	.985	-1142.48	617.23
		SaturationblueLoD0	-410.906	287.815	.844	-1290.76	468.94
		TransparencyLoD0	-424.813	287.815	.820	-1304.66	455.04
	HueLoD0	AbstractobjecthueLoD0	-323.125	287.815	.951	-1202.98	556.73
		BrightnessredLoD0	-73.250	287.815	1.000	-953.10	806.60
		BrightnessblueLoD0	-153.875	287.815	.999	-1033.73	725.98
		ContourLoD0	661.188	287.815	.299	-218.66	1541.04
		SaturationredLoD0	398.563	287.815	.864	-481.29	1278.41
		SaturationblueLoD0	250.281	287.815	.988	-629.57	1130.13
		TransparencyLoD0	236.375	287.815	.992	-643.48	1116.23
	SaturationredLoD0	AbstractobjecthueLoD0	-721.688	287.815	.197	-1601.54	158.16
		BrightnessredLoD0	-471.813	287.815	.726	-1351.66	408.04
		BrightnessblueLoD0	-552.438	287.815	.539	-1432.29	327.41
		ContourLoD0	262.625	287.815	.985	-617.23	1142.48
		HueLoD0	-398.563	287.815	.864	-1278.41	481.29
		SaturationblueLoD0	-148.281	287.815	1.000	-1028.13	731.57
		TransparencyLoD0	-162.188	287.815	.999	-1042.04	717.66
	SaturationblueLoD0	AbstractobjecthueLoD0	-573.406	287.815	.489	-1453.26	306.44
		BrightnessredLoD0	-323.531	287.815	.951	-1203.38	556.32
		BrightnessblueLoD0	-404.156	287.815	.855	-1284.01	475.69
		ContourLoD0	410.906	287.815	.844	-468.94	1290.76
		HueLoD0	-250.281	287.815	.988	-1130.13	629.57
		SaturationredLoD0	148.281	287.815	1.000	-731.57	1028.13
		TransparencyLoD0	-13.906	287.815	1.000	-893.76	865.94
	TransparencyLoD0	AbstractobjecthueLoD0	-559.500	287.815	.522	-1439.35	320.35
		BrightnessredLoD0	-309.625	287.815	.961	-1189.48	570.23
		BrightnessblueLoD0	-390.250	287.815	.876	-1270.10	489.60
		ContourLoD0	424.813	287.815	.820	-455.04	1304.66
		HueLoD0	-236.375	287.815	.992	-1116.23	643.48
		SaturationredLoD0	162.188	287.815	.999	-717.66	1042.04
		SaturationblueLoD0	13.906	287.815	1.000	-865.94	893.76

According to the ANOVA test results of LoD 1 in the final user tests, the means are not significantly different with a 95% confidence level (Table 9-32). As seen from the mean plot, the highest mean response time occurs when **brightness-blue** is used. The lowest mean response time occurs when **contour** is used (Figure 9-27). **Saturation-red** follows **contour**.

Table 9-31: ANOVA Test Results for Response Time - LoD 1 - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
BrightnessredLoD1	35	2905.83	1381.887	233.581	2431.13	3380.52	271	5000
BrightnessblueLoD1	35	2951.00	1283.899	217.019	2509.97	3392.03	79	5000
ContourLoD1	35	2438.29	1074.406	181.608	2069.21	2807.36	360	4312
HueLoD0	35	2844.34	1424.495	240.784	2355.01	3333.67	131	5000
SaturationredLoD1	35	2697.20	1331.531	225.070	2239.80	3154.60	158	5000
SaturationblueLoD1	35	2681.17	1134.695	191.798	2291.39	3070.95	516	5000
TransparencyLoD1	35	2835.20	1284.623	217.141	2393.92	3276.48	257	5000
Total	245	2764.72	1273.660	81.371	2604.44	2925.00	79	5000

Table 9-32: ANOVA Test Results for Response Time - LoD 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6440621.396	6	1073436.899	.656	.685
Within Groups	389378388.171	238	1636043.648		
Total	395819009.567	244			

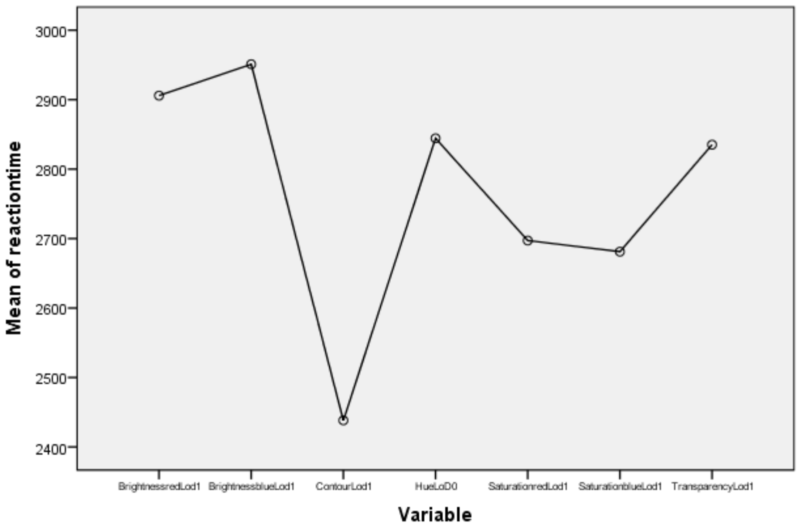


Figure 9-30: Mean Response Time for the Variables for LoD 1

Table 9-33: Post Hoc Tests - Multiple Comparisons – LoD 1

	(I) Variable	(J) Variable	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	BrightnessredLoD1	BrightnessblueLoD1	-45.171	305.758	1.000	-954.42	864.07
		ContourLoD1	467.543	305.758	.727	-441.70	1376.79
		HueLoD0	61.486	305.758	1.000	-847.76	970.73
		SaturationredLoD1	208.629	305.758	.993	-700.62	1117.87
		SaturationblueLoD1	224.657	305.758	.990	-684.59	1133.90
		TransparencyLoD1	70.629	305.758	1.000	-838.62	979.87
	BrightnessblueLoD1	BrightnessredLoD1	45.171	305.758	1.000	-864.07	954.42
		ContourLoD1	512.714	305.758	.632	-396.53	1421.96
		HueLoD0	106.657	305.758	1.000	-802.59	1015.90
		SaturationredLoD1	253.800	305.758	.982	-655.45	1163.05
		SaturationblueLoD1	269.829	305.758	.975	-639.42	1179.07
		TransparencyLoD1	115.800	305.758	1.000	-793.45	1025.05
	ContourLoD1	BrightnessredLoD1	-467.543	305.758	.727	-1376.79	441.70
		BrightnessblueLoD1	-512.714	305.758	.632	-1421.96	396.53
		HueLoD0	-406.057	305.758	.838	-1315.30	503.19
		SaturationredLoD1	-258.914	305.758	.980	-1168.16	650.33
		SaturationblueLoD1	-242.886	305.758	.985	-1152.13	666.36
		TransparencyLoD1	-396.914	305.758	.852	-1306.16	512.33
	HueLoD0	BrightnessredLoD1	-61.486	305.758	1.000	-970.73	847.76
		BrightnessblueLoD1	-106.657	305.758	1.000	-1015.90	802.59
		ContourLoD1	406.057	305.758	.838	-503.19	1315.30
		SaturationredLoD1	147.143	305.758	.999	-762.10	1056.39
		SaturationblueLoD1	163.171	305.758	.998	-746.07	1072.42
		TransparencyLoD1	9.143	305.758	1.000	-900.10	918.39
	SaturationredLoD1	BrightnessredLoD1	-208.629	305.758	.993	-1117.87	700.62
		BrightnessblueLoD1	-253.800	305.758	.982	-1163.05	655.45
		ContourLoD1	258.914	305.758	.980	-650.33	1168.16
		HueLoD0	-147.143	305.758	.999	-1056.39	762.10
		SaturationblueLoD1	16.029	305.758	1.000	-893.22	925.27
		TransparencyLoD1	-138.000	305.758	.999	-1047.25	771.25
	SaturationblueLoD1	BrightnessredLoD1	-224.657	305.758	.990	-1133.90	684.59
		BrightnessblueLoD1	-269.829	305.758	.975	-1179.07	639.42
		ContourLoD1	242.886	305.758	.985	-666.36	1152.13
		HueLoD0	-163.171	305.758	.998	-1072.42	746.07
		SaturationredLoD1	-16.029	305.758	1.000	-925.27	893.22
		TransparencyLoD1	-154.029	305.758	.999	-1063.27	755.22
	TransparencyLoD1	BrightnessredLoD1	-70.629	305.758	1.000	-979.87	838.62
		BrightnessblueLoD1	-115.800	305.758	1.000	-1025.05	793.45
		ContourLoD1	396.914	305.758	.852	-512.33	1306.16
		HueLoD0	-9.143	305.758	1.000	-918.39	900.10
		SaturationredLoD1	138.000	305.758	.999	-771.25	1047.25
		SaturationblueLoD1	154.029	305.758	.999	-755.22	1063.27
Dunnett t (2-sided)a	BrightnessredLoD1	TransparencyLoD1	70.629	305.758	1.000	-719.92	861.17
	BrightnessblueLoD1	TransparencyLoD1	115.800	305.758	.998	-674.75	906.35
	ContourLoD1	TransparencyLoD1	-396.914	305.758	.612	-1187.46	393.63
	HueLoD0	TransparencyLoD1	9.143	305.758	1.000	-781.40	799.69
	SaturationredLoD1	TransparencyLoD1	-138.000	305.758	.995	-928.55	652.55
	SaturationblueLoD1	TransparencyLoD1	-154.029	305.758	.991	-944.57	636.52

According to the ANOVA test results for LoD 2 in the final user tests, the means are not significantly different with a 95% confidence level (Table 9-35). When the mean plot and Tukey multiple comparisons are analyzed, there is no significant relationship between the variables. As seen from the mean plot, the highest mean response time occurs when **transparency** is used; the lowest mean response time occurs when **self-illumination-hue** is used (Figure 9-31).

Table 9-34: ANOVA Test Results for Response Time - LoD 2 - Descriptives

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BlurLoD2	35	2885.23	1208.743	204.315	2470.01	3300.45	513	5000
ContourLoD2	35	3022.14	1200.625	202.943	2609.71	3434.57	56	5000
Self IlluminationLoD2	35	2848.23	1287.875	217.691	2405.83	3290.63	283	5000
TransparencyLoD0	35	3143.91	1404.659	237.431	2661.40	3626.43	609	5000
Total	140	2974.88	1269.695	107.309	2762.71	3187.05	56	5000

Table 9-35: ANOVA Test Results for Response Time – LoD 2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1920951.564	3	640317.188	.392	.759
Within Groups	222164459.371	136	1633562.201		
Total	224085410.936	139			

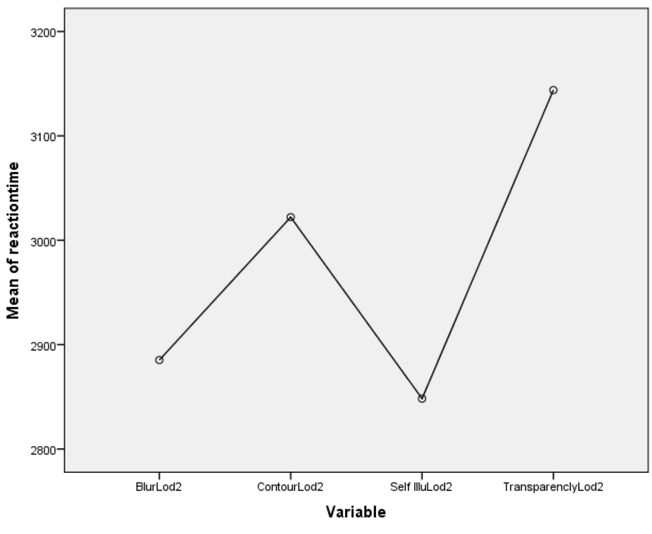


Figure 9-31: Mean Response Time for the Variables for LoD 2

Table 9-36: Post Hoc Tests - Multiple Comparisons – LoD 2

	(I) Variable	(J) Variable	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	BlurLod2	ContourLod2	-136.914	305.526	.970
		Self IlluLod2	37.000	305.526	.999
		TransparenclyLod2	-258.686	305.526	.832
	ContourLod2	BlurLod2	136.914	305.526	.970
		Self IlluLod2	173.914	305.526	.941
		TransparenclyLod2	-121.771	305.526	.978
	Self IlluLod2	BlurLod2	-37.000	305.526	.999
		ContourLod2	-173.914	305.526	.941
		TransparenclyLod2	-295.686	305.526	.768
	TransparenclyLod2	BlurLod2	258.686	305.526	.832
		ContourLod2	121.771	305.526	.978
		Self IlluLod2	295.686	305.526	.768
Dunnett t (2-sided)[a]	BlurLod2	TransparenclyLod2	-258.686	305.526	.732
	ContourLod2	TransparenclyLod2	-121.771	305.526	.959
	Self IlluLod2	TransparenclyLod2	-295.686	305.526	.648

In the final user tests, the accuracy results are considered according to the ground truths proposed for the *highest risk* for each variable. The ground truth for each variable for each LoD depends on the literature, pilot user tests and expert evaluation. Here is the list:

- Abstract Object-Hue LoD 0: red
- Brightness-Red LoD 0: the most bright
- Brightness-Blue LoD 0: the most bright
- Contour LoD 0: the thickest contoured
- Hue LoD 0: red
- Saturation-Red LoD 0: the most saturated
- Saturation-Blue LoD 0: the most saturated
- Transparency LoD 0: the least transparent

- Brightness Red LoD 1: the most bright
- Brightness Blue LoD 1: the most bright
- Contour LoD 1: the thickest contoured
- Hue LoD 1: red
- Saturation Red LoD 1: the most saturated

- Saturation Blue LoD 1: the most saturated
- Transparency LoD 1: the least transparent
- Blur LoD 2: the least blurred
- Contour LoD 2: the thickest contoured
- Self-Illumination-Hue LoD 2: red
- Transparency LoD 2: the least transparent

According to the Kruskal-Wallis Test results for LoD 0 in the final user tests, the means are significantly different with a 95% confidence level (Table 9-39). It can be seen that when the accuracy results are turned into the mean accuracy percentages for each variable, the percentages are so different from each other. However, it should be stated that accuracy is according to the ground truths proposed. Especially for **brightness-blue** and **contour**, most of the participants determine the *highest risk* as just the contrary to the ground truths prosed for them. It is interesting that for the variable usage of **brightness-red**, the participants prefer *bright red*; however, they preferred *dark blue* for the variable usage of **brightness-blue** for referring to *highest risk*. The highest accuracy occurs when the variable **saturation-red** and **transparency** are used (Figure 9-32).

Table 9-37: Analysis of Accuracy for LoD 0 - Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	280	.45	.499	0	1
variable	280	4.50	2.295	1	8

Table 9-38: Kruskal-Wallis Test – Ranks for LoD 0

	variable	N	Mean Rank
accuracy	AbstractObjectHueLoD0	35	169.00
	BrightnessRedLoD0	35	161.00
	BrightnessBlueLoD0	35	97.00
	ContourLoD0	35	93.00
	HueLoD0	35	109.00
	SaturationRedLoD0	35	177.00
	SaturationBlueLoD0	35	141.00
	TransparencyLoD0	35	177.00
	Total	280	

Table 9-39: Kruskal-Wallis Test – Chi Square for LoD 0

	Accuracy
Chi-Square	64.886
df	7
Asymp. Sig.	.000
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

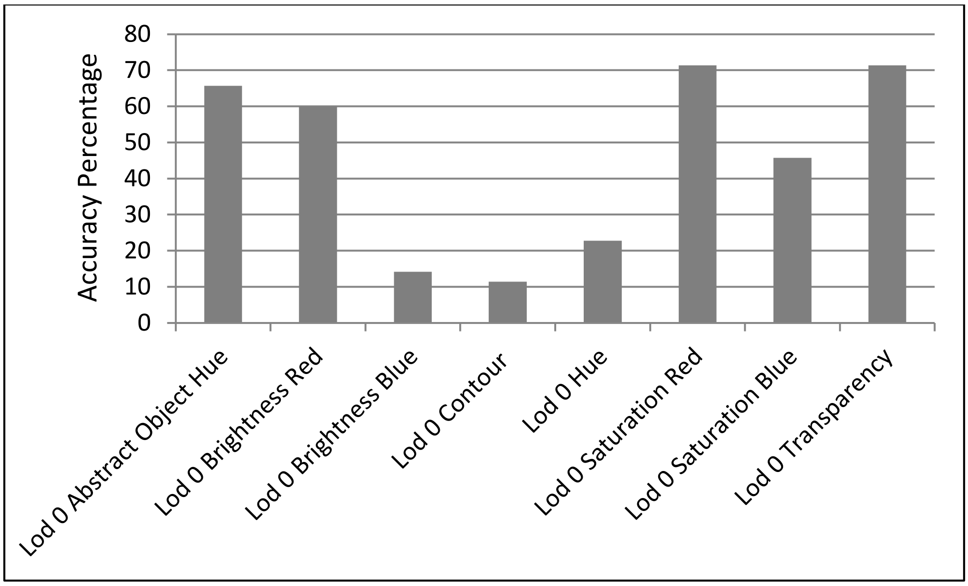


Figure 9-32: Accuracy Percentages for LoD 0 Variables

According to the Kruskal-Wallis Test results for LoD 1 in the final user tests, the means are significantly different with a 95% confidence level (Table 9-42). When the accuracy results are turned into mean accuracy percentages for each variable and seen from the bar gram, the percentages are different from each other. When the Level of Detail changes to LoD 1, the results differ especially for **contour** and **brightness-blue**. Accuracy is higher when they are used. For LoD 1 most *bright blue*, but *darkest red* is chosen. (Figure 9-33).

Table 9-40: Analysis of Accuracy for LoD 1 – Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	245	.44	.497	0	1
variable	245	4.00	2.004	1	7

Table 9-41: Kruskal-Wallis Test – Ranks for LoD 1+

	variable	N	Mean Rank
accuracy	BrightnessRedLoD1	35	101.00
	BrightnessBlueLoD1	35	139.50
	ContourLoD1	35	143.00
	HueLoD1	35	125.50
	SaturationRedLoD1	35	108.00
	SaturationBlueLoD1	35	111.50
	TransparencyLoD1	35	132.50
	Total	245	

Table 9-42: Kruskal-Wallis Test – Chi Square for LoD 1

	Accuracy
Chi-Square	15.202
df	6
Asymp. Sig.	.019
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

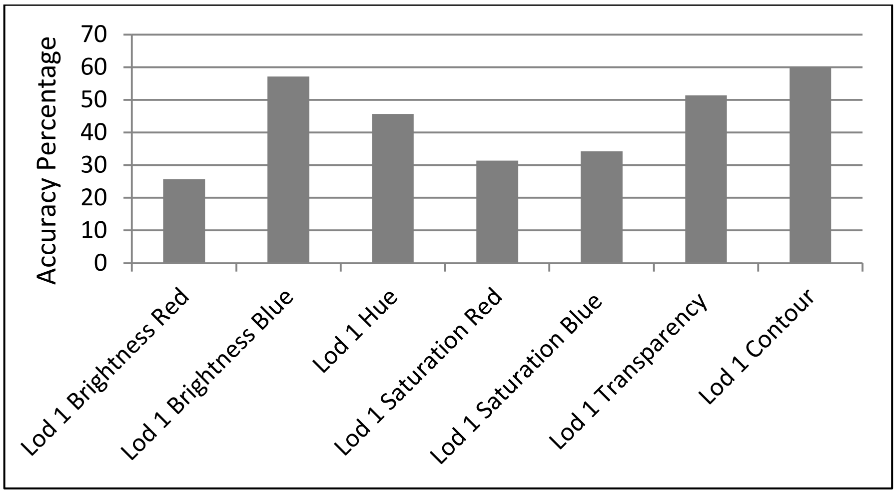


Figure 9-33: Accuracy Percentages for LoD 1 Variables

According to the Kruskal-Wallis Test results for LoD 2 in the final user tests, the means are significantly different with a 95% confidence level (Table 9-45).When the accuracy results are turned into the mean accuracy percentages for each variable and seen from the bar gram, the percentage of **transparency** is different from the others. The participants mostly prefer the most **transparent** one for the *highest risk* (Figure 9-34).

Table 9-43: Analysis of Accuracy for LoD 2 – Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
accuracy	140	.47	.501	0	1
variable	140	2.50	1.122	1	4

Table 9-44: Kruskal-Wallis Test – Ranks for LoD 2

	variable	N	Mean Rank
accuracy	BlurLoD2	35	77.50
	ContourLoD2	35	71.50
	SelfilluLoD2	35	77.50
	TransparencyLoD2	35	55.50
	Total	140	

Table 9-45: Kruskal-Wallis Test – Chi Square for LoD 2

	Accuracy
Chi-Square	15.202
df	6
Asymp. Sig.	.019
a. Kruskal Wallis Test	
b. Grouping Variable: variable	

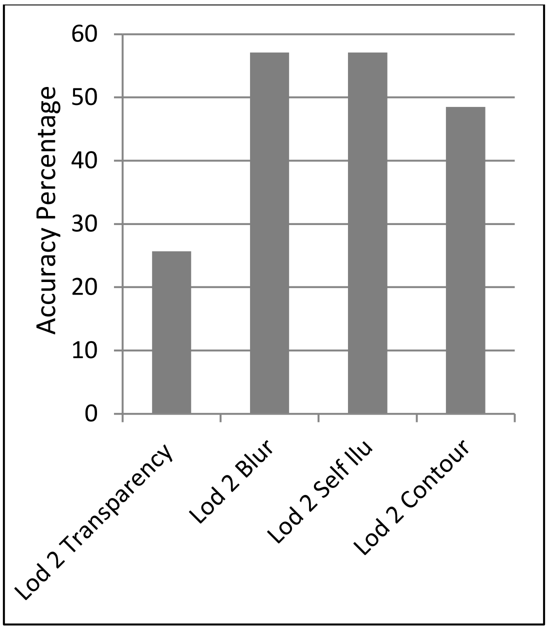


Figure 9-34: Accuracy Percentages for LoD 2 Variables

When the number of clicks for all of the LoDs are analyzed, it is found that for the variables **hue**, **abstract object-hue** and **self-illumination-hue,** *red* has the highest click scores (Figure 9-35 and 9-36). The scores of *red* exceed those of *blue* and *yellow*. Therefore, it is understood that the color *red* can be distinguishable when *risk* is considered.

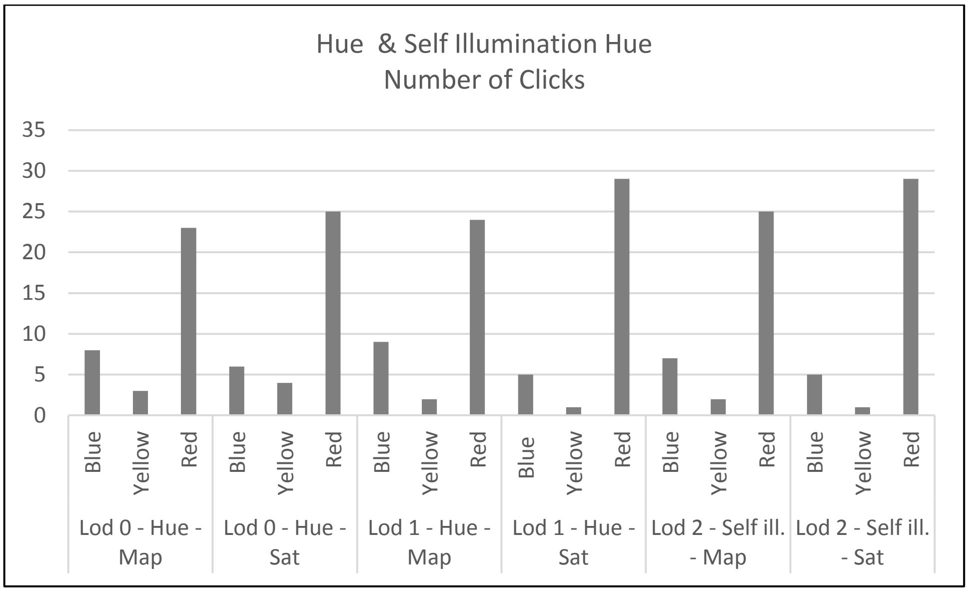


Figure 9-35: Number of Clicks (Choices) for Hue and Self-Illu.-Hue of all Participants

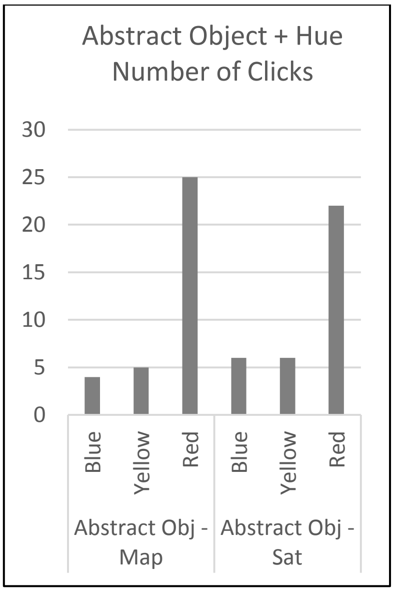


Figure 9-36: Number of Clicks (Choices) for Abstract Object-Hue of all Participants

The participants prefer the thickest **contour** indicating *highest risk* (Figure 9-37). In terms of **saturation,** the participants click on the most saturated ones (Figure 9-38). Especially the variable **saturation-red** has the highest click score for LoD 0 and 1 among all the other variables. Therefore, when the number of clicks is considered, it can be considered as the most effective one for LoD 0 and 1.

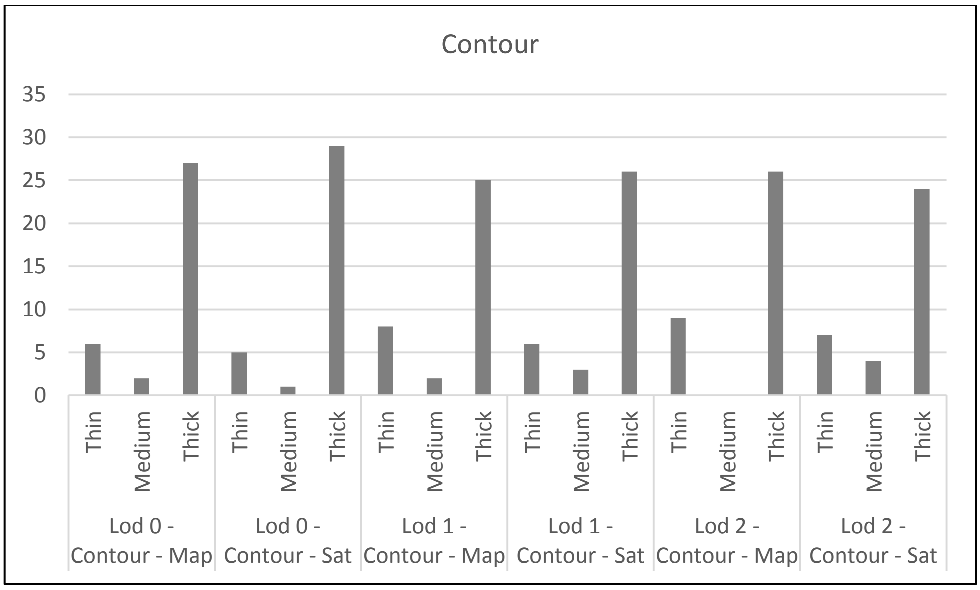


Figure 9-37: Number of Clicks (Choices) for Contour of all Participants

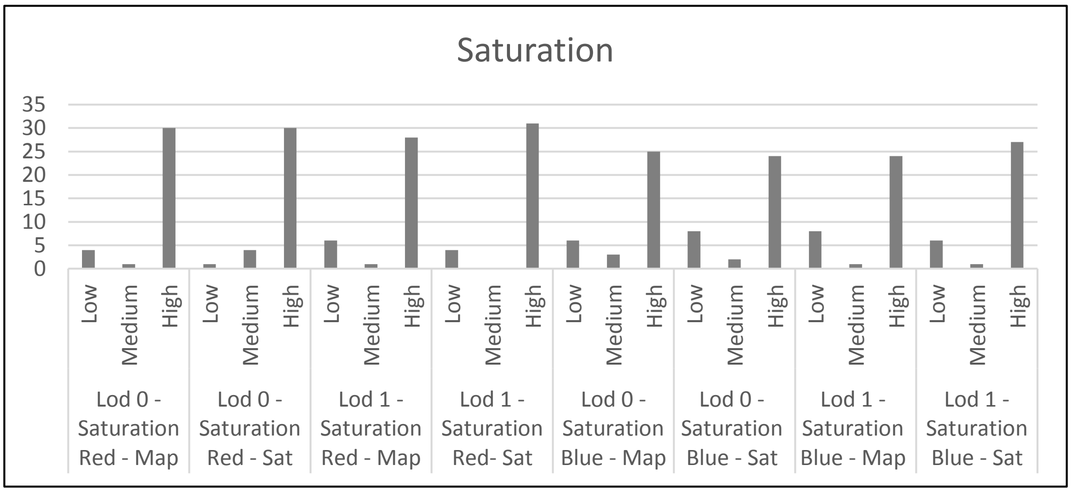


Figure 9-38: Number of Clicks (Choices) for Saturation of all Participants

Brightness is confusing for the participants. Participants both click on the buildings having low **brightness** and high **brightness** for the highest risk. There is no prominent tendency for choosing the lowest or the highest bright ones. Mid value claret red is also clicked by the participants (Figure 9-39). The numbers of clicks for each of them can be seen in Figure 9-39 in detail.

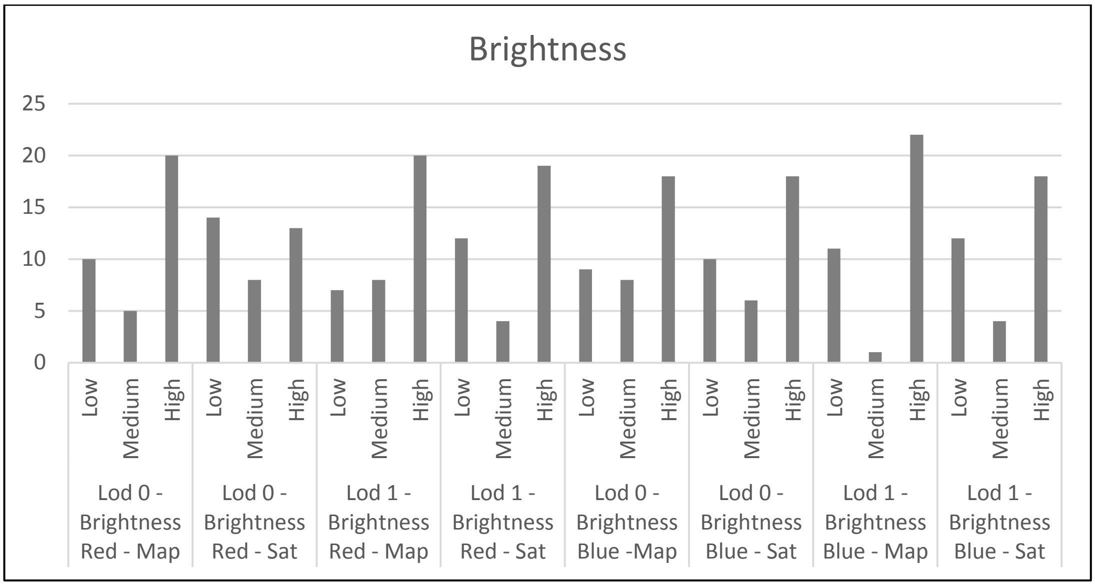


Figure 9-39: Number of Clicks (Choices) for Brightness of all Participants

Transparency for LoD 1 and 2 is confusing for the participants. Most of the participants prefer the most **transparent;** however, over seven clicks take place for the least **transparent** for all LoDs (Figure 9-40). The same confusion can be seen for **blur** for LoD 2 (Figure 9-41). 17 clicks are collected for the buildings which have low **blur** and 17 clicks are collected for the ones which have high **blur** when the background image is map. 19 clicks are collected for the buildings which have low **blur** and 15 clicks are collected for the ones which have high **blur** when the background image is satellite. There are no clicks on the buildings that have mid **blur**.

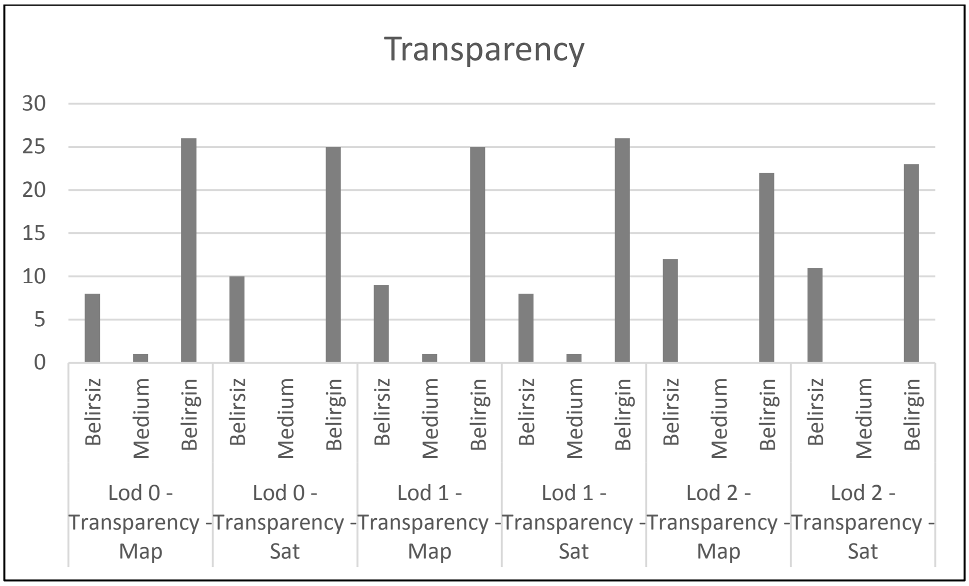


Figure 9-40: Number of Clicks (Choices) for Transparency of all Participants

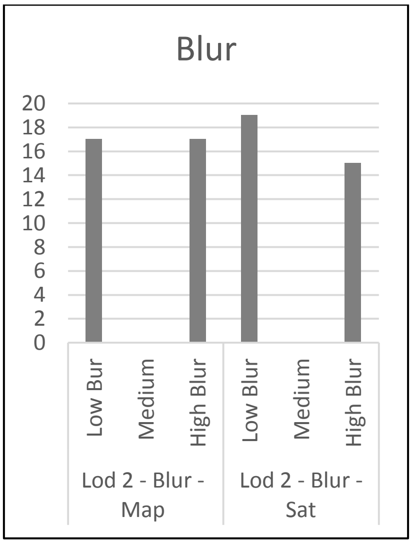


Figure 9-41: Number of Clicks (Choices) for Blur of all Participants

Eye fixation durations and *eye fixation counts* give clues about the effectiveness of the visual variable. If the participant's fixation duration or fixation counts on the image are high, that means the visual variable may not be effective. The mean fixation durations are similar between the variables. However, the mean fixation counts differ between the visual variables (Figure 9-42). The lowest fixation counts are obtained when **saturation-red** is used. The highest fixation counts are obtained when **transparency** and **blur** are used. The fixation counts when b**rightness-blue** is used are more than the ones when the **brightness-red** is used. Low fixation counts are obtained when **transparency** for LoD 0 is used as well. Although fixation counts are low for **hue** LoD 0, they are high for LoD 1 and 2 (Figure 9-42).

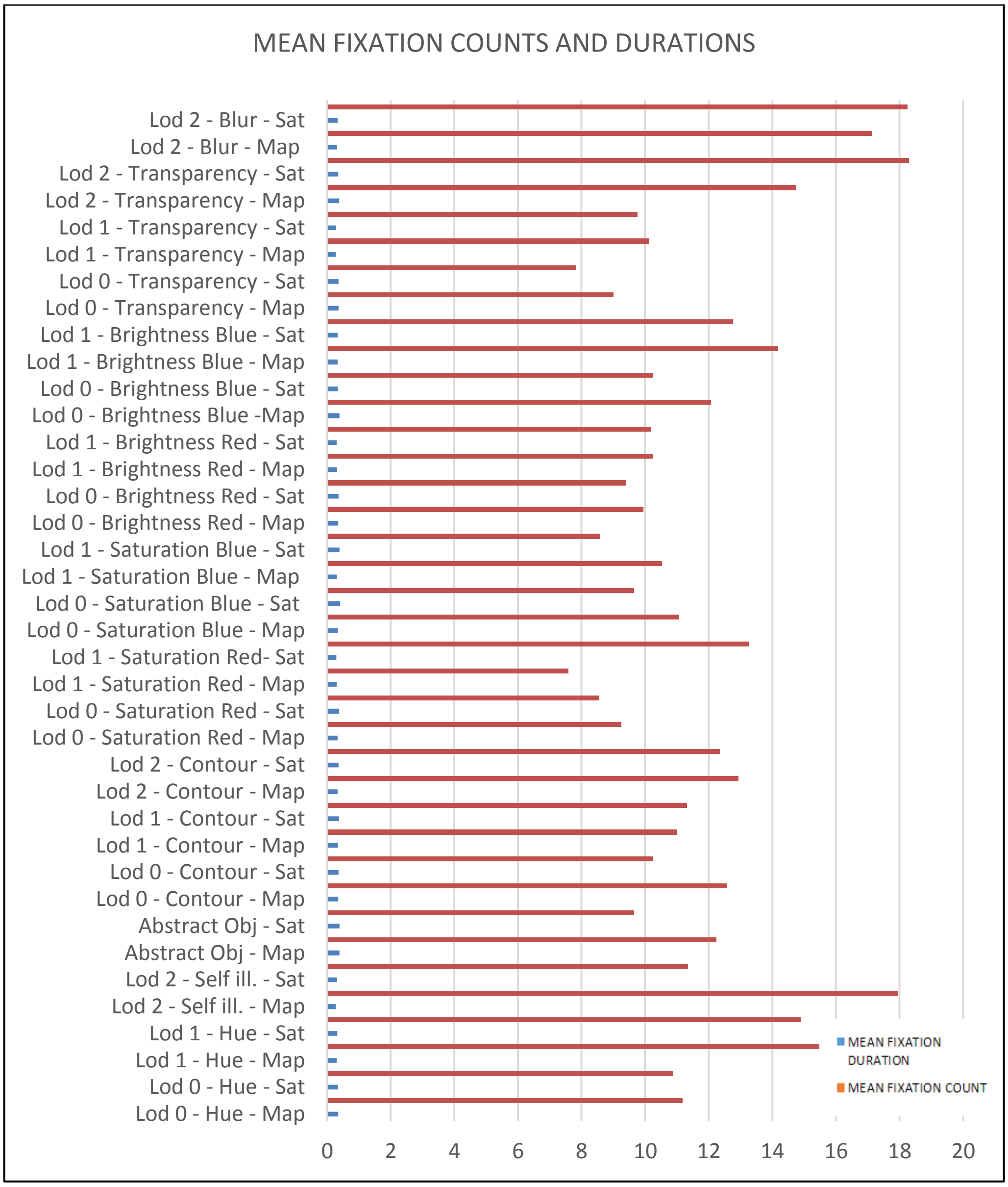


Figure 9-42: Mean Fixation Counts and Durations for Each Variable

Although the participants are asked to think that they are looking at a visualization without a map legend and to concentrate on only visualizations, six participants are affected by the volume and placement of the buildings. These participants are mainly civil engineers. They are affected by previous knowledge and experience.

Most of the participants agree that red recalls danger. However, eight participants click on blue buildings for representing *highest risk*. The participants who have visual design backgrounds (map designers, city and regional planners) mainly preferred **saturation** or **brightness** for representing *ordinal risk* data. However, the others (most of the engineers) thought that **hue** is better to convey *ordinal risk* data. On the other hand, nobody is consistent in choosing the colors. Most of the participants think that the colors of each range should be blue, yellow and red. However, two participants suggest the colors of each range as brown, red and yellow and five participants suggest the colors of each range as red, yellow and green. One participant states that green refers to landslide, blue refers to flood, and hence, these colors should not be preferred for earthquake risk visualizations.

The least bright (dark) buildings are perceived as black and out of the topic. **Brightness-red** is especially confusing; whether bright red or dark red represents the *highest risk* is not understandable. Few participants click on claret colored buildings. **Transparency** and **blur** are not clear. It is stated that the geometry of the buildings becomes indefinite because of the usage of these variables. **Transparency** and **contour** are meaningful for the participants only if the *highest risk* is shown in the map.

The LoD 2 is found to be unnecessary by most of the participants. Over ten participants state that public buildings can be modelled in LoD 2, and others could remain as LoD 1. One participant states that the modeling level should increase when the user wants to zoom in to a specific area. In other words, the LoD should change with the scale of the map. More than half of the participants state that LoD 0 and 1 are enough to show earthquake *risk* to the executive level of decision makers. When additional decisions have to be made, LoD 2 could be considered. Two participants state that parcels should be seen instead of buildings in LoD 0. These are the city and regional planners.

Five participants state Level of Detail 1 is enough, but they want to see additional information on the buildings when they click on them. One participant suggests that the type of the buildings could be represented with symbology on the top of the buildings.

Most of the participants state that they did not notice that the background shifted. According to them, the satellite view is important when additional decisions are needed to be taken. To show the *risk* visualization, map view is found to be enough in the background.

9.4.5 Comparison of Saliency Maps and Eye Tracker Heat Maps

Visual saliency is a process performed computationally, which identifies important locations and structures in the visual field. The typical visual saliency methods use *color, intensity, gradient* in order to figure out the unique regions from the rest of the visual field (Ciptadi et al., 2013). In addition, Ciptadi et al. (2013) incorporate the component of depth into the computation of saliency.

The research as to how the saliency can be computed neurophysically has influenced the development of computational models of saliency in the computer vision community. The early example of this work is done by Itti et al. (1998), in which they are inspired by the behavior and the neuronal architecture of the early primate visual system. They propose a model that creates saliency maps based on *color*, *intensity* and *orientation* information, where objects that are locally different are differentiated through center surround computations.

Similar methods for computing saliency maps have been developed latterly. Bruce and Tsotsos (2005) and Itti and Baldi (2005) emphasize “self-information” and “surprise” in their saliency model. Harel et al. (2006) suggest a *bottom-up* saliency model which is called Graph-Based Visual Saliency (GBVS). It first forms activation maps on certain feature channels and then normalizes them. Hou and Zhang (2007) present a saliency method based on a fast spectral analysis. The spectral residual of an image is extracted in spectral domain to obtain the saliency map in spatial domain. Li et al. (2009) suggest a saliency detection model both for video and image in which saliency is defined locally. Location is measured by Incremental Coding Length (ICL) in which the center patch is presented as the sparsest linear represented of its surroundings. Goferman (2010) computes saliency with a context-based approach. According to them, salient regions should contain not only important objects but also the background parts that convey the concept.

Cheng et al. (2011) extend the saliency computation on super pixels and proposed a regional contrast-based saliency extraction algorithm which simultaneously evaluates the global contrast differences and spatial coherence. Duan et al. (2011) propose a new visual saliency detection method based on the spatially weighted dissimilarity. They measure saliency by integrating three elements which are the dissimilarities between image patches, the spatial distance between image patches and the central bias. The dissimilarities are inversely weighted based on the corresponding spatial distance.

In this thesis, the saliency maps of the visualizations that are used in the second part of the final user tests are obtained. These visualizations are created according to the fundamental Itti-Koch model, which is a *bottom-up* model, in which saliency is extracted according to *color*, *intensity*, *orientation* information and **figure-background** relationship. They are obtained by the saliency map algorithm written in the Matlab source code written by Harel (2012). The code can be downloaded free from charge and generated easily in the Matlab. In this thesis study, the orientation information is fixed in all the images in the same LoDs. Background information changes according to whether a map or satellite image is used. Color and intensity information changes in each visualization. The saliency maps of the visualization for each visualization alternative can be seen in Appendix I.

The main reason to create the saliency maps is to investigate if the users directly focus on the salient parts or they are affected by a simple knowledge or coding in their brain that lead them to make decisions when they examine the visualizations. When the eye tracker heat maps are compared with the saliency maps, some clear deductions can be made.

Eye tracker maps totally differ from saliency maps when **brightness** is used. In the saliency maps, when the background is a map view which is light in color, the least bright (dark) buildings become distinct. On the other hand, when the background map is a satellite image which is dark in color, the brightest (light) buildings become distinct. However, when the eye tracker heat maps for **brightness** variable are considered, both dark and light ones are tracked by the participants. Although *bottom-up* model shows the salient parts, the participants are confused to immediately decide whether they should click on the dark or the bright ones. This is valid for both **brightness-blue** and **brightness-red**. However, this confusion can be seen more clearly when **brightness-red** is used especially in Level 0 and 1 (Figure 9-43 to Figure 9-46).

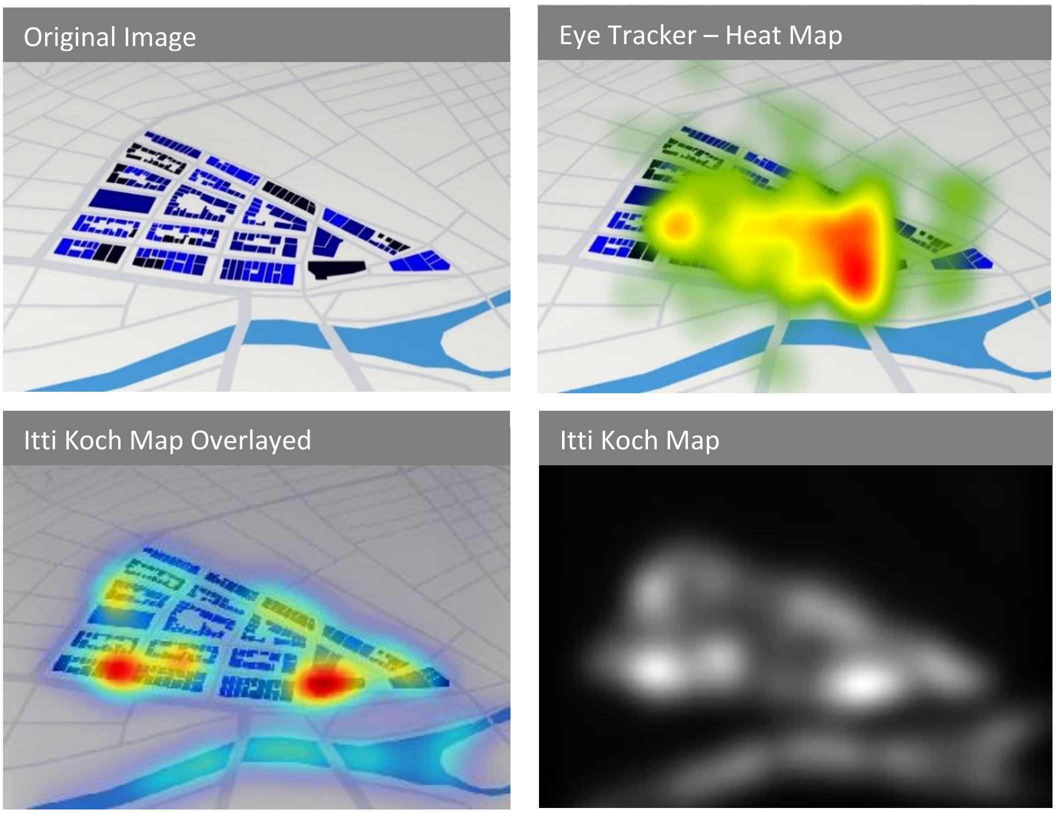


Figure 9-43: LoD 0 Brightness Blue - Background: Map

Figure 9-44: LoD 0 Brightness Blue - Background: Satellite

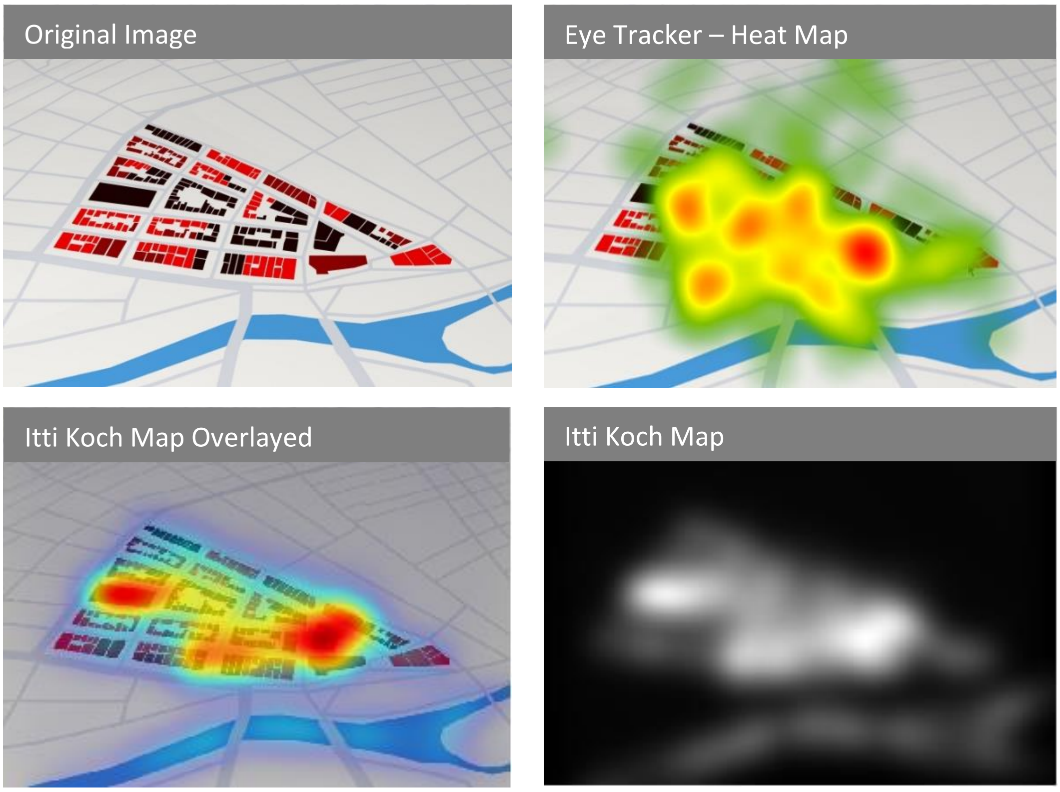


Figure 9-45: LoD 0 Brightness Red - Background: Map

Figure 9-46: LoD 0 Brightness Red - Background: Satellite

When the **saturation-red** and **saturation-blue** variables are used, the participants tend to track mostly the most saturated ones for LoD 0 and 1. This can be seen in the saliency maps as well, which means that it is very intuitive to select the most saturated ones. Also, the decision to select the most saturated ones seems to be consistent with the participants' background experience, which can be more related to the *top-down* processes and observed in the eye tracker heat maps (Figure 9-47 to Figure 9-50).

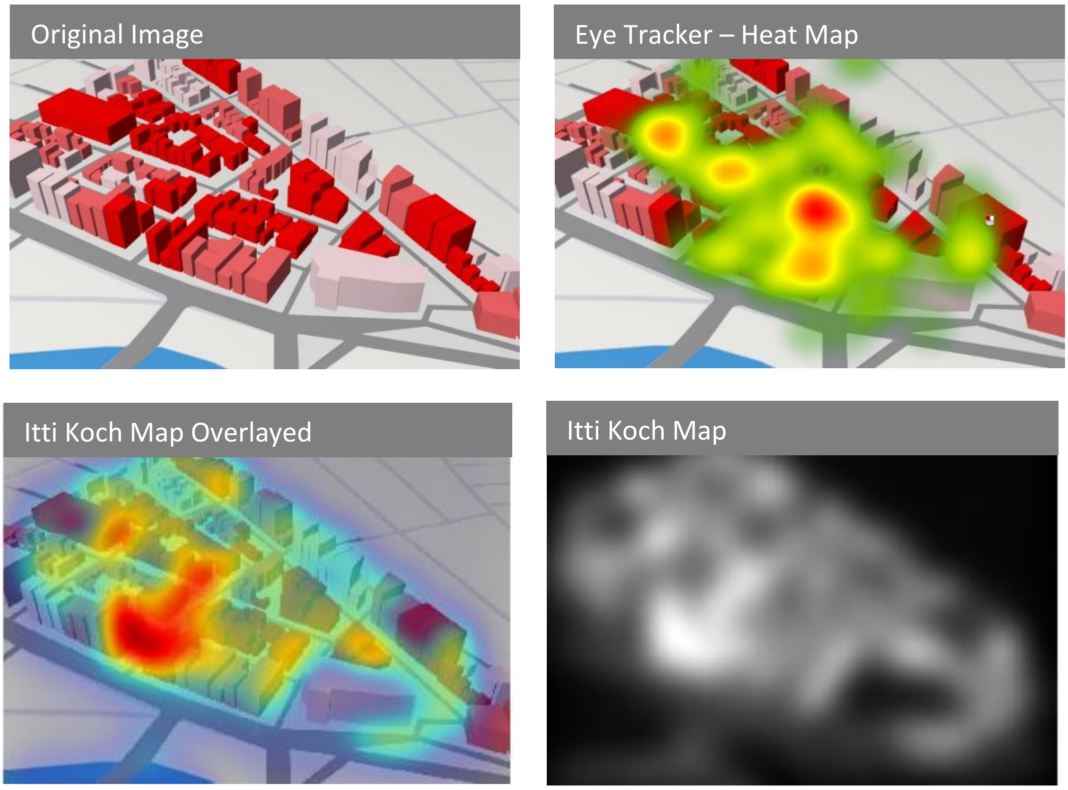


Figure 9-47: LoD 1 Saturation Red - Background: Map

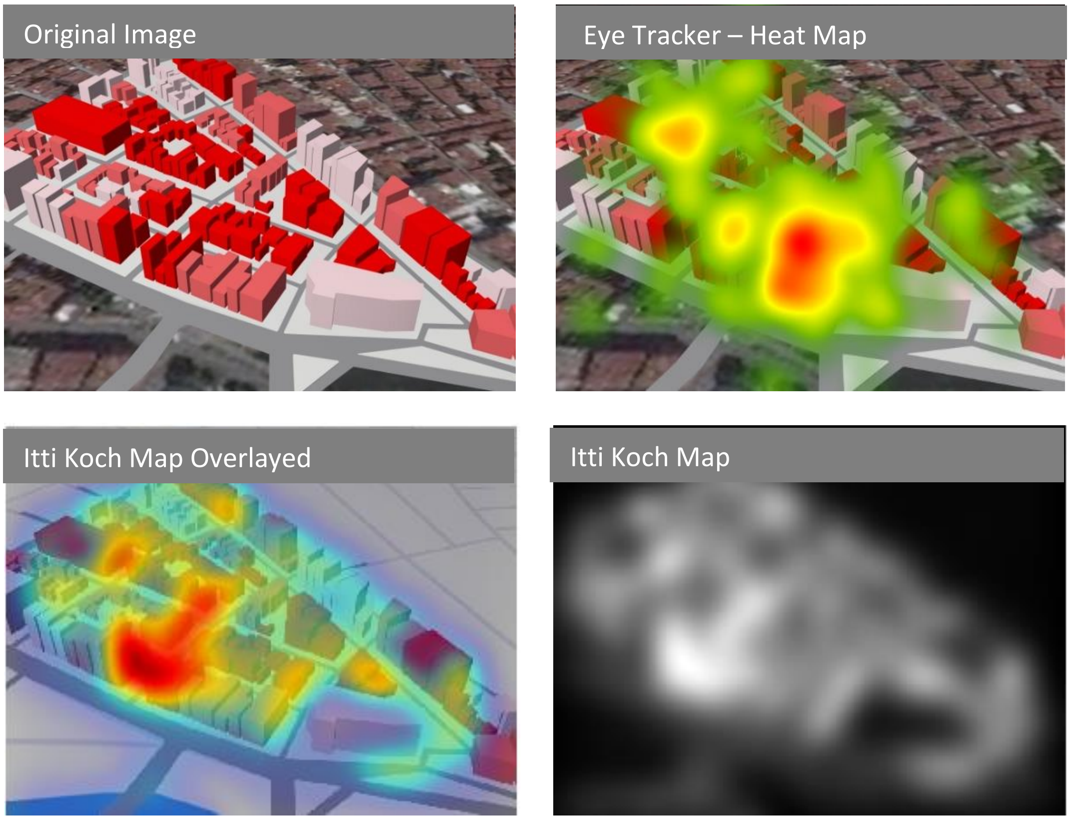


Figure 9-48: LoD 1 Saturation Red - Background: Satellite

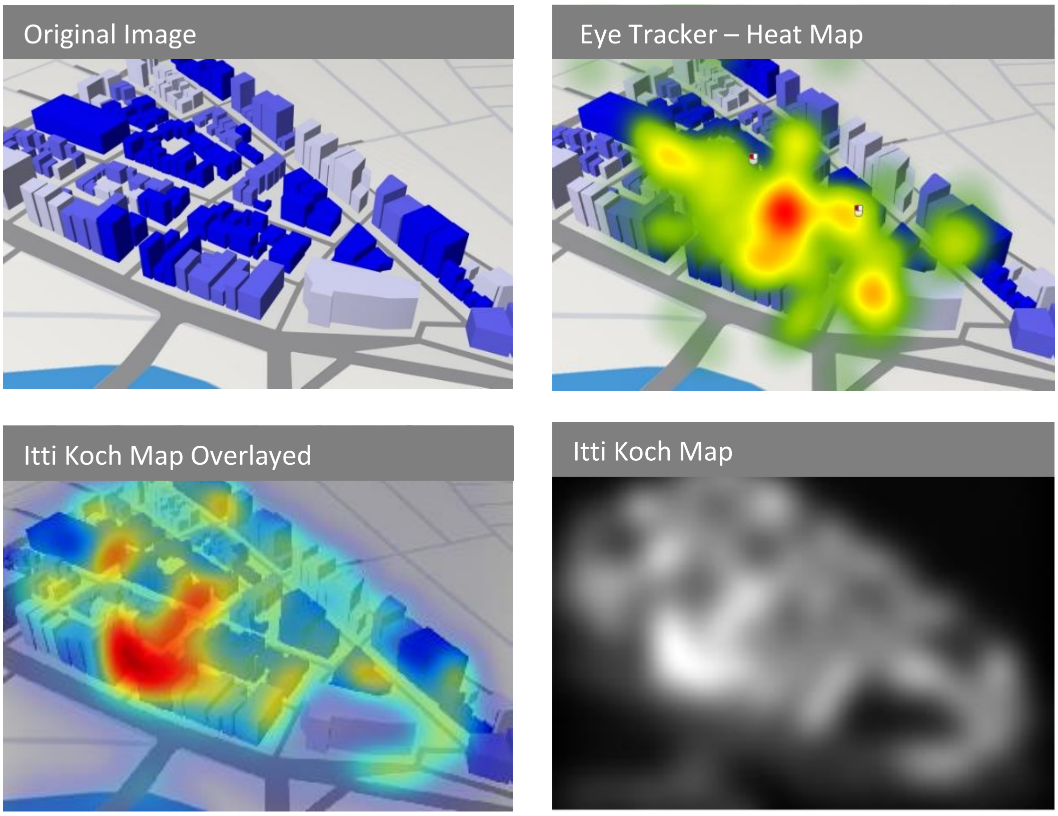


Figure 9-49: LoD 1 Saturation Blue - Background: Map

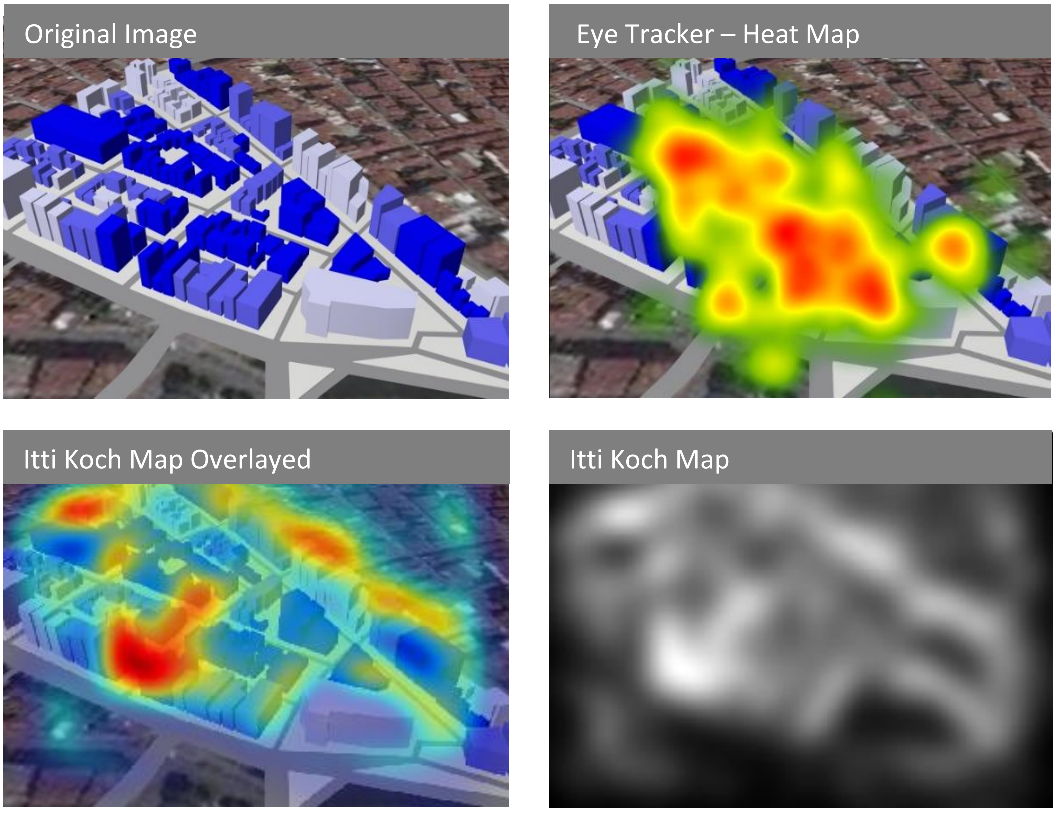


Figure 9-50: LoD 1 Saturation Blue Satellite - Background: Satellite

When the eye tracker heat maps for **hue** are considered, it can be seen that most of the participants focused on *red* buildings. Although the salient parts are *red*, there are focuses on *blue* and *yellow*. Although the thickest **contoured** ones become distinct in the saliency maps, the focus of the participants is on different levels of **contour** in the heat maps. The least **transparent** ones become distinct in the saliency maps and are tracked by the participants as seen in the eye tracker heat maps. For all images see Appendix I.

9.5 Discussion of the Validation Process

Regarding LoD 2, **saturation** is found to be the most effective for visualizing *ordinal risk* data on the buildings. Particularly according to the results of the pilot user tests and final user tests, **saturation-red** has a low response time and a high accuracy for LoD 0 and 1. **Saturation** again (after **hue**) is considered to be effective in the expert evaluation as well. It is observed in the eye tracker heat maps that most **saturated-red** buildings are mostly tracked. Moreover, the highest number of participant clicks is observed when **saturated-red** is used. In addition, the fixation counts are the lowest when **saturation-red** is used. This means that participants can easily decide without concentrating on too many areas of the visualization. During the discussion part, the participants who create visualizations for DM mainly stated that **saturation-red** is the most effective for LoD 0 and 1. **Saturation-red** is found to be more effective than **saturation-blue.** The results do not differ with background image as well.

When **contour** usage in the first part of the user tests is analyzed, the response time is very low and the accuracy is high for all the LoDs. During the expert evaluation, **contour** usage around the building is suggested by one of the participants who is a designer. During the interview part, two participants state that **contour** looks aesthetic. However, **contour** is found to be effective only if the *high risk* buildings are supposed to be shown. It is not found to be effective when the ranges of *ordinal* data are shown. In the second part of the test, especially some civil engineers click on the least **contoured** buildings. They think that they look structurally vulnerable as they are not surrounded by a thick structure (**contour**).

Hue is found to be effective when the results of pilot user tests and expert evaluation are considered. When the final user tests are analyzed, **hue** is not found to be good for LoD 0, but slightly good for LoD 1 and LoD 2. Especially for LoD 2, **self-illumination-hue** is found to be effective when the accuracy results of final user tests are considered. Most of the clicks by the participants are on the *red* buildings. However, there are clicks on the *blue* ones (more than seven). Different colors such as claret red, green, brown and purple instead of blue and yellow are suggested by the participants. When the heat maps are considered, it is obvious that the participants do not only concentrate on *red* buildings.

Brightness is confusing especially when *red* is used. The fact that *light red* or *dark red* refers to the *highest risk* becomes a discussion topic for the participants. The same discussion is held by two experts. It is clearer when *blue* is used. When LoD 1 accuracy data of the final user tests are analyzed, **brightness-blue** has the most accurate choice by the participants. Seven participants state that *dark blue* and *dark red* buildings are close to black so that buildings can be understood as out of topic.

Transparency and **blur** are not found to be confusing by the experts. The same result is obtained in the pilot and final user tests. Although accuracy is slightly high when **blur** is used in LoD 2, the experts and participants state that the geometry of the objects becomes unreadable when **blur** is used. **Transparency** is found to be effective for LoD 0. **Abstract object-hue** is not understandable by the users of pilot and final user tests. Two participants decide that **abstract objects** are the buildings. In the expert evaluation, **abstract object** usage is not found effective as well.

In general, the number of fixation increases when LoD increases. This means that the participants consume too much energy as the modelling level increases. 22 participants state that LoD 2 is not necessary, and LoD 0 and 1 are enough to present the *risk* information on the buildings. It is found that visualizations in LoD 0 are quite different from LoD 1 and LoD 2. The reason for that is in LoD 0 the visualization of the city objects are in 2D format (apart from the terrain). In the expert evaluation, the participants state that 3D elements are used as in LoD 1 and LoD 2, so there is the risk of visibility of information. On the other hand, the participants of the final user tests are mainly positive about 3D modelling and the perspective view. LoD 1 is the most preferred one in particular. Two participants state that shading in LoD 1 enhances the visual perception. Three participants preferred top view for LoD 0. The participants think negatively about the concept of walking as an avatar in the 3D city model. Manipulating the 3D scene of the model such as moving and rotating is found time confusing for DM. Static screenshots are found more effective than dynamic interactions in the model.

When the participants' statements are analyzed, it is found that the change in the background view does not change the opinions of the participants in terms of effectiveness. Two types of images are stated to be effective to be used in the backgrounds of the visualizations. Two participants state that the satellite image can be prepared with 20% transparency.

CHAPTER 10

GUIDELINES FOR THE FINAL VISUALIZATIONS (STEP 5)

In this chapter the guidelines are given according to the validation results. These guidelines are expected to be helpful to the designers who create visualizations for Disaster Management (DM). Visualizations are firstly given for different user types. Two types of users are considered, who are executive level decision makers, mainly administrative staff and DM specialists, and researchers. For the first type of users (executive level decision makers), the visualizations presented in Figure 10-1 to 10-4 can be used. For the second type of user (DM specialists and researchers) the visualization presented in Figure 10-5 can be used. The representations of the visualizations according to the legend are given in the second part. The ordinal risk data visualization suggestions in the 3D model when ranges of three, five and seven used are given in this part.

10.1 Visualization Guidelines for Different User Types

When executive level decision makers are considered;

- The usage of LoD 2 is unnecessary for this type of user.
- LoD 0 and LoD 1 can be used together. LoD 0 and 1 are enough in terms of modeling level to convey *ordinal risk* data.
- The model in LoD 0 can be given as the top view together with the model in LoD 1 as the perspective view.
- Saturation is used. In this variable, the value of **saturation** changes, the value of brightness is fixed, and the value of hue is fixed as red (Figure 10-1).

- Public buildings can be defined with icons on the top of buildings (Figure 10-1).
- Instead of using iconic expressions on the top of public buildings, only the public ones can be presented in LoD 2 (Figure 10-2).
- The buildings in LoD 2 can be viewed in another layer.
- Pop-up information which is necessary for the user can be given when the public buildings are clicked (Figure 10-3).
- **Saturation** can be used when satellite view is used in the background (Figure 10-4).

Figure 10-1: Final Guidelines for High Level Decision Maker – Background: Map

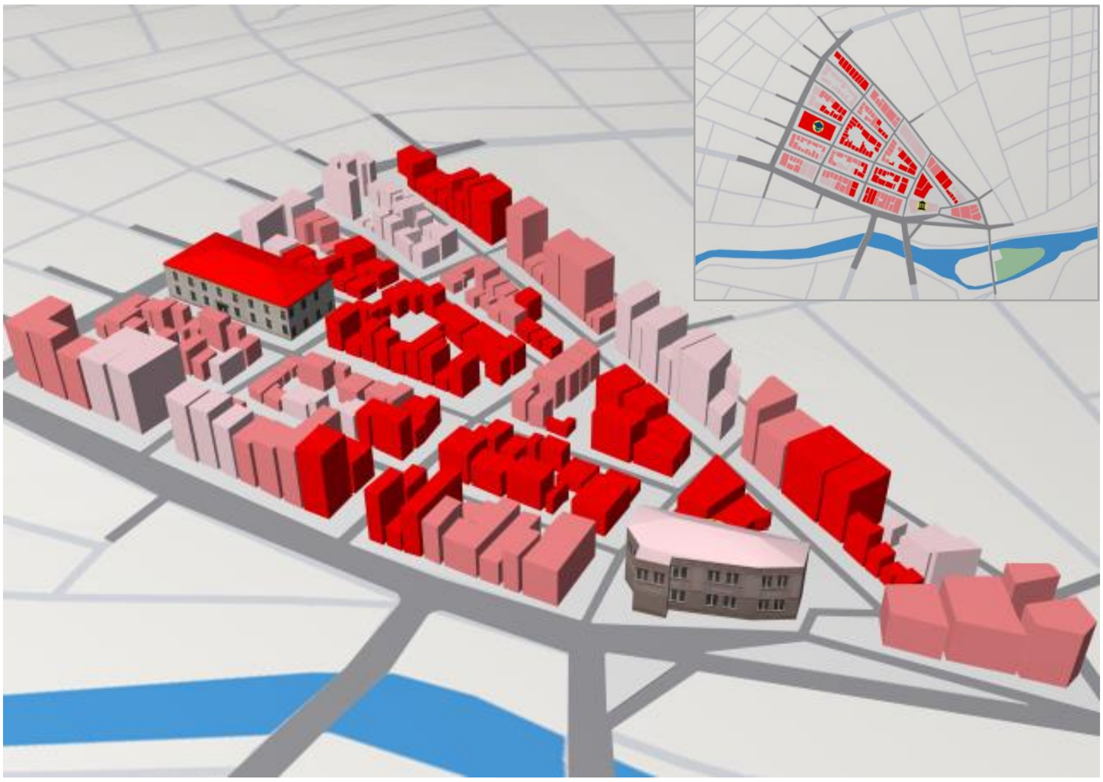


Figure 10-2: Final Guidelines for High Level Decision Maker – Public Ones /LoD 2

Figure 10-3: Final Guidelines for High Level Decision Maker – Public Ones Clicked

Figure 10-4: Final Guidelines for High Level Decision Maker – Background: Satellite

When DM specialists and researchers are considered;

- LoD 2 can be used.
- The *ordinal risk* visualization can be given on the roof of the buildings. In this way, the textures of the buildings can be seen. In this LoD, all the city objects are visualized in a more detailed way (Figure 10-5).

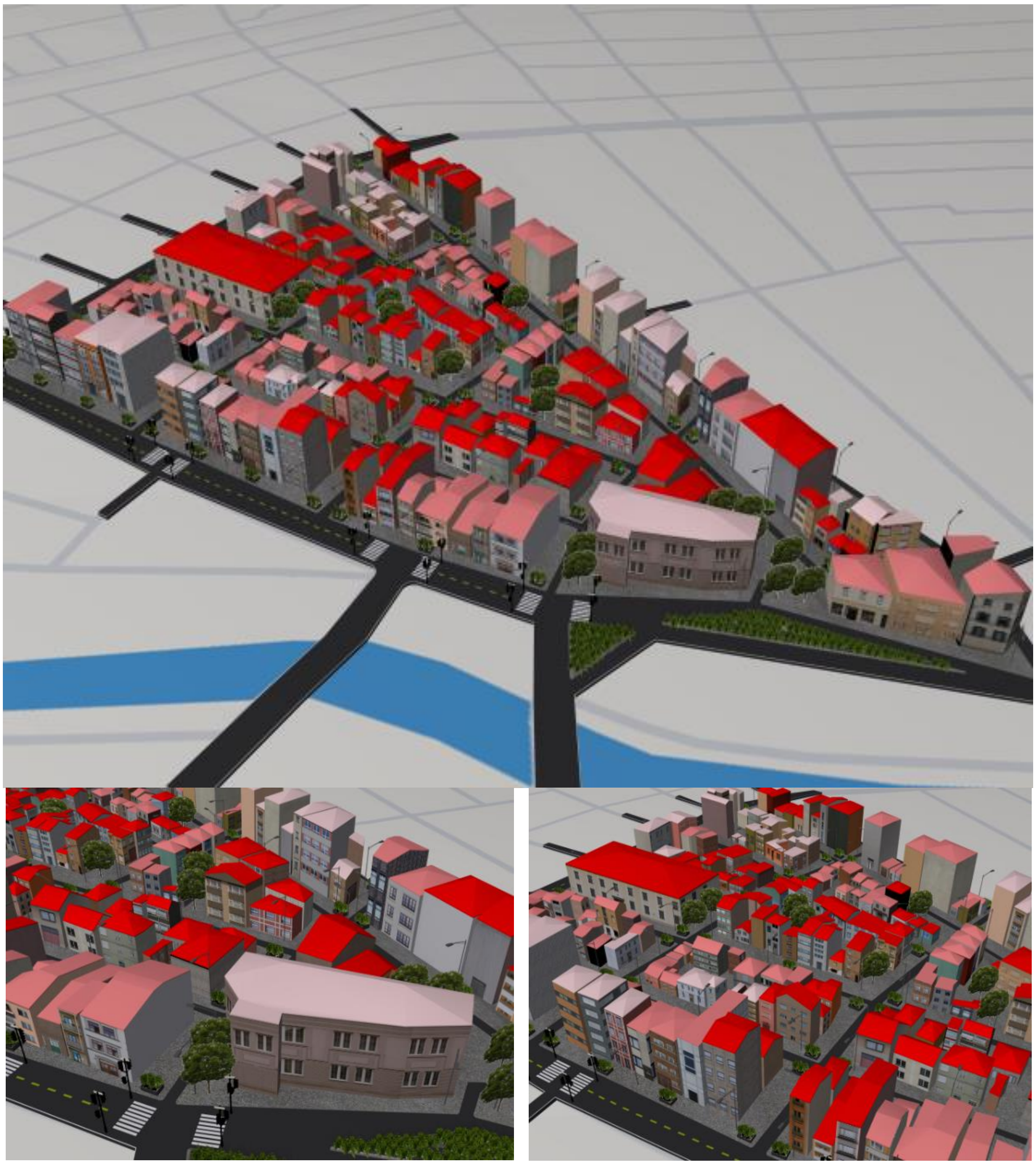


Figure 10-5: Final Guidelines for DM Specialists – Background: Map

For both type of users effective zooming levels for each LoD as minimum and maximum are suggested. These levels are defined according to the participants' suggestions during the tests in the discussion part. However, this part should be tested with users in a more quantitative way. The prepared zoom levels can be seen in Table 10-1. The visualizations using each LoD level can be rendered between the minimum and maximum map scales.

Table 10-1: Effective Zooming Levels for each LoD

	Minimum zooming distance	**Maximum zooming distance**
LoD 0	1/10000	1/5000
LoD 1	1/5000	1/2500
LoD 2	1/2500	1/1000

10.2 Visualization Guidelines for the Legend

The range of the *ordinal* data cannot be always three. Therefore, suggestions for the ranges of five and seven are given:

- In all of them **saturation** decreases when the *risk* level decreases (Figure 10-6 to 10-8).
- When the range of five is used, defining all of them with **saturation** can increase the cognitive load. Therefore, the usage of different **hues** (red to yellow) is preferred. However, **brightness** is fixed (Figure 10-7).
- In the range of seven, **brightness** increases although **saturation** decreases when the *risk* level **decreases** with changing **hues** (Figure 10-8).
- When only the *highest risk* is visualized, **contour** and **transparency** with **hue** *red* can be used according to the participants' view (Figure 10-9 and Figure 10-10).

Figure 10-6: LoD 1– Three Range Ordinal Risk Visualization

Figure 10-7: LoD 1 – Five Range Ordinal Risk Visualization

Figure 10-8: LoD 1 – Seven Range Ordinal Risk Visualization

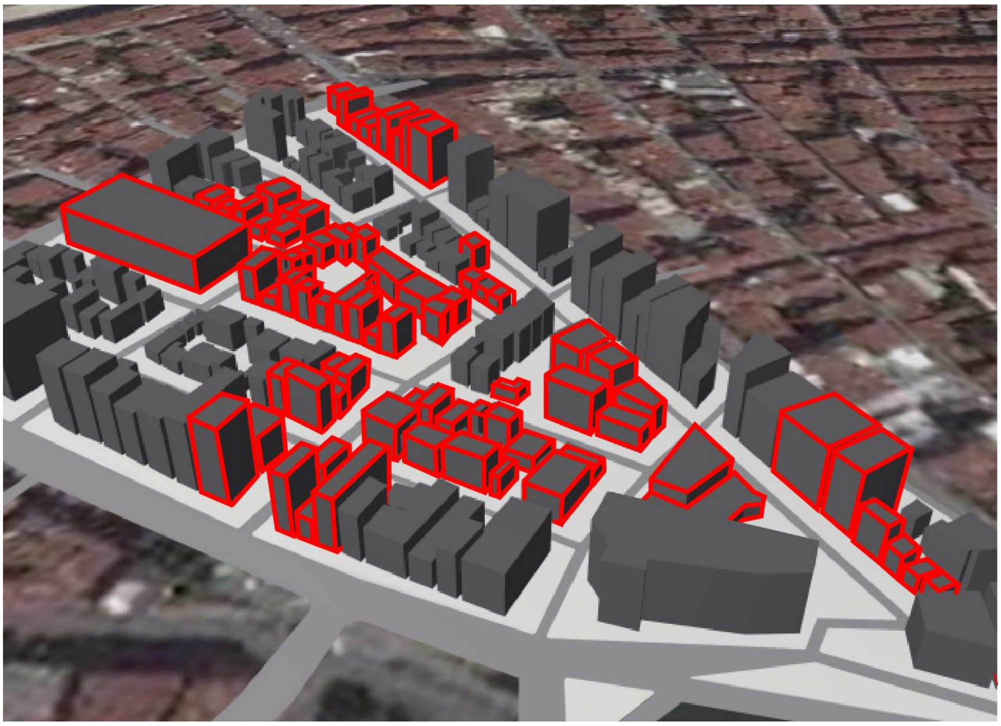


Figure 10-9: The Highest Risk Visualization with Contour

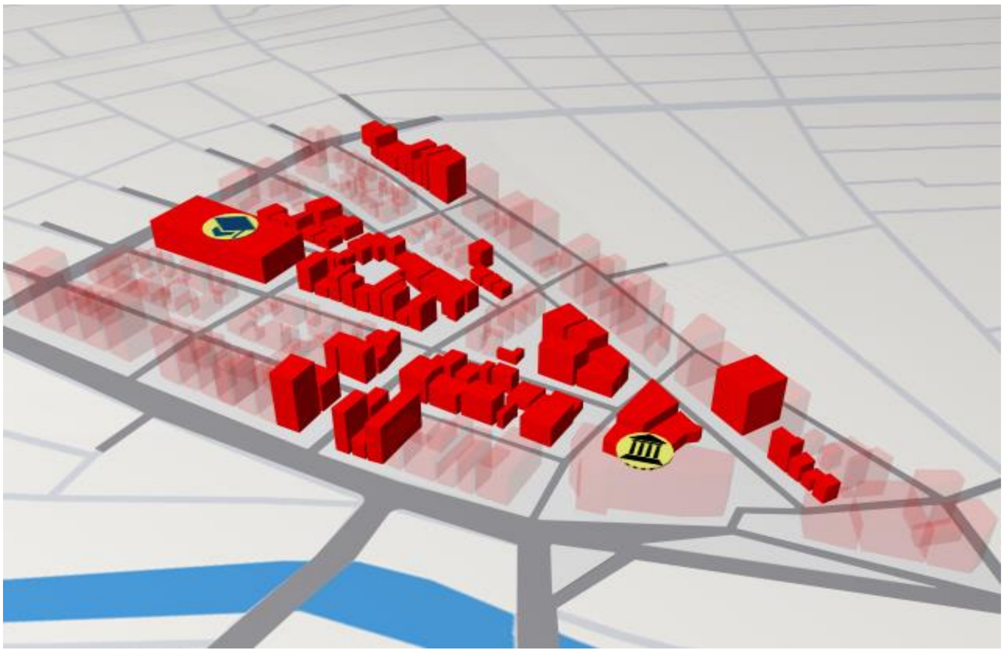


Figure 10-10: The Highest Risk Visualization with Transparency

The values of **hue**, **saturation**, **brightness** are adjusted in the 3Ds Max (Figure 10-11). The values for each one is given in Table 10-2. Each value for the legend is obtained from the least shadowed part of the buildings.

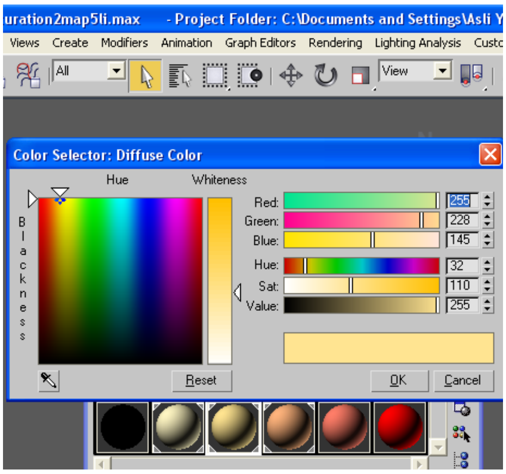


Figure 10-11: Adjusting Hue, Saturation and Brightness in 3Ds Max

Table 10-2: Hue, Saturation and Brightness Values for the Legend

Usage of three ranges in the legend							
	H:255 S:255 B:255	H:255 S:115 B:255	H:255 S:35 B:255				
	H-fixed, S-decreases, B- fixed						
Usage of five ranges in the legend							
	H:255 S:255 B:255	H:6 S:150 B:255	H:18 S:130 B:255	H:32 S:110 B:255	H:36 S:60 B:255		
	H-changes, S-decreases, B-fixed						
Usage of seven ranges in the legend							
	H:255 S:255 B:100	H:255 S:230 B:150	H:255 S:180 B:200	H:6 S:150 B:240	H:18 S:130 B:255	H:18 S:80 B:255	H:18 S:40 B:255
	H-changes, S-decreases, B-increases						

CHAPTER 11

CONCLUSIONS

In this thesis, a framework is proposed to provide visualizations used in Disaster Management (DM) with a systematic and standardized approach. The target users of the framework are *researchers* who study geovisualization, *designers* who perform visualizations for DM, and *GIS vendors* and *end users* who are *DM decision makers (executive level decision makers and DM specialists and researchers*). The main model of the framework is the waterfall model because what is performed in each step starts with the consideration of the outcomes of the previous step. However, iterations are suggested between the first step (Exploration of The User Requirements) and the second step (Defining the Context to be Visualized), the first step (Exploration of The User Requirements) and the fourth step (Validation Process), which are not performed in the thesis study. The framework is proposed to provide the researchers with insight since they can adapt the methodologies to their studies to create information visualizations in any type of domain that decision making process is considered. The visual taxonomy created in the third step is expected to be useful for designers to create their visualizations in a systematic way. The fifth step (Guidelines for the Final Visualizations) of the framework is proposed especially for designers and GIS vendors. In this step, guidelines are proposed for the visualization of disaster risk in a 3D city model. Designers can follow these guidelines and GIS vendors can add specific tools for DM in their software modules considering these guidelines. In this part, the way the research questions are answered is explained.

The research questions of the thesis are;

1. What would be the main steps of a framework that would help creating visualizations to increase the effectiveness and efficiency of the decision-making process of DM specialists? What would be the advantages and disadvantages of each proposed step when the results are considered?
2. What would be the negative and positive feedbacks of the users and experts about visualizations in a 3D city model?
3. Could there be a systematic approach in defining the visualization of an attribute throughout taxonomy? What would be the dimensions of this taxonomy?
4. What kind of design mechanisms should be considered when 2D visual variables are adapted to the 3D environment?
5. Which visual variable(s) should be considered for visualizing information utilizing which Level of Detail of the model?

Discussion of the advantages and disadvantages of each step of the framework corresponds to the *first research question*. The first step of the framework, which is "Exploration of the User Requirements", involves a comprehensive understanding of the end user needs and expectations about visualization in a 3D city model. First of all, the end users in the framework are the ones who interact with the information visualizations in DM; they are executive level decision makers and DM specialists and researchers. In order to define the users better, each user's *profiles* and *roles* are determined. During this step, taking different opinions from a wide range of user types makes the framework applicable to a wide range of users. In addition, the whole structure of user interactions in DM can be clear by interviewing a wide range of user types working in different phases of DM. For this reason, interview and questionnaire method is used. During the interviews, a simulation of a 3D city model including the city objects is shown. This presentation is effective in terms of getting the initial responses of the users to the city model in 3D visualization platform. Moreover, it allows the researcher to express himself/herself better. In this step, if the context to be visualized is predefined, specific questions should be asked to the users. In this thesis study, it is defined after analyzing the results of the first step.

In the second step, “Defining the Context to be Visualized”, the data collected in the first step is analyzed. Understanding the profiles and roles of all types of users is an important part of the thesis since the results discussed in Chapter 4 and 5 can be helpful for the people who will perform visualization for any scenario of a DM process using the framework. As explained in Chapter 5, a Hierarchical Task Analysis is performed and *risk assessment* is found to be so fundamental that all the phases are related to it and therefore the attribute of *earthquake risk* is considered for the visualizations. After setting the DM phase as *risk assessment* and the attribute as *risk*, another short interview or questionnaire with the users could have been performed especially for *risk* visualization in the 3D city model, which could enhance the analysis of end user requirements.

In the third step, Level of Detail (LoD) dimension is based on the City GML standards but different modeling level standards can also be used. Three LoDs are taken in to account for this study, which are LoD 0, 1 and 2. The main reason is that LoD 3 and 4 require a high level modeling, which is deemed unnecessary by the end users of DM. In this thesis study viewing angle and global properties are retained fixed. The adaptation of visual variables should be discussed when viewing and global properties change as their perception changes with these properties. In the visualizations, the inclination angle of the camera is set as 45^o and lighting is placed slightly from a head. These are decided according to the guidelines given by Haeberling (2004a) for 3D maps. The last dimension is the Measurement Scale, which is composed of *nominal, ordinal* and *interval/ ratio* measurement scales. The attribute to be visualized is defined as *ordinal* data. Therefore, firstly, the effective or ineffective variables for visualizing *ordinal* data are researched from the literature. Information about the modeling part including the visualization platform and texturing details is given. Alternative visualizations are created using the Autodesk 3Ds Max in this step. The ArcGIS is not regarded practical for texturing the faces of the buildings for LoD 2. Especially with the property of UVW mapping in 3Ds Max, the objects can be textured better. However, this process is still time consuming. The main disadvantage of 3Ds Max is that it has only XYZ Cartesian coordinate system and lacks in a geographic coordinate system. A standard rendering process takes approximately 5 seconds for each visualization. Extra mechanisms such as V-ray and

Mental Ray plugins are not used. If those kinds of plugins are used for the visualizations, it would be more realistic. On the other hand, the use of such functions would be quite time consuming. The most difficult part is texturing the terrain with a real city map and a satellite map. The buildings should be well fit on the right regions as they are. This would be more precise if a geographical coordinate system and the right projection type is used, which can be simply done in any GIS software.

During the “Validation Process”, which is the fourth step of the framework, an eliminative approach is embraced, which is quite effective. Alternative visualizations are created using the visual variables that are effective for *ordinal* data visualizations expressed by expert cartographers in the literature. Then, these visualizations are eliminated by the visualization experts who are the participants of the pilot user tests and expert evaluation. The visualizations prepared with the selected variables are presented to the end users who are the participants of the final user tests. The most difficult part is the arrangement of the users for the final tests. They have to come to the test place in User Testing and Research Lab (UTRLAB) in METU Technopolis, because in the final user tests, an eye tracker is used and it is not effective to take it to the users’ premises. Therefore, permissions should be attained from the head of the departments of the users especially in governmental organizations. The other problem is arranging a balanced user *profile* according to their educational background. Most of the users of DM specialists and even some of the designers who prepare the visualizations are engineers. Therefore, in order to make better quantitative comparisons of the various user preferences based on their background, various users from a balanced background should be selected from a larger sample. There are only three executive level decision makers in the study, which is a minor drawback. The usage of an eye tracker with the users who wear glasses is problematic too, because the data obtained from them is unusable.

In the last step of the framework, “Guidelines for the Final Visualizations”, guidelines are proposed to be helpful to give insight to visualizing *ordinal risk* data for DM. Example visualizations are developed and presented according to the proposed guidelines. In the guidelines, suggestions are made according to the types of the end users. For the executive level decision makers LoD 1 is proposed. However, public buildings are suggested to be modeled in LoD 2, symbolically, which are different from the other buildings. For this type of user, LoD 0 is presented together with LoD 1 in top view format. For DM specialists and academicians, LoD 2 is also suggested. However, risk levels are visualized only on the roof of the buildings in LoD 2. Zooming levels for each LoD is suggested. The variable **saturation-red** is used in all visualizations that have three ranges of ordinal risk information. The same variable is suggested when the satellite view is selected in the background. It is suggested that when the range is more than three (five and seven), changing only saturation increase the workload. Therefore, the variables that are found effective in the validation process, which are **hue** and **brightness,** are used in combination with **saturation**. It should be stated that for all the legend types, **saturation** is the key variable which should always decrease when the *risk* decreases. For each legend type HSB values are given. For the visualization of the highest risk barely, **contour** and **transparency** are suggested.

The effectiveness of **saturation** and **brightness** for ordinal data is high in 2D visualizations, which is proposed by Bertin (1983) and Morrison (1974). It is found in this thesis that the same is valid for 3D visualizations. Bertin (1983) found **hue** as not acceptable for visualizing ordinal data. However, when the domain is considered as DM, it can be analyzed from the validation process that **hue** usage from claret red to yellow in the color panel can be applicable. *Green* and *blue* are not coded the same by all the participants. *Red* should not be bright and saturated except for that it refers to the highest range. The reason is that it is directly associated with the highest risk. Hence, if darker red such as claret red is used for visualizing the highest *risk*, its saturation should be the highest. *Red* in the same visualization should be given with lower saturation if it is used for visualizing medium risk. *Red* should not be very dark; otherwise it can be seen as close black, which gives the impression that the attribute is outlier. These suggestions can be given when the global properties are fixed. The perception of each variable differs when the shading, lighting and atmospheric properties change. Therefore, user tests should be planned to investigate the most effective global settings.

Users negative and positive feed backs are taken in the first step that corresponds to the second research question. During this step, the users can decide whether 3D visualization can be more effective than 2D visualization or not. Especially a simulation presentation is helpful to get the initial ideas. The negative and positive feedbacks of the users about visualizations in a 3D city model are gathered using the interview method. During the validation process which is the fourth step, the users' feedbacks related to the 3D model are also obtained again but in a more comprehensive way. 3D model is shown to the participants in three different LoDs. Their opinions for each model are asked.

During the third step, "Creation of the Visualizations according to the Visual Taxonomy", the *third research question* is considered. In order to suggest a systematic approach in defining the visualization of an attribute, a Visual Taxonomy based on three dimensions is proposed. These dimensions are Level of Detail, Measurement Scale and Visual Variable. Visual variable dimension is based on a comprehensive literature review on 2D cartographic visual variables. However, their usage in 3D is not directly adapted and tested with users. The definitions of visual variables in 3D environment are basically proposed in this step. This also partly contributes to the *fourth research question*. However, in the case study, design mechanisms of 3D environment are not totally considered as the alternatives are not evaluated with different global properties.

In the fifth step, guidelines are given for ordinal earthquake risk visualization on the buildings. Which visual variable(s) should be considered for visualizing information utilizing which Level of Detail of the model are explained. This corresponds to the *fifth research question*. However, only the attribute risk is evaluated and the suggested visualizations are given according to the results of validation process. Which visual variables in which LoD are appropriate for other attribute visualizations in DM can be another research topic in future studies.

11.1 Recommendations for Future Studies

For the future studies, DM decision makers can be considered under two headings, namely the ones who are executive level decision makers like administrative level decision makers and the ones who are involved in specific analysis and DM strategies like DM specialists and researchers. This way, different end user perspectives can be taken into account. The interview questions can be extended to analyze the requirements of a specific attribute or the scenario to be visualized according to different end user types. Exploration of user requirements should be prepared in a more iterative way when researchers are of concern.

During the preparation of the visualizations 3Ds Max is used. The capabilities of different programs can be tested. Instead of Open Sesame, different behavioral experiment software programs can be preferred. The technical setup and preparing the graphs and maps using Tobii is practical. However, the participants who have eye vision problems can be asked to wear contact lenses for eye tracker studies if they prefer. The pupil size of the participants can be analyzed as well.

For further studies, it is strongly recommended that a visualization module for DM is created by GIS vendors or 3D visualization modules are involved in DM decision support systems based on the proposed guidelines in thesis. This module can lead to visualization of specific attributes used in DM. For instance, for visualizing earthquake *risk* on the city objects, saturation palette can be given on the toolbox. Specific symbols can be prepared in the library to express the public buildings.

In the guidelines, the minimum and maximum zoom levels to be used for the maps prepared with different LoDs are given. However, the effectiveness of zoom levels is another research topic that can be validated with user tests. Moreover, the effect of global properties like lighting, shading and shadows can be analyzed by making different set of visualization alternatives and their effectiveness can be analyzed by making expert evaluation and user tests. Different visual variables, combinations and dynamic variables can be used in the visualizations and the results can be validated with the visualization experts and end users.

REFERENCES

Abras, C., Maloney-Krichmar, D. & Preece, J. (2004). User-centered design. Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications, 37(4), 445-456.

Albert, W. (2002). Do web users actually look at ads? A case study of banner ads and eye-tracking technology. In Proceedings of the Eleventh Annual Conference of the Usability Professionals' Association.

Altmaier, A. & Kolbe T. H. (2003). Applications and Solutions for Interoperable 3d Geo-Visualization. In D. Fritsch (ed), Proceedings of the Photogrammetric Week, 2003 in Stuttgart, WichmanVerlag.

Andrienko, G., Andrienko, N., Jankowski, P. Keim, D., Kraak, M., MacEachren, A. & Wrobel, S. (2007). Geovisual Analytics for Spatial Decision Support: Setting the Research Agenda. International Journal of Geographical Information Science. 21(8).

Asian Disaster Reduction Center (ADRC) (2005). Total Disaster Risk Management.- Good Practices. Retrieved from http://www.adrc.asia/publications/TDRM2005/TDRM_Good_Practices/PDF/PDF-2005e/Chapter1_1.2.pdf [Last accessed on 24.02.2015].

Baig, S.U. & Rahman, A. A. (2011). Dynamic Generalization of 2D Maps and 3D Building Models-A Review. Retrieved from http://www.siddiquebaig.com/siddique/wp-content/uploads/2011/09/Review-Paper-ISPRS-27-03-11.pdf [Last accessed on 20.02.2015].

BBC News (2011). Earthquakes have a bigger health toll than other disasters. Retrieved from http://www.bbc.co.uk/news/health-15573361 [Last accessed on 03.03.2015].

Beck, M. (2003). Real-Time Visualization of Big 3D City Models. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 34 (5/W10).

Bertin, J. (1967). Semiologie graphique. Paris/Den Haag: Gauthier-Villars/Mouton.

Bertin, J. (1983). Semiology of Graphics: diagrams, Networks, Maps. Madison: University of Wisconsin Press.

Bleisch, S. (2012). 3D Geovisualization- Definition and Structures for the Assessment of Usefulness. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume I-2, 2012 XXII ISPRS Congress, 25 August - 01 September 2012, Melbourne, Australia.

Brodersen, L. Andersen, H.H.K., and S. Weber. (2002). Applying eye-movement tracking for the study of map perception and map design. Publications Series 4, Volume 9. National Survey and Cadastre, Denmark.

Brodlie, K.W., Carpenter, L.A., Earnshaw, R.A., Gallop, J .R., Hubbard, R. J., Mumford, A .M. Osland, C.D.& Quarendon, P. (1992). Scientific Visualization, Techniques and Applications, Springer-Verlag.

Bruce, N. & Tsotsos, J. (2005). Saliency Based on Information Maximization. NIPS.

Brychtova, A., & Coltekin, A. (2014). An Empirical User Study for Measuring the Influence of Colour Distance and Font Size in Map Reading Using Eye Tracking. The Cartographic Journal.

Byrne, M. D., Anderson, J. R., Douglas, S., & Matessa, M. (1999). Eye tracking the visual search of clickdown menus. Proceedings of CHI'99 (pp. 402-409). NY: ACM Press.

Card, S. K., Mackinlay, J. D. & Schneiderman, B., (eds). (1999). Readings in Information Visualization: Using Vision to Think. San Francisco: Morgan Kaufmann Publishers.

Carpendale MST (2003) Considering Visual Variables as a Basis for Information Visualisation. Department of Computer Science, the University of Calgary. Retrieved from http://pharos.cpsc.ucalgary.ca/Dienst/UI/2.0/Describe/ncstrl.ucalgary_cs/2001-693-16. [Last accessed on 09.08.2014].

Chen, C. (1999). Information Visualization and Virtual Environments. London: Springer-Verlag.

Cheng, M., Zhang, G., Mitra, N.J., Huang, X. & Hu, S. (2011).Global contrast based salient region detection. In IEEE Conference on Computer Vision and Pattern Recognition (CVPR).

Ciptadi, A., Hermans, T., & Rehg, J. M. (2013). An in depth view of saliency. In Eds: T. Burghardt, D. Damen, W. Mayol-Cuevas, M. Mirmehdi, In Proceedings of the British Machine Vision Conference (BMVC 2013) (pp. 9-13).

Coppala, D.P. (2007). Introduction to International Disaster Management. United States of America: Elsevier.

Coltekin A., Heil, B., Garlandini, S., & Fabrikant, S. I. (2009). Evaluating the effectiveness of interactive map interface designs: a case study integrating usability metrics with eye-movement analysis. Cartography and Geographic Information Science, 36(1), 5-17.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. Nature reviews neuroscience, 3(3), 201-215.

Cowen, L., Ball, L. J., & Delin, J. (2002). An eye-movement analysis of web-page usability. In X. Faulkner, J. Finlay, & F. Détienne (Eds.), People and Computers XVI—Memorable yet Invisible: Proceedings of HCI 2002 (pp. 317-335). London: Springer- Verlag Ltd.

DiBiase, D, MacEachren, A.M. Krygier, J.B. & Reeves, C. (1992). Animation and the Role of Map Design in Scientific Visualization. Cartography and Geographic Information Systems, 19(4).

Dix, A.J., Finlay, J. E., Abowd, G. D. & Beale, R. (1998). Human-Computer Interaction. Englewood Cliffs: Prentice Hall.

Dong, W.H., Ran J. & Wang J. (2012). Effectiveness and Efficiency of Map Symbols for Dynamic Geographic Information Visualization. Cartography and Geographic Information Science, 39(2), p. 98-106.

Döllner, J. and Buchholz, H. (2005). Expressive Virtual 3D City Models. Proceedings of the 22nd International Cartographic Conference, A Coruña, Spain.

Döllner, J. (2009).Virtual 3D City Models as Computation Tools. Geoviz, 3-5 March, 2009, Hamburg.

Duan, L., Wu, C., Miao, J., Qing, L., & Fu, Y. (2011). Visual saliency detection by spatially weighted dissimilarity. In Computer Vision and Pattern Recognition (CVPR), 2011 IEEE Conference on (pp. 473-480).

Eason, K. (1987). Information technology and organizational change. London: Taylor and Francis.

Electronic Visualization Laboratory. (2012). Geospatial Visualization. Retrieved from http://www.evl.uic.edu/aej/424/week07.html [Last accessed on 20.04.2015].

Ellul, C. & Joubran, J. A. (2012). Preliminary investigations into the potential of improving rendering performance of 3D datasets using 2D generalization. European Cost Action TU801 Final Conference.

Ergünay, O., Gülkan, P., Güler, H., İnan, E., Koçak, D., Gönen, A., Çolakoğlu, Z., Uran, T., Çoruh, E., Çayırtepe, F., Özmen, B. (2013). Retrieved from http://afetler.net [Last accessed on 12.05.2015].

European Commission. (2010). The Four Phases of a Disaster. Retrieved from http://blogs.ec.europa.eu/georgieva/the-four-phases-of-a-disaster/ [Last accessed on 11.04.2015].

Fabrikant, S.I. & Skupin, A. (2005). Cognitively Plausible Information Visualization in Exploring Geovisualization, Dykes, J., MacEachren, A.M. &Kraak, M.J. (eds.). UK: Elsevier Ltd.

Fabrikant, S.I., S. Rebich-Hespanha, N. Andrienko, G. Andrienko, and D.R. Montello. (2008). Novel method to measure inference affordance in static small multiple displays representing dynamic processes. The Cartographic Journal 45(3): 201-15.

Filippakopoulou V., Kontoes Ch., Michaelidou E., Nakos B. & Tzelepis N. (1999). Design and production of series of basic topographic maps at scale of 1:25,000. Technical Report (Part A).

Fosse, J. M., Veiga, L. A. K., & Sluter, C. R. (2013). Color hue as a visual variable in 3D interactive maps.

Friedmannová, L., Konečný, M., & Staněk, K. (2006). An adaptive cartographic visualization for support of the crisis management. In Proceedings of AutoCarto (pp. 100-105).

Fuhrmann, S., Ahonen-Rainio, P., Edsall, R.M., Fabrikant, S.I., Koua, E.L., Tobon, C., Ware, C. and Wilson, S. (2005). Making useful and useable Geovisualization: design and evaluation issues. In Exploring Geovisualization, J. Dykes, A.M. MacEachren and M.J. Kraak (Eds), pp. 553–566 (Amsterdam: Elsevier).

Garlandini, S. & Fabrikant, S.I. (2009). Evaluating the Effectiveness and Efficiency of Visual Variables for Geographic Information Visualization. In: Stewart Hornsby K, Claramunt C, Denis M and Ligozat G (eds), Spatial Information Theory. 9th International Conference, COSIT 2009, AberWrac'h, Springer, Berlin, Heidelberg, p.195-211.

Gibson, J. J. (2002). A theory of direct visual perception. Vision and Mind: selected readings in the philosophy of perception, 77-90.

Godschalk, D.R., Berke, P.R. & Kaiser, E, J. with Rodriguez, D. A. (2006). Urban Land Use Planning. Champaign: University of Illinois Press.

Goferman, S., Zelnik-Manor, L., & Ayellet T. (2010). Context-aware saliency detection. In IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2010.

Goldberg, H. J., & Kotval, X. P. (1999). Computer interface evaluation using eye movements: Methods and constructs. International Journal of Industrial Ergonomics, 24, 631-645.

Goldberg, H. J., & Wichansky, A. M. (2003). Eye tracking in usability evaluation: A practitioner's guide. In J. Hyönä, R. Radach, & H. Deubel (Eds.), The mind's eye: Cognitive and applied aspects of eye movement research (pp. 493-516). Amsterdam: Elsevier.

Gouin D., Evdokiou P., Vernik R. (2002). A Showcase of Visualization Approaches for Military Decision Makers, RTO IST Workshop on "Massive Military Data Fusion and Visualization: Users Talk with Developers", Halden, Norway, 10-13 September 2002, published in RTO-MP-105.

Government of Japan, World Bank & GFDRR. (2012). The Sendai Report. Managing Disaster Risks for a Resilient Future. Retrieved from http://www.gfdrr.org/sites/gfdrr.org/files/Sendai_Report_051012. Pdf [Last accessed on 24.06.2014].

Gröger, G., Kolbe, T. H., Czerwinski, A., & Nagel, C. (2012). OpenGIS® city geography mark-up language (CityGML) encoding standard. Version: 1.0. 0, OGC 08-007r1.

Gutmann, Amy (2011). On Risk and Disaster: Lessons from Hurricane Katrina. Eds. Ronald J. Daniels, Donald F. Kettl, and Howard Kunreuther. Univ of Pennsylvania Press

Haala, N. (2005). Towards Virtual Reality GIS. Photogrammetric Week ’05. P.285-294. Dieter Fritsch, Ed.WichmannVerlag, Heidelberg

Haeberling (2004a). Cartographic Design Principles for 3D Maps – A Contribution to Cartographic Theory. 22nd International Cartographic Conference, A Coruna

Haeberling, C. (2004b). Highly Focussed Selected Design Aspects and Graphic Variables for 3D Mountain Maps. In Ica Mountain Cartography Workshop.

Haklay, M. & Tobon, C. (2003). Usability evaluation and PPGIS: toward a user-centered design approach. International Journal of Geographical Information Science, 17, pp. 577–592.

Halik, L. (2012). The analysis of visual variables for use in the cartographic design of point symbols for mobile Augmented Reality applications. Retrieved from http://www.degruyter.com/view/j/geocart.2012.61.issue-1/v10277-012-0019-4/v10277-012-0019-4.xml [Last accessed on 14.09.2014].

Harel, J., Koch, C., & Perona, P. (2006). Graph-based visual saliency. In Advances in neural information processing systems (pp. 545-552).

Harel, J. (2012). A Saliency Implementation in MATLAB: Retrieved from http://www.klab.caltech.edu/~harel/share/gbvs.php [Last accessed on 14.03.2015].

Hauland, G. (2003). Measuring team situation awareness by means of eye movement data. In Proceedings of HCI International 2003: Vol 3 (pp. 230-234). Mahwah, NJ: Lawrence Erlbaum Associates.

Herrmann, J. (2007). Disaster Response Planning & Preparedness: Phases of Disaster. New York Disaster Interfaith Services (NYDIS) Programme.

Herold, S., Sawada, M. and Wellar, B. (2005) Integrating Geographic Information Systems, Spatial Databases and the Internet: A Framework for Disaster Management, Proceedings of the 98th Annual Canadian Institute of Geomatics Conference, Ottawa, Canada, June 13, 2005.

Hijazi, I, M. Ehler and S. Zlatanova (2010). BIM for geo-analysis (BIM4GEOA): setup of 3D information system with open source software and open specifications (OS), In: Kolbe, Köning, Nagel (Eds.); International Archives of the Photogrammetry, Remote sensing and Spatial Information Sciences, Volume XXXVIII-4/W15, November 4-5, 2010, Berlin, Germany, pp. 45-49

Hou, X., Zhang, L. (2007). Saliency detection: A spectral residual approach. In IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pages 1–8

International Federation of Red Cross and Red Crescent Societies (IFRC). (n.d.). About Disaster Management. Retrieved from http://www.ifrc.org/en/what-we-do/disaster-management/about-disaster-management/ [Last accessed on 08.08.2014].

International Strategy for Disaster Reduction (ISDR). (2004). Living with Risk. A Global Review of Disaster Reduction of Initiatives. United Nations.

Isikdag, U. and S. Zlatanova (2009). Towards defining a framework for automatic generation of buildings in CityGML using BIM, in Lee and Zlatanova (Eds.), 3D geo-information sciences, LNG&C, Springer Verlag, pp. 79-96.

Itti, L., Koch, C., & Niebur, E. (1998). A model of saliency-based visual attention for rapid scene analysis. IEEE Transactions on pattern analysis and machine intelligence, 20(11), 1254-1259.

Itti, L. & Baldi, P. (2005). Bayesian Surprise Attracts Human Attention. NIPS.

Jobst, M., Kyprianidis, J. E. & Döllner, J. (2008). Mechanisms on Graphical Core Variables in the Design of Cartographic 3D City Presentations. In: MOORE; DRECKI 2008: Geospatial Vision, S. p.45-59.

Just, M. A., & Carpenter, P. A. (1976). Eye fixations and cognitive processes.Cognitive psychology, 8(4), 441-480.

Kemeç, Ş. & Düzgün, Ş. (2006). 3D Visualization for Urban Earthquake Risk. ECI Conference: Geohazards - Technical, Economical and Social Risk Evaluation, p.37-47.

Kemec, S., Zlatanova, S., & Duzgun, S. (2009). Selecting 3D Urban Visualization Models for Disaster Management: A Rule-Based Approach. In Proceedings of TIEMS 2009 Annual Conference, June (pp. 9-11).

Kemec, S., Zlatanova, S., & Duzgun, H. S. (2010). A framework for defining a 3D model in support of risk management. In Geographic Information and Cartography for Risk and Crisis Management (pp. 69-82). Springer Berlin Heidelberg.

Kemeç, S. (2011). A Conceptual Framework for 3D Urban Disaster Risk Visualization in Geo-Spatial Environment. PhD Thesis. Middle East Technical University.

Kolbe, T.H., Gröger, G. & Plümer, L. (2005). City GML-Interoperable Access to 3D City Models. Oosterom, P., Zlatanova, S. & Fendel, E. (eds.): Proceedings of the Int. Symposium on Geo-information for Disaster Management, 21-23 March 2005. Delft, Springer Verlag.

Koua, E.L. and Kraak, M.J. (2004). Evaluating self-organizing maps for geovisualization. In Exploring Geovisualization, J. Dykes, A.M. MacEachren and M.J. Kraak (Eds) (Amsterdam: Elsevier).

Koua, E. L., MacEachren, A., & Kraak, M. J. (2006). Evaluating the usability of visualization methods in an exploratory geovisualization environment. International journal of geographical information science, 20(4), 425-448.

Krygier, J.B. (2004). Sound and Geographic Visualization. In Visualization in Modern Cartography, ed.by A.M. MacEachren and D.R.F. Talor, Oxford: Pergamon.

Kumar, C., Poppinga, B., Haeuser, D., Heuten, W., & Boll, S. (2013). Geovisual interfaces to find suitable urban regions for citizens: A user-centered requirement study. In Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication (pp. 741-744). ACM.

Lee, J., & Zlatanova, S. (2008). A 3D data model and topological analyses for emergency response in urban areas. Geospatial information technology for emergency response, 143, C168.

Li, Y., Zhou, Y., Xu, L., Yang, X., & Yang, J. (2009). Incremental sparse saliency detection. In Image Processing (ICIP), 2009 16th IEEE International Conference on (pp. 3093-3096). IEEE.

MacEachren, A.M. (1992). Visualizing Uncertain Information. Cartographic Perspectives, 13, p.10-19.

MacEachren, A. M. (1994). Visualization in Modern Cartography: Setting the Agenda. MacEachren, A. M. & Taylor, D.R.F. (eds). In Visualization in Modern Cartography. London: Pergamon.

MacEachren, A. M. (1995). How Maps Work: Representation, Visualization, and Design. New York: The Guildford Press.

MacEachren, A, M & Kraak, M. (1999). Virtual Environments for Geographic Visualization: Potential and Challenges. In Proc of ACM Workshop on New Paradigms in Information Visualization and Manipulation. Kansas City, p.35-40.

MacEachren, A. M. & Kraak, M. J. (2001). Research Challenges in Geovisualization. Cartography and Geographic Information Science 28(1).

Marincioni, F. (2007). Information Technologies And The Sharing Of Disaster Knowledge: The Critical Role Of Professional Culture, Disasters, 31 (4): 459–476. Blackwell Publishing, USA.

Marsh, S. L. (2007). Using and evaluating HCI techniques in geovisualization: Applying standard and adapted methods in research and education.

McCormick, B. H., Defanti, T. A. & Brown, M. D. (1987). Visualization in Scientific Computing. Computer Graphics, 21(6).

Meijers, M., Zlatanova, S., & Pfeifer, N. (2005). 3D geoinformation indoors: structuring for evacuation. In Proceedings of Next generation 3D city models (pp. 21-22).

Mello-Thomas, C., Nodine, C. F., & Kundel, H. L. (2004). What attracts the eye to the location of missed and reported breast cancers? In Proceedings of the Eye Tracking Research and Applications Symposium 2002 (pp. 111-117). NY: ACM Press.

Montello, D. R. (2005). Cognition of Geographic Information. McMasteri, R.B. & Usery, E.L. (eds). A Research Agenda for Geographic Information Science. p. 61-91. Boca Raton, FL: CRC Press.

Morrison, J.L. (1974). A theoretical framework for cartographic generalization with the emphasis on the process of symbolization. International Yearbook of Cartography, 14, p.115-117.

Muehrcke, P.C. & J.O. Muehrcke (1992). Map use. Reading, Analysis, Interpretation, 3rd ed. Madison: J.P. Publications.

Muehlenhaus, I. A. (2010). Lost in visualization: using quantitative content analysis to identify, measure, and categorize political cartographic manipulations (Doctoral dissertation).

National Research Council (NRC). (2007). Committee on the Effective use of Data, Methodologies, and Technologies to Estimate Subnational Populations at Risk. Tools and methods for estimating populations at risk from natural disasters and complex humanitarian crises Ishington, DC: National Academy Press.

Nielsen, J. (1993) Usability Engineering. San Francisco: Morgan Kaufmann.

Nielsen , J. (1998). 2D is better than 3D. Retrieved from http://www.nngroup.com/articles/2d-is-better-than-3d/ [Last accessed on 21.02.2015].

Norman, D. (1988). The design of everyday things. New York: Doubleday.

Office of Disaster Preparedness & Emergency Management (ODPEM). (2008). The Disaster Management Proce. Retrieved from http://www.odpem.org.jm/DisastersDoHappen/DisasterManagementinJamaica/TheDisasterManagementProcess /tabid/240/Default.aspx [Last accessed on 01.09.2014].

Open Geospatial Consortium (OGC) (2012). OGC City Geography Markup Language (CityGML) Encoding Standard. Retrieved from http://www.opengeospatial.org/standards/citygml. [Last accessed on 14.01.2015].

OPUS International Consultants. (2005). Earthquake Hazard and Risk Assessment Project. Report No: U04/108 Final. New Zealand: Wellington.

Pegg, D. (2012). Design Issues with 3D Maps and the Need for 3D Cartographic Design Principles. Retrieved from http://lazarus.elte.hu/cet/academic/pegg.pdf [Last accessed on 22.05.2015].

Petzold, B. & Matthias, E. (2011). Killerapplikation geseucht.gis.BUSINESS, 7, p.40-42.

Poole, A., Ball, L. J., & Phillips, P. (2004). In search of salience: A response time and eye movement analysis of bookmark recognition. In S. Fincher, P. Markopolous, D. Moore, & R. Ruddle (Eds.), People and Computers XVIII-Design for Life: Proceedings of HCI 2004. London: Springer-Verlag Ltd.

Poole, A., & Ball, L. J. (2006). Eye tracking in HCI and usability research. Encyclopaedia of human computer interaction, 1, 211-219.

Robinson, A. (2009). Visual highlighting methods for geovisualization. In 24th International Cartographic Conference, November, p.15-21. Retrieved from http://www.geovista.psuedu [Last accessed on 02.01.2015].

Sapaz, B., V. Isler (2006). Visualization in Transportation: A Theoretical Reference Model Framework, TRODSA: 3rd. Intl. Traffic and Road Safety Congress.

Sebastiaan, M. About. Opensesame. 2015. Retrieved from osdoc.cogsci.nl/about/ [Last accessed on 14.05.2015].

Sebrechts, M. M., Cugini, J. V., Laskowski, S. J., Vasilakis, J., & Miller, M. S. (1999). Visualization of search results: a comparative evaluation of text, 2D, and 3D interfaces. In Proceedings of the 22nd annual international ACM SIGIR conference on Research and development in information retrieval(pp. 3-10). ACM.

Shen, Y., Wu, L., Li, Z., & Li, X. (2010). 3D Visualization of Seismic Buildings in Yushu Earthquake for Disaster Management. In Multimedia Technology (ICMT), 2010 International Conference on (pp. 1-4). IEEE.

Shneiderman, B. (1987) Designing the User Interface: Strategies for Effective Human-Computer Interaction. Reading, MA: Addison-Wesley Publishing Co.

Sibert, J. L., Gokturk, M., & Lavine, R. A. (2000). The Reading Assistant: Eye gaze triggered auditory prompting for reading remediation. In Proceedings of the Thirteenth Annual ACM Symposium on User Interface Software and Technology (pp. 101-107). NY: ACM Press.

Slocum, T.A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D.R., Fuhrmann, S. & Hedley, N.R. (2001). Cognitive and Usability Issues in Geovisualization. Cartography and Geographic Information Science, 28(1).

Steinke, T.R. 1987. Eye movement studies in cartography and related fields. Cartographica 24(2): 40-73.

Swienty, O., Zhang, M. & Reichenbacher, T. (2006). Attention guiding visualization of geospatial information.Proc. SPIE 6421, Geoinformatics 2006: Geospatial Information Technology, 642101.

Travis, D. (2011). ISO 13407 is dead. Long live ISO 9241-210. London, UK: Userfocus Ltd., June, 6.

Tsou, M. H. (2011). Revisiting web cartography in the United States: The rise of user-centered design. Cartography and Geographic Information Science, 38(3), 250-257.

Uitto, J.I. (1998). The Geography of Disaster Vulnerability in Megacities, Applied Geography, Vol.18, No: 1, p. 7-16.

United Nations Development Programme (UNDP). (2010). Bureau for Crisis Prevention and Recovery. Disaster Risk Management. United Nations Development Programme.

United Nations Office for Disaster Risk Reduction (UNISDR) (2004). Living With Risk. United Nations International Strategy for Disaster.

Usability.gov (2015). User Experience Basics. Retrieved 22.03.2015 from http://www.usability.gov/what-and-why/user-experience.html [Last accessed on 13.07.2014].

UVW Coordinates (2014). in Autodesk Knowledge Network. Retrieved from http://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2015/ENU/3DSMax/files/GUID-8712A53B-CAFB-4EAF-B00E-E95B65C8FB71-htm.html [Last accessed on 10.05.2015].

UX Matters. (2010). Hierarchical Task Analysis. Retrieved from http://www.uxmatters.com/mt/archives/2010/02/hierarchical-task-analysis.php [Last accessed on 14.02.2015].

Ware, C. (2000). Information Visualization: Perception for Design. San Francisco: Morgan Kaufmann Publishers.

Ware, C. (2008). Visual Thinking Design. Burlington: Morgan Kaufmann Publishers.

Wolfe, J.M., Horowitz, T.S. (2004). What attributes guide the deployment of visual attention and how do they do it? Nature Reviews Neuroscience, 5 1-7.

World Health Organization (WHO)/ Emergency Preparedness and Humanitarian Action (EHA)/ Emergency Health Training Programme (EHTP) (1998a). Hazard Classifications. Panafrican Emergency Training Center, Addis Ababa.

World Health Organization (WHO)/ Emergency Preparedness and Humanitarian Action (EHA) /Emergency Health Training Programme (EHTP) _2 (1998b). Risk Assessment for Emergency Management. Panafrican Emergency Training Center, Addis Ababa.

World Meteorological Organization (WMO) (2002). Guide on Public Understanding and Response to Warnings. WMO, Genova.

Zlatanova, S., & Holweg, D. (2004). 3D Geo-information in emergency response: a framework. In Proceedings of the 4th International Symposium on Mobile Mapping Technology (MMT'2004), March (pp. 29-31).

Zlatanova, S., D. Holweg and M. Stratakis (2007). Framework for multi-risk emergency response, in: Tao&Li (Eds.) Advances in Mobile Mapping Technology, Taylor&Francis, London, ISPRS Book Series, pp. 159-171.

APPENDIX A

INTERVIEW DOCUMENT

INTERVIEW DOCUMENT

Hi, my name is Aslı Yılmaz. I am a PhD student in the Department of Geodetic and Geographic Information Technologies of Middle East Technical University. My PhD thesis advisor is Prof. Dr. Şebnem Düzgün. In my thesis, I am carrying out research on the determination of proper visualization in order to provide the decision makers in Disaster Management with an accurate, easy and quick perception of the data they analyze. In this context, I organized several interviews with the experts on different phases of Disaster Management. In fact, my goal is to gather information about the necessities of the decision makers on this subject. I have learned from ____ (this specific person /web/…) that you have gained expertise on ____ (this specific field). I am very grateful to you for giving me this opportunity to interview with you.

Participation in this study is at your discretion and is based on voluntariness; there is no obligation as to the participation in this study. Please let us know if you feel any discomfort during the study. If you need to rest, you can tell me and take some rest. You can leave the study any time you want without any requirement for explanation.

I want to voice-record during the interview. This record will never be used for any purpose other than the thesis scope. Your identity will never be matched and will be archived and kept safe upon completion of the study.

If everything is okay up to here, I guess we can start;

General Information

May I learn your occupation?

In which institution and under which department do you work?

How many years have you been working in this department?

How many years have you been working on Disaster Management?

Do you work individually or as part of a team? If you are working in a team, which departments or occupational groups do you work with?

Could you please briefly explain to me the way you work? *For example, I am a city and regional planner. I work on the city plan of this city. Currently, I am working on this project / these projects actively. These are the scopes of this project / these projects, and these are my responsibilities. I work this much hours per week. These are the regular duties that I perform etc.*

Specific Information

Could you please tell me about your decision-making process? What are the stages of the process?

Which subjects do you work on? Which decision-making process do they relate to? Which subjects do you think will gain importance in the future? Could you please tell me these subjects according to the order of importance? (*If they happen to say more than 3, it will be reduced down to 3, "Then, may I ask the first 3 most important titles?"*)

Which information technology tools do you use in the process? What kind of problems did you encounter with these tools? Do you remember any concrete events that you or anyone else has experienced? That caused you trouble, led you to make a wrong decision...

Have you ever performed analyses on a 3D virtual environment before?

SAMPLE VISUALISATION OF THE 3D ENVIRONMENT

(In this part, the sample model will be shown on the screen)

Recently, it is possible to visualize the geographical spatial knowledge on new platforms using new methods. I want to show you a couple of short video demonstrations.

Do you think that such a model could be used in the decision-making process of a city model? How can it be used? Would 3D visual design be advantageous on your side? From which aspects would it be advantageous? From which aspects would it not be advantageous? What else is required to improve it?

Would you need 2D visualization in addition to that? From which views would you like to see this environment? Perspective, top, sides… If it is perspective view, could you show us here what kind of a perspective view it is?

In such a visualization, which city objects are absolute must for you? Which objects are required? Could you please check the boxes here?

Say we have selected the objects... What kind of information do you need to be known in such an environment? *(“We can go over one by one, you had selected the building, which element/elements of the building must be shown?” After listing them on a piece of paper with the participant... Which one is the most critical? If you would have 100 points and distribute it among these items, how would you do that?)*

Would it be useful for you to display the environmental factors and time information (weather condition, pollution, day mode etc.) in such a visualization? What kind of environmental factor information would be meaningful to you?

SELECTION OF CITY OBJECTS U ___

	Low Importance	Medium Importance	High Importance
Building	☐	☐	☐
Transportation (roads, bridges, tunnels etc.)	☐	☐	☐
Waterbody (lakes, rivers etc.)	☐	☐	☐
City Furniture (traffic lambs, banks, bus stops, billboards etc.)	☐	☐	☐
Land Use (parks, industrial areas, residential areas etc.)	☐	☐	☐
Vegetation (forests, meadows etc.)	☐	☐	☐
Terrain	☐	☐	☐
Lifelines (electricity, water, gas, communication networks etc.)	☐	☐	☐
Additional Objects:			
____________________	☐	☐	☐
____________________	☐	☐	☐
____________________	☐	☐	☐

Building ______________________________

Transportation (roads, bridges, tunnels etc.) ______________________________

Waterbody (lakes, rivers etc.) ______________________________

City Furniture (traffic lambs, banks, bus stops, billboards etc.) ______________________________

Land Use (parks, industrial areas, residential areas etc.) ______________________________

Vegetation (forests, meadows etc.) ______________________________

Terrain ______________________________

Lifelines (electricity, water, gas, communication networks etc.) ______________________________

Additional Objects:

APPENDIX B

USER PROFILES

Table B.1: Interviewed User Profiles

	Profession	Department/Foundation (In Turkish)	Job Title	Co-workers	Experience
U1	Civil Engineer	Çankaya University-İnşaat Mühendisliği Bölüm Başkanlığı	Academician (Professor, Chair of the Department, President of IAEE)	Urban and Regional Planners, Earth Scientists, Geological Engineers, Disaster Risk Managers	43 years
U2	Geological Engineer	AFAD-Deprem Dairesi Başkanlığı-Deprem Bilgi Sistemleri Çalışma Grubu	Geological Engineer,M.Sc.	Earth Scientists, Civil Engineers, Geological Engineer, Geophysical Engineers	14 years
U3	Geological Engineer	AFAD- Deprem Dairesi Başkanlığı-Güvenli Yapı Güvenli Yerleşim Çalışma Grubu	Geological Engineer, M.Sc.	Earth Scientists, Civil Engineers	8 years
U4	Geophysical Engineer	AFAD- Deprem Dairesi Başkanlığı- Ulusal Kuvvetli Yer Hareketi Gözlem Ağı Çalışma Grubu	Geophysical Engineer	Geological Engineers, Geophysical Engineers	9 years
U5	Geophysical Engineer	AFAD-Planlama ve Zarar Azaltma Dairesi Başkanlığı	Geophysical Engineer, M.Sc.	Geological Engineers, Geophysical Engineers, Civil Engineers, Environmental Engineers	15 years
U6	Geological Engineer	Gazi Üniversitesi- Deprem Araştırma Merkezi Başkanlığı	Academician	Engineers, Academicians, Sociologists, Pyschologists	11 years
U7	Geological Engineer	AFAD-Bilgi Sistemleri ve Haberleşme Dairesi Başkanlığı / CBS Sistemleri Çalışma Grubu	Geological Engineer	Geomatic Engineers, Geological Engineers	16 years
U8	Statistician	ODTÜ Afet Yönetimi Uygulama ve Araştırma Merkezi	Academician (Assistant Professor)	Sociologists, Psychologists, Civil Engineers Urban and Regional Planners, Business Administrators, Architects, Environmental Engineers, Geological Engineers	14 years
U9	Geological Engineer	AFAD-Planlama ve Zarar Azaltma Dairesi Başkanlığı	Geological Engineer	Earth Scientists, Geological Engineers	24 years

Table B.1 (Continued)

	Profession	Department/Foundation (In Turkish)	Job Title	Co-workers	Experience
U10	Civil Engineer	AFAD-İyileştirme Dairesi Başkanlığı- Hasar Tespit Çalışma Grubu	Civil Engineer (Assistant specialist)	Civil Engineers, Architects	2 years
U11	Political Science and Public Administrator	AFAD-Müdahale Dairesi Başkanlığı-Afet ve Acil Durum Yönetim Merkezi	Assistant specialist	Engineers, Sociologists, Psychologists, Public Administrators	3 years
U12	Economist	AFAD-Müdahale Dairesi Başkanlığı-Arama Kurtarma ve İtfaiye Çalışma Grubu	Group Leader	Civil Defense Groups, Public Administrators, Engineers	25 years
U13	Geophyscial Engineer	Retired- Kızılay, Deprem Araştırma Enstitüsü	Previous Chair of Kızılay	Economists, Sociologists, Engineers, People from many disciplines	50 years
U14	Civil Engineer	AKUT Arama Kurtarma Derneği	Group Leader	Engineers, Mountaineers, Psychologists, Educators	17 years
U15	Geological Engineer	Çevre ve Şehircilik Bakanlığı - Alt Yapı ve Kentsel Dönüşüm Hizmetleri Genel Müdürlüğü-İzleme ve Değerlendirme Dairesi	Geological Engineer	Earth Scientists, Civil Engineers, Architects	24 years
U16	Urban and Regional Planner	Çevre ve Şehircilik Bakanlığı - Alt Yapı ve Kentsel Dönüşüm Hizmetleri Genel Müdürlüğü	Branch Manager	Geological Engineers, Architects, Urban and Regional Planners, Civil Engineers, Sociologists, Geomatic Engineers	4 years
U17	Urban and Regional Planner	Çevre ve Şehircilik Bakanlığı - Alt Yapı ve Kentsel Dönüşüm Hizmetleri	General Manager Assistant	Geological, Civil and Geomatic Engineers, Architects, Urban and Regional Planners, Sociologists	6 years

Table B.1 (Continued)

	Profession	Department/Foundation (In Turkish)	Job Title	Co-workers	Experience
U18	Physics Engineer	Kızılay-Afet Müdahale Birimi	Member of the Unit	Psychologists, Educators, Civil Defense Teams, Nutritionists, Non-Governmental Search & Rescue Groups	12 years
U19	Statistician	ODTÜ-Uygulamalı Matematik Enstitüsü	Academician	Statiscians, Mathematicians, Insurers, Economists, Earthquake Engineers, Civil Engineer	24 years
U20	Economist	TC Başbakanlık Hazine Müsteşarlığı-Sigortacılık Genel Müdürlüğü	General Manager	Treasury specialists, Economists	22 years

APPENDIX C

USER ROLES

Table C.1: Interviewed User Roles

	DM Phase	Scope	Used Tools	Main Decision Process	Advantage of 3D Environment
U1	Ex-Ante Strategies - *Risk Assessment, Risk Mitigation*	Good building practices, standards and specifications, seismic risk map preparation, hazard map preparation, nuclear safety	Digital maps, satellite images, on field work, GIS maps	Field work > Analysis of each building > Calculation of vulnerability for each building (Each building has 100 points in the beginning, each bad feature such as unregular geometry, poor quality material, soft building ground, limited columns etc. reduces from total point 100)	*Advantageous. *Analyzing building damages from 2D images is insufficient. *Updated building conditions after disaster by using disaster surveys can be good.
U2	Ex-Ante Strategies - *Risk Assessment* Ex-Post Strategies - *Response*	Earthquake preliminary damage assessment (Deprem ön hasar tespit), damage estimation by creating scenarios for real case situations, damage estimation after earthquake occurs	Arc Map, Map Info, Net Cad Google Earth, special softwares estimating damage (Eg. Deprem Erken Uyarı ve Tahmin yazılımı)	Earthquake occurs > Parameters of the earthquake are taken from "Kuvvetli ve Zayıf Yer Hareket Birimleri" (eg. Peak Ground Acceleration, Magnitude,Latitude, Longitude, Epicentral Distance, Depth of Focus etc. //// Before earthquake occurs, scenario of an earthquake that occurs in a specific area is designed (worst case) > Estimation of damage is conducted using softwares > Visualization of damage with GIS softwares	*It is important to see information of topography on Y axis (depth) as well. *2D images are necessary as well.
U3	Ex-Ante Strategies - *Risk Assessment*	On field work, literature review of previous hazards, Preparation of seismic hazard maps and seismic risk maps, assessment of active fault lines, preparation of settlement suitability (yerleşime uygunluk) maps	ERDAS, satellite images GIS softwares	Field Work + Digital Maps > Determination of active faults > Geological surveys > Hazard Assessment > Risk Assesment > Visualization of hazard and risk maps	*Geotecnic survey results could be better viewed when modelled in 3D *2D top view is necessary as well.
U4	Ex-Ante Strategies - *Risk Assessment*, Ex-Post Strategies- *Response*	On field work, set up of accelerographs on field, peak ground acceleration calculation	GPRS, ADSL, softwares for calculation, web service	Field Work/ Set up of accelerographs on field > Earthquake occurs > Magnitude and size parameters are calculated by Zayıf Hareket Birimi > Data is gathered from accelerographs > Peak ground acceleration is calculated by special softwares to understand the damage to buildings and other city objects.	*Not advantageous for them
U5	Ex-Ante Strategies - *Risk Assessment*	Geophysical and geological effects, effect of ground properties, peak ground acceleration maps, damage on social and economical status, determining response activites	Map Server, GDAL, GMT, Fortran	Selection of a high-risk location (eg.Bursa) > Determination of the most effective fault that can cause damage when earthquake occurs > Determination of the area to be analyzed > Preparation of seismic hazard maps according to the fault > Integration of ground properties > Preparation of seismic risk maps including the factors such as population information, building, infrastructure and lifelines information	*Advantageous, but 2D top view is also necessary

Table C.1 (Continued)

	Scenario(s)	City Objects	Attributes
U1	Definition of quantitative vulnerability judgement for each building.	Importance/ High: Building, Transportation Importance/ Mid: Terrain, Water Body, Lifelines Importance/ Low: City Furniture, Vegetation, Land Use **City Infrastructure (such as sewage)	*Building: Building type(hospital, school, industrial building..etc.), building age, geometry of the building, number of occupants, number of floors, material, ground properties etc. *Terrain: Slope *Land Use: Industrial Use *Transportation: Type (Main streets, side streets), traffic density (after earthquake) **Night/day mode, season
U2	Estimation of damage when eartquake with this___ parameters occurs. In which places (which provinces, districts etc.) damage would occur? How many people would die or get injured? How many buildings would be damaged?	Importance/ High: Building, Transportation, Land Use, Terrain, Lifelines Importance/ Mid: Waterbody Importance/ Low: City Furniture, Vegetation	*Building: Building type(hospital, school, industrial building..etc.), building age, number of floors, material, population *Transportation: Main streets, side streets *Water Body: Dams *Terrain: Population, VS 30 (ground properties), geological information, fault lines **Night/day mode, season
U3	* Creating seismic hazard and seismic risk maps for a specific place * Creating suitability for settlement maps (yerleşime uygunuk haritaları)	Importance/ High: Land Use, Terrain, Life Lines Importance/ Mid: Building, Transportation	Terrain: Slope, fault lines(length, branch) Water body: Drainage basin ** Population as an attribute
U4	Calculation of Peak Ground Acceleration (PGA) for a specific location	Importance/ High: Stations	Stations: Location of the stations
U5	* Creating seismic hazard maps and integrating ground properties (1) * Creating seismic risk maps for a specific place (2)	For scenario: 1: Importance/ High: Terrain	*Terrain: Geological and geophysical properties, morphological properties, PGA, PGV, Fault lines, ground amplification maps **Night/day mode, season

Table C.1 (Continued)

	DM Phase	Scope	Used Tools	Main Decision Process	Advantage of 3D Environment
U6	Ex-Ante Strategies-*Risk Mitigation*	Disaster management education, long-term strategies for minimizing loss, acting as a consultant	GIS programs, digital maps	Analysis of seismic hazard and risk maps > Preparation of strategies for minimizing the loss	*Advantageous, especially for mitigation process *Modeling underground can also be helpful.
U7	Ex-Ante Strategies-*Risk Assessment*	Data integration, data organization in GIS platforms	GIS programs, digital maps, satellite images, ortophotos	Preparation of GIS based maps (topographic, geological, geophysical, cadastral maps etc.)	*Advantageous, especially for damage assessment
U8	Ex-Ante Strategies-*Risk Assessment, Risk Mitigation*	Mitigation strategies (UDSEP Deprem Strateji ve Eylem planı), preparing data bank for researchers and risk managers (Afet Bilgi Bankası Projesi) , preparing glossary (Afet Terimler Sözlüğü), economic, social and psychological effects of disasters	Maps, reports, documents	Analyzing seismic hazard and risk maps > > focusing on vulnerable groups on high-risk-areas > preparing strategies for minimizing economic, social and psychological damages	*Advantageous, but 2D top view is also necessary * On the buildings the vulnerable groups such as children, older people, women etc. can be shown in 3D environment
U9	Ex-Ante Strategies-*Risk Assessment*	Seismic hazard map preparation, seismic risk map preparation, GIS analyses, field work	Digital maps, satellite Images, on field work, GIS maps, GIS programs such as GRASS, Arc GIS, Map Info	Selection of a location > Determination of the most effective fault that can cause damage when earthquake occurs > Determination of the location to be analyzed > Preparation of seismic hazard maps according to the fault > Integration of ground properties > Preparation of seismic risk maps including the factors such as population information, building information, infrastructure and lifelines information	*3D seismic hazard map is not advantageous by itself.
U10	Ex-Post Strategies-*Response, Recovery*	Damage assessment (Ön Hasar Tespit+ Kesin Hasar Tespit+ İtiraz Hasar Tespit)	Excel and Macro softwares, 2D & 3D GIS maps	Earthquake occurs > Analysis of each building > Definition of the damage scale > Decision of the building to be distracted or not	*Analyzing building damages from 2D images is not sufficient. *It would be advantageous. Mobile application can be usefull for real time data sharing of building damage scale

Table C.1 (Continued)

	Scenario(s)	City Objects	Attributes
U6	Preparing road maps for minimizing loss after a possible earthquake	Importance/ High: Building, Transportation, Land Use, Lifelines Importance/ Mid: Water body, Terrain Importance/ Low: City Furniture, Vegetation **City Infrastructure	*Building: Ground properties, construction plan (imar planı), suitability for settlement (yerleşime uygunluk), occupants (age, gender and other properties) *Transportation: Transportation network, width *Terrain: Ground characteristics, underground properties, slope, population **Night/day mode, season
U7	Estimation of damage when eartquake with this____ parameters occurs. In which places (which provinces, districts etc.) damage would occur? How many people would die or get injured? How many buildings would be damaged? Which lifelines, bridges, tunnels would be effected?	Importance/ High: Building, Transportation, Land Use, Lifelines, Water body, Terrain, City Furniture, Vegetation	*Building: Building type, number of occupants, construction information, ownership information *Transportation: Direction, slope, width, type *Waterbody: Dam *Land Use: Grassland, Forest, High population area, Flood area *Terrain: Fault lines, Geological properties,slope, aspect **night/day mode, season
U8	What if an earthquake with ___ parameters occur in ___ place? * How many people would get injured or effected? What are their properties? * In which places damage would occur? What are the properties of these places and occupants (In terms of social and economic properties)	Importance/ High: Building, Land Use, Lifelines Importance/ Mid: Vegetation, City Furniture	*Building: Type of the building, economic and social status of occupants, age of the occupants **Night/day mode, season
U9	* Creating seismic hazard maps and integrating ground properties (1) * Which objects do the hazard affect? * Creating seismic risk maps for a specific place (2)	Importance/ High: Terrain Importance/ Mid: Building, Land Use, City Furniture, Lifelines, Vegetation, Transportation, Water body	*Terrain: Slope, Aspect, DEM, ground type, faults, geological properties *Transportation: drainage plans *Waterbody: type **Night/day mode
U10	Earthquake with ___ parameters occurred at ___ * Which buildings are damaged and at what scale?	Importance/ High: Building, Transportation, Lifelines	*Building: Type, residents information, owners information (ikamet bilgileri ve mal sahibi bilgileri)

Table C.1 (Continued)

	DM Phase	Scope	Used Tools	Main Decision Process	Advantage of 3D Environment
U11	Ex-Post Strategies - *Preparedness, Response*	Response plan, arranging supply, coordination of response teams	Telephones, radiophones, satellite phones, visual screens	Earthquake occurs > Parameters of earthquake are taken from "Kuvvetli ve Zayıf Yer hareket Birimleri" (eg. Peak Ground Acceleration, Magnitude,Latitude, Longitude, Epicentral Distance, Depth of Focus etc. > Estimation of damage is taken > Response plan is prepared	*It would be advantageous
U12	Ex-Post Strategies - *Preparedness, Response*	Search & rescue, fire-fighting	GIS based maps, telephones, radiophones, satelite maps	Earthquake occurs > Search & Rescue plan is prepared > Search & Rescue starts	*It would be advantageous *It would save time
U13	Ex-Ante Strategies - *Risk Assessment, Mitigation, Preparedness* Ex-Post Strategies - *Response, Recovery*	Seismic risk and hazard map preparation, mitigation strategies, response plan, planning temporary and permanent settlement	GIS based maps, satelite maps, satellite Images, On field work, softwares (deprem erken uyarı ve tahmin, hasar tahmin)	Analysis of seismic hazard and risk maps > Preparation of strategies for minimizing the loss Earthquake occurs > Response activites begin according to response plan > Recovery plan is prepared such as permanent settlement plan	* Advantageous * Especially buildings shown as 3D is adventagous * Perspective view is important
U14	Ex-Ante Strategies - *Preparedness,* Ex-Post Strategies - *Response*	Search & rescue (lost pet, lost person, under- water search), search & rescue training, fire-fighting	Satellite maps, digital maps, telephones, radiophones, sound locators, image recorders	Earthquake occurs > Response plan is prepared > Search & Rescue plan is prepared	*Real time visualization can be difficult, 3D visualization can be advantageous
U15	Ex-Ante Strategies - *Risk Assessment, Risk Avoidance*	Recycling and of ruins, evaluation of buildings for demolition, demolition of high-risk public buildings	Technical equipments for demolition, on field work, maps are not necessary	Technical analysis of each building > Risk analysis of buildings and ground properties > Demolition if necessary > Following -up whole process (main duty of the department)	*It would be perfect to understand the relationship of the building to be demolished with other neighbour buildings in terms of occupational health and safety

Table C.1 (Continued)

	Scenario(s)	City Objects	Attributes
U11	Earthquake with___ parameters occurred at ___ *How many people are affected, how many of them need hospital? How many of them need shelter? *How much should be the food supply? *How many search rescue workers should go to the place?	Importance/ High: Building, Transportation, Waterbody, Land Use, Lifelines Importance/ Mid: Terrain Importance/ Low: City Furniture, Vegetation	*Building: Number of occupants, number of floors *Transportation: Open/closed roads *Waterbody: Usable water sources *City Furniture: Traffic light's working status *Land Use: Areas that can create secondary disasters *Lifelines: Communication lines and their status **Night/day mode, weather
U12	Earthquake occurred at ___ / Or a realistic scenario How many search& rescue team member should go? How should they be coordinated?	Importance/ High: Building, Transportation, Lifelines	*Building: Number of occupants, damage scale, plan of the building *Transportation: Availability of roads, main/sub roads, traffic density *Lifelines: Communication in the building **night/day mode, weather
U13	What if an earthquake with ___ parameters occur in ___ place? * How many people would get injured or effected? What are their properties? *How many buildings would be damaged? * In which places damage would occur? What are the properties of these places and occupants (In terms of social and economic properties) Earthquake occurred at ____ *How many people are affected, how many of them need hospital? How many of them need shelter? *How much should be the food supply? *How many search rescue workers should go to the place? * What kind of settlement should be planned for the people affected ?Permanent or temporal ? * Where should they be built?	Importance/ High: Transportation, Land Use, Lifelines Importance/ Mid: Building, Waterbody, Vegetation, Terrain	*Building: Type (critical buildings, industrial building, hospital, school, a building that can cause secondary disasters, etc.) number of floors, material, structure, damage *Transportation: Availability of roads *Land Use: Vacant areas *Vegetation:Location (Important for planning temporal/ permanent settlement) *Terrain: Slope, ground properties, Important for planning temporal/ permanent settlement **Night/day mode
U14	Earthquake occurred at ____ How many search& rescue team member should go? How should they be coordinated?	Importance/ High: Building, Transportation, Lifelines, Waterbody, Land Use, Terrain Importance/ Mid: City Furniture, Vegetation **City cameras	*Building: Type, number of occupants, plan of the building, facility plans, lifelines *Transportation: Availability of roads (open/closed), main roads/side roads *Waterbody: Status of dam *Land Use: Vacant places (Important for planning temporal settlement) *Terrain: Vacant places (Important for planning temporal settlement)
U15	What are the risk properties of the building? Which building should be demolished? How should it be demolished safely? What is the location of the building?	Importance/ High: Building, Transportation, Terrain, Lifelines Importance/ Mid: Waterbody, City Furniture, Land Use Importance/ Low: Vegetation	*Building: Installation of the building, type of the building, neighbour buildings, use of space, static information *Transportation: Neighbour transportation properties

Table C.1 (Continued)

	DM Phase	Scope	Used Tools	Main Decision Process	Advantage of 3D Environment
U16	Ex-Ante Strategies - *Risk Avoidance* Ex-Post Strategies *Reconstruction*	Urban Renewal, renewal of high-risk areas, renovation or reconstruction of housing and public works	GIS based maps, digital maps, satellite maps, plans, 3D models, on field work	Risk analysis of building and areas > creating current situation mock-ups > In place renewal by regarding social and economic conditions > If in place renewal is not possible because of ground properties, renewal of buildings and areas, demolition of high-risk buildings and areas moving residents to low-risk and habitable areas	*Advantageous. They can use it especially for convincing the residents to the renewed urban area and building
U17	Ex-Ante Strategies - *Risk Avoidance* Ex-Post Strategies *Reconstruction*	Urban renewal, renewal of high-risk areas, renovation or reconstruction of housing and public works	GIS based maps, digital maps, satellite maps, plans, 3D models, on field work	Risk analysis of building and areas > creating current situation mock-ups > In place renewal by regarding social and economic conditions > If in place renewal is not possible because of ground properties, renewal of buildings and areas, demolition of high-risk buildings and areas moving residents to low-risk and habitable areas	*It is advantageous, for analysis of area to be renewed and present the renewed urban area
U18	Ex-Ante Strategies- *Preparedness,* Ex-Post Strategies- *Response*	Preparing response plan by creating realistic scenarios, educating people and raising awareness, educating volunteers for response, determination of standards of response activities food supply, temporary shelter supply, providing health service and psychological support	Sphere project standards, City plans, GIS based maps, telephones, radiophones, satelite maps	Earthquake occurs > Response plan is prepared > Supply and teams to be sent are prepared > Response activities start according to the plan	*Advantageous, especially for planning response
U19	Ex-Ante Strategies- *Risk Assessment, Risk Transfer*	Seismic risk assessment (probabilistic risk assessment), statistical modeling, earthquake risk definition and quantification, insurance, risk transfer methods, damage modelling,	Statistical softwares, SPSS, R Project	Damage modeling > Loss modeling > Risk assessment > Calculation of maximum risk cost> Analysis of how much risk should be transferred to which stakeholders or authorities> Preparation of reports that explains which areas or city objects will be affected (to the insurance companies)	*Advantageous, risk visualization of buildings can be done in 3D perspective
U20	Ex-Ante Strategies- *Risk Transfer, Preparedness* Ex-Post Strategies *Response*	Risk transfer strategies, increasing insured dwellings, developing awareness of earthquake insurance, adress standardization within national database (UAVT), monitoring and managing the insurance portfolio, damage assessment and strategies for compensating damage (After disaster)	Softwares serving both for calculating insured damage, insurance costs, insurance premiums etc.and for acting as database management systems	1) Pre-disaster: A) Risk assessment (worst scenario) -*What is risk, What is cumulative risk?*> Evaluation of which part of the insurance portfolio (areas, buildings etc) will be affected > Insurance cost and premium calculations > Arrangement of financial capacity B) Response plan in terms of insurance, (Where are the damage spots? Where should the response team focus?) 2) Post-disaster: Damage assessment > expert analysis (comparison of pre-disaster and post-disaster)> Compensating procedures	*Can be advantageous for monitoring insurance portfolio and information of the portfolio, also for monitoring risk and risk cumulatives, preparing response plan insurance

Table C.1 (Continued)

	Scenario(s)	City Objects	Attributes
U16	During renewal of high-risk areas… Can it be a in place renewal or residents should be moved to low-risk areas? Where should be the buildings relocated? What should be the new economic and social conditions of residents in the renewed urban area?	Importance/ High: Building, Terrain Importance/ Mid: Transportation, Waterbody, City Furniture, Land Use, Lifelines Importance/ Low: Vegetation	*Building: Type, material, ownership properties, distance to neighbour buildings, year of construction *Transportation: Network, main roads/side roads *Terrain: Slope, ground properties **Economic and social properties of people **Neighbourhood properties **Educational properties **Season, energy efficiency **Time (previous version-renewed version)
U17	During renewal of high-risk areas… Can it be a in place renewal or residents should be moved to low-risk areas? Where should be the buildings relocated? What should be the new economic and social conditions of residents in the renewed urban area?	Importance/ High: Building, Transportation, Waterbody, Land Use, Vegetation, Terrain, Lifelines Importance/ Mid: City Furniture	*Building: Population, number of floors, material, structural properties *Waterbody: Creek beds, channels *Terrain: Ground properties, geological properties, faults **Time (previous version-renewed version)
U18	Earthquake occurred at__/Or a realistic scenario How many people are/ would be affected? How much food supply should be sent? How many shelters should be sent? Where should be the shelters located? How should be the health service?	Importance/ High: Transportation, Waterbody, Land Use, Vegetation, Terrain, Lifelines Importance/ Mid: Building, City Furniture	*Building: Occupants (age, gender..etc.) *Transportation: Network, main/ side roads *Waterbody: Accessiblity to water *Land Use: Vacant places *Terrain: Ground properties, Slope **Season, population, night/day
U19	After risk quantification and definition; Which areas or city objects will be affected? How much risk should be transferred to which stakeholders or authorities?	Importance/ High: Building, Transportation, Land Use, Terrain, Lifelines Importance/ Mid: Vegetation Importance/ Low: City Furniture	* Building: Type, risk information according to floors, material, year of construction *Transportation: Network, main/side roads, escape routes, safety points *Land Use: Type, Population *Terrain: Ground properties, kind of soil, geological properties *Lifelines: Working status, alternatives **Neighbourhood positions should be shown by using smaller scales
U20	After risk quantification and definition (Risk+Cumulative Risk) Which part of the insurance portfolio (areas, buildings etc) will be affected? What should be the insurance cost?	Importance/High: Building, Land Use Importance/Mid: Transportation Importance/Low: Waterbody, City Furniture, Vegetation, Terrain, Lifelines	*Building: Number of floors, year of construction, surface area of apartment, type of structure, type of the building, zoning legislation, *Land Use: Ground properties, type of the land use

APPENDIX D

PILOT USER TEST VISUALIZATIONS

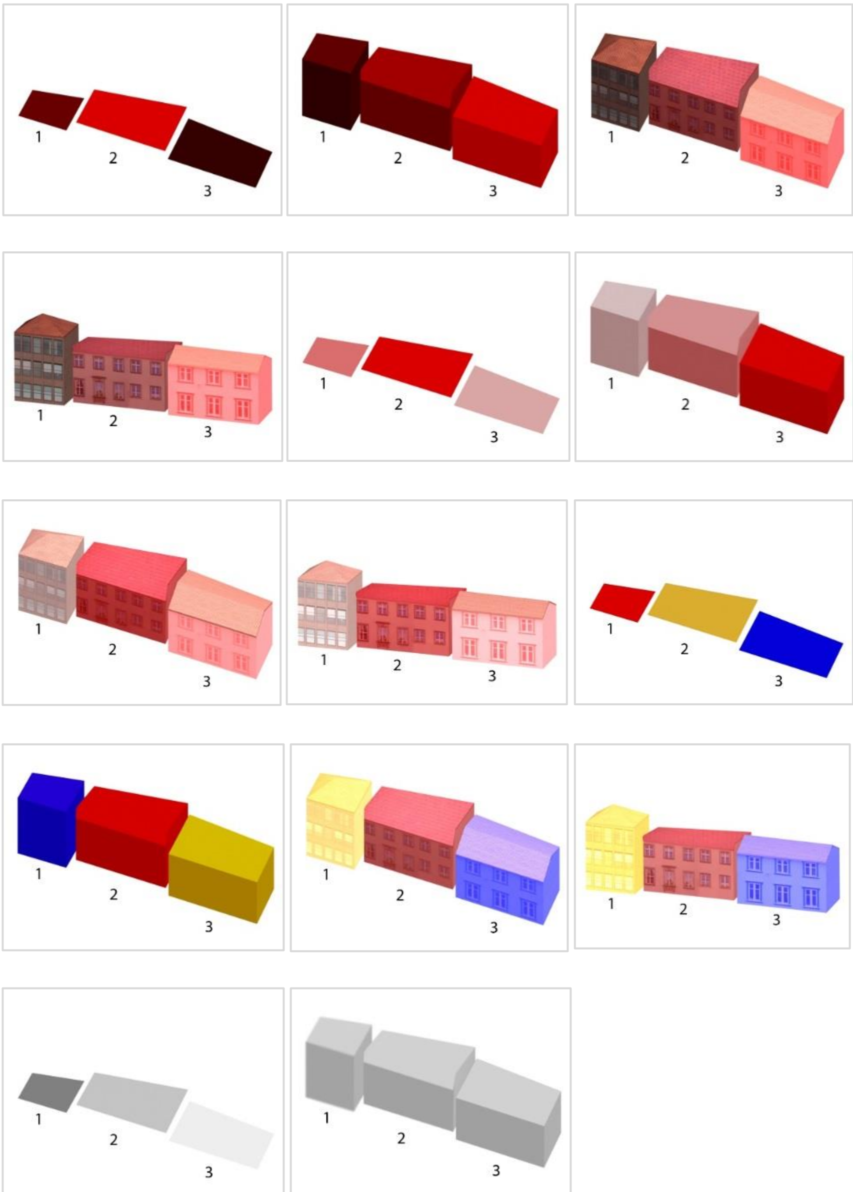


Figure D.1: Pilot Test Visualizations

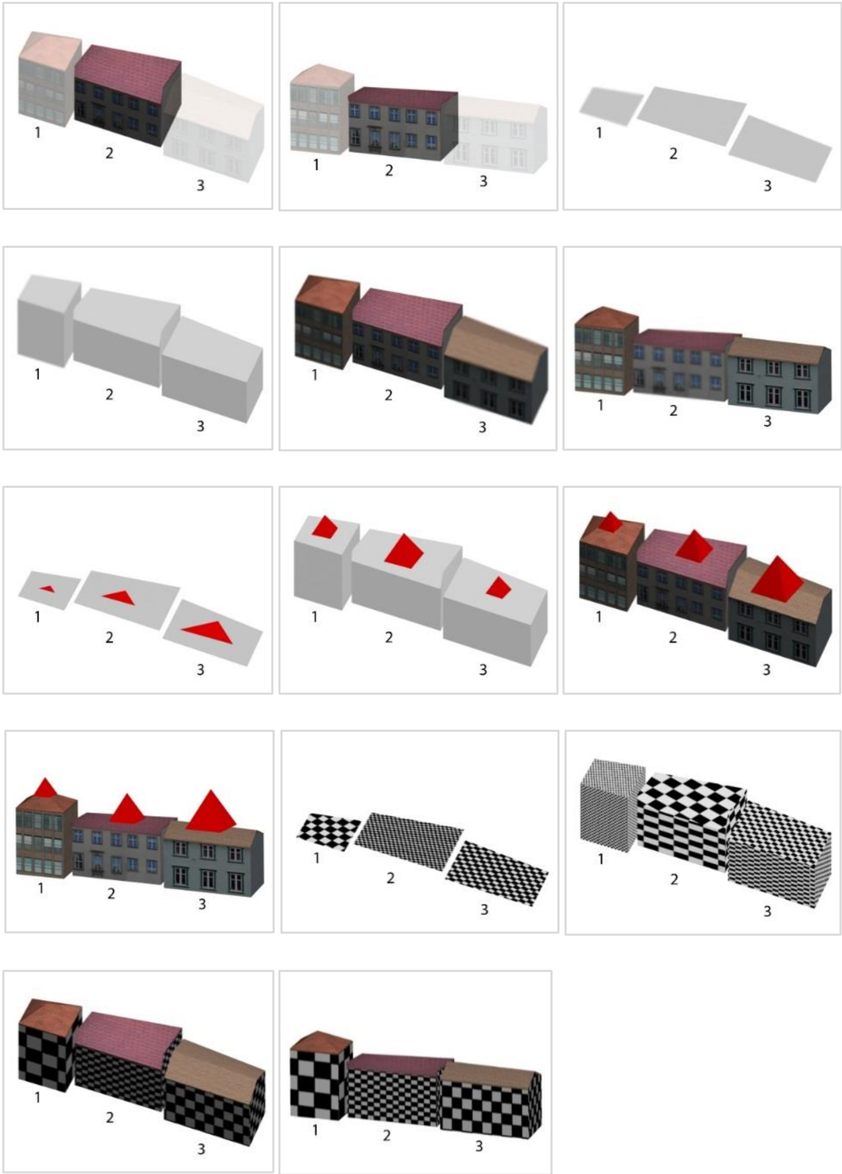
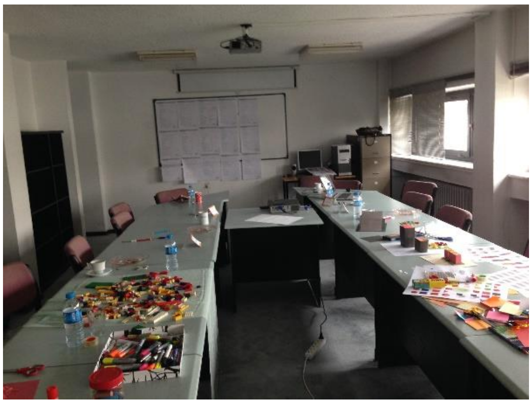


Figure D.1 (Continued)

APPENDIX E

PHOTOGRAPHS FROM THE WORKSHOP



APPENDIX F

WORKSHOP VISUALIZATIONS

SET 1.1 - LoD 0 - In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

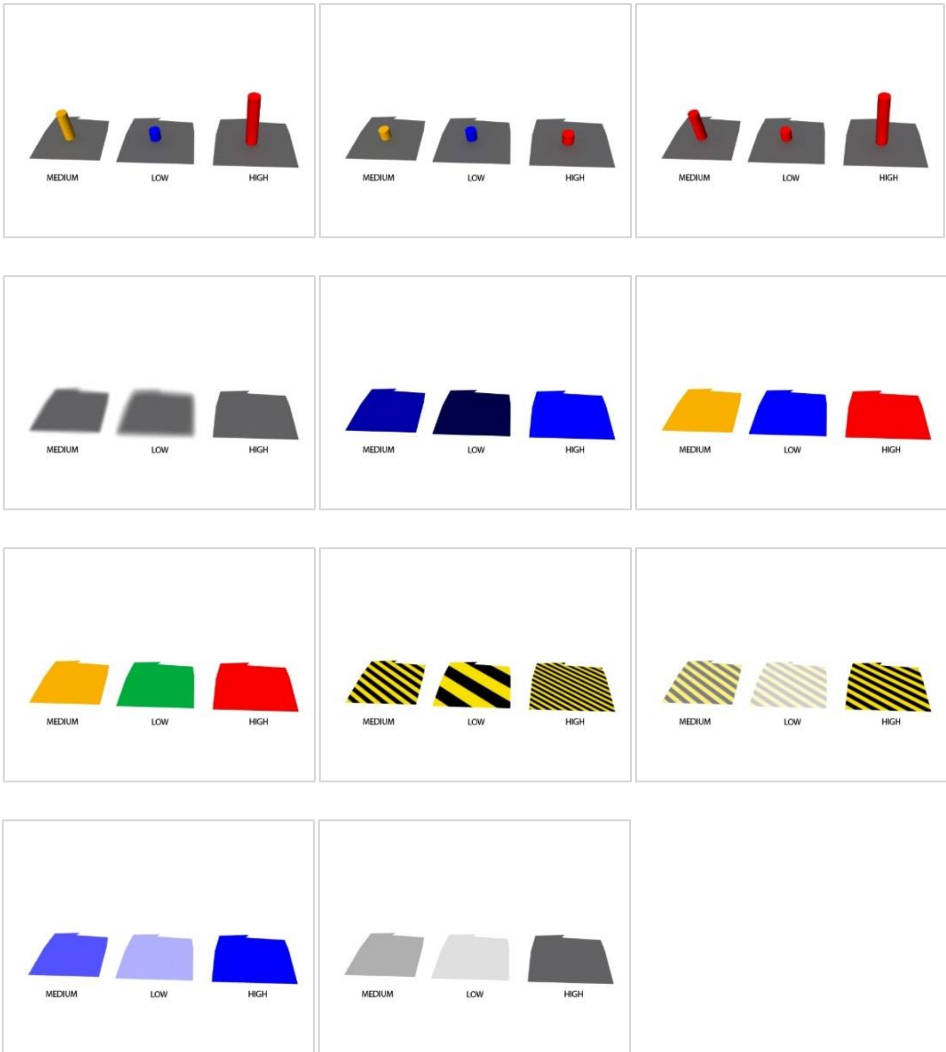


Figure F.1: Workshop Visualizations Set 1.1

SET 1.2 - LoD 0 - In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

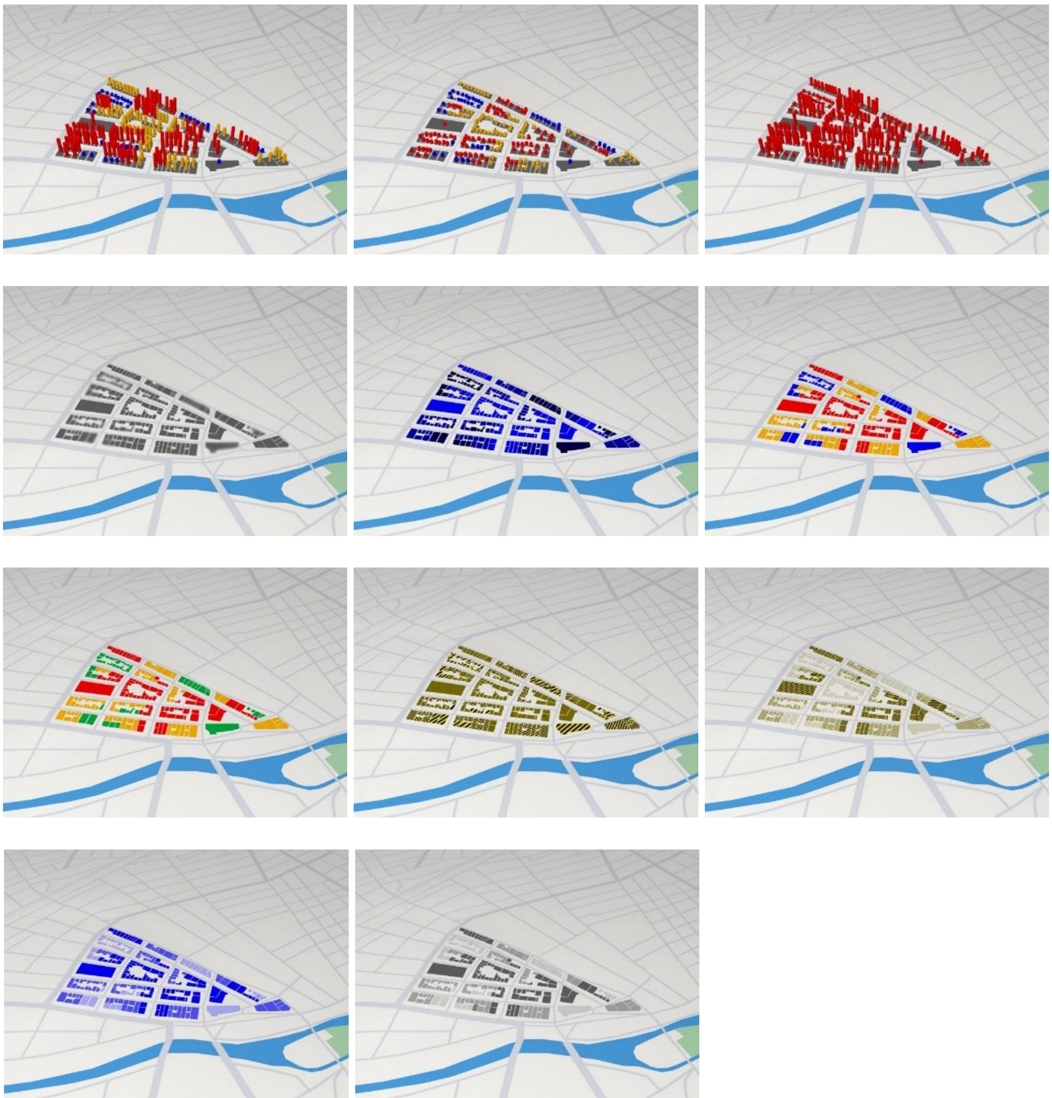


Figure F.2: Workshop Visualizations Set 1.2

SET 1.3 - LoD 0 - In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

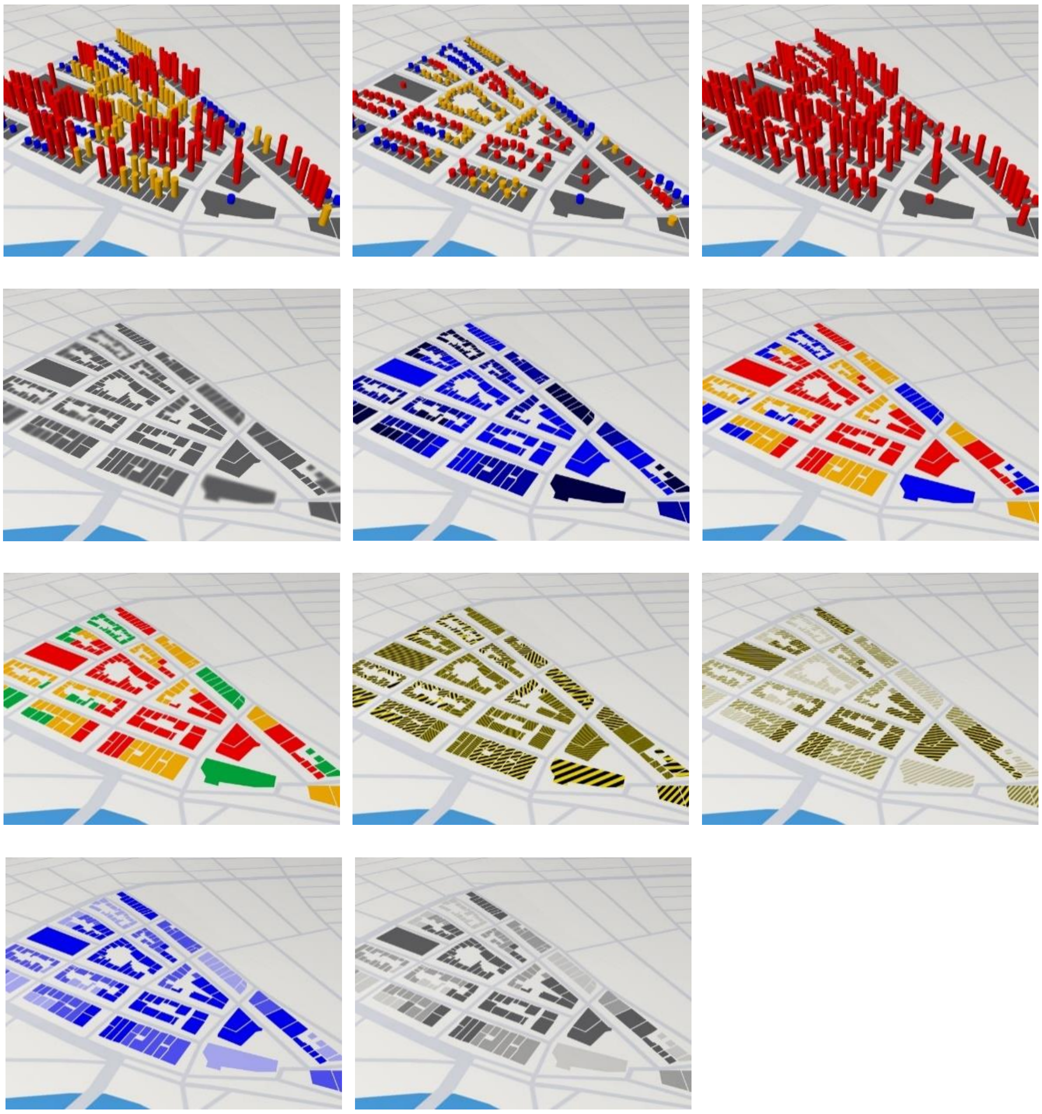


Figure F.3: Workshop Visualizations Set 1.3

SET 1.4 - LoD 0 - In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

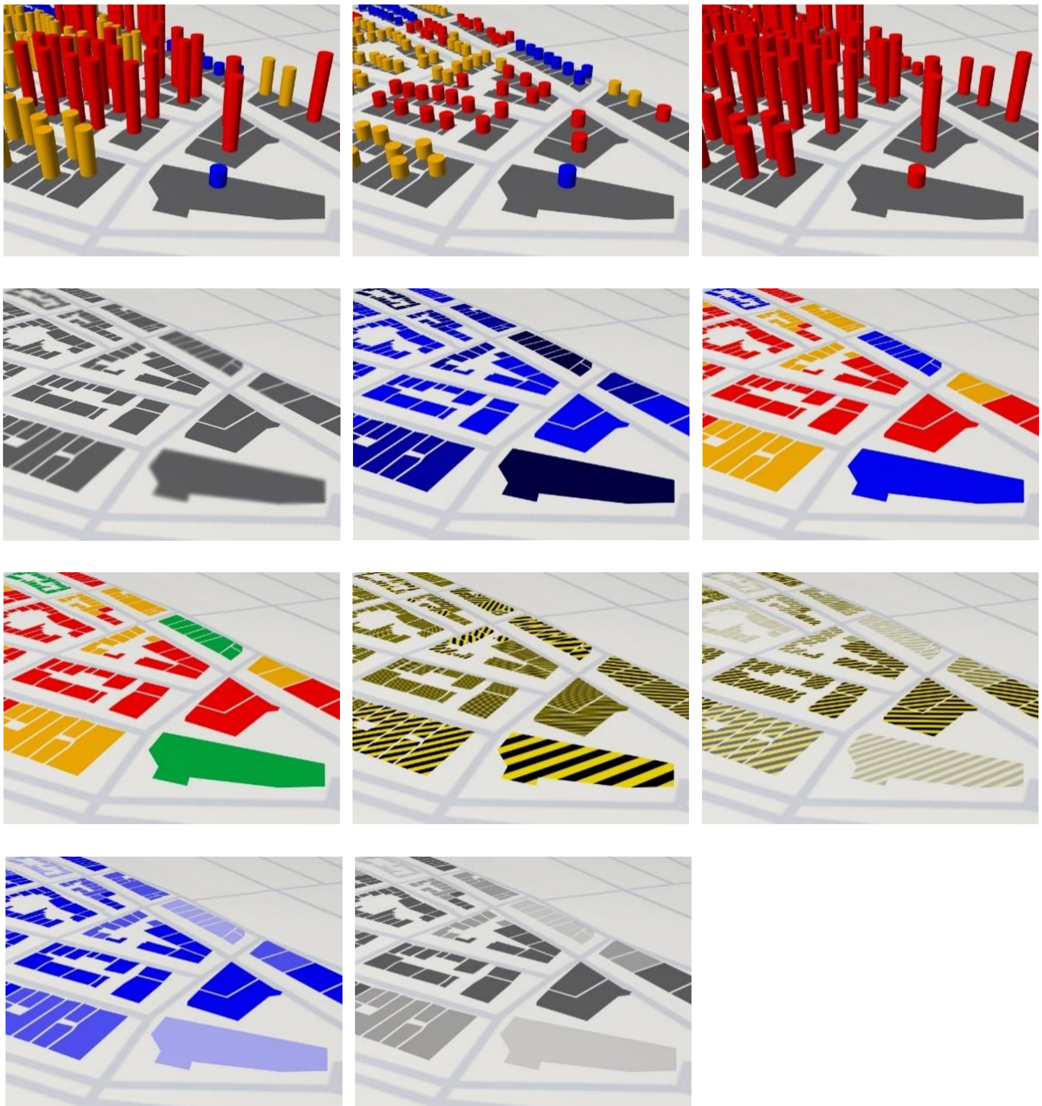


Figure F.4: Workshop Visualizations Set 1.4

SET 2.1 - LoD 1- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

Figure F.5: Workshop Visualizations Set 2.1

SET 2.2 - LoD 1- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

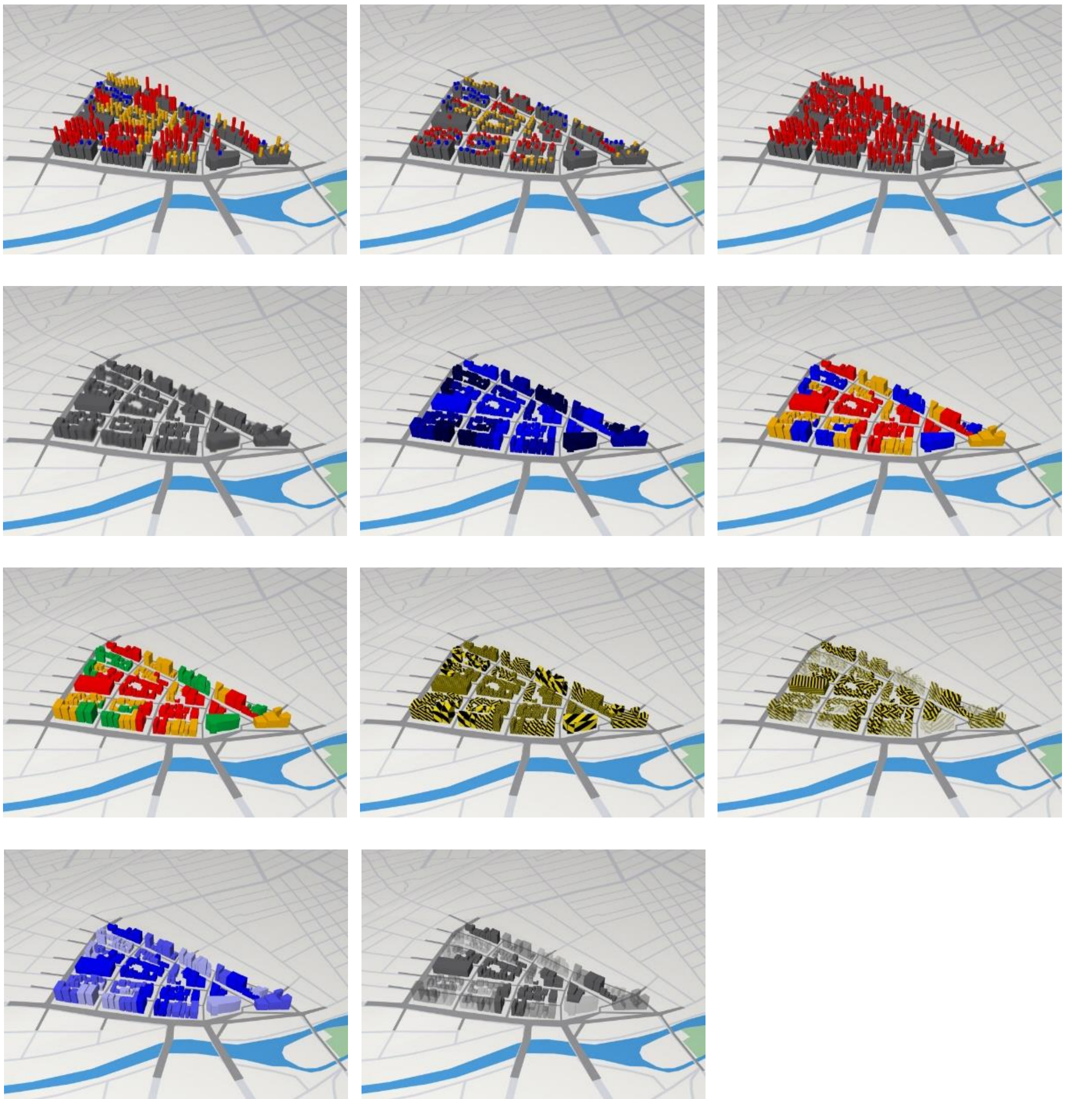


Figure F.6: Workshop Visualizations Set 2.2

SET 2.3 - LoD 1- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

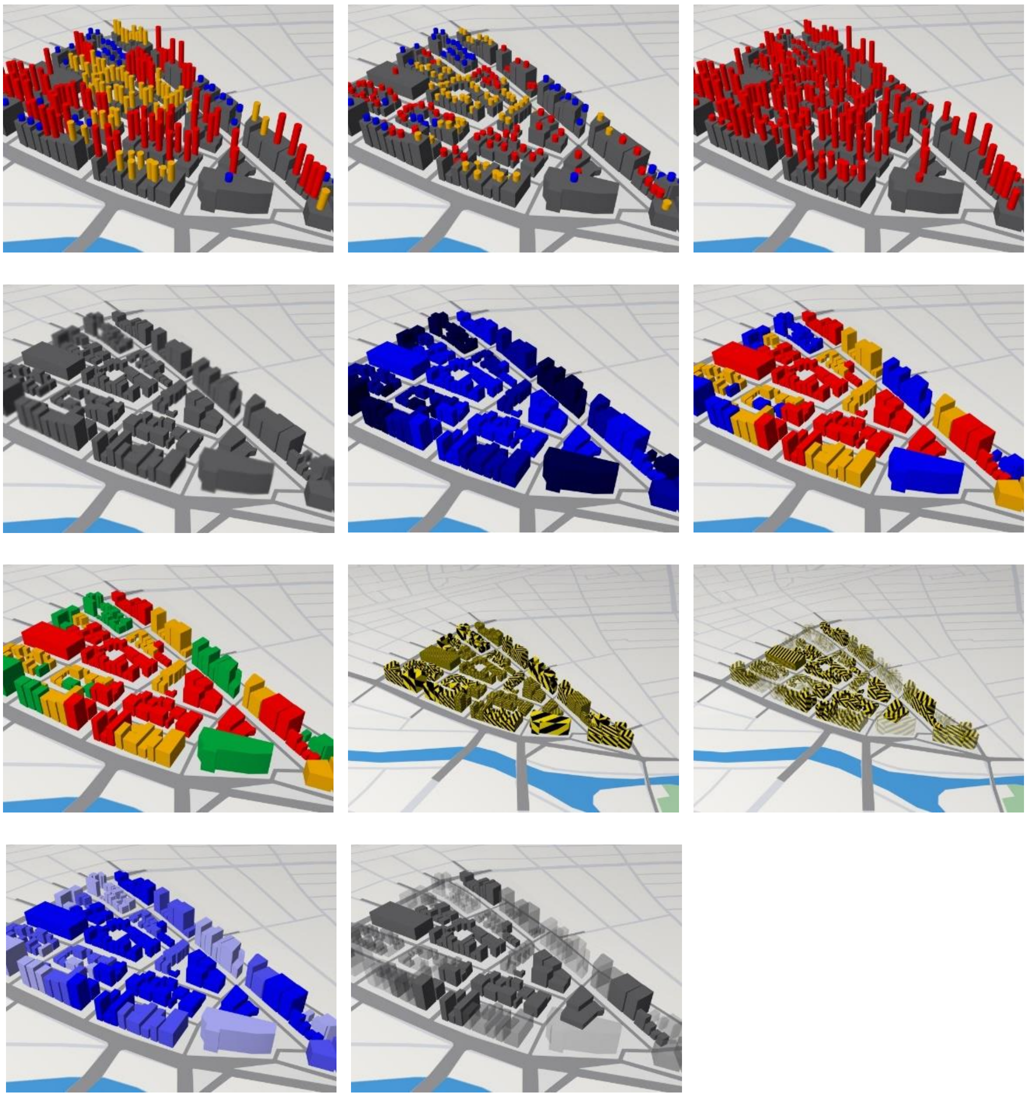


Figure F.7: Workshop Visualizations Set 2.3

SET 2.4 - LoD 1- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Brightness, Hue 1, Hue 2, Pattern-Size, Pattern-Transparency, Saturation, Transparency

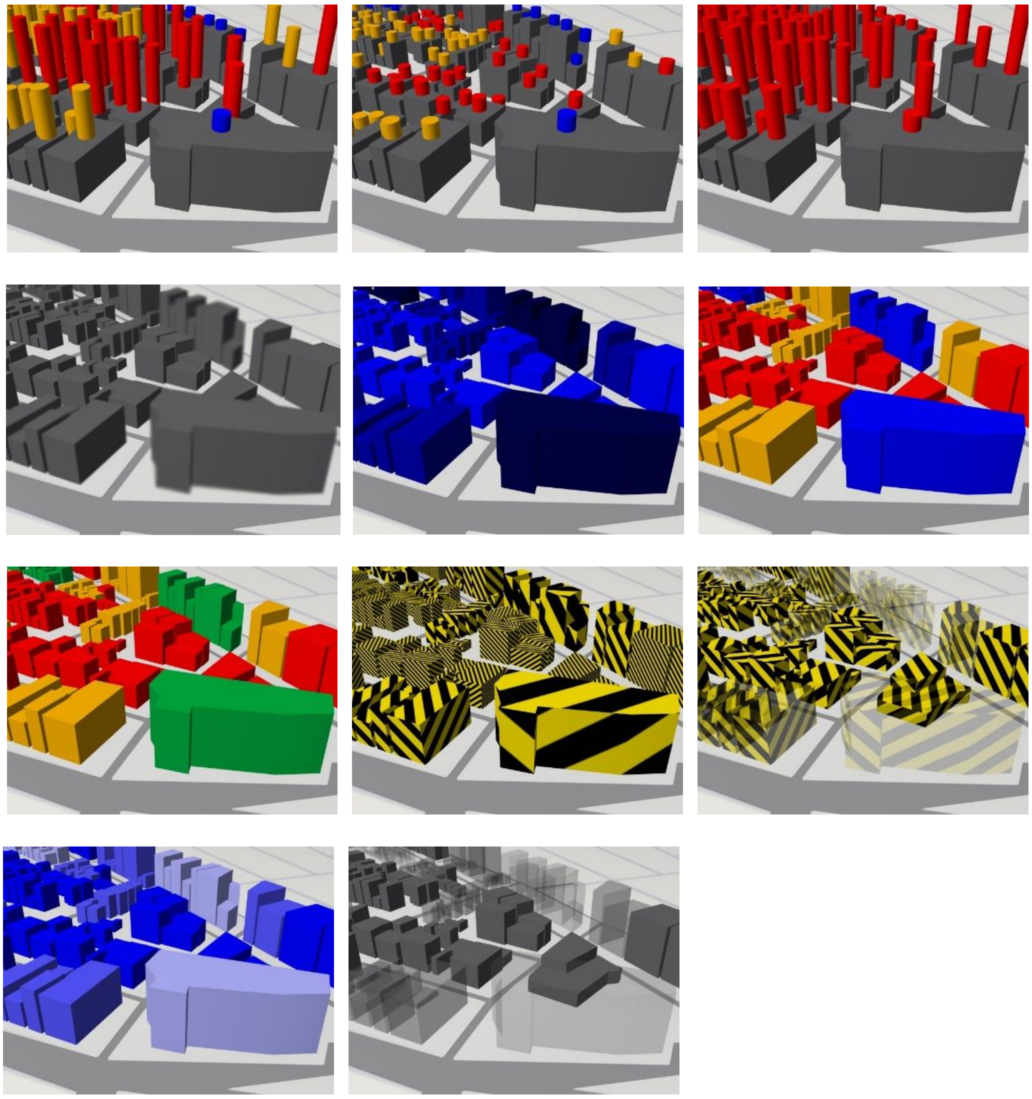


Figure F.8: Workshop Visualizations Set 2.4

SET 3.1 - LoD 2- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Self-Illumination-Brightness, Self-Illumination-Hue 1, Self-Illumination-Hue 2, Pattern-Size, Pattern-Transparency, Self-Illumination-Saturation, Transparency

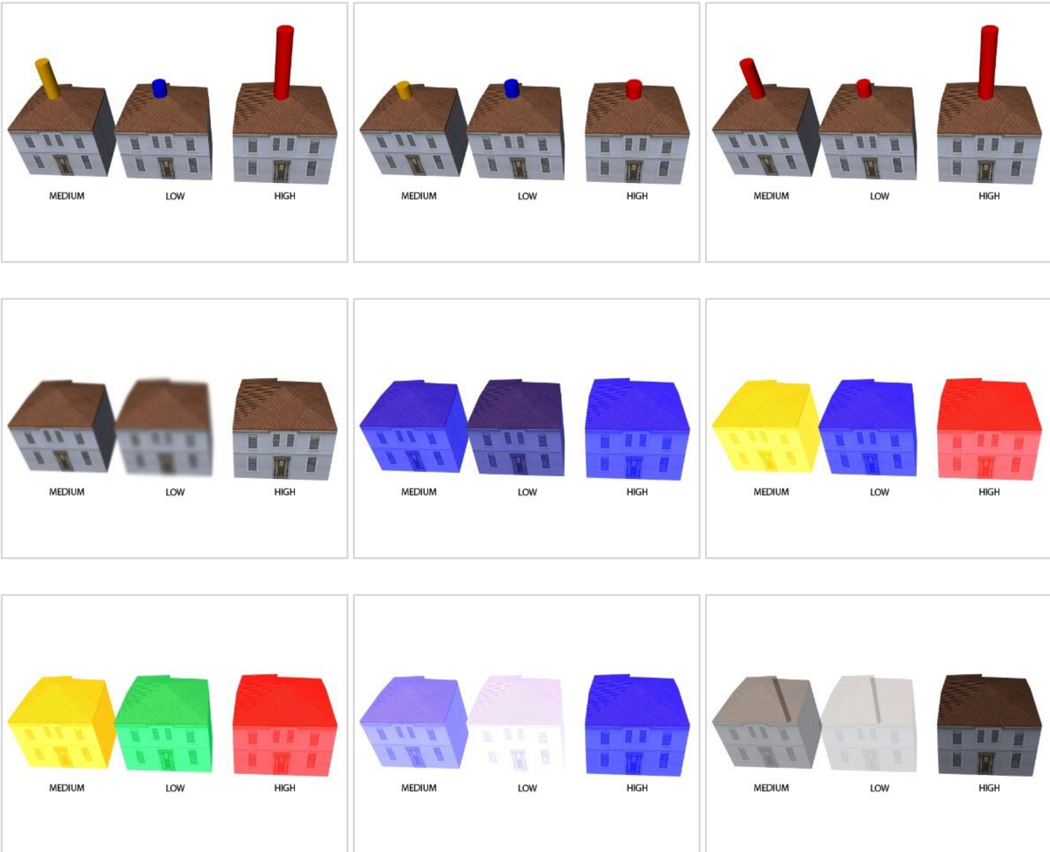


Figure F.9: Workshop Visualizations Set 3.1

SET 3.2 - LoD 2- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Self-Illumination-Brightness, Self-Illumination-Hue 1, Self-Illumination-Hue 2, Pattern-Size, Pattern-Transparency, Self-Illumination-Saturation, Transparency

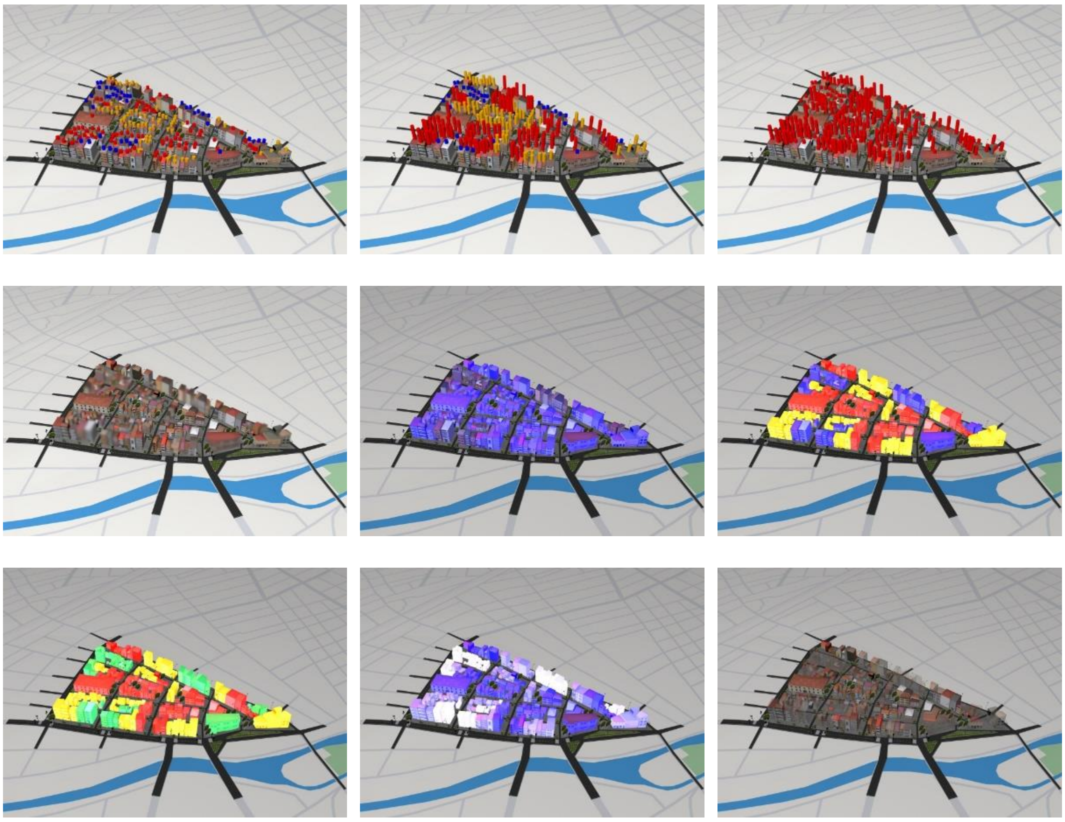


Figure F.10: Workshop Visualizations Set 3.2

SET 3.3 - LoD 2- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Self-Illumination-Brightness, Self-Illumination-Hue 1, Self-Illumination-Hue 2, Pattern-Size, Pattern-Transparency, Self-Illumination-Saturation, Transparency

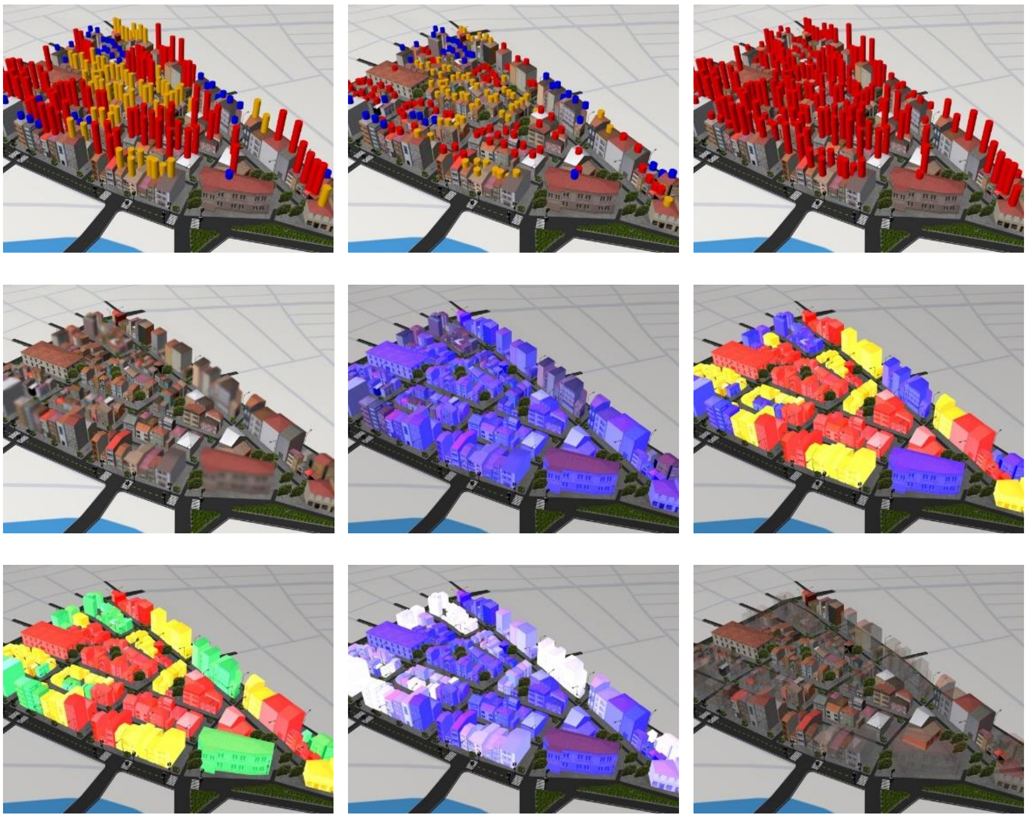


Figure F.11: Workshop Visualizations Set 3.3

SET 3.4 - LoD 2- In sequential order- Abstract Object-Size-Hue, Abstract Object-Hue, Abstract Object-Size, Blur, Self-Illumination-Brightness, Self-Illumination-Hue 1, Self-Illumination-Hue 2, Pattern-Size, Pattern-Transparency, Self-Illumination-Saturation, Transparency

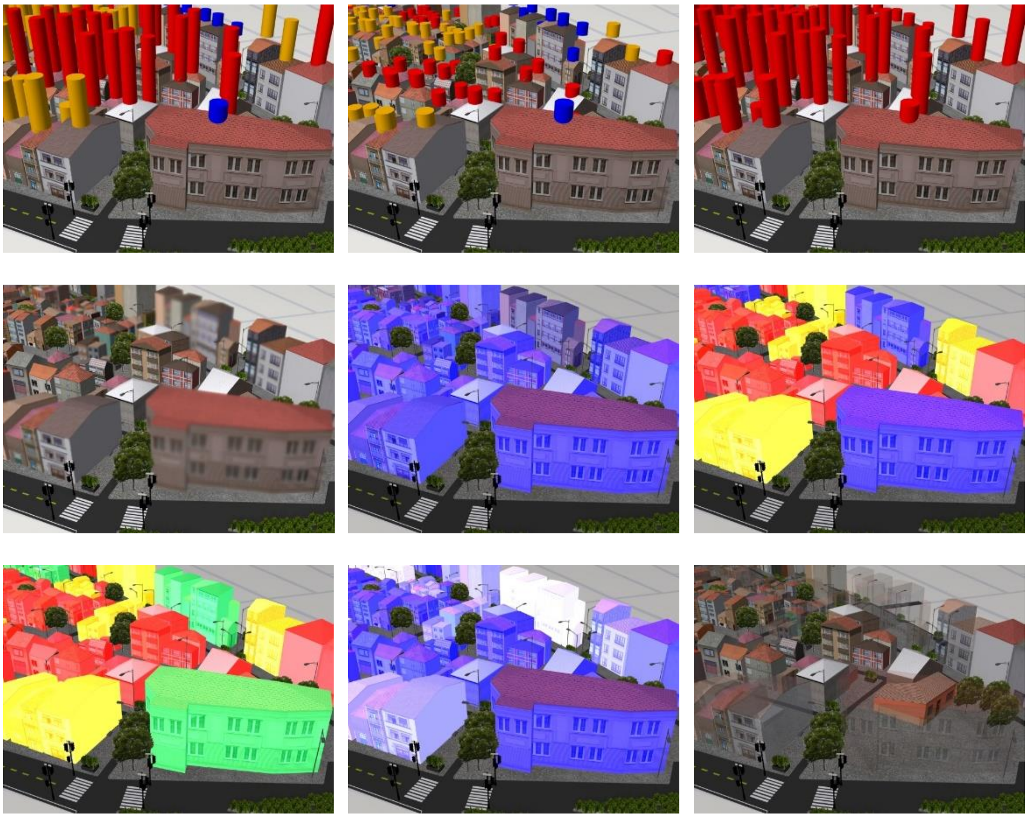


Figure F.12: Workshop Visualizations Set 3.4

APPENDIX G

VISUALIZATIONS OF THE FIRST PART OF THE FINAL USER TESTS

In sequential order- Abstract Object- Hue LoD 0, Blur LoD 2, Brightness-Red LoD 1, Brightness-Red LoD 0, Brightness-Blue LoD 0, Contour LoD 0, Contour LoD 1,Contour LoD 2, Hue LoD 0

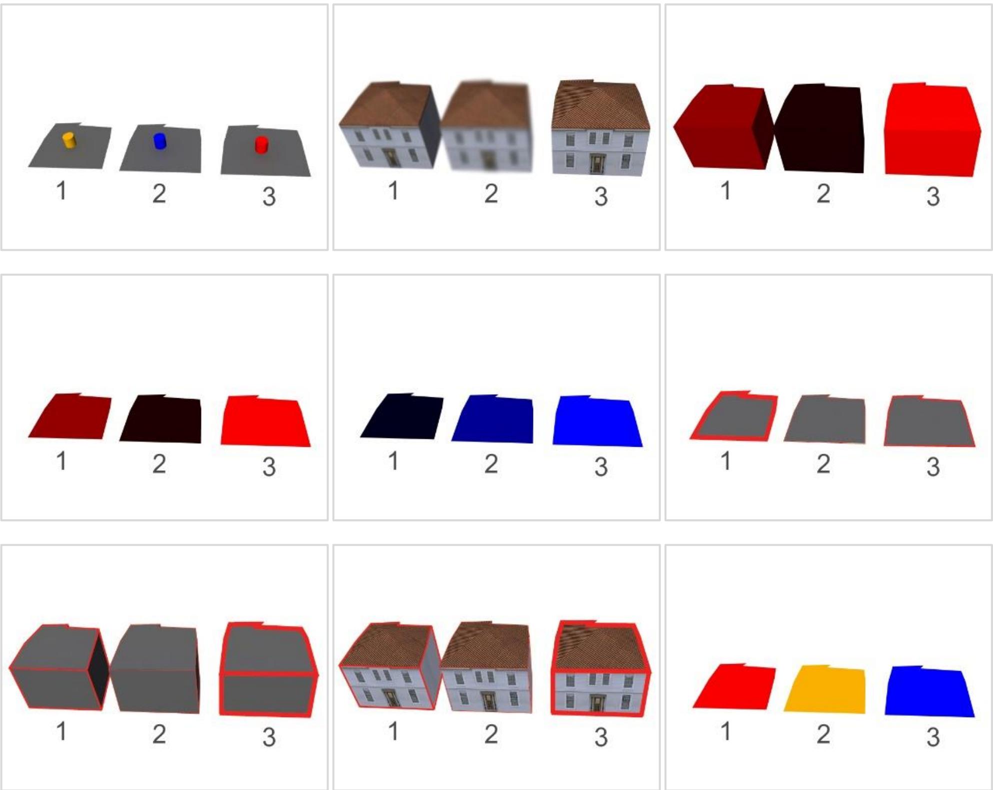


Figure G.1: Final Test First Part Visualizations

In sequential order- Hue LoD 1, Self-Illumination-Hue LoD 2, Saturation-Red LoD 0, Saturation-Red LoD 1, Saturation-Blue LoD 1, Saturation-Blue LoD 0, Brightness-Blue LoD 1, Transparency LoD 0, Transparency LoD 1, Transparency LoD 2

Figure G.1 (continued)

APPENDIX H

VISUALIZATIONS OF THE SECOND PART OF THE FINAL USER TESTS

LoD 0 - Background: Map - In sequential order - Brightness-Blue, Brightness-Red, Saturation-Blue, Saturation-Red, Transparency, Abstract Object-Hue, Hue, Contour

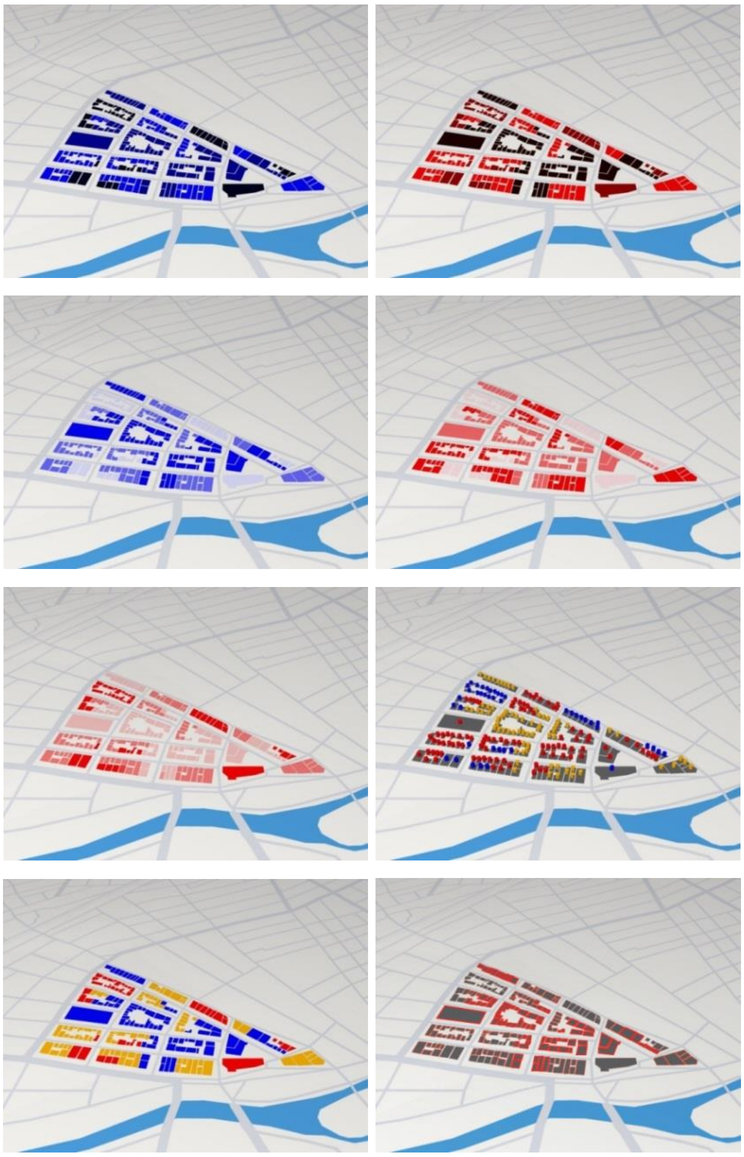


Figure H.1: Final Test Second Part of the Visualizations

LoD 0 - Background: Satellite - In sequential order - Brightness-Blue, Brightness-Red, Saturation-Blue, Saturation-Red, Transparency, Abstract Object-Hue, Hue, Contour

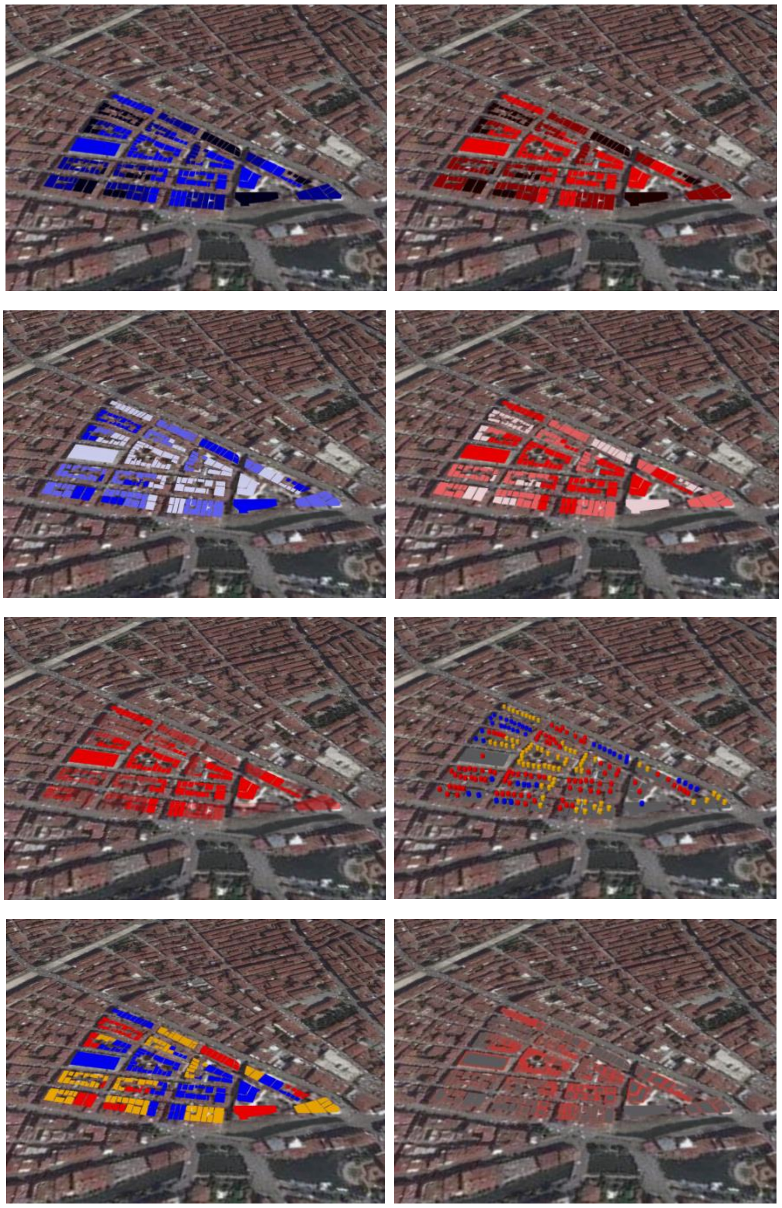


Figure H.1 (continued)

LoD 1 - Background: Map - In sequential order - Brightness-Blue, Brightness-Red, Saturation-Blue, Saturation-Red, Transparency, Hue, Contour

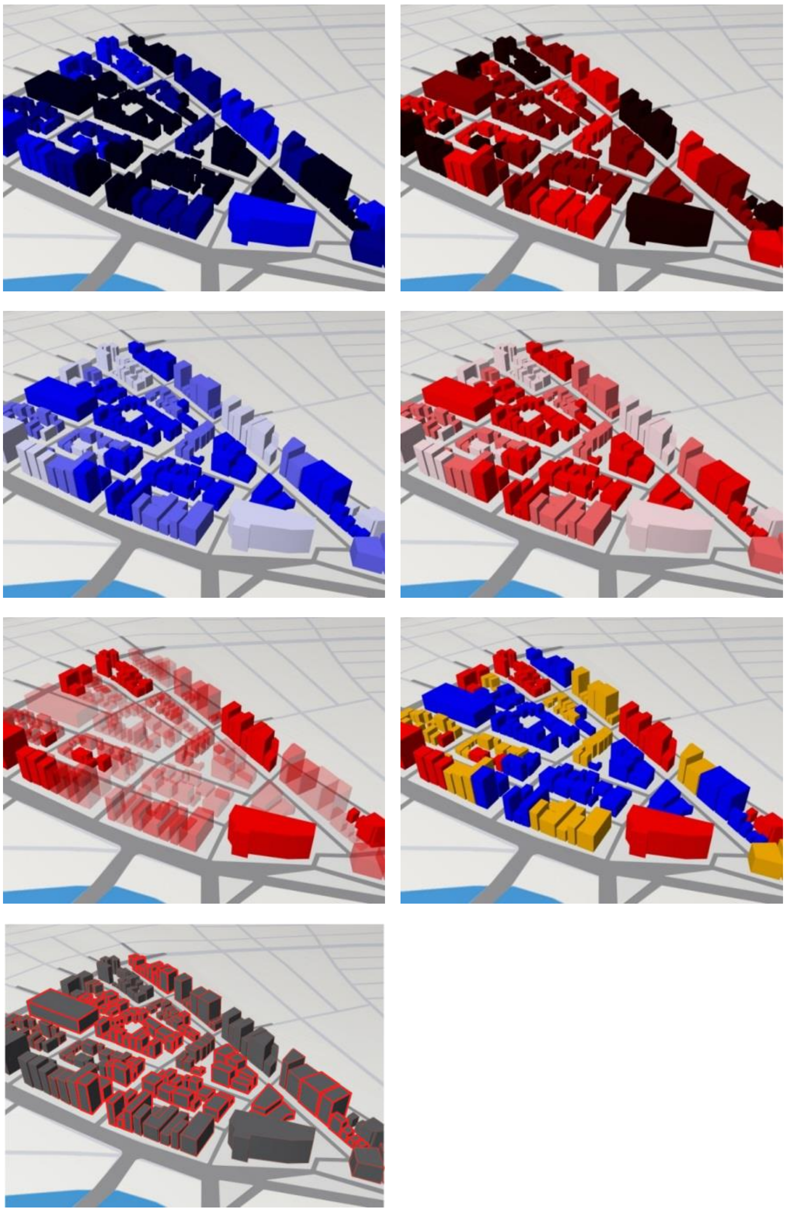


Figure H.1 (continued)

LoD 1 - Background: Satellite - In sequential order - Brightness-Blue, Brightness-Red, Saturation-Blue, Saturation-Red, Transparency, Hue, Contour

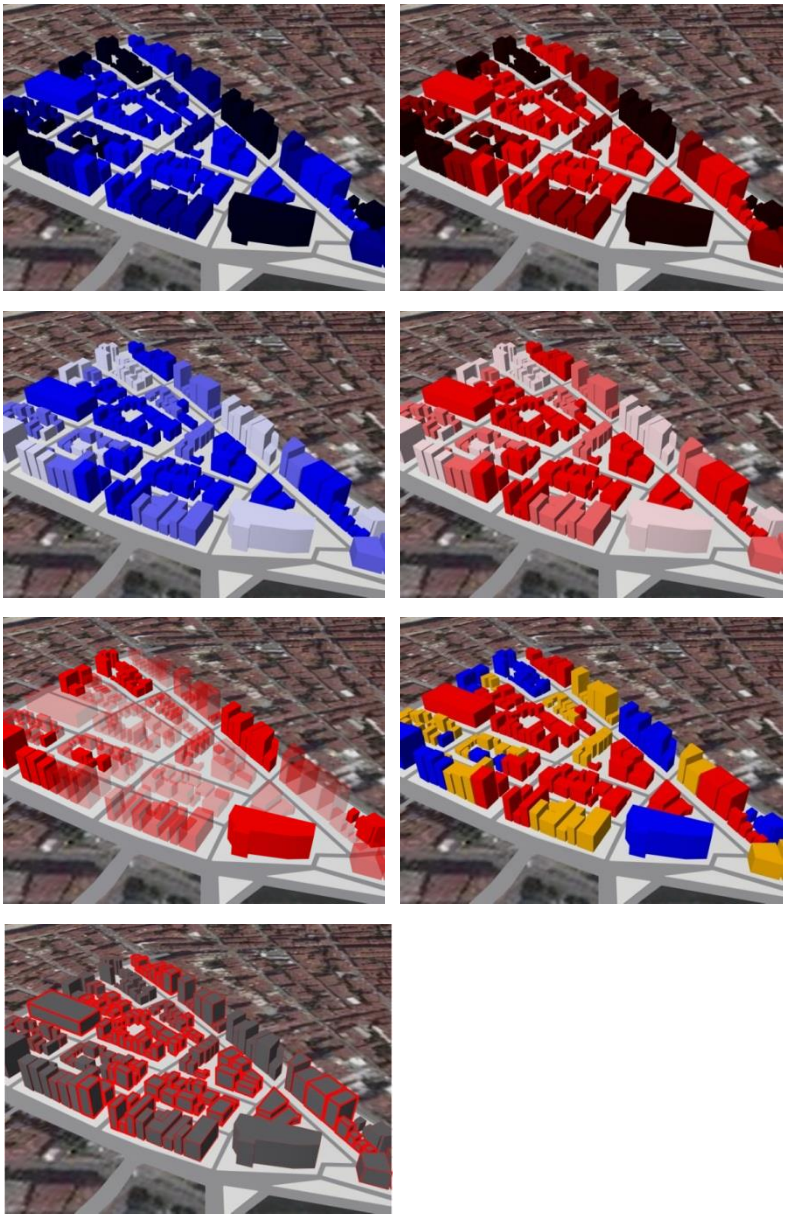


Figure H.1 (continued)

LoD 2 - Background: Map - In sequential order - Self Illumination-Hue, Transparency, Blur, Contour

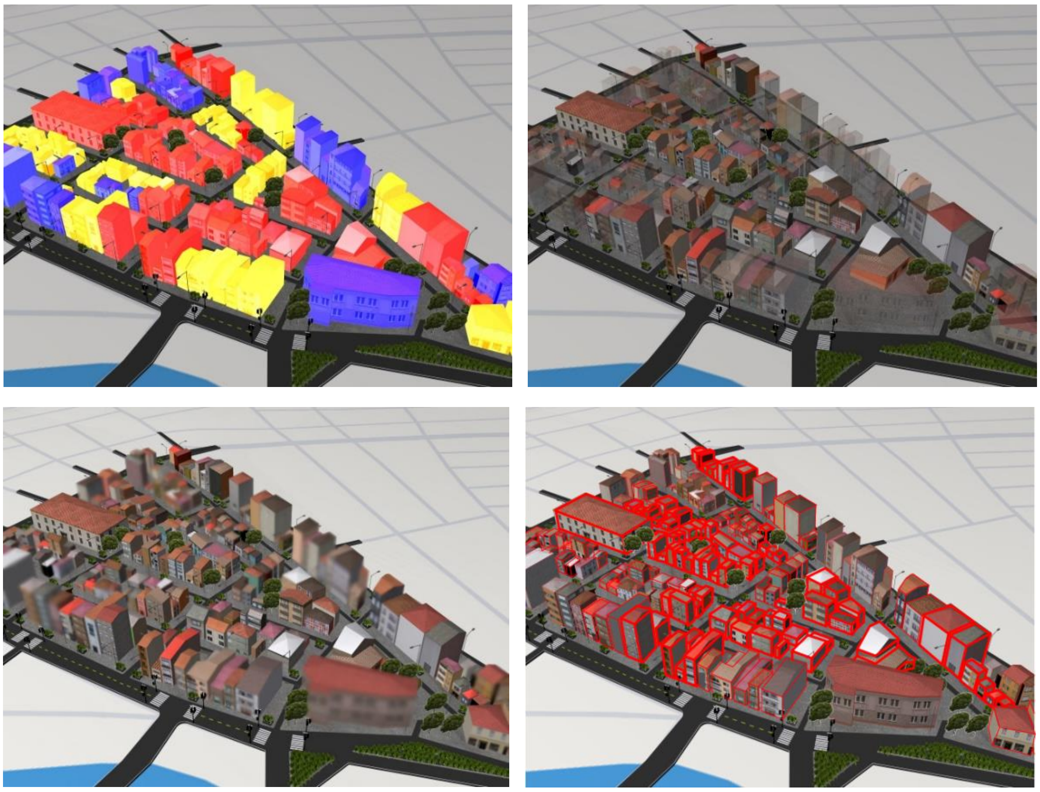


Figure H.1 (continued)

LoD 2 - Background: Satellite - In sequential order - Self Illumination-Hue, Transparency, Blur, Contour

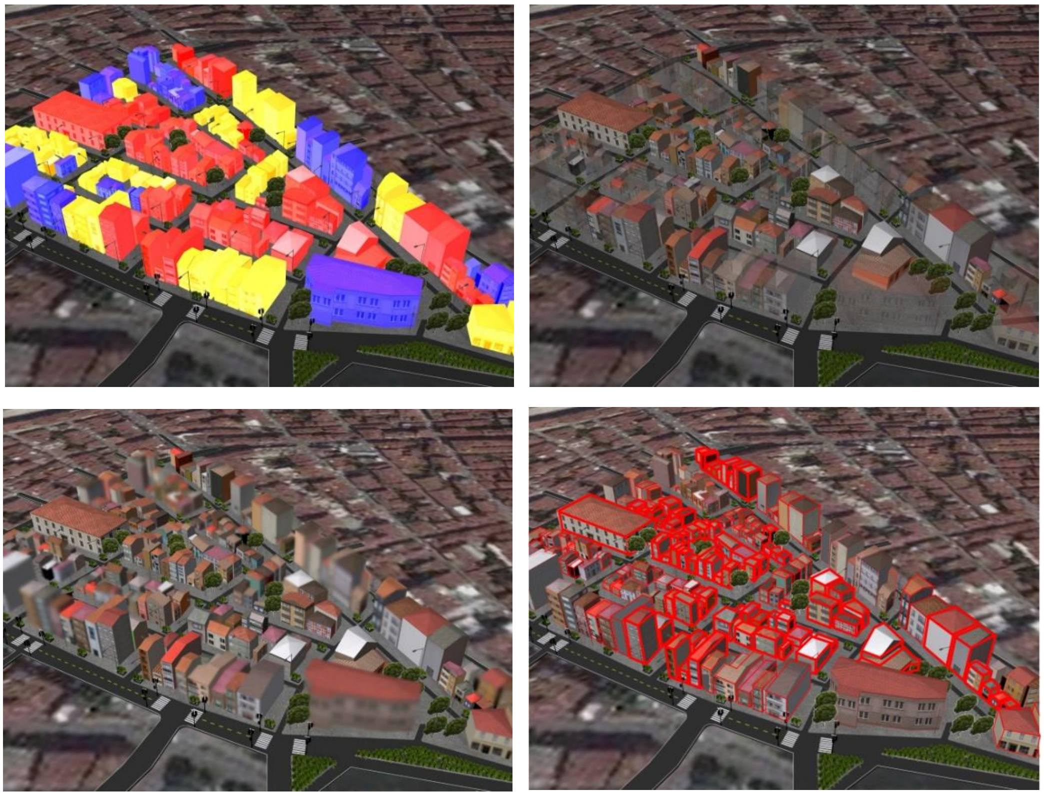


Figure H.1 (continued)

APPENDIX I

SALIENCY MAPS VERSUS EYE TRACKER HEAT MAPS

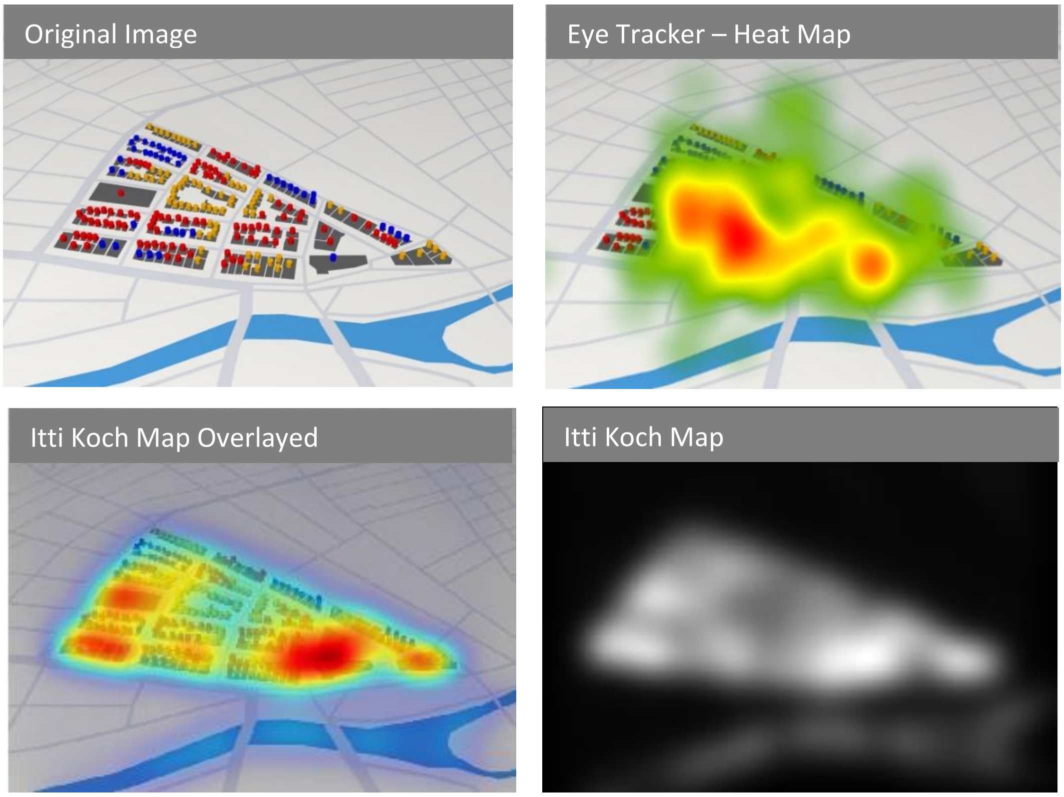


Figure I-1: Map Comparison of LoD 0 Abstract Object Hue with Map Background

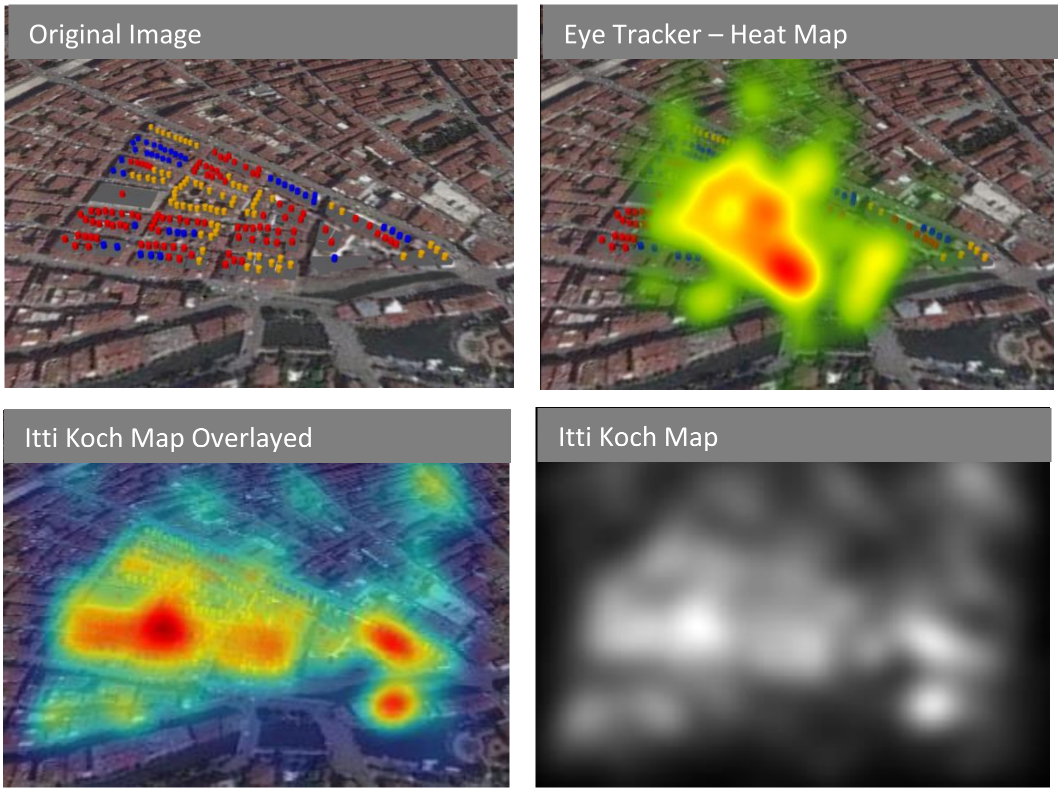


Figure I-2: Map Comparison of LoD 0 Abstract Obj Hue with Satellite Background

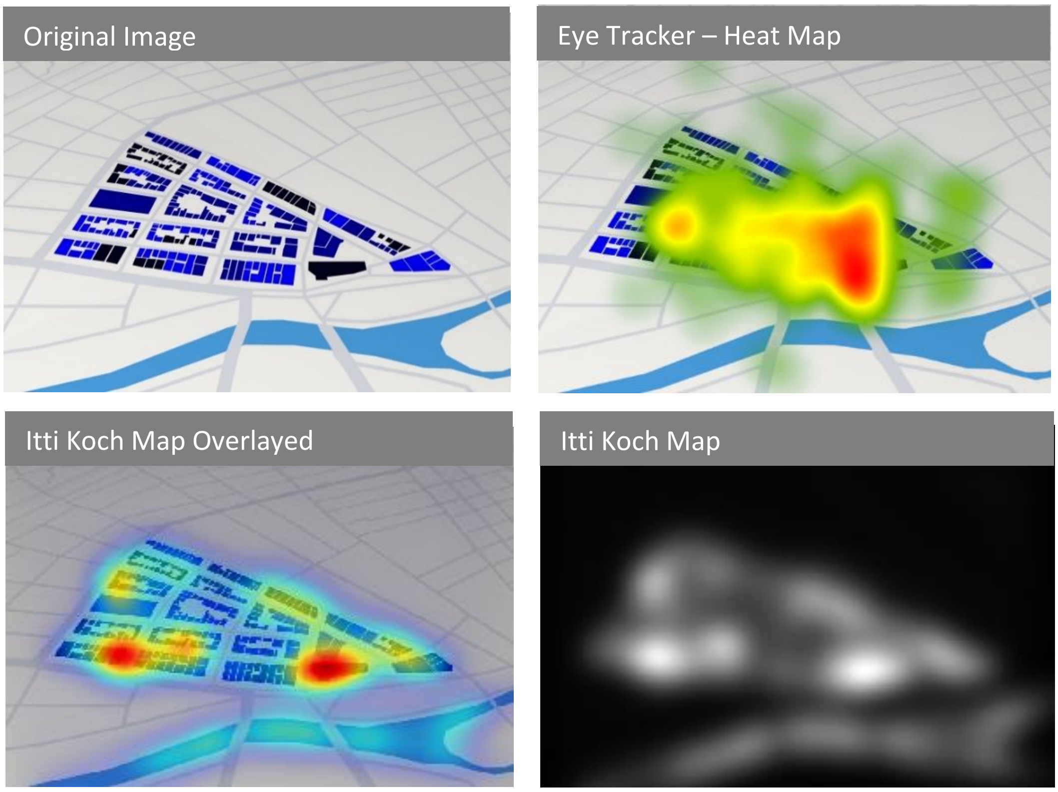


Figure I-3: Map Comparison of LoD 0 Brightness-Blue with Map Backgroun

Figure I-4: Map Comparison of LoD 0 Brightness-Blue with Satellite Background

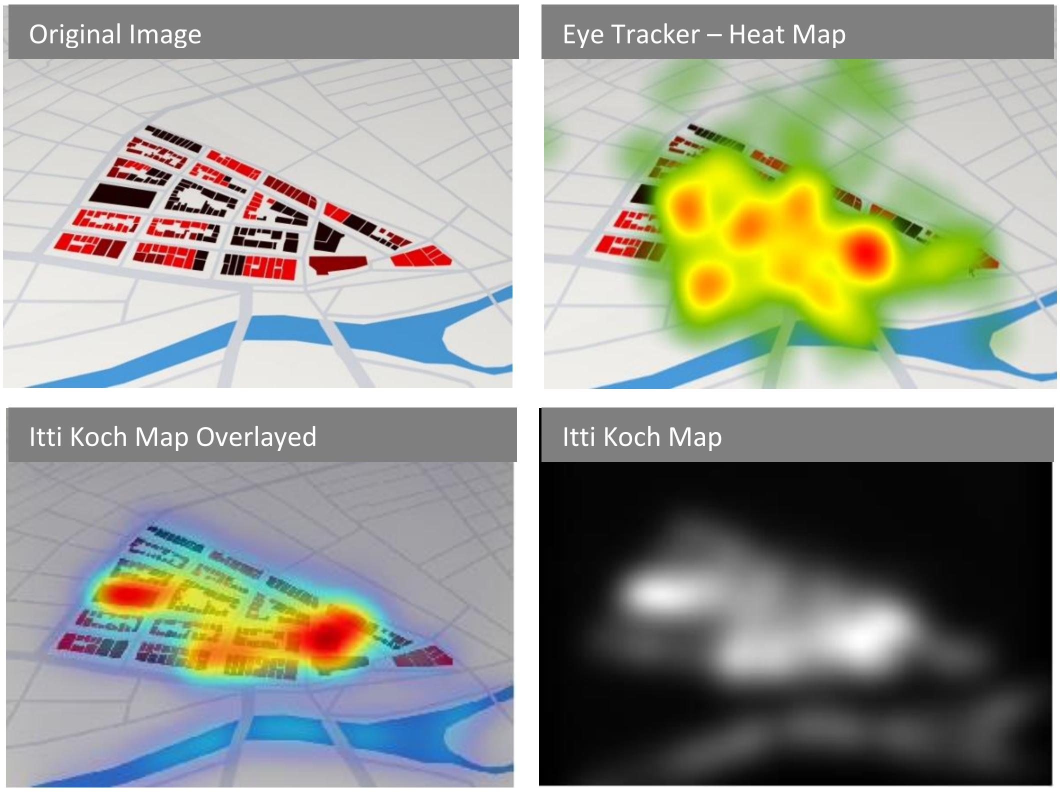


Figure I-5: Map Comparison of LoD 0 Brightness-Red with Map Background

Figure I-6: Map Comparison of LoD 0 Brightness-Red with Satellite Background

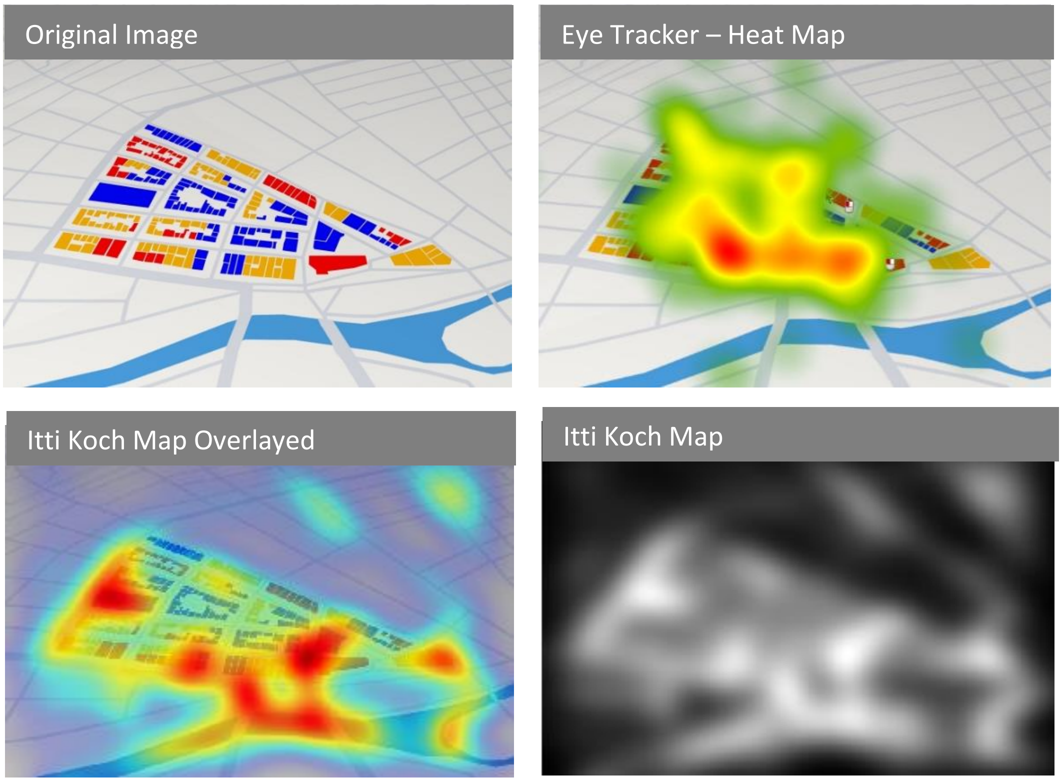


Figure I-7: Map Comparison of LoD 0 Hue with Map Background

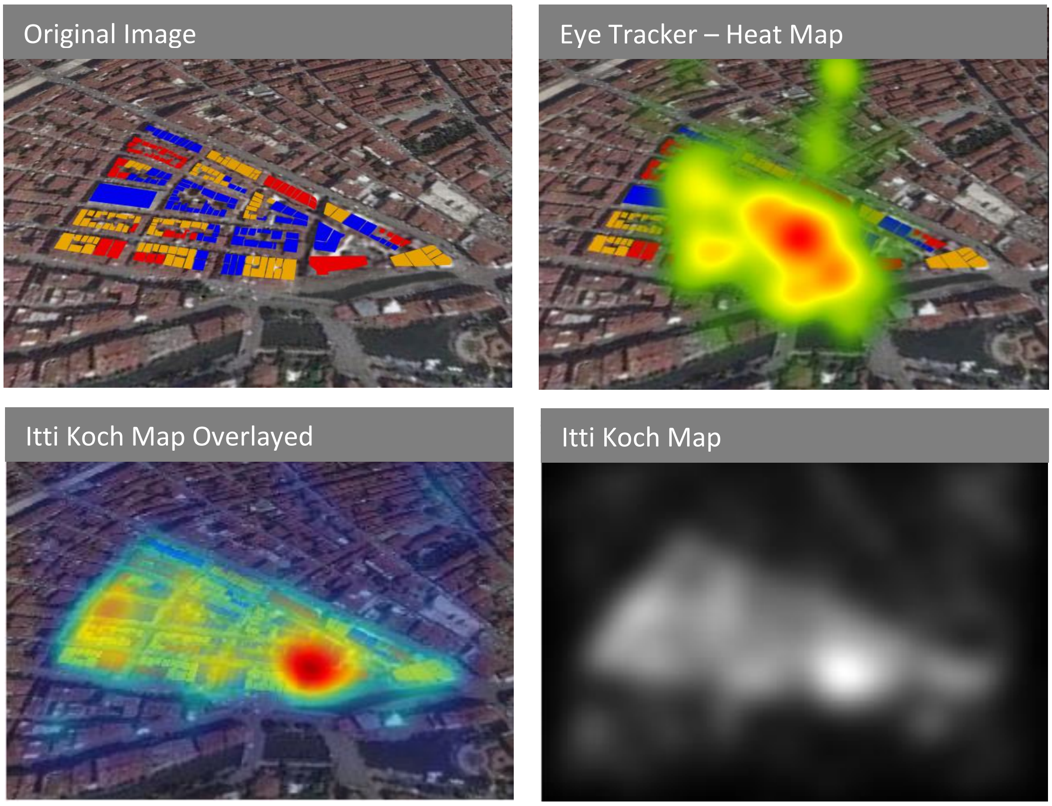


Figure I-8: Map Comparison of LoD 0 Hue with Satellite Background

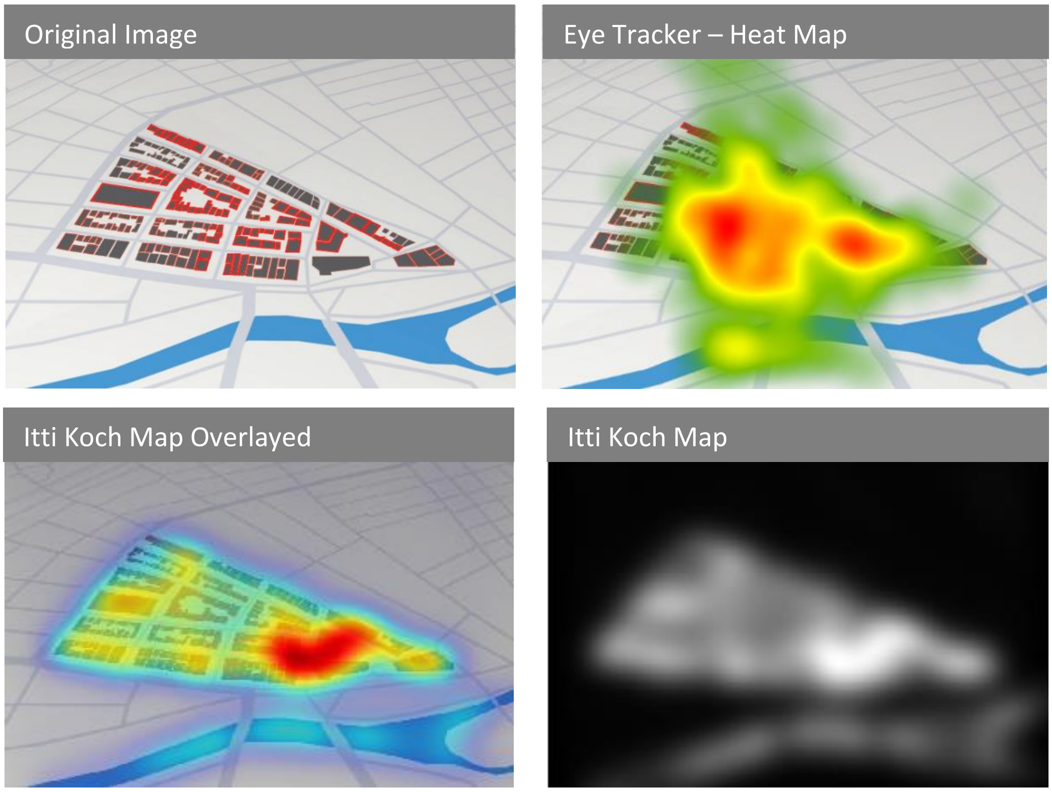


Figure I-9: Map Comparison of LoD 0 Contour with Map Background

Figure I-10: Map Comparison of LoD 0 Contour with Satellite Background

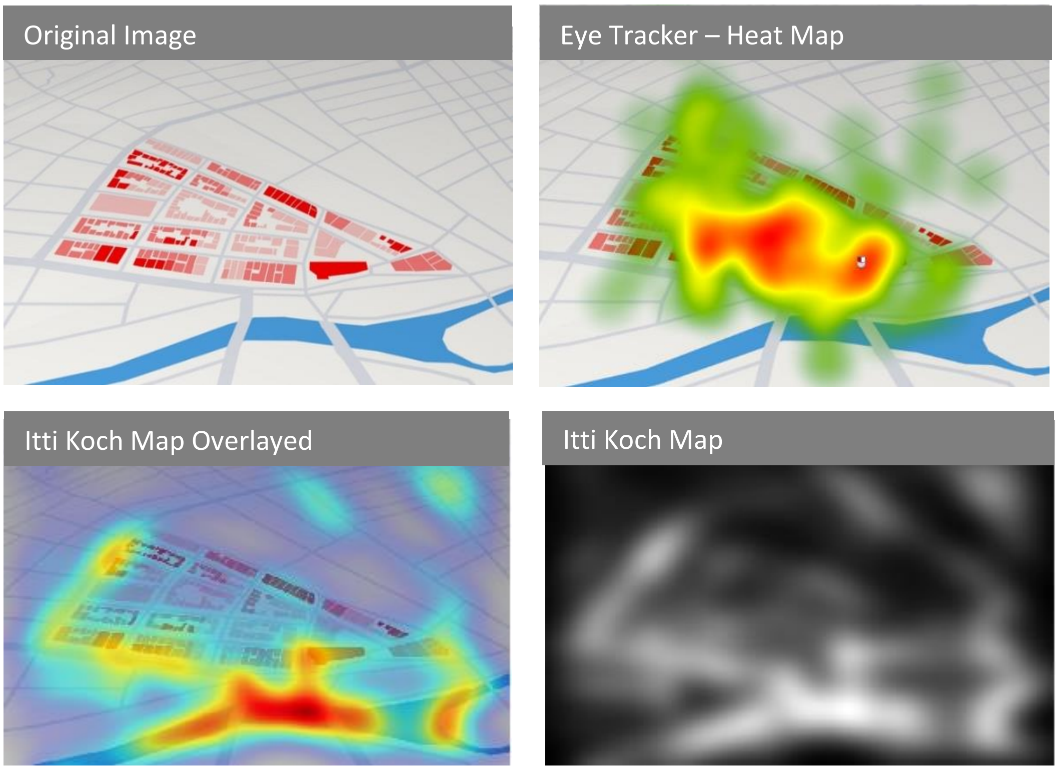


Figure I-11: Map Comparison of LoD 0 Saturation-Red with Map Background

Figure I-12: Map Comparison of LoD 0 Saturation-Red with Satellite Background

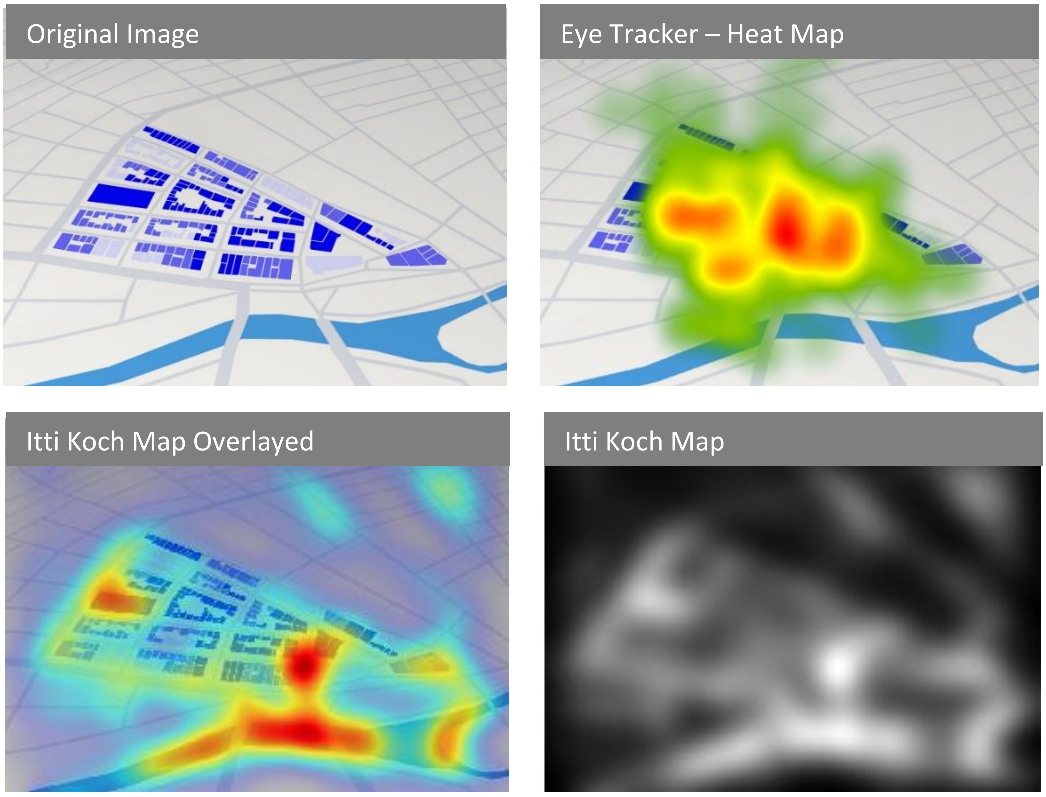


Figure I-13: Map Comparison of LoD 0 Saturation-Blue with Map Background

Figure I-14: Map Comparison of LoD 0 Saturation-Blue with Satellite Background

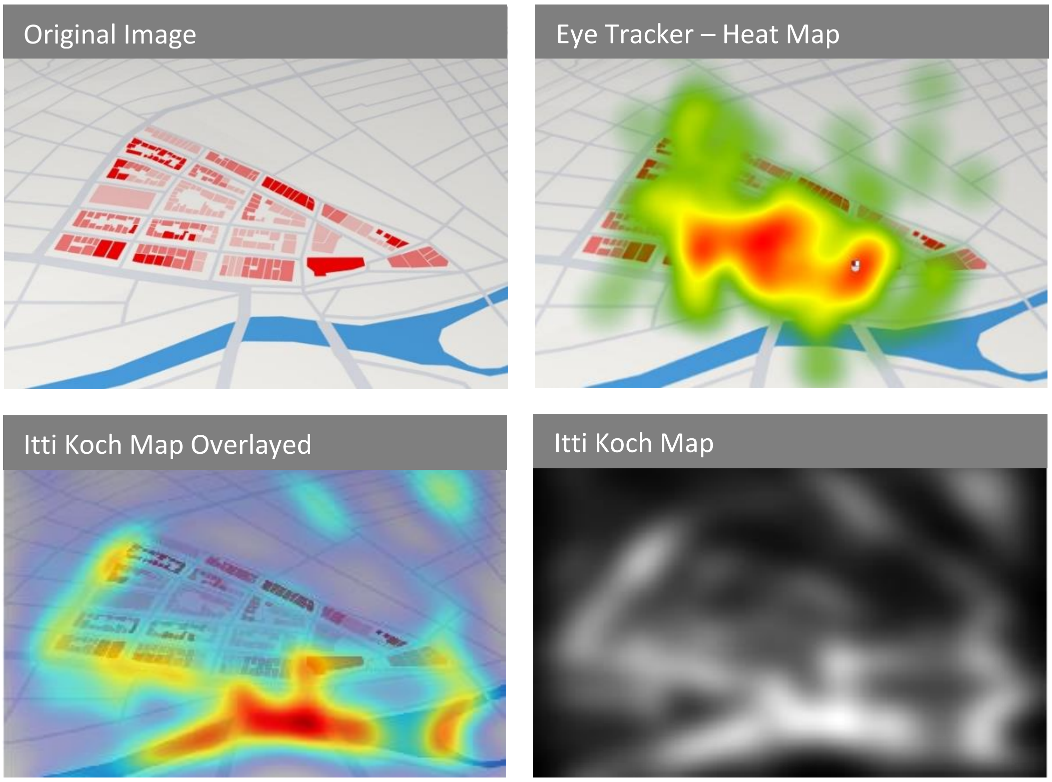


Figure I.15: Map Comparison of LoD 0 Transparency with Map Background

Figure I.16: Map Comparison of LoD 0 Transparency with Satellite Background

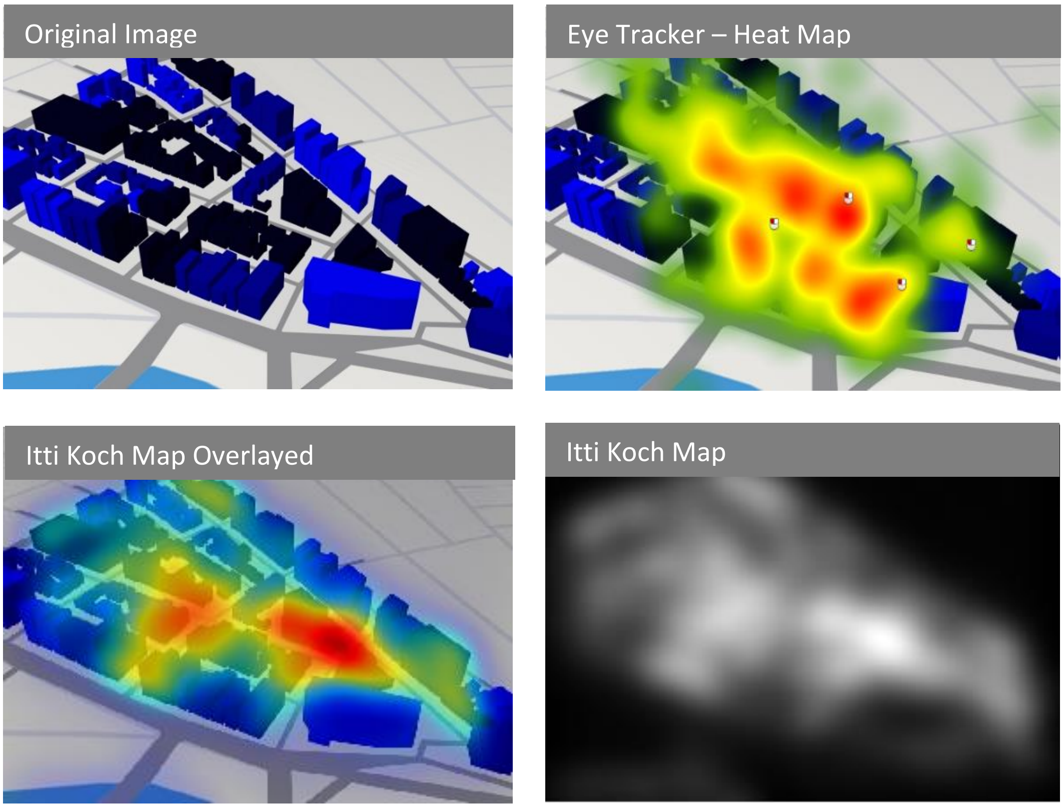


Figure I.17: Map Comparison of LoD 1 Brightness Blue with Map Background

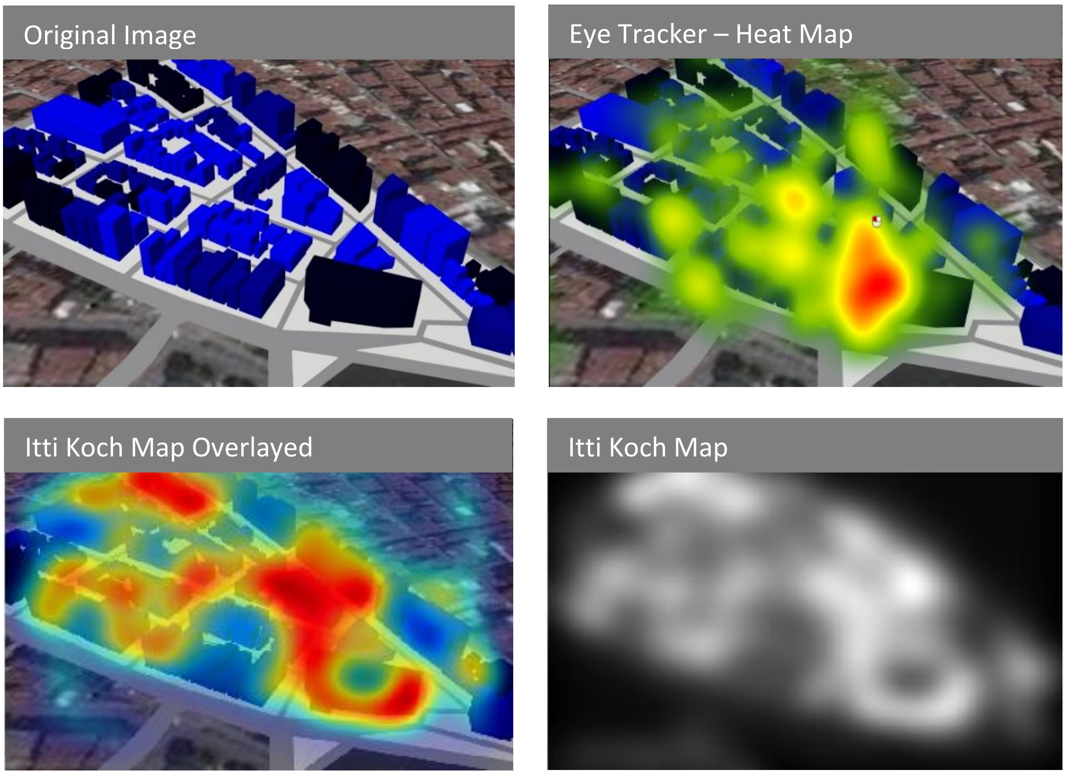


Figure I.18: Map Comparison of LoD 1 Brightness Blue with Satellite Background

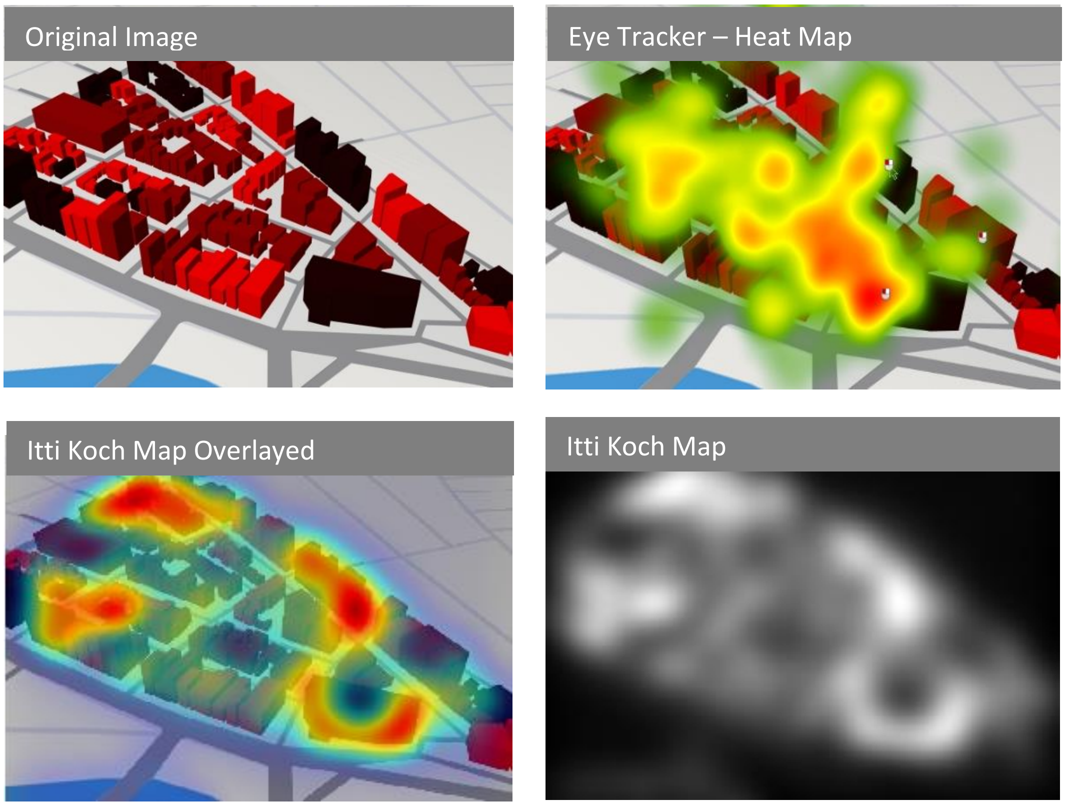


Figure I.19: Map Comparison of LoD 1 Brightness Red with Map Background

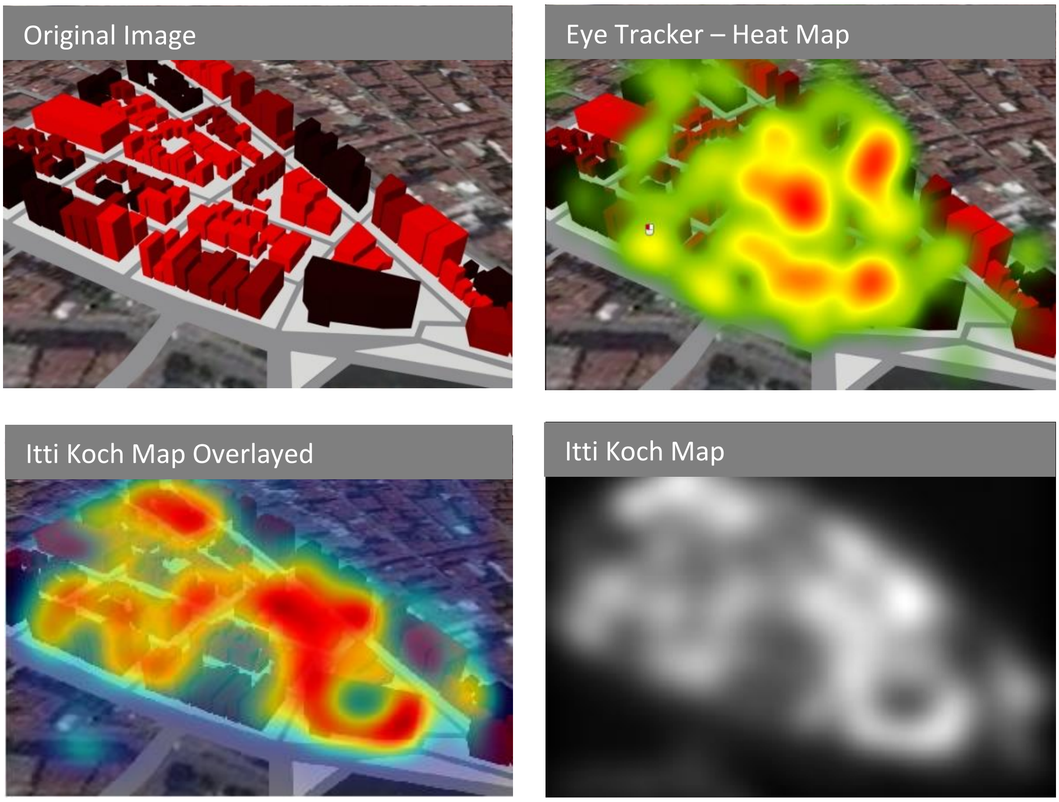


Figure I.20: Map Comparison of LoD 1 Brightness Red with Satellite Background

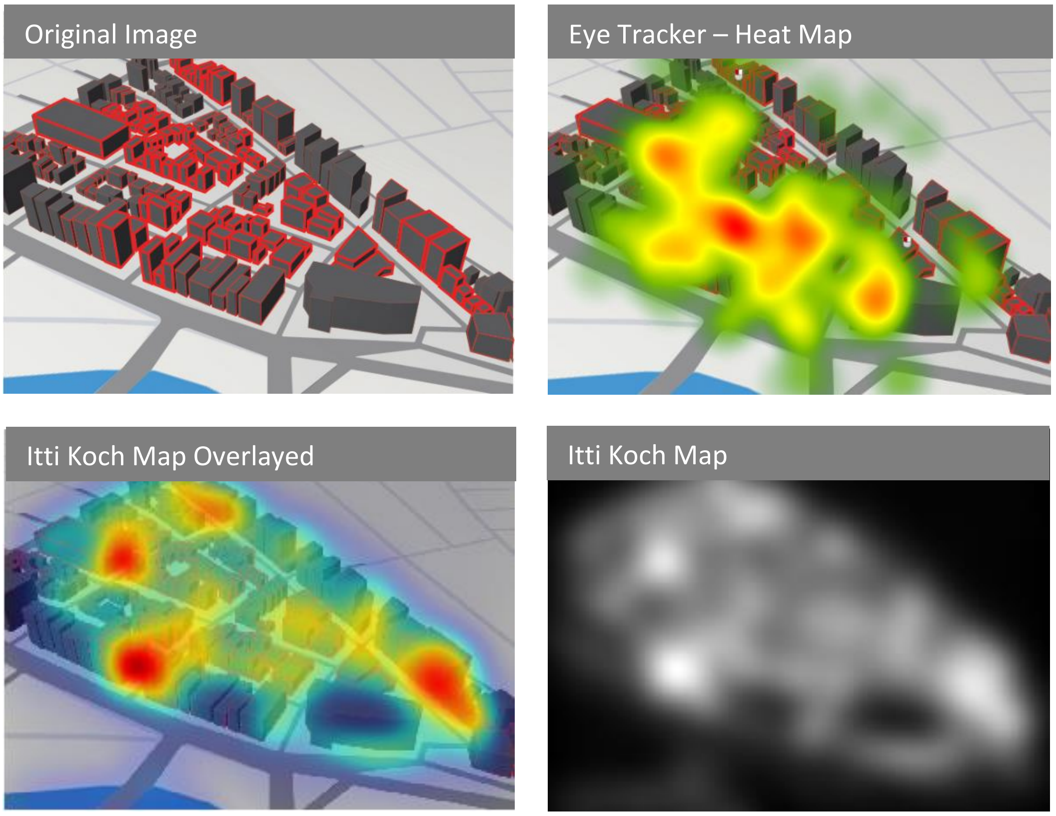


Figure I.21: Map Comparison of LoD 1 Contour with Map Background

Figure I.22: Map Comparison of LoD 1 Contour with Satellite Background

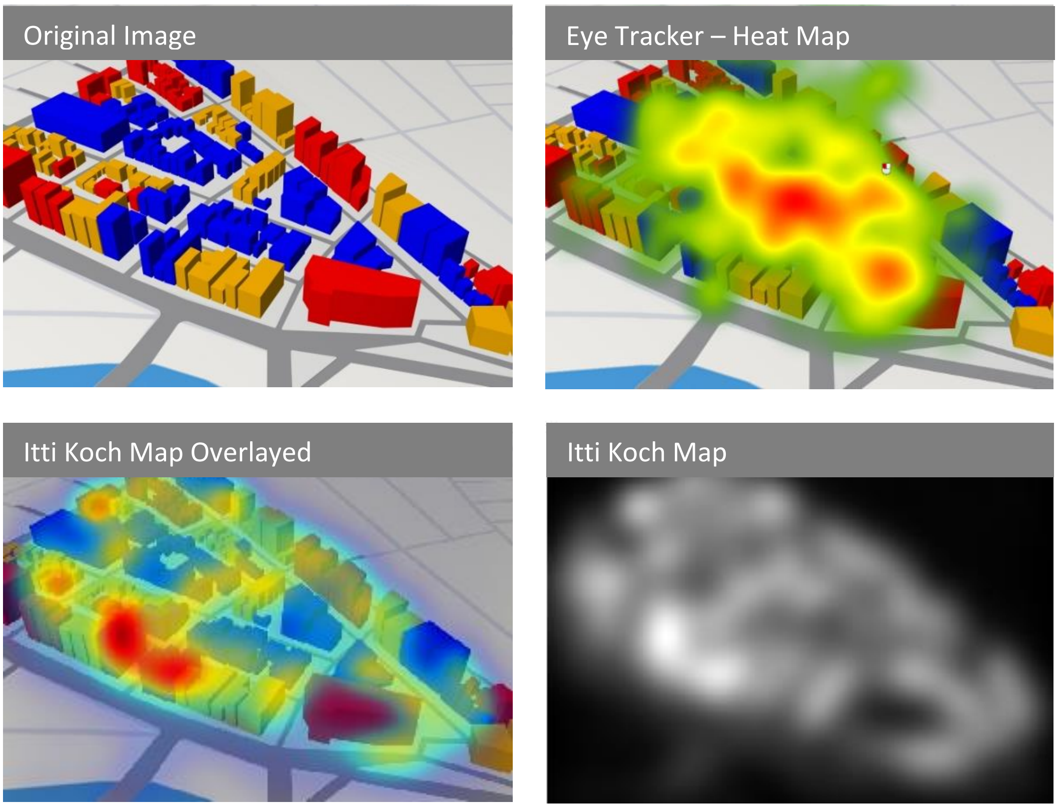


Figure I.23: Map Comparison of LoD 1 Hue with Map Background

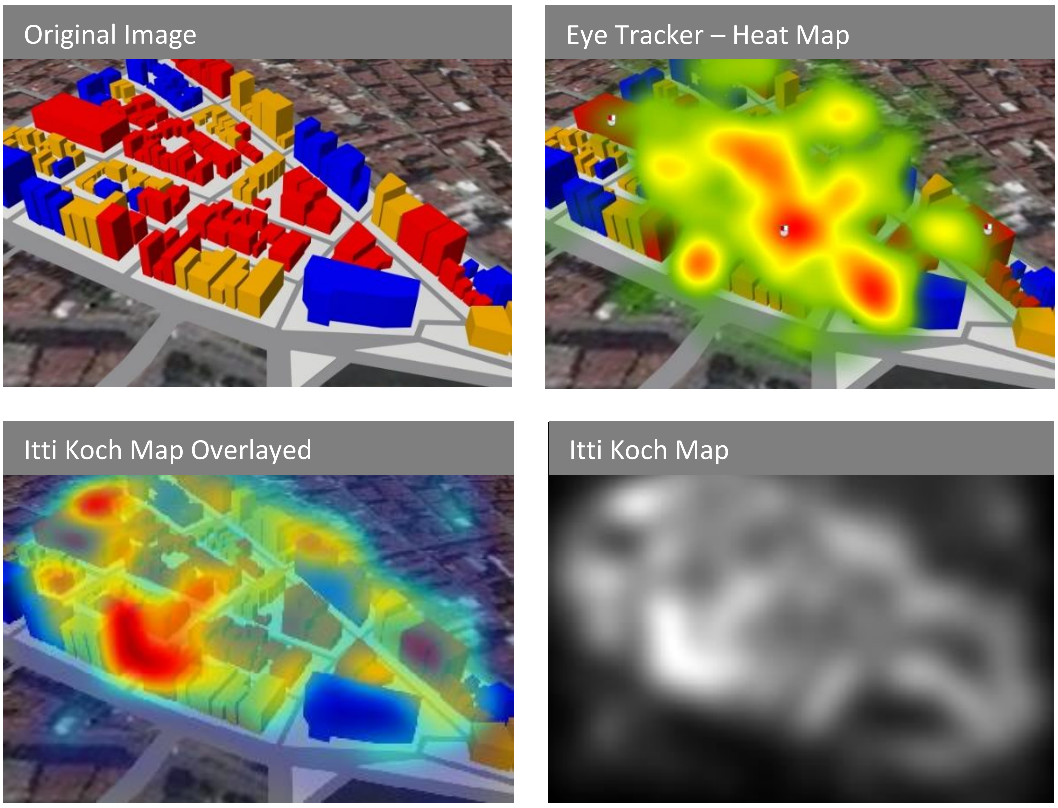


Figure I.24: Map Comparison of LoD 1 Hue with Satellite Background

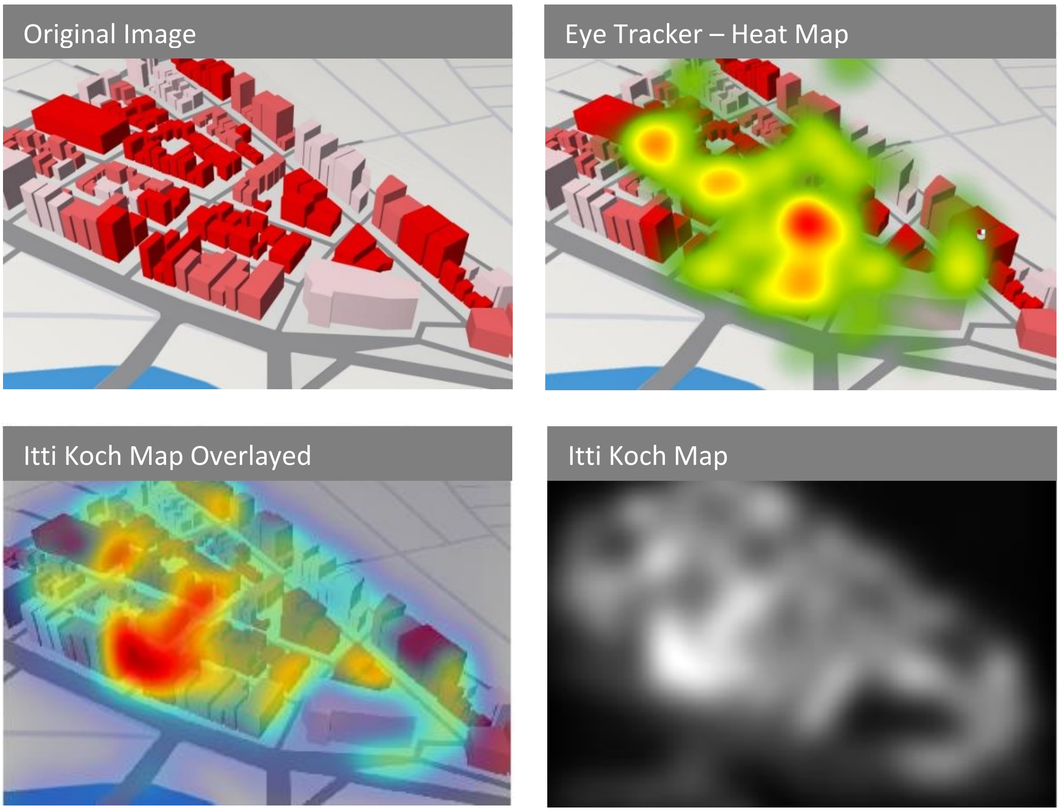


Figure I.25: Map Comparison of LoD 1 Saturation Red with Map Background

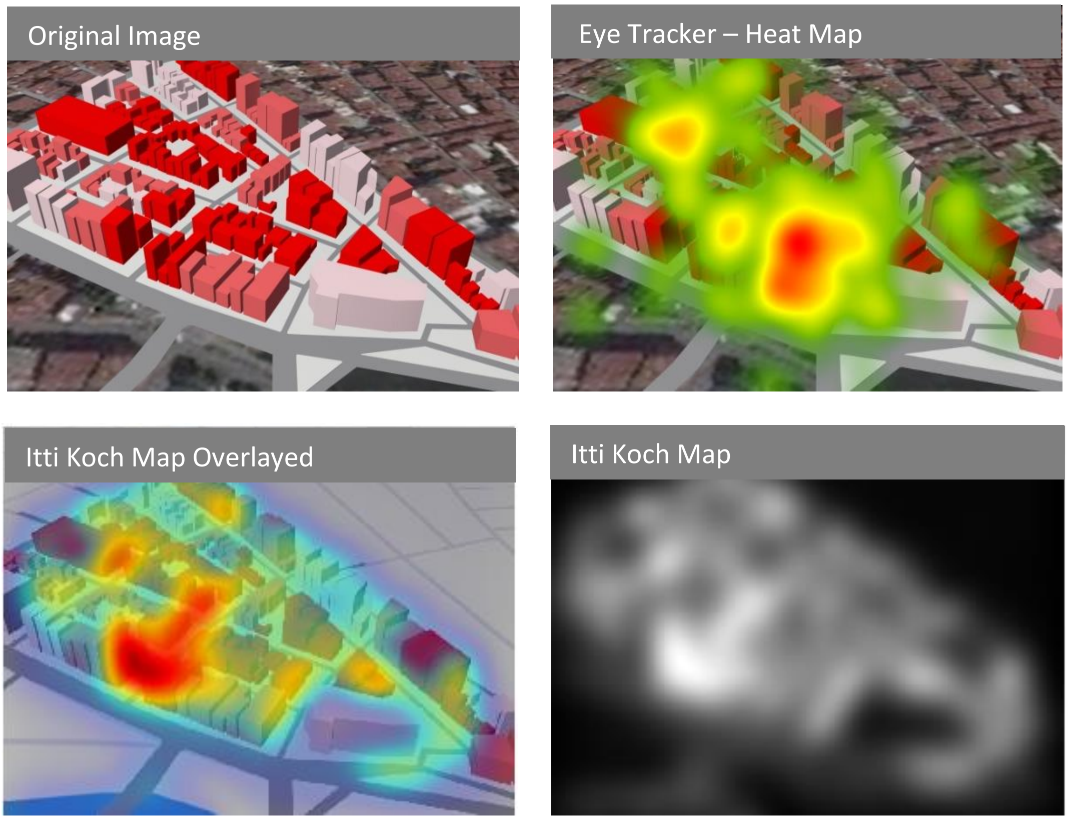


Figure I.26: Map Comparison of LoD 1 Saturation Red with Map Background

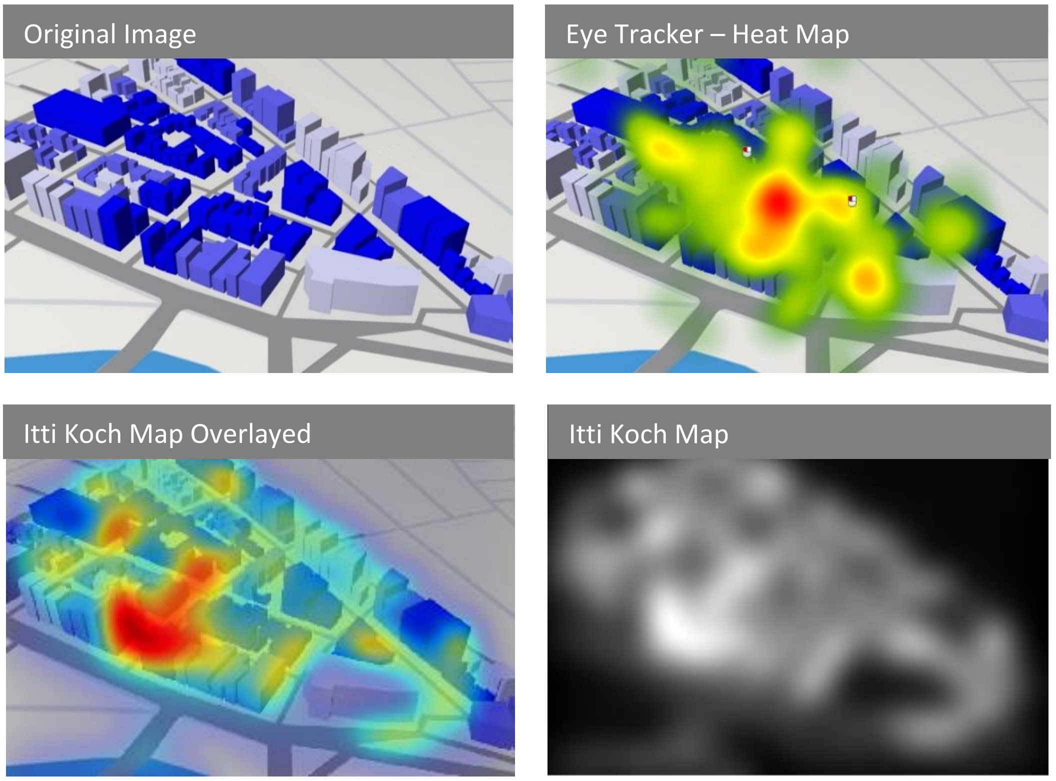


Figure I.27: Map Comparison of LoD 1 Saturation Blue with Map Background

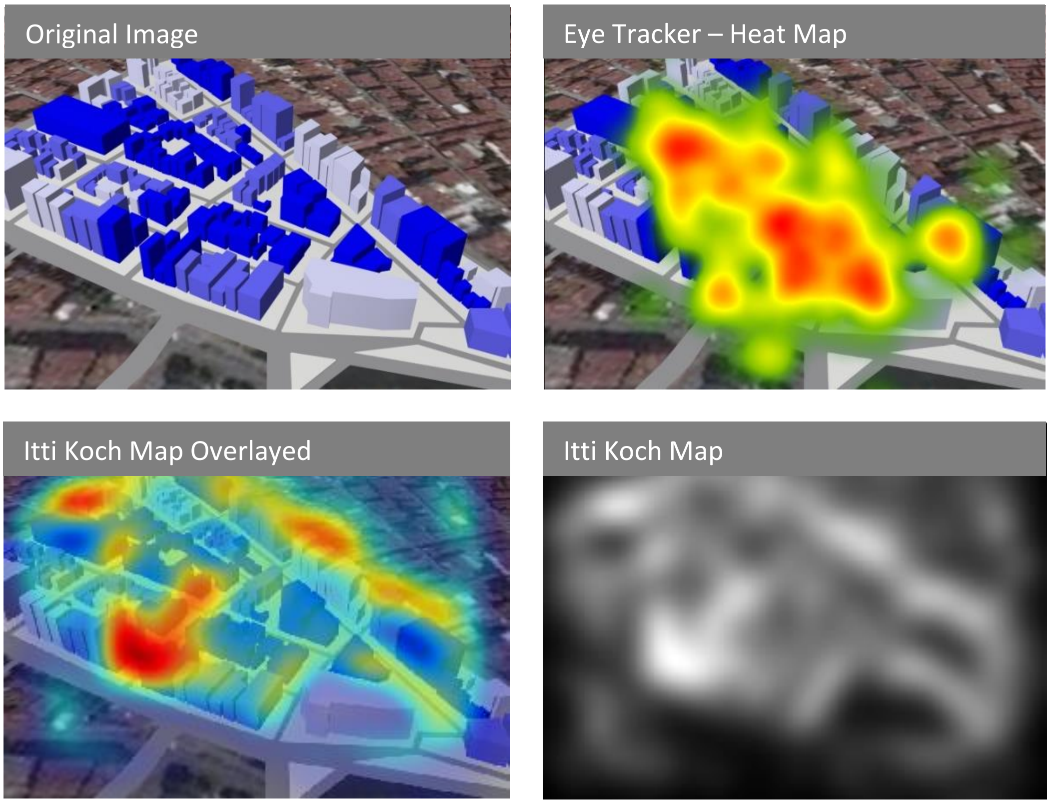


Figure I.28: Map Comparison of LoD 1 Saturation Blue with Satellite Background

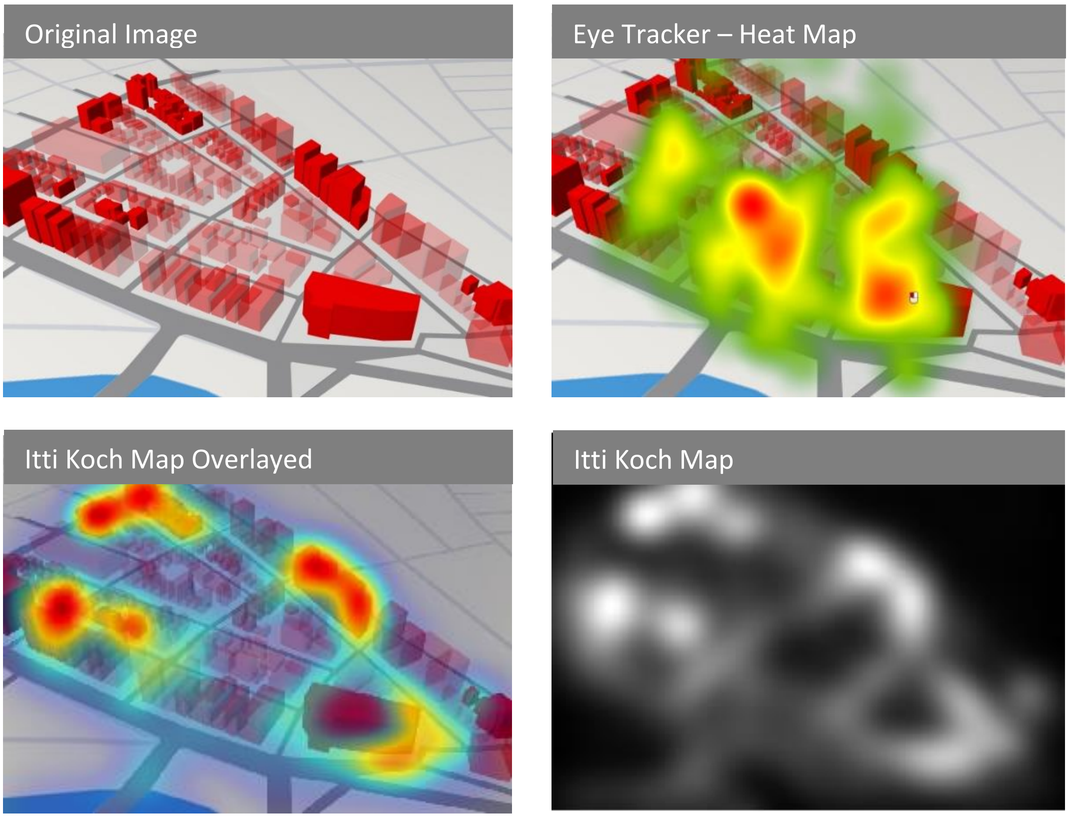


Figure I.29: Map Comparison of LoD 1 Transparency with Map Background

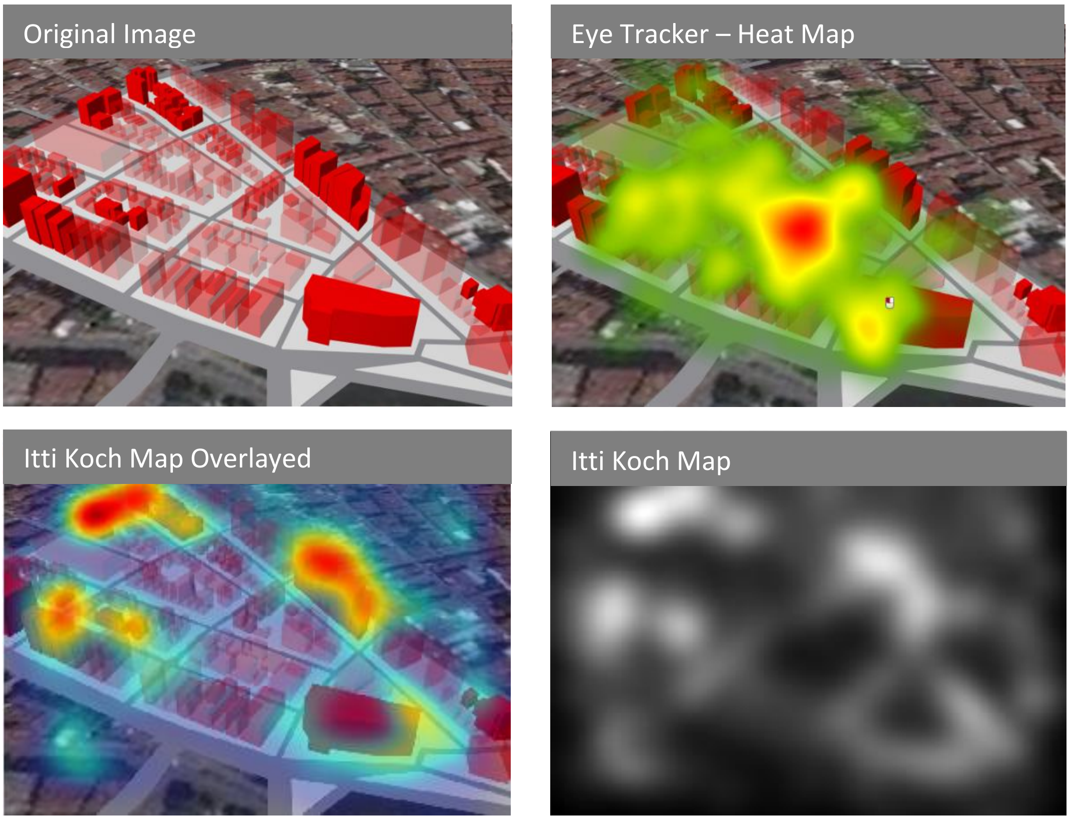


Figure I.30: Map Comparison of LoD 1 Transparency with Satellite Background

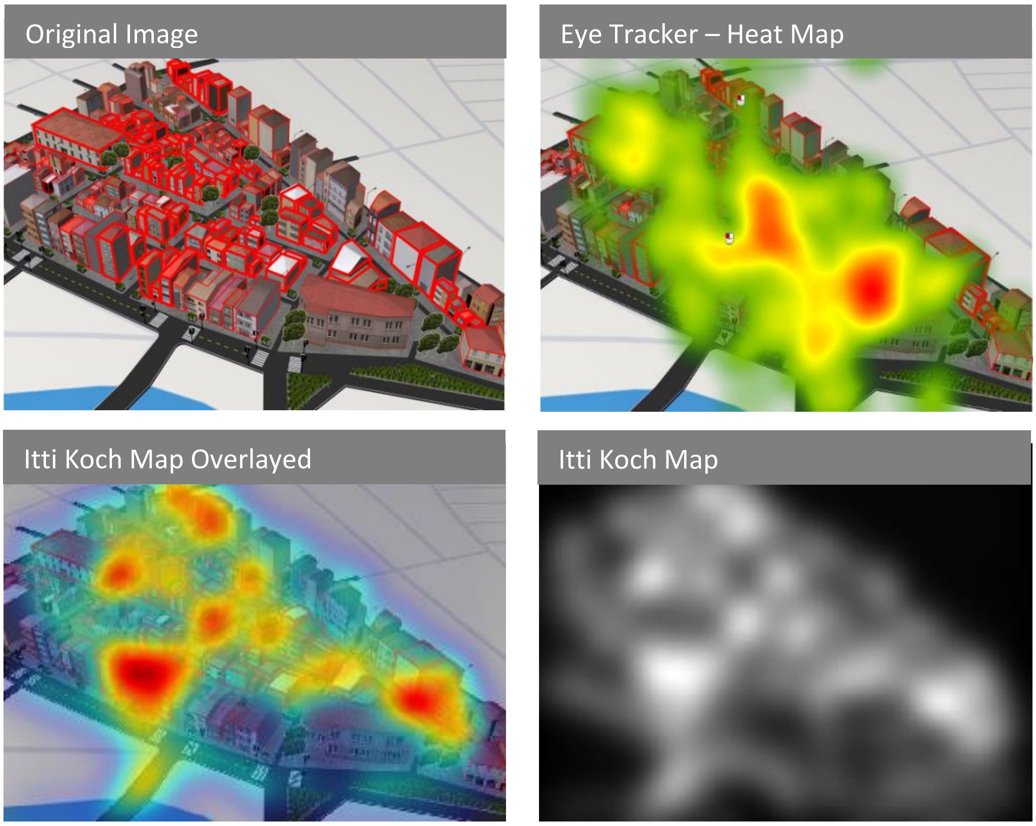


Figure I.31: Map Comparison of LoD 2 Contour with Map Background

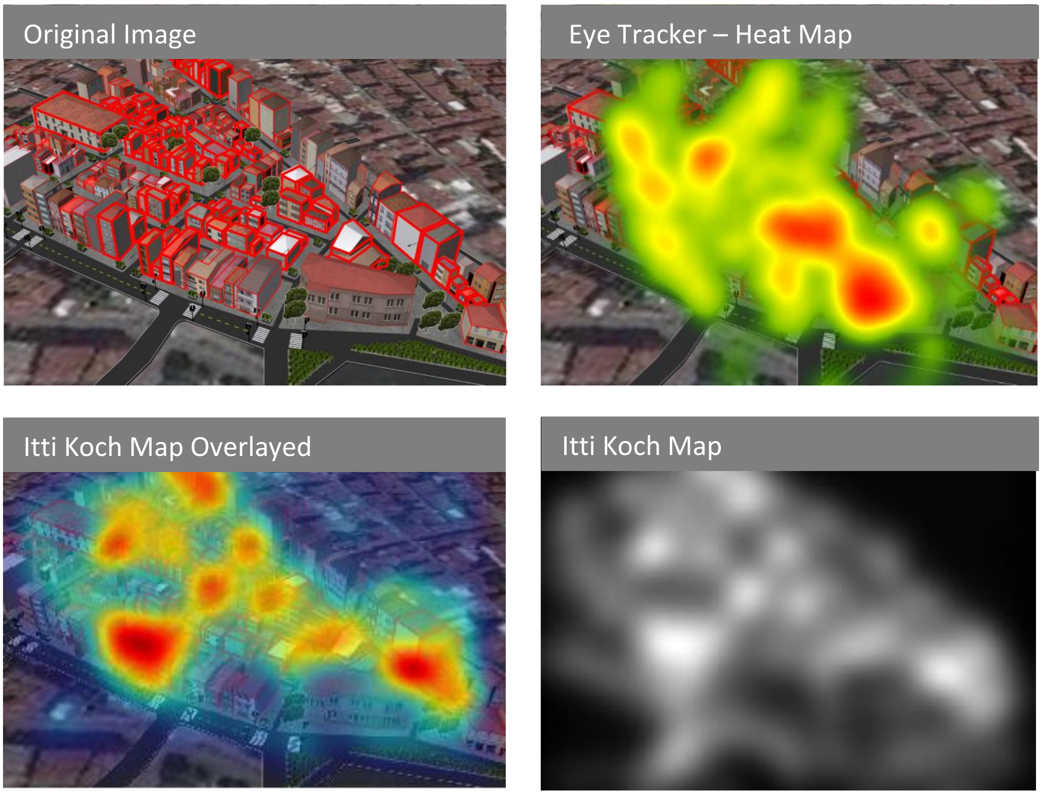


Figure I.32: Map Comparison of LoD 2 Contour with Satellite Background

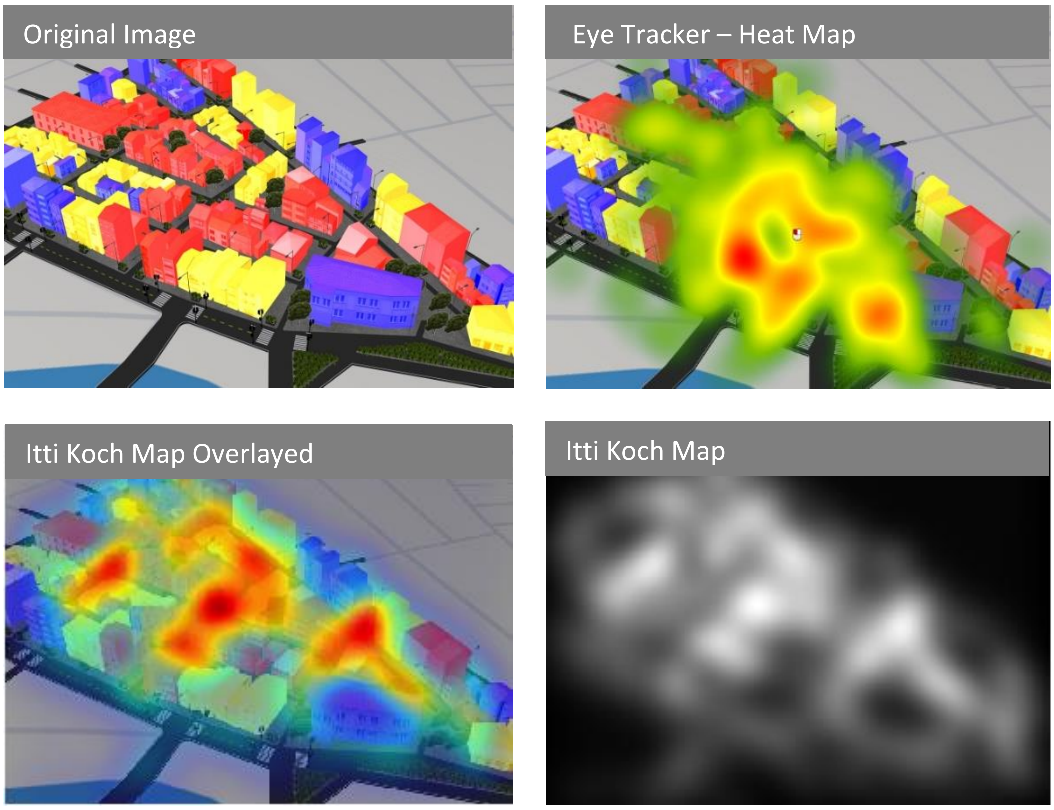


Figure I.33: Map Comparison of LoD 2 Self Illu-Hue with Map Background

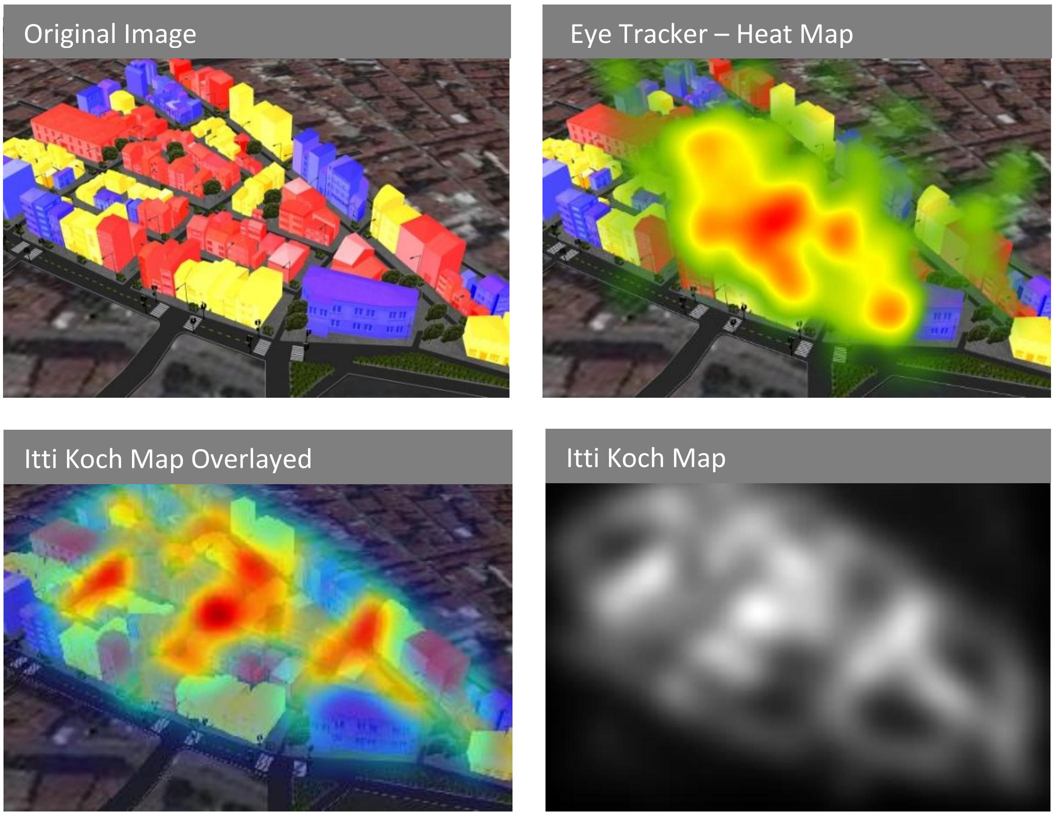


Figure I.34: Map Comparison of LoD 2 Self Illu-Hue with Satellite Background

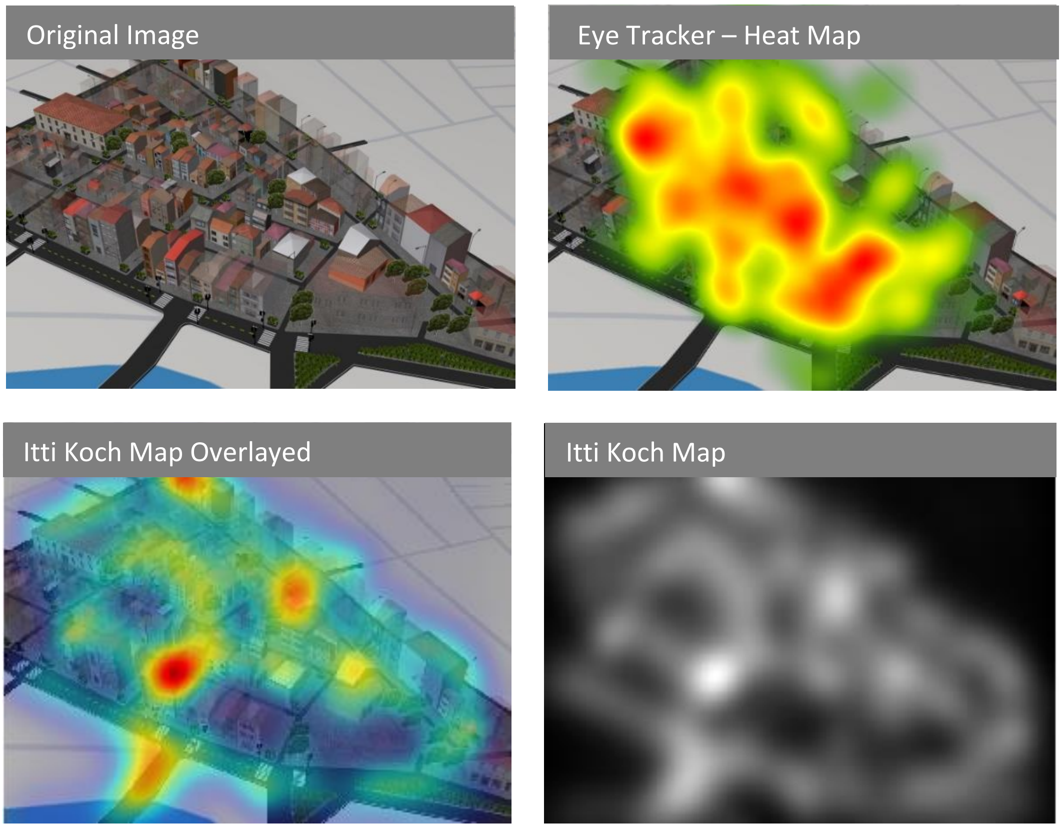


Figure I.35: Map Comparison of LoD 2 Transparency with Map Background

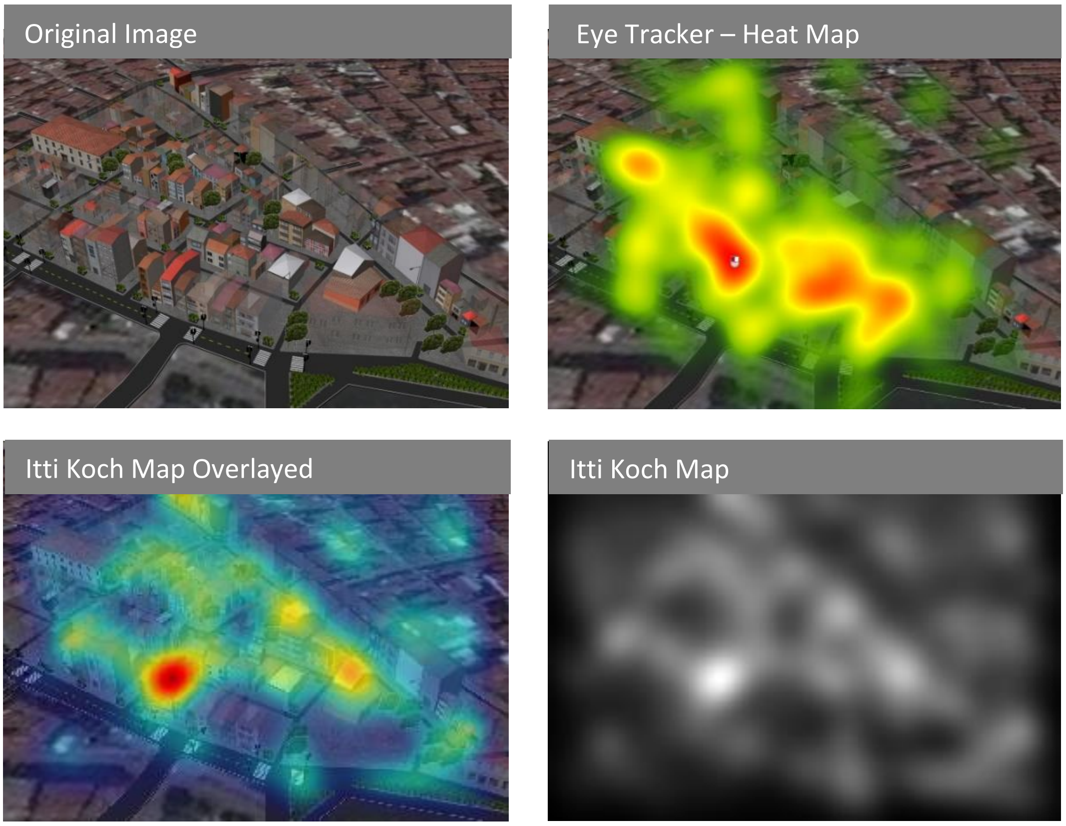


Figure I.36: Map Comparison of LoD 2 Transparency with Satellite Background

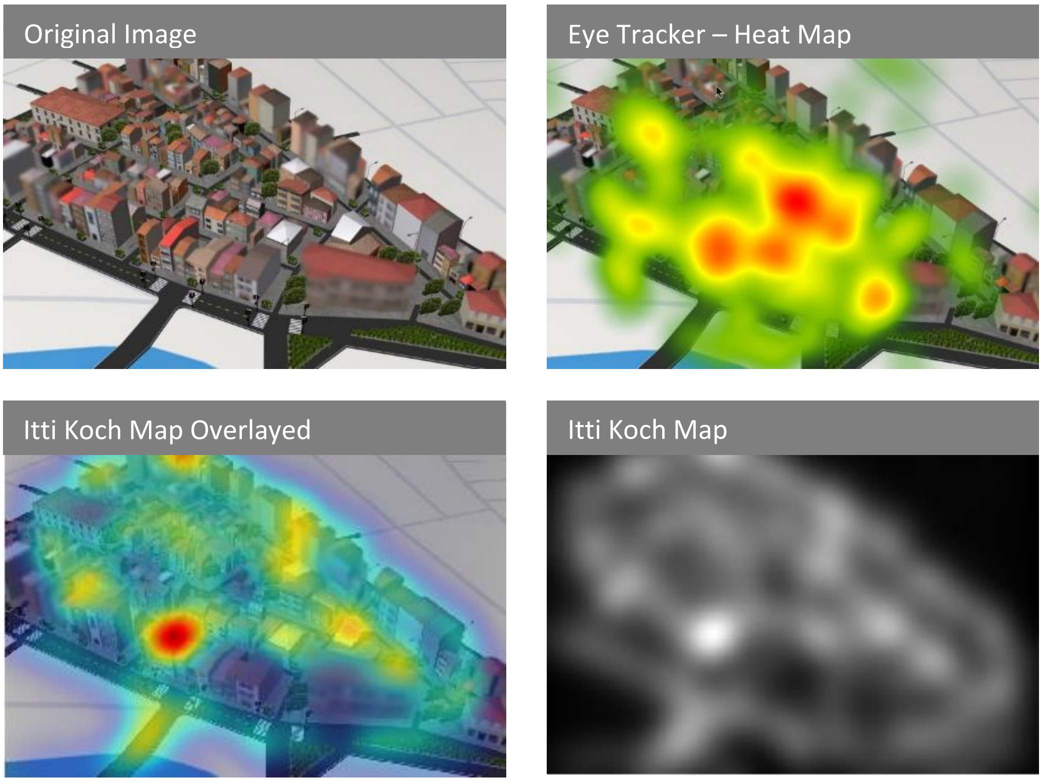


Figure I.37: Map Comparison of LoD 2 Blur with Map Background

Figure I.38: Map Comparison of LoD 2 Blur with Satellite Background

CURRICULUM VITAE

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EDUCATION AND QUALIFICATIONS

2010-Present	Middle East Technical University – Ankara, TURKEY Graduate School of Natural and Applied Sciences, Department of Geodetic and Geographic Information Technologies *PhD Degree*
2005-2007	Bilkent University – Ankara, TURKEY Faculty of Art, Design and Architecture, Department of Interior Architecture and Environmental Design *Master Degree with Full Scholarship*
1999-2005	Middle East Technical University – Ankara, TURKEY Faculty of Architecture, Department of Industrial Design *Bachelor Degree*

WORK EXPERIENCE

2012-Present	UTRLAB-User Testing and Research Lab – Ankara, TURKEY
2010-2011	METU TAF MODSIMMER – Ankara, TURKEY
2007-2008	TÜRK TELEKOM SEBİT – Ankara, TURKEY
2006-2007	BİLKENT UNIVERSITY, Department of Interior Architecture and Environmental Design – Ankara, TURKEY

2005-2007 PRO-TIP – Ankara, TURKEY

AWARDS

- 2008-2009, Eddie Awards 2008 Winner, Ednet 2008 winner, Adaptive Curriculum Wins 2009 Teacher's Choice Award, Adaptive Curriculum Earns AEP's Distinguished Achievement Award, CODiE Award for the Education Newcomer of the year, at SEBIT A.S., team work
- 2004, Exhibition in Milano Furniture Fair, Milano, Italy, exhibited the product "Popcorn" which was a studio project with the theme of mobility (Mobile Mobilia)
- 2004, International Conference on Design and Emotion, METU Cultural and Convention Center, Ankara, exhibited the product "Popcorn"
- 2004, A Design Fair, Istanbul, Turkey, exhibited product "Popcorn"

PROJECTS AND PRACTICES

- 2015, L'Oréal, focus group testing
- 2014, Arçelik, VUX, focus group and usability testing
- 2014, Enocta, E-Learning website development
- 2014, Pearson, usability testing of Pearson products with primary school schildren
- 2014, STM, Ground Mission Planning Software development and testing
- 2013, Garanti Bank, usability testing of iGaranti mobile application
- 2013, PayPal, usability testing of the web site for PayPal prepaid card, test analysis, redesign suggestions
- 2013, www.sahibinden.com, usability testing of the web site, test analysis
- 2012-2013, Arçelik, usability testing of kitchen appliances (induction oven, oven, dishwasher, washing machine, dryer), test analysis, redesign suggestions
- 2012, Tesco Kipa, usability testing of online shopping from the web site
- 2012, Kuveyt Türk Bank, usability testing of banking system interfaces
- 2012, OSTİM Medikal, user context research
- 2011, SİMSOFT A.S.-ASELSAN -Project on development and usability testing of an interface of a device
- 2011, SİMSOFT A.S.-ASELSAN -Project on development and usability testing of an interface of a device
- 2010, METU-TAF MODSIMMER - HAVELSAN, Ankara. Project on "Development and Validation of User Interface Guide for Trainer Console Software"
- 2007, Dicle University Hospital, Oncology Department, Diyarbakır. Interior Design Project

- 2005, Graduation Project, Eczacibasi, Artema, Istanbul. Armature Design
- 2003, Summer Practice, Oser Art, Mersin. Graphic Design and Advertisement
- 2003, Winter Practice, TRT, Ankara. Stage Decoration. (Studied with Servet Isık who was the head of the Designer Team of Eurovision 2004 Song Contest. Participated in designing the stage decoration of the contest “Ya Hep Ya Hiç”)
- 2002, Summer Course, Boston University, Boston, USA. Graphic Design, Art and Design School, Grade: 4.00/4.00. (Studied with graphic designer; Professor Richard Bryan Doubleday
- 2002, Summer Practice, Osel Mobilia, Mersin. Furniture Manufacturing and Mass Production
- 2001, Summer Practice, METU, Department of Industrial Design, Ankara. Computer Literacy in Design

PUBLICATIONS

Yılmaz, A., Yılmaz, D., Şenyiğit, A. M., Görür, B. K., & İşler, V. (2012). Genel Amaçlı Araştırma Simülatörü: Donanım ve Yazılım Altyapısının Tasarlanması ve Geliştirilmesi. Savunma Bilimleri Dergisi, 11(1), pp. 147-161.

Yilmaz, A., Kemec, S., Sebnem Duzgun, H., & Cakir, M. P. (2014). Cognitive Aspects of Geovisualisation: A Case Study of Active and Passive Exploration in a Virtual Environment. In Thematic Cartography for the Society (pp. 157-170). Springer International Publishing.

Kurşun, E., Karakuş, T., Yılmaz, A., İşler, K. Ç. V., Gürdal, S., & Tezcan, Ü. (2012). Eğitmen Konsol Yazılımları için Kullanıcı Arayüzü Kılavuzu Geliştirilmesi ve Geçerleme Süreci. Savunma Bilimleri Dergisi, 11(1), pp.177-186.

COMPUTER SKILLS

- Rhinoceros
- Map Info
- Quantum GIS
- Autodesk 3Ds MAX
- Autodesk Motion Builder
- Adobe Master Collection (ALL)
- Solidworks
- IBM SPSS
- Photomodeler Scanner
- Unity
- Autodesk AutoCAD

- Corel Draw Graphics Suite
- Microsoft Office
- Think Design

ADDITIONAL SKILLS

- 2010, Turkish Cuisine Chef Certificate. Turkish Ministry of Education approved
- 2001, METU Communication Student Club, volunteered in teaching English for primary school children in Sincan, Ankara
- 2000, Wollongong, Australia, volunteered in working as a chef in the restaurant “Gate Way to Atlantis”.
- Having artistic hobbies such as illustration, painting, playing violin, sketching, portrait drawing, digital photography
- Doing physical activities such as swimming, dancing, yoga, fitness