FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Human-Computer Interaction's role in Geographical Information Systems Development

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Report of Dissertation

Master in Informatics and Computing Engineering

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Abstract

Geographical Information Systems (GIS) are becoming very popular. Nowadays, this kind of applications are becoming available to all types of devices since computers to PDAs, cell phones, and even satellite tracking systems, supporting the task of decision making in the areas of regional and central planning, distribution and route planning. With this increasing popularity, the GIS users are not only domain experts but also the common user that does not pose any type of experience using these types of applications or devices and is starting to use them in his daily routine with increasing frequency.

However these applications have a problem. They are not very easy to work with and the learning curve is yet too slow. In fact too little attention has been paid to usability aspects and user experience of GIS, existing only a few specific frameworks for the design and evaluation of those applications.

In this project the goal is to analyze and discuss the usability main aspects to be integrated in the development of GIS applications. A user-centred methodology will be proposed for the design, conception and implementation of such applications, and an analysis will be made concerning the methodology viability.

Resumo

Os Sistemas de Informação Geográfica (SIG) estão a tornar-se cada vez mais populares. Hoje em dia, este tipo de aplicações está disponível para vários dispositivos desde computadores, PDAs, telemóveis, e até mesmo sistemas de localização por satélite. Este tipo de sistema tem como principal objectivo apoiar a tomada de decisões nas áreas do planeamento regional e central, distribuição e planeamento de rotas. Com esta crescente popularidade, os utilizadores de SIG já não são apenas especialistas, mas também utilizadores comuns, sem qualquer tipo de experiência nestes sistemas, que estão a começar a usá-los na sua rotina diária com uma frequência cada vez maior.

No entanto, estas aplicações têm um problema. Não é fácil trabalhar com elas e apresentam ainda uma curva de aprendizagem demasiado lenta. De facto muito pouca atenção tem sido dada aos aspectos usabilidade e experiência de utilizador de SIG, existindo apenas alguns *frameworks* para a sua concepção e avaliação.

O principal objectivo deste trabalho é analisar e discutir os principais aspectos de usabilidade a serem integrados no desenvolvimento de aplicações SIG. Será proposta uma metodologia centrada no utilizador para a concepção, desenho e implementação de tais sistemas. No fim será feita uma análise sobre a viabilidade da metodologia.

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Susana Vilaça

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Abbreviations

HCI	Human-Computer Interaction
GIS	Geographical Information System
GPS	Global Positioning System
GRASS	Geographic Resources Analysis Support System
I/O	Input/Output
PC	Personal Computer
ROI	Return on Investment
SDK	Software Development Kit
STCP	Sociedade de Transportes Colectivos do Porto, SA
UI	User Interface
WWW	World Wide Web

Chapter 1

Introduction

In the last decades the software industry has been growing at an incredible pace. Software products are becoming more and more essential on people's everyday life at work, leisure, shopping, etc. The amount and types of information people have to deal with is increasing rapidly and, in spite of that, they are required to do their work efficiently. And, even they want a product that it is easy to learn and that satisfies them. As technology is becoming more accessible to everyone, the selling point of software as become their ability to allow users to efficiently execute their tasks, and satisfy their needs. However achieving this level it is not easy and it is one of the main problems software faces nowadays.

Geographical Information Systems (GIS) are a type of information system that deals with a large amount of information from various sources, and normally that information is presented to users on a map. Presenting spatial information in an accessible, pleasant and easy way is hard and many GIS fail to do it.

To cope with these problems the concept of user-centred development emerged. This type of development sees user involvement and the use of usability techniques has key for the product's success. User involvement and usability techniques are a way of development teams knowing what users want, and subsequently develop a product that fits their needs.

In spite of all the benefits user involvement and usability techniques bring to the software product, applying them to the development process it is not straightforward, being necessary a previous analysis of the project's variables.

The purpose of this thesis is to find how better to integrate users and usability techniques on the development process of a Geographical Information System considering the various variables involved in a software project.

1.1 Scope

This work is integrated across three main areas:

- Human-Computer Interaction,
- Geographical Information Systems, and
- Software Development Processes

A software development process is a set of guidelines for the development of software products. It can be seen as a process for the transformation of the product concept into a working product.

The Human-Computer Interaction area is an area "concerned with the design, evaluation and implementation of interactive computer systems for human use and with the study of major phenomena surrounding them" [Hew96]. This area studies the user involvement on the development process, and its integration with usability techniques.

Finally a Geographical Information System is an information system used to store, manipulate, analyze and display geographically referenced information.

This thesis studies the contribution of each of the described areas to the creation of user-centred methodology for the development of GIS

1.2 Motivation and Goals

In the last years Geographical Information Systems have been experiencing a continuous growth. Companies, like UPS, integrate them on their workflow to optimize operations and therefore saving money [GIS07]. Also with the spread of free Web-based GIS and Global Positioning Systems (GPS), GIS became more available to the normal user, who is using them with increasing frequency. Because all of this, it is important to invest on the usability of this type of systems with the goal of increasing their efficiency, productivity and users' satisfaction.

The main goal of this work is creating a user-centred methodology for the development of GIS. With the creation of this methodology the aim is to help the community of GIS developers to develop better quality GIS that fits the users' needs.

To achieve the proposed goal first it will be done some literature research about the three areas referred above: Human-Computer Interaction, Geographical Information Systems and Software Development Processes. Then a connection between Human-Computer Interaction and GIS will be established to find out the effect the first has on the second, and which are the main usability problems GIS faces. To do this, two approaches will be taken:

- Analysis of case studies of GIS usability evaluation,
- Realization of usability tests and heuristic evaluation on some GIS.

After having done the research about the referred areas and having a clear idea of some of the main GIS usability problems, the next step will be to put it all together and develop a set of guidelines to try to deal with those problems.

But because simply having a set of guidelines is not enough to know their viability, an analysis of the benefits of integrating usability techniques and users on the development process will be made.

1.3 Document Structure

This document is composed by 9 chapters being the first this Introduction to the developed work.

On the second chapter are described some insights about Human-Computer Interaction, namely its definition, target areas and some evaluation methodologies used to assess the user interface.

On the third chapter a background and state of the art of Geographical Information Systems is made. An analysis about the value of geographical information is also made.

On the fourth chapter it is made an overview of the software development process, describing its phases, methodologies principles and the role user plays.

On the fifth chapter a relation between Human-Computer Interaction and GIS is established by analyzing the importance Human-Computer Interaction has on GIS, by studying the cognitive aspects of spatial data visualization, and by researching which are the main usability problems GIS faces. This research involved not only the analysis of some case studies but also the realization of heuristic evaluation and usability tests on some GIS applications. The findings of this evaluation are also shown on this chapter.

On the sixth chapter the user-centred methodology created for the development of GIS is described.

On the seventh chapter a Return on Investment analysis is made to analyze the viability of the developed methodology.

The eighth chapter is composed by a critical analysis and the conclusions of the developed work.

Finally, on the ninth chapter some notes about future work are taken.

Chapter 2

Human-Computer Interaction

During the 1970s technology explosion the user interface became of major concern for both designers and researchers. Soon companies became aware that if they could somehow improve the user interface they would have a better chance of being successful in the market-place. In the start this simply meant improving aesthetically the interface, but as the field developed it became clear that other aspects such as training issues, working practices, management and organizational issues and health hazards were also important factors contributing to the success or failure of using computer systems.

The term Human-Computer Interaction (HCI) emerged in the 1980s as a new field of study. HCI not only is concerned with the design of the interface but also with all those aspects related to the interaction between humans and computers. Although there is no agreed definition for HCI the most recent and broader characterization provided by the ACM's Special Interest Group on Computer-Human Interaction is the following: "human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [Per08].

2.1 The Scope of Human-Computer Interaction

As can be seen on Figure 2.3 HCI takes place within a social and organizational context. Different purposes require different applications and it is necessary to divide tasks between humans and machines, allocating the repetitive and routine activities to machines, and the more creative and non-routine activities to humans. Knowing about human psychological, abilities and limitations is very important. This involves knowing about human information processing, language, interaction and ergonomics. On the technology side, the main issues involve input and output techniques, dialogue techniques, dialogue genre or style, computer graphics and dialogue architecture. As can be seen at the bottom of the figure, all this as to be brought into the design and development of computer systems with good HCI. Tools and techniques are needed to develop computer systems. Evaluation is also important as it enables designers to check that their ideas really are what users want.

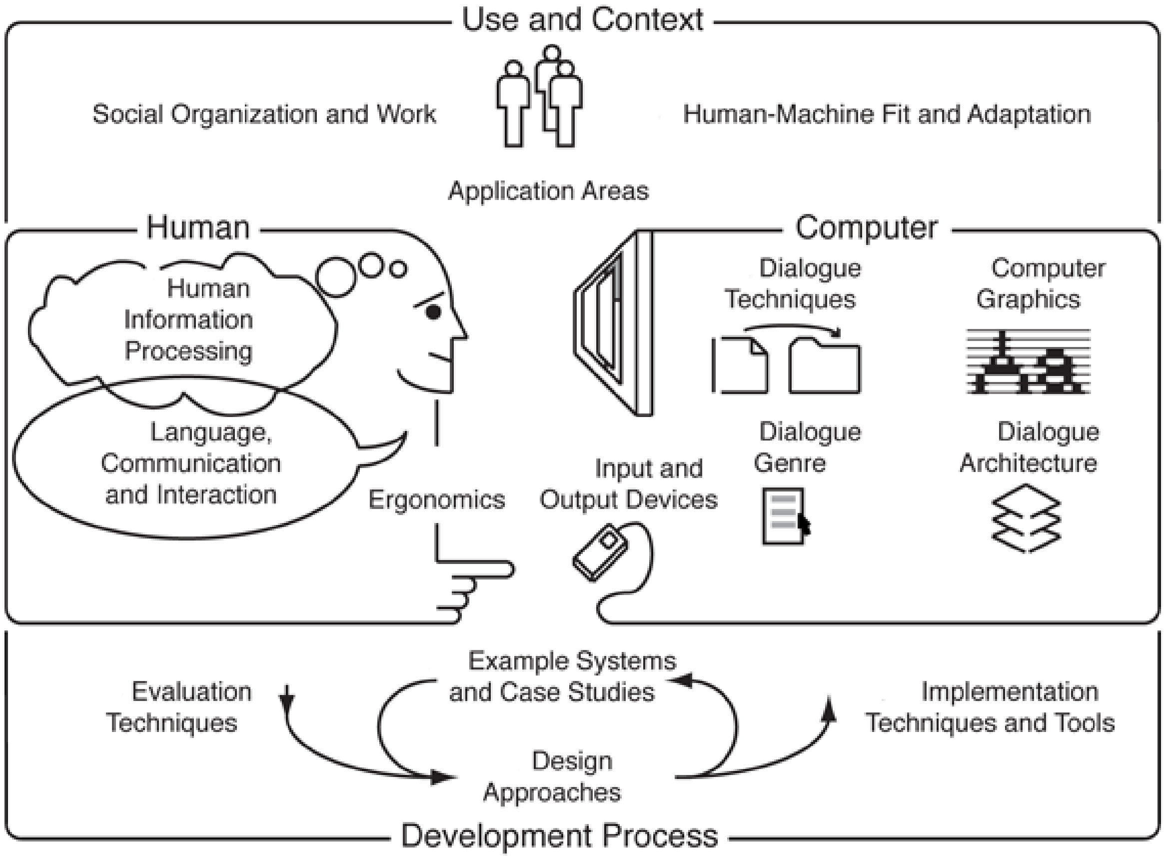


Figure 2.1: Human-Computer Interaction scope [Med93]

2.2 Disciplines contributing to HCI

As a broad field of study, HCI has several other disciplines that bring more insight to this field. They are:

- **Computer Science**: this discipline contributes to HCI by bringing knowledge about technology capabilities and how best to take advantage of its potential. In addition it also develops various kinds of techniques to support software design, development and maintenance.
- **Cognitive Psychology**: this discipline is a major contributor to HCI as it provides the means to understand how people learn and think. This knowledge can later be used do predict human behaviour and improve user satisfaction.

- **Social and organizational psychology**: knowing how humans behave in a social context is very important as it allows designers to be familiar with the user's working practices, information flow and work environment.
- **Ergonomics and human factors**: this discipline contributes by building tools and artefacts that improve the user's safety, efficiency and reliability. It also makes the task easier, increasing the user's feelings of comfort and satisfaction.
- **Linguistics**: linguistics is important as it allows understanding the structure (syntax) and meaning (semantics) necessary to develop natural language interfaces.
- **Artificial Intelligence**: the relationship between HCI and Artificial Intelligence is related to understand the user's needs when interacting with intelligent systems.
- **Philosophy, sociology and anthropology**: these disciplines contribute to HCI by studying the impact of information technology on society.
- **Engineering and design**: engineering uses the knowledge from science to build artefacts and design contributes with creativity to this process. The greatest contribution from engineering and design to HCI is through software engineering.

2.3 The Human Side of HCI

A human can be seen as a smart real time system with the capability of processing information intelligently via a number of I/O channels, namely the visual channel (eyes), the auditory channel (ears), and the haptic channel (touch).

Knowing how people think and learn is a very hard challenge. Cognitive psychology studies this field and its goal is to understand the psychological processes involved in the acquisition and use of knowledge by people. This includes domains such as perception, attention, memory, learning, thinking, and the importance of social and environmental influences on those domains [Gia01]. Cognitive psychology contributes to HCI by providing psychological principles to understand and help develop models that explain and predict human performance.

One of those contributions was to develop a model that helps understand how humans process information. This model can be seen on Figure 2.2.

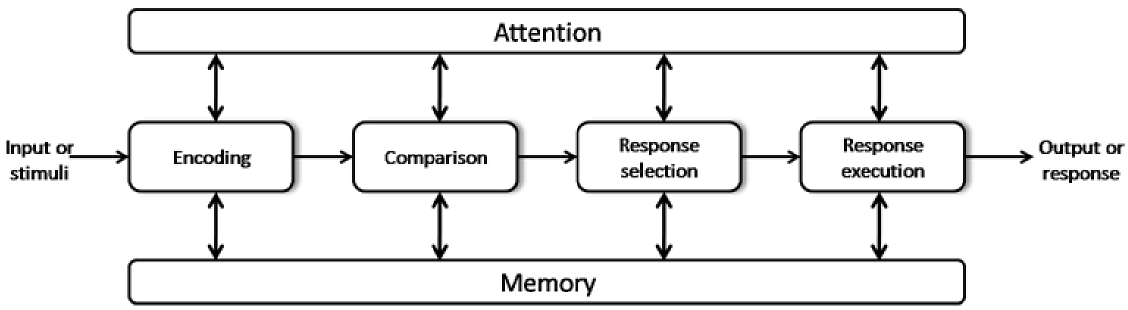


Figure 2.2: Information processing model [Pre94]

The basic idea behind the model is that information enters and exits the human mind through a series of ordered processing stages. “Stage 1 encodes information from the environment into some form of internal representation. In stage 2, the internal representation of the stimulus is compared with memorized representations that are stored in the brain. Stage 3 is concerned with deciding on a response to the encoded stimulus. When an appropriate match is made the process passes on to stage 4, which deals with the organization of the response and the necessary action. The model assumes that information is unidirectional and sequential and that each of the stages takes a certain amount of time generally thought to depend on the complexity of the operations performed” [Pre94]. During the process, information is attended to (attention), processed and stored in memory.

Bringing together the information processing model with the studies from HCI has provided the means of conceptualizing user behaviour that enables predictions to be made about user performance. As a result some models emerged being one of them the human information processing model. The model human processor consists of three interacting systems: the perceptual system, the motor system and the cognitive system. Similar to the notions of human information processing, human performance is viewed as a series of processing stages, whereby the different processors and memories are organized in a particular way. Figure 2.3 shows the processing stages involved when someone presses a button in response to seeing something on a screen.

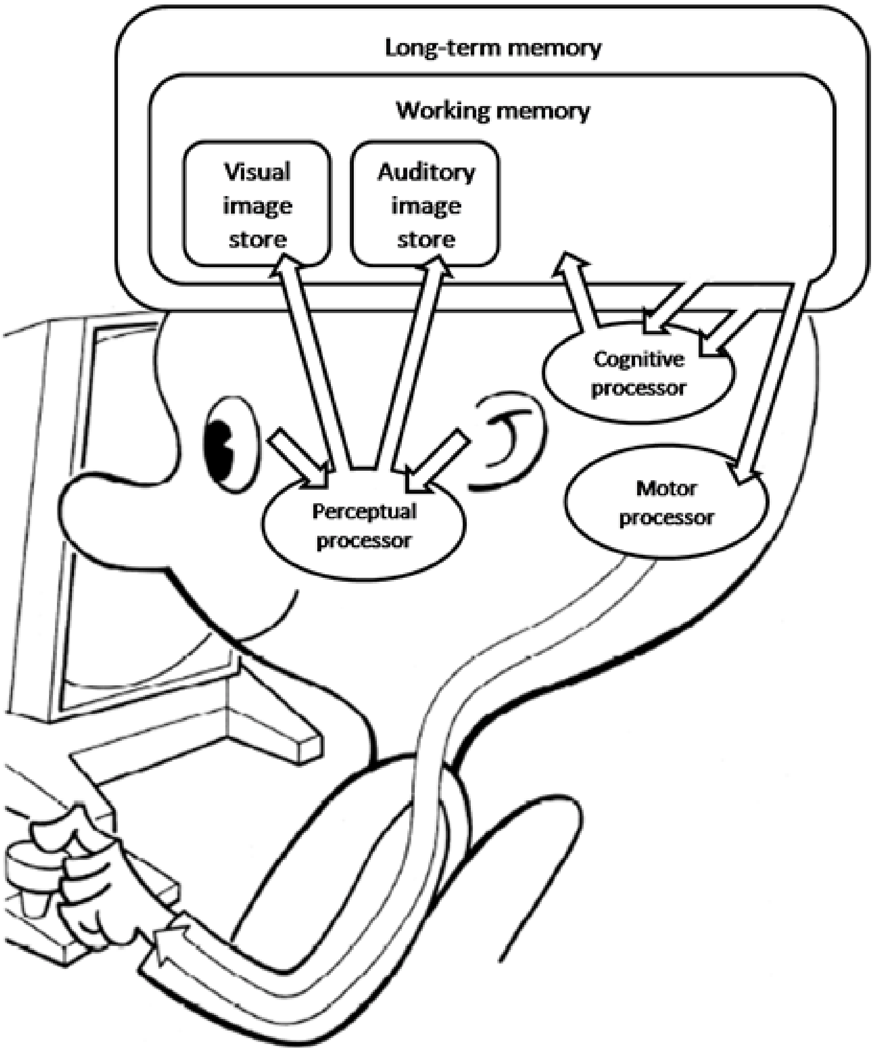


Figure 2.3: Human Information processing model [Pre02]

One of the most important factors of the human side of HCI is the user experience. User experience describes the overall experience and satisfaction a user has when using a system. Its aim is to create systems that are satisfying, enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing, supportive of creativity, rewarding and emotionally fulfilling for the user.

2.4 The Technology Side of HCI

A computer is a machine with a series of input and output devices that allow the interaction with a human. As an example of input devices there is the keyboard, mouse, joystick, microphone, scanner, among others. As for output devices there are monitors, printers, speakers, etc.

As the way information is processed there is no mystery, once it was built by humans, and, contrary to what happens with humans, information processing on machines can be done parallel and sequentially.

When talking about building a computer system the buzzword, concerning HCI, is usability. Usability is concerned with optimizing the interaction users have with computer systems. Its main goal is to ensure that systems have the following characteristics:

- **Effectiveness**: refers to how good a system is at doing what it is supposed to do.
- **Efficiency**: refers to the way a system supports users in carrying out their tasks.
- **Safety**: involves protecting the user from dangerous conditions and undesirable situations.
- **Utility**: refers to the extent to which the system provides the right kind of functionality so that users can do what they need or want to do.
- **Learnability**: refers to how easy a system is to learn to use.
- **Memorability**: refers to how easy a system is to remember how to use, once learned.

2.5 HCI Methodologies

A central aspect of HCI methodologies is that they are based on a user-centred design philosophy. This philosophy follows the idea that users must play a central role in the design of any computer system. Users, designers and technical practitioners must work together to understand the wants, needs and limitations of the user and to create a system that addresses these elements.

A HCI methodology involves "designing interactive products to support people in their everyday and working lives" [Pre02]. This is also the definition of interaction design. More specifically, interaction design is "about creating user experiences that enhance and extend the way people work, communicate and interact" [Pre02].

The process of interaction design involves four activities:

1. Identifying needs and establishing requirements.
2. Developing alternative designs that meet those requirements.
3. Building interactive versions of the designs so that they can be communicated and assessed.
4. Evaluating what is being built throughout the process.

This last point is very much the heart of interaction design as its focus is on ensuring that the product is usable.

There are some methodologies based on interaction design [Pre02], being one the Star Lifecycle Model, described on Figure 2.4.

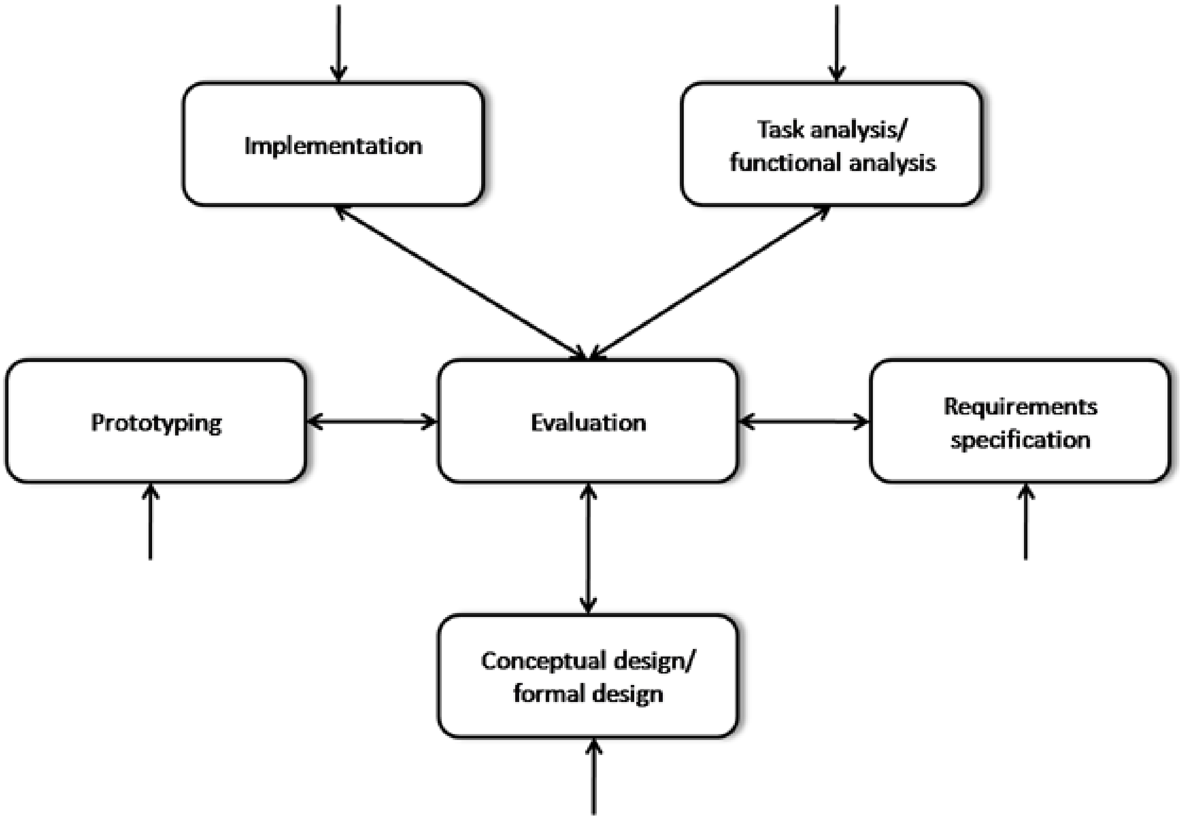


Figure 2.4: The Star Model [Pre94]

In this model there is no order by which the tasks must be accomplished. In spite of that, all aspects of the systems development must be subject to constant evaluation by users and experts. The basic idea is that the requirements, design and the product will gradually evolve, becoming increasingly well defined.

On the next section it will be given more insight about evaluation activities, and what they involve.

2.6 Evaluation on HCI

As systems evolve from initial ideas, to concepts and prototypes, evaluation is essential to help ensure that they meet user's needs. Evaluation is driven by questions about how well the design satisfies user's needs. Practical constraints, like low budget, tight schedule, among others also play an important role by constraining what can be done. Planning evaluation with advance can be very helpful in spotting problems and in finding ways of dealing with them.

The difficult part of the process of evaluation is to choose ***what*** to evaluate and ***when***, namely which evaluation techniques to apply on which stages of the development. There are many evaluation techniques and they can be categorized in the following ways [Pre02]:

- **Observing users**: Help identify needs leading to new types of products and help evaluate prototypes. Notes, audio and video are ways of storing information about the observation. This technique's challenge is how to observe without disturbing the people observed and how to analyze the data.
- **Asking users their opinions**: asking users what they think of a product it is the most obvious way of getting feedback. Interviews and questionnaires are the main techniques for doing this.
- **Asking experts their opinions**: Guided by heuristics, experts step through tasks role-playing typical users and identify problems. This approach is usually relatively inexpensive and quick to perform compared with laboratory and field evaluation that involve users.
- **Testing users' performance**: These tests are usually conducted in controlled settings and involve typical users performing typical well-defined tasks. Data is collected so that performance can be analyzed. Generally the time taken to complete a specific task, the number of errors made and the navigation path through the system are recorded. Results are reported using statistical measures such as means and standard deviations.
- **Modelling users' task performance to predict the efficacy of a user interface**: Attempt to model human-computer interaction to predict the problems associated with different designs at an early stage. These techniques are successful for systems with limited functionality.

Related to these categories are evaluation techniques like, for example, heuristic evaluation where a system is evaluated against a set of heuristics, and usability testing that consists of observing users while they perform predefined tasks on the system. These techniques will be used later on the evaluation of some GIS, and are described in more detail on section 5.3.3.

2.7 Summary and Discussion

Human-Computer Interaction is a vast area, with contributions from several sources, that studies humans and the way they interact with computers. The human side of HCI studies how humans process information in order to predict their behaviour. The technology side of HCI is concerned with building usable systems.

Bringing together the human and the technology side of HCI, some methodologies were developed. These methodologies are based on a user-centred paradigm where users must be involved throughout the development process participating on the system's evaluation.

The evaluation activity is central to a user-centred methodology and there are several evaluation techniques that can be used. These techniques include:

- Observing users,
- Asking users their opinions,
- Asking experts their opinions,
- Testing users' performance**,** and
- Modelling users' task performance to predict the efficacy of a user interface.

As can be seen the HCI area is a major contributor to the development of better quality software, studying the way users interact with software and improving their experience. The question here is how to integrate HCI on the software development process in an efficient way so that all the inherent benefits can arise. Simply applying the HCI principles is not enough, it is necessary to study the best way to implement them and plan in advance otherwise the success of the software product may be harmed.

Chapter 3

Geographical Information Systems

A Geographical Information System (GIS) can be defined as “a system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth” [Von93]. From this definition it is possible to say that GIS, apart from the computing ability and data, also includes managers and users from the organization within they operate and the institutional relationships that govern their management and use of information. This can be seen on Figure 3.1.

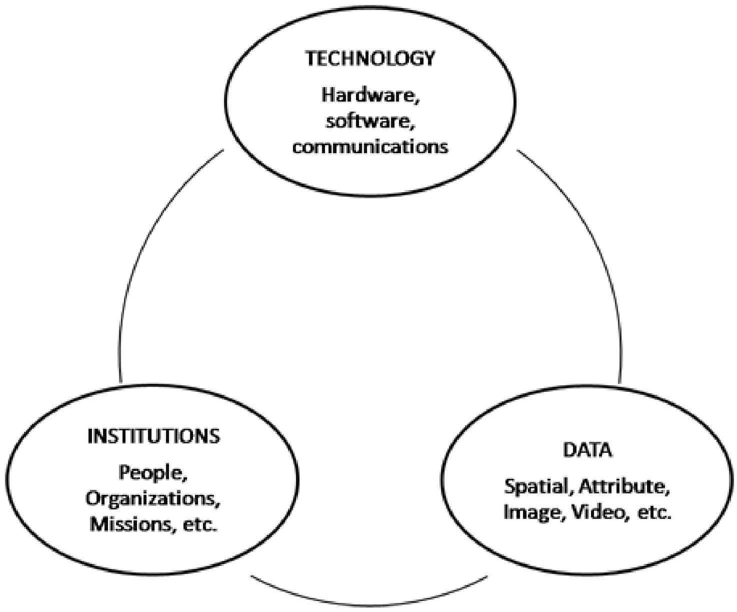


Figure 3.1: Geographical Information Systems Domain [Lon99]

3.1 Historical Perspective

Although a GIS is not necessarily a computer system, the association between GIS and computers is very common. GIS has its origins on cartography, which is the art of map-making and has been part of human history for a long time. From cave paintings to ancient maps of Babylon, Greece and Asia, through the Age of Exploration, and on into the 21st century, people have created and used maps as essential tools to help them define, explain and navigate their way through the world and beyond.

The role of technology in GIS is very important and suffered many changes in order to meet the demands of generations of users. From brushes and parchment, passing trough compass, printing press, quadrant, among others, to the creation of computers, GIS has suffered a lot of changes and its fields of application have grown. GIS can be used in a large number of fields, going from agriculture, meteorology, to health and urban planning, passing from transport planning and census studies.

Since the first computer's creation, developers and researchers have tried to automate GIS. By the 1950s, Swedish meteorologists were using weather maps with the aid of computers [Lon99], and Terry Coppcock [Cop62] was analyzing agricultural data also by computer.

By the 1960s, in Canada, born what is said to be the first “real” GIS, with the name of Canada Geographic Information System (CGIS). This system was created by Roger Tomlinson [Wik08b], who had the vision of using computers to perform labour intensive tasks related with Canada Land Inventory. Also in the 1960's appeared the vision of the world as a set of layers, each one containing specific information.

Tough the potential of computers was highly appreciated at the time, they implied enormous costs and existed several limitations regarding the computers performance.

In the 1970s appeared some mechanisms that allowed cartography automation. Tools like map digitizer, interactive graphics display device, and plotter allowed the information's conversion into a digital form, and made it easy to manipulate, copy, edit and transmit [Lon99].

More recently, by the 1990s, the vision of GIS became more distant from the system definition and became closer to a sociotechnical definition, putting together technology, data, users and organizations.

With the growth of electronic communications networks, GIS became highly distributed, being unnecessary for software, data and users to be in the same place at the same time.

Also the advent of more powerful PCs has increased GIS functionalities and performance, making it more easy to use. Because of its complex nature, GIS are more difficult to use than traditional information systems. As a result, on the past they were only used by experts on the subject who were trained specifically for the task. With the emergence of more powerful PCs, more work was put on improving GIS functionalities, performance and usability making GIS available to both experts and novices.

Also the advent of the World Wide Web (WWW) is perhaps the most important event in GIS history once it allowed the database linkage between different hardware in different countries, making GIS more global [Lon99] and available to a wide range of users.

3.2 State of the Art

The world of GIS applications is an evolving world. From the digitalization of geographic information to the creation of complex computer systems, the evolution is obvious. However the most important evolution happened with the advent of the Internet, allowing the creation of GIS networks providing the means to globally share geographic knowledge.

Nowadays GIS software is very popular and is being used with increasing frequency. In the area of commercial software, one organization is the centre of attentions - ESRI. ESRI's software, ArcGIS [ESR08] is the most popular and used GIS in the market. It allows maps querying, editing, analysis and data manipulation.

Regarding open source software, there are also some interesting applications. GRASS [GRA08] (Geographic Resources Analysis Support System), originally developed by the U.S. Army Construction Engineering Research Laboratories, is a free, open source GIS used for data management, image processing, graphics production, spatial modelling, and visualization of many types of data.

More recently, there has been a great investment on Web-based GIS. Google's Google Maps [Wik08c] and Virtual Earth [Mic08], from Microsoft, are free web-based GIS that offer street maps, a route planner, and an urban business locator for numerous countries around the world. Also integrated on Google Maps is Google Transit[1]. This service was launched on December 2005 and is a Web application able to plan a trip using public transportation information [Wik08c]. Built on top of Google Transit is a Web-based application developed by the Helsinki City Transport[2]. This application allows viewing real time information on the map about the public transports location, and also is able of locating bus stops on the streets of Helsinki.

There is also Via Michelin [Via08] who provides tourism information in Europe by offering a route planner, information about hotels, streets maps, among other features.

People use information systems in order to obtain the information needed to perform a task. In spite of the individual use of GIS is growing within public settings, the literature describes the current GIS usage in a more organizational context. In fact individuals feel more motivated to use GIS because of the responsibilities of their work activities within their organizations [Med93].

Since GIS evolved into a more usable and functional systems, they are used by a huge number of industries and agencies to help plan, design, build and maintain information that

[1] http://www.google.com/transit
[2] http://transport.wspgroup.fi/hklkartta/

affects our everyday lives [Que08]. The Table 3.1 lists the major areas of GIS and its applications.

Table 3.1: Geographical Information Systems applications (based on [Que08])

Area	GIS Applications
Facilities Management	managing underground pipes and cables networks planning facility maintenance managing telecommunication network services energy use tracking and planning
Environment and Natural Resources Management	study of agricultural cropping management of forests, crop fields, water resources, wetlands, etc. environmental impact analysis disaster management and mitigation waste facility site location
Street Network	routes and schedule planning locating houses and streets ambulance services transportation planning
Planning and Engineering	urban planning regional planning highways location and planning development of public facilities
Land Information	taxation land use land acquisition
Demographic and Marketing Analysis	locating target customers census studies
Military Management	troop movement field analysis route planning

This list of areas of GIS applications is not exhaustive but is representative of the breath of applications.

3.3 Geographic Information's Value

As we said before the history of GIS starts almost at the same time as Human history. Geographic information has been a powerful tool since Man was exploring the seas, in wars, on urban and health planning, agriculture, environment, among others, helping him survive through generations until the present.

To help understand how valuable geographic information is we can divide our world in two [Dan03]:

- a natural world that is self-regulating;
- a human made world that must be managed.

Because of population rapid growth, consumption and land occupation, several of our natural resources are declining, creating problems for both worlds. To deal with these problems, humans need to take more responsibility for the evolution of the planet, doing it in a global context.

As we are moving towards a more human-controlled world, we need something to help us organize the world we live in. Here is where geography serves its purpose by providing a framework and language for helping Man in his task.

GIS also plays an important role by allowing geographic information to be available in a digital form. This way of encapsulating geographic information in one system and making it available for everyone provides the means to improve human efficiency, decision making, planning, communication, and is a powerful mechanism to help humans manage the world.

3.4 Summary and Discussion

The history of GIS dates many centuries ago, being GIS used to help Man on his everyday tasks mainly at work. Geographical Information Systems are sociotechnical systems that aggregate people, technology and data. Being the current used technology the computer.

Nowadays, as GIS becomes more accessible to the common user its popularity is increasing. Now, there are not only the professional GIS, like ArcGIS and GRASS, used for professional activities, but also free Web-based GIS, like Google Maps and Via Michelin, which are used by normal users for their everyday tasks at work and leisure.

As GIS become more popular the value of the information they provide is increasing. GIS provide valuable information about Earth resources and can be used to effectively manage them. As it was referred, the world can be divided in two: a natural world that is self-regulating, and a human world that needs to be managed. The human world is rapidly growing and consuming the resources of the natural world, which is not being able to catch the fast rhythm of the human world. GIS provide the tools to effectively manage this unbalance and achieve a better world.

Chapter 4

Software Development Process Overview

The software development process is a transformation of the customer's ideas about what the system should be, into a working system that matches his expectations. This transformation is a long and complex one, varying from project to project.

Along the history, as systems got more complex and large, developers felt the necessity to make the software development task a more manageable one dividing it into phases, each one with specific tasks.

With the growing complexity of systems, and the demanded flexibility and speed development teams must have, software development processes have been suffering changes over the years.

On this chapter it will be covered the phases involved in software development process, how this process has been changing over the years, and the user's role in all the process.

4.1 Software Development Phases

Software development phases are defined in a natural progressive way that leads, at each phase, to a more complete system. The way a software product comes to existence follows normally this way [Bir85]:

1. Decide to do something for some reason;
2. Agree on what is to be done;
3. Work out how to do it;
4. Do it;
5. Have it accepted;

6. Look after it following delivery;
7. Look back at how it all went.

Associated with this progression are the phases which define the software development process [Bir85]:

1. **Project inception**: this is the phase where the need for the system is conceived and justified. Also on this phase the system requirements are defined.
2. **System definition**: this is the phase where it is defined *what* is to be produced and *how* it is to be produced.
3. **System design**: on this phase the software structure is defined. This phase is divided in the following way:
   a. Architectural design: defines the system's architecture.
   b. Interface design: defines the interface structure and navigation.
   c. Components design: defines the components that compose the system.
   d. Data structure design: define the data structure of the system (database design).
   e. Algorithm design: defines the main algorithms of the system.
4. **System production**: this phase translates the system's design into an executable piece of software.
5. **System acceptance**: this is the phase where the software is tested before it is released.
6. **Post-acceptance development**: after the software is released is normal the appearance of bugs and necessity to alter, add or remove some functionalities. This phase deals with these situations.
7. **Project debriefing**: on this phase all team looks back to all that happened and tries to figure out what went well, what could be improved and what went wrong. This phase is important because it allows the team and the company to learn with the experience they passed, and next time apply the good things and avoid the bad ones.

4.2 From the Waterfall Model to Agile Methodologies

On its beginnings the software development process was a simple sequential model with the name of Waterfall Model. On this model each phase starts after the previous has ended. This type of software development process is characterized by being a rigid methodology where the goal, on each phase, is to make all the work that phase involves at one time, avoiding this way coming back to previous phases. As software products got bigger and more complex, and customers started to demand shorter deadlines the Waterfall Model was not fitting the development teams' needs. So to improve the situation other models were created. These models had the goal to allow the software development process to be more flexible, adapt to the customer's demands, showing him results more rapidly. One of these models was the Spiral Model. On this model the various phases are organized in cycle, where on each cycle are added new functionalities to the system. Although this was a more flexible model, the development team still was not able to deliver good quality software on time.

Nowadays the software industry is increasingly growing. Everyday development teams face new challenges, appearing new technologies on the market at an incredible pace, customers being more demanding than ever and wanting to make last minute changes, and systems becoming more complex and bigger than ever. To face this environment a new approach to the software development process has emerged: the agile methodologies. Agile methodologies follow the same phases described earlier but in a more adaptive way, meaning with this that is not project that has to be adapted to the methodology but the methodology adapted to the project.

Agile methodologies also try to put more emphasis on the human factor of software development. This emphasis is for one hand on the development team that must work in a coordinated and harmonious way in order to be able to follow the deadlines and resolve the problems they face. On the other hand the emphasis is put on the user, without who the system will be a failure because it does not meet his expectations.

Traditional methodologies like the Waterfall and Spiral models involved the development of many documents of the system's specification, architecture and so on, most of which was not useful. This took precious time to development teams that could be using their time in a more productive way. Agile methodologies try minimizing this problem reducing documentation to the least useful. Other problem with traditional methodologies was the fact that they followed a pre-established plan, which defined the deadlines from the beginning of the project until the end. This did not allow teams to deal with changes in the best way because most of the times it implied remaking, not only one phase, but several. Agile methodologies try to resolve this problem planning only the minimum indispensable, and dealing with changes as they appear.

Although agile methodologies may seem a solution to the problems involved in the software development process, many work is yet to be done on this area. The proof is that many projects still are a disaster either because the team was not able to finish it or did not met users' expectations or because it was over budget or delivered out of time [Hum05].

4.3 Software Development Principles

The way development teams' face the software project has been changing since agile methodologies appeared. While the "old" values are still valued, new ones emerged. The agile movement created an agile manifesto that reflects this situation [Bec01]:

"**Individuals and interactions** over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

That is, while there is value in the items on
the right, we value the items on the left more."

Linked to these values are principles. Which are the following [Bec01]:

- "Our highest priority is to satisfy the customer through early and continuous delivery of valuable software. "
- "Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage. "
- "Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale."
- "Business people and developers must work together daily throughout the project."
- "Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done."
- "The most efficient and effective method of conveying information to and within a development team is face-to-face conversation."
- "Working software is the primary measure of progress."
- "Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely."
- "Continuous attention to technical excellence and good design enhances agility.
- "Simplicity--the art of maximizing the amount of work not done--is essential."
- "The best architectures, requirements, and designs emerge from self-organizing teams."
- "At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behaviour accordingly. "

These principles aim helping people develop better quality software and, achieving project success.

4.4 The User's Role on Software Development Process

The user's role on Software Development is a polemic topic that raised questions like [Iiv04]:

- Why involve users?
- How to involve them?

On its primordial times, the software development process did not involved users at all. The software specification was made with the customer, which is not necessarily the user, and only when it was fully developed presented to users. What happened most of the times was that software was not used, either because users found it was harder to do their job using the software, or because the software did not allow them to do their work properly.

After several failures the idea that involving the users on the software development process was the solution to the problem aroused. However this idea was not famous among development teams who thought users would only get in their way taking them the freedom they previously had.

As the idea started to be implemented on some projects, and the results were positive, the reasons why users should be involved on the development process emerged. Not only it improved the design process and implementation, making the project less subject to big changes, as the empowerment of users, enabling them to participate in the decision making process in their workspace, made them more predisposed to use the software [Iiv04].

As the answer to the question *why* users should be involved on software development process is simple, the answer to *how* users should be involved it is not that simple. Best practices [Lef03], say that users should be involved early on the development process, since the Software inception phase, because earlier problems are detected, less resources are spent on fixing them. On Figure 4.1 that scenario is illustrated. The more we advance on the project more expensive is to fix an error, either in terms of time or in terms of money.

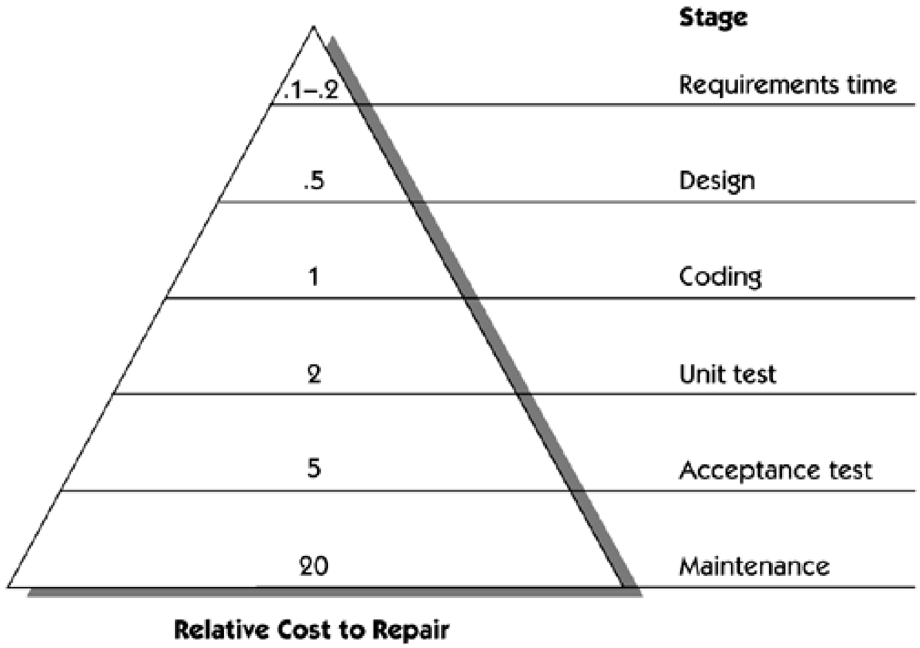


Figure 4.1: Relative cost to repair a defect at different lifecycle phases [Dav93]

In spite of these studies and best practices, most of the times users are only included, if included, on the acceptance phase where errors are expensive and take more time to fix. This leads to an overall higher project cost, and causes it, most of the times, to be delivered out of time.

4.5 Summary and Discussion

A software development process can be seen as the transformation of a product concept into a working product. This transformation can be divided into phases. The phases in which a software development can be divided are:

- Inception,
- Definition
- Design,
- Construction,
- Production,
- Acceptance,
- Post-acceptance, and
- Debriefing.

The way these phases are connected is called a methodology. Over the years software methodologies have been changing. As the software industry evolves the old sequential models, like the Waterfall model, do not function as before. So it was necessary to deal with the market demands and try to found a methodology that enables a more flexible and efficient way of develop software. From these needs appeared the agile methodologies, which proud themselves of being a flexible, quick and efficient way of develop quality software. With the agile methodologies came a series of development principles, based on the Agile Manifesto, that embrace change, flexibility, user involvement, and continuous customer feedback.

Other important aspect of software development it is the user's role. Many controversies are around this topic being the main question why to involve users and how. Results show that involving users improved the design process and implementation, making the project less subject to big changes, and made them more predisposed to use the software. This involvement has to be done in the early stages of software development, where errors are cheaper to fix.

Chapter 5

Human-Computer Interaction and Geographical Information Systems

Geographical Information Systems are a complex, rapid growing type of system. Key factor for the success of these systems is the quality of the user interface. Quality in a user interface brings user satisfaction, efficiency, and subsequently a greater GIS diffusion. This quality has to be continuously improved as “technology is becoming more inexpensive and is therefore reaching more, normally non-expert, users within the general public” [Bon].

On this chapter the importance of Human-Computer Interaction to GIS will be analyzed, also some cognitive aspects of geo-spatial visualization will be studied. Finally some GIS applications will be evaluated, and the obtained results shown and analyzed.

5.1 Human-Computer Interaction's Importance on GIS

The reason people use information systems seems pretty obvious: to use the information in order to carry out a task. However since the scope of GIS data processing includes a combination of data capture, data display, spatial analysis and database activities in the context of complex decision-making, GIS use tends to be more complicated than the use of traditional information systems. Because of its complex nature, extra attention must be paid to the interface and it is here where HCI plays its part. There is evidence that employing the processes, techniques and tools developed by the HCI community can decrease costs and increase productivity. Such benefits were attributed to decreased task time, fewer errors, reduced burden on support staff, elimination of training, and avoidance of changes in software after release.

As GIS become more flexible, interactive and used by a wider range of people, the more important is to optimize the relationship between users and such systems. In fact, one of the reasons for unsuccessful GIS implementation is the user problems in interacting with the interfaces. An effective user interface is indispensable in such systems.

The challenge here is to understand the relevant human factors issues involved in the use of GIS to develop procedures for optimizing HCI in GIS in terms of a user-centred paradigm.

5.2 Cognitive aspects of geo-spatial visualization

In its beginnings visualization was seen as a simple “method of computing, a tool both for interpreting data fed into a computer, and for generating images from complex multi-dimensional data sets” [Buc00]. MacEachren, *et al*. [Mac92] expanded this view, arguing that visualization “it is first and foremost an act of cognition, a human ability to develop mental representations that allow us to identify patterns and create or impose order”. Geo-spatial visualization, also known as geovisualization, is considered to involve not only the development of theory, tools and methods for the visualization of spatial data, but also the understanding of how the tools and methods are used for hypothesis formulation, pattern identification, and the facilitation of decision making.

People in their everyday life interact, through their senses, within a space-time continuum. In fact, an understanding of the spatial world surrounding them is essential to human existence as it is a mean to access and understand information, and for navigating around the world, dealing with a wide range of geographic concepts.

To better understand how humans process spatial information it is important first to know the concepts of spatial information, spatial cognition and spatial thinking.

Information can be defined as “the result of processing, manipulating and organizing data in a way that adds to the knowledge of the receiver [...] it is the context in which data is taken” [Wik08d]. Spatial information is information about geographic spaces and can be classified in three categories [Med93]:

- **Declarative spatial information**: geographic facts about locations, sizes, populations, etc. of geographic objects. May be acquired from real-world experience, from maps or, more directly, from books, newspapers, films, television, and other sources.
- **Procedural spatial information**: this type of information is evidenced by the ability of people to find their way from place to place.
- **Configurational spatial information**: is map-like and might show connections between objects and allow a person to estimate distances between them.

The way people perceive and structure these kinds of spatial information is called spatial cognition. According to Mark [Mar92a] there are three cognitive sources of spatial information:

- **haptic spaces** defined by touching and bodily interaction;

- **pictorial spaces** understood through visual experiences;
- **transperceptual spaces** learned through inference during way finding.

These spaces are arranged hierarchically in the above order, with each being built in part on concepts from the previous ones.

Important to spatial cognition is the context on which the transformation data-to-information occurs. According to the Committee on Support for Thinking Spatially ***et al*** [Nat06] there are three contexts in which that transformation happens. Those are life spaces, physical spaces, and intellectual spaces. The geography of our life spaces can be interpreted in terms of cognition ***in*** space, which "involves thinking about the world in which we live. It is exemplified by way finding and navigation, actions that we perform in space" [Nat06]. To the geography of our physical spaces we might call cognition ***about*** space and "involves thinking about the ways in which the world works" [Nat06]. Finally, the geography of our intellectual spaces might also be called cognition ***with*** space and "involves thinking with or through the medium of space in the abstract" [Nat06].

After being perceived, spatial information is processed. This stage is called spatial thinking and is composed by tools of representation, which "provide the forms within which structured information can be stored, analyzed, comprehended, and communicated to others" [Nat06], and processes of reasoning that "provide the means of manipulating, interpreting, and explaining the structured information" [Nat06]. Spatial thinking helps us by providing an understanding of structure and function. An understanding of structure provides a description of how something is organized. For example, we can visualize the arrangement of objects in space and speak about their order, relation and pattern. An understanding of function allows us to describe how and why something works. For example, it can express how something changes with time and explain why that change happens. Therefore, spatial thinking cannot be seen as a static process, but as a dynamic one that "allows us to describe, explain, and predict the structure and functions of objects and their relationships in real and imagined spatial worlds. It allows us to generate hypotheses, to make predictions, and to test their consequences" [Nat06].

An example where we can see all these concepts at work is a cartographic map, a typical two-dimensional road map where we can see places and roads that connect them. On Figure 5.1 there's an example of a two-dimensional road map.

Figure 5.1: Two dimensional map

Observing Figure 5.1 we can perceive different things. For example, by visualizing the shaded relief symbols on the map we are able to perceive the topography of that place, and from the colours of each road we can perceive the type of road it is (spatial cognition). With the map, we are also capable of select a route between two places such that is easy to follow and/or minimizes travel time (spatial thinking).

However it is important to state that cognition of spatial data is not necessarily made through graphic representations. For example, we can estimate the position of an approaching car by the sound that arrives at our ears, also smells can characterize places, among other examples. Overall the main idea is that we access the world through multiple senses and each one pays is contribution.

5.3 Geographic Information Systems Usability Problems

Over the years GIS interfaces have been improving and becoming more user friendly. However there is still much to improve and the several studies conducted on GIS usability are the proof.

For a better understanding of what are the main GIS usability problems two approaches were taken. First some papers about studies already conducted on the field were analyzed and, second some GIS applications were evaluated. For the purposes of the evaluation first a heuristic evaluation was made and then usability tests were conducted. Finally, the obtained results were analyzed.

5.3.1 Case Studies

As usability on GIS is becoming a top issue, many authors are conducting case studies to identify its main usability problems. Analyzing some publications ([Gol97], [Mar92b], [Ing] and [Tii03]) it is possible to see what other people are finding and what conclusions they are arriving.

For identifying their problems authors adopted usability techniques like interviews, usability testing, among others. Regarding their findings, one of the main problems found is related with the systems' error messages. Authors point out that, when they exist, error messages are uninformative and do not provide the necessary help for fixing the error.

The interface was also the source of many usability problems, with the weak integration of different system's parts, the excessive switching between keyboard and mouse, the weak automation of repetitive tasks and, the non-existence of an undo command. The map interface is also pointed out, as the functions of navigation buttons were not properly understood ("The navigation buttons were recognized but sometimes their usage was not understood correctly." [Ing]).

The learnability, performance and feedback of the systems were also pointed out by the authors as characteristics needing improvement.

The results also show that users found that they had large amounts of information to handle, and that they needed external aid for maintaining information about their work.

From these studies it is possible to see that concerning GIS usability problems there is yet much to be done. On the following section it will be explained the conducted evaluation on some GIS applications and the obtained results shown.

5.3.2 Applications Description

For the purposes of the evaluation, four applications were chosen:

- Google Earth,
- Virtual Earth,
- Transporlis, and
- Itinerarium.

On the following sections they will be described.

5.3.2.1 Google Earth

Previously known as Earth Viewer, Google Earth was originally created by Keyhole, Inc. [Wik08a], a company acquired by Google in 2004. Google Earth is a web-based geographical information system that represents a virtual 3D Earth globe. It displays images of the Earth, allowing users to visually see things like houses, streets, monuments, and obtain the directions from one point to another.

Google Earth has a great community support with many people adding their own data and making it available through various sources, such as blogs, Wikipedia[3], Google Skecthup[4], which is a program where users create 3D models of buildings, bridges, etc. Through the use of layers it allows users to filter the information they want, like hotels, monuments, public transports, weather, etc. Google also uses data collected by NASA's Shuttle Radar Topography Mission (SRTM)[5] to display 3D images of Earth's topography.

Beside the common Earth View or Street View, Google Earth also has a Sky Mode. This mode was developed by Google with a partnership with the Space Telescope Science Institute[6] in Baltimore, the science operations centre for the Hubble Space Telescope[7]. Sky Mode allows users to navigate through space seeing images of galaxies, stars, planets, etc. provided by the Hubble Space Telescope.

Google Earth is available in three types of licenses:

- Google Earth Plus
- Google Earth Pro
- Google Earth Free Edition

The version used for evaluation is the free one.

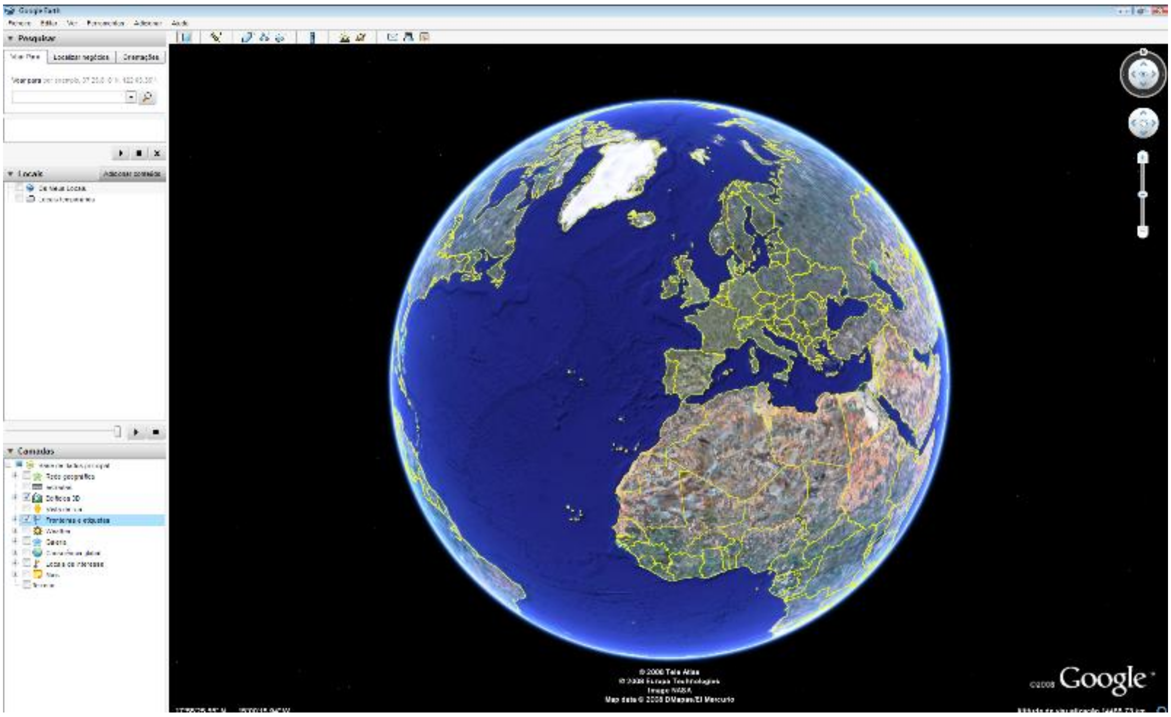


Figure 5.2: Google Earth interface

[3] http://en.wikipedia.org/wiki/Main_Page
[4] http://sketchup.google.com/
[5] http://en.wikipedia.org/wiki/Shuttle_Radar_Topography_Mission
[6] http://en.wikipedia.org/wiki/Space_Telescope_Science_Institute
[7] http://en.wikipedia.org/wiki/Hubble_Space_Telescope

5.3.2.2 Virtual Earth

Virtual Earth is a web-based geographical information system developed by Microsoft[8]. The Virtual Earth platform integrates a set of services to provide geospatial data, rich imagery, and good performance using top technologies. It aims helping organizations better visualize geospatial data and provide users with an immersive user experience. Using Virtual Earth users can easily find locations, businesses and obtain directions. To provide rich imagery functionality, Virtual Earth uses precise views of the world through bird's eye technology, which allows to view geospatial rich imagery 3D photorealistic, and through good quality 3D models.

Virtual Earth is also a customizable platform that allows creating new applications on top of Virtual Earth technology or simply customizing it to fit the business needs. This can be obtained through Virtual Earth SDK (Software Development Kit).

The version of Virtual Earth used in its evaluation was the version available online with the Virtual 3D add-in installed.

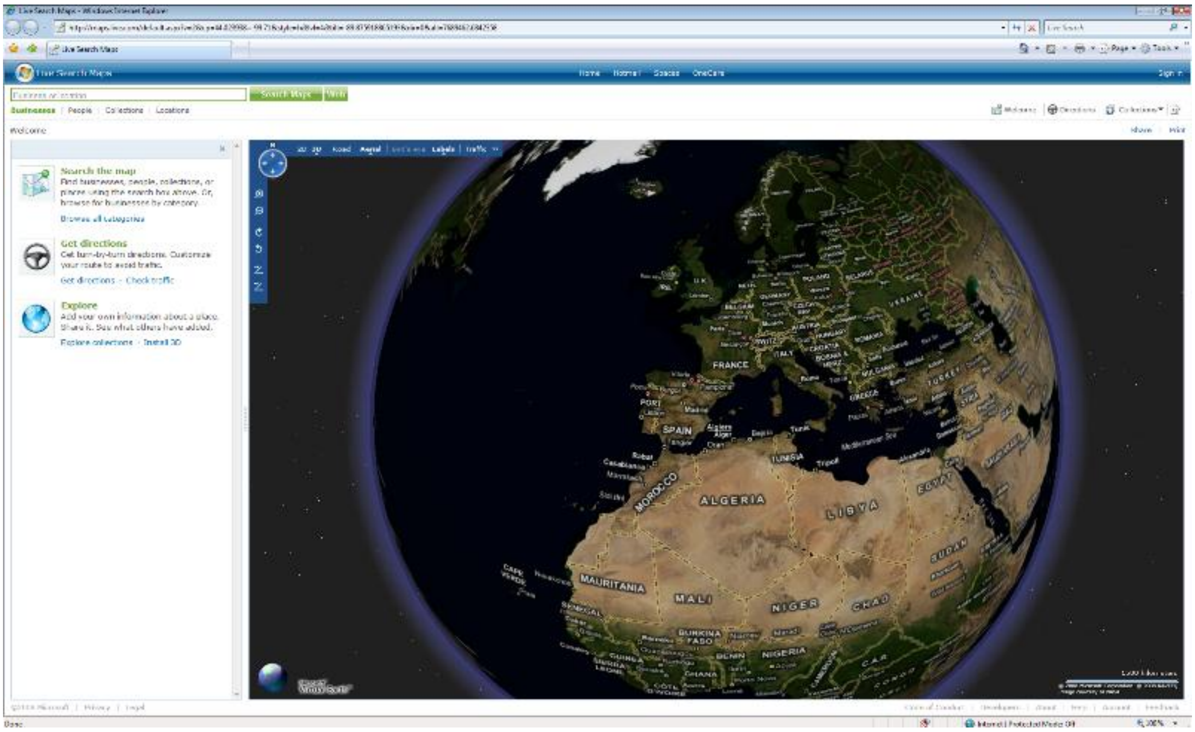


Figure 5.3: Virtual Earth interface

5.3.2.3 Transporlis

Transporlis is a Web portal that functions on top of a geographical information system, for public transportation's network of the metropolitan area of Lisbon. Although the project

[8] http://www.microsoft.com

dates 1998, the system's official announcement occurred on November 2007. Transporlis is a system that allows users to search for routes, obtain information about transports schedules and pricing. These tasks are possible due to the established partnerships among companies of public transports that provide the system the necessary information properly updated.

The system is available for everyone at http://transporlis.sapo.pt.

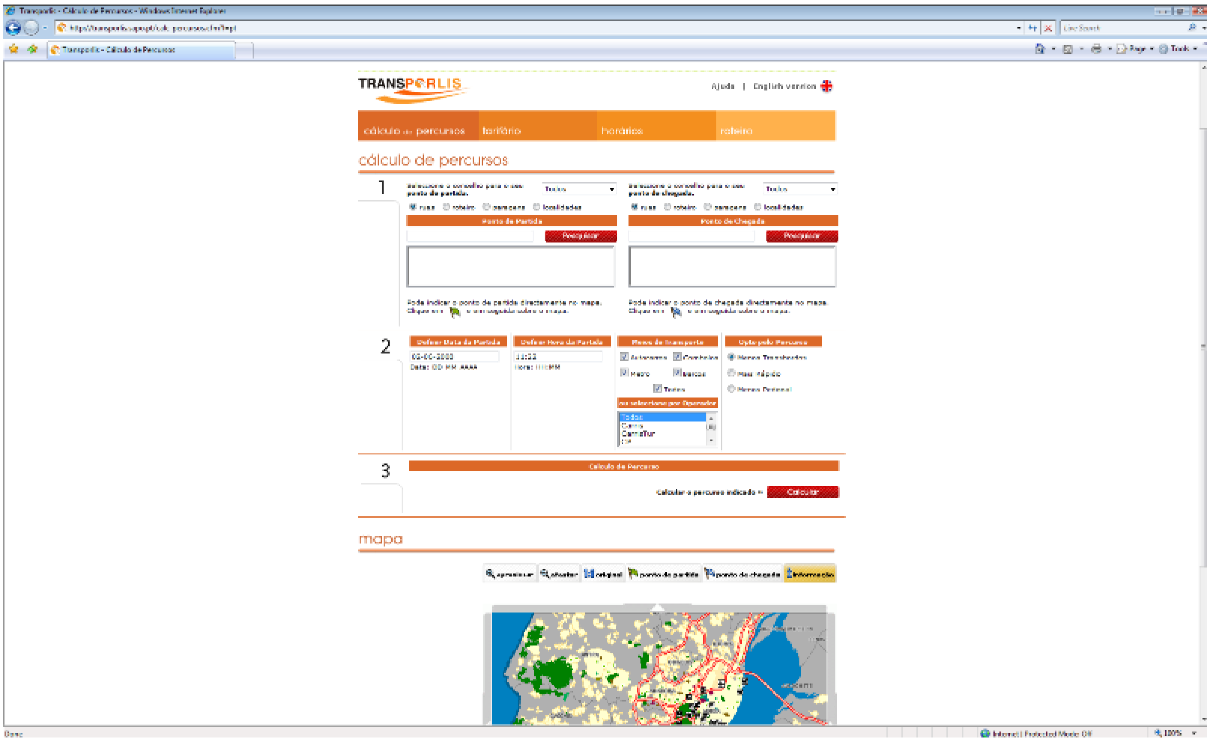


Figure 5.4: Transporlis interface

5.3.2.4 Itinerarium

Itinerarium is an interactive georeferential system for STCP (Sociedade de Transportes Colectivos do Porto, SA), a public transportation company for Oporto's metropolitan area. It was developed by Imediata, in partnership with SIG2000, and it uses ESRI technologies [Gis07].

Itinerarium is a solution that allows users to obtain information about routes between two points on Oporto's city. The provided information is very rich, being the results not limited to presenting the route but also the path that the user will have to walk, how much it will cost, how much time he will have to wait, among other interesting information.

This system is available for everyone at http://www.itinerarium.net.

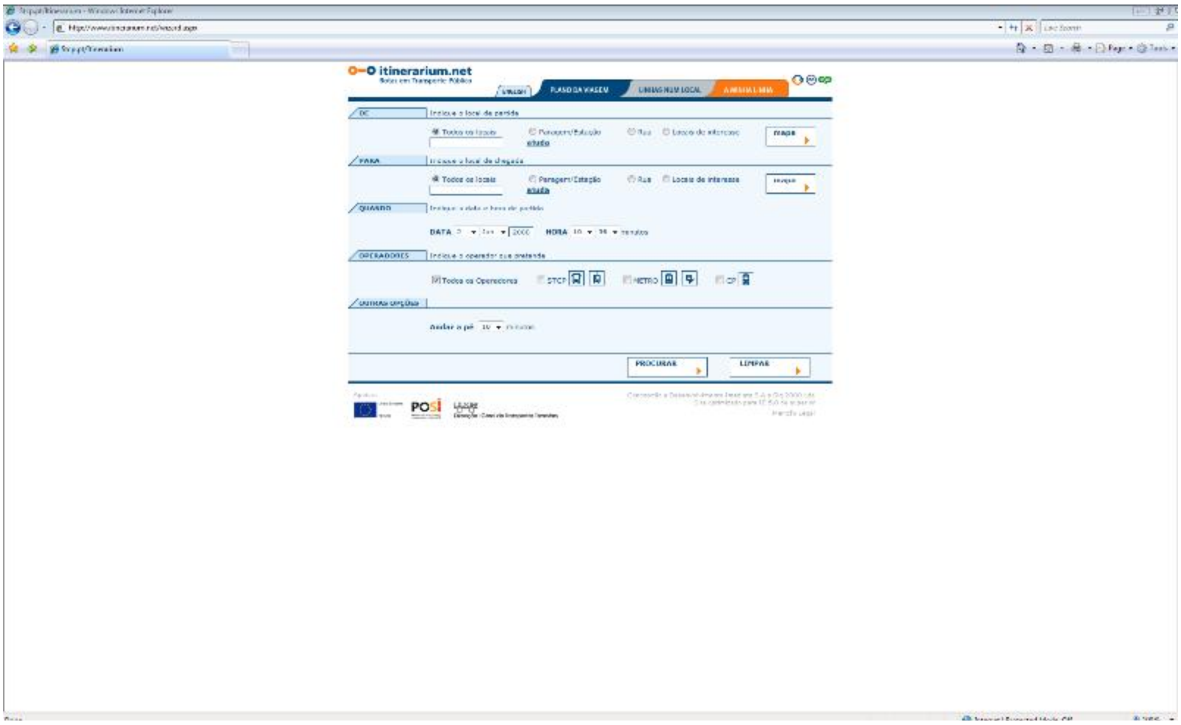


Figure 5.5: Itinerarium interface

5.3.3 Evaluation Techniques

After choosing the applications the next step was defining how to evaluate them. For this purpose two techniques were chosen:

- Heuristic evaluation, and
- Usability testing.

Heuristic evaluation is an evaluation technique where the system is evaluated, by an expert, against a set of heuristics. This technique was chosen because is "a quick, cheap, and easy evaluation of a user interface design" [Usa08a]. In fact it is a very good technique for finding usability problems on the user interface, and therefore to generate improvements on the same.

Usability testing is a technique that evaluates the system by testing it on users. This is a very important technique since it provides direct input from users.

By using these two techniques to evaluate the described applications, the results have an expert view, from the heuristic evaluation, and a user view, from the usability testing. These views are important as they highlight different aspects of the systems.

Also by comparing these techniques with others, like interviewing, prototyping and modelling which aim at discover new things about the systems while they are being defined, these techniques are more appropriate for the established goals for this evaluation. This evaluation does not aim at discovering users' needs, but at discovering usability problems with the systems, which is the purpose of the chosen techniques.

On the following section these techniques will be defined, and the way they will be applied described.

5.3.3.1 Heuristic Evaluation

This technique is referred early on this document on section 2.6, Evaluation on HCI, and its first step was defining the heuristics against which the system was to be evaluated and then create a checklist with specific points for each heuristic. The defined heuristics are based on the 10 recommended heuristics by Jakob Nielson [Nie05] which are the following:

1. **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within reasonable 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 good error messages is 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.

After having the heuristics defined, it was time to define a checklist to evaluate the system regarding each defined heuristic. This checklist can be found on Appendix A of this document. The various points of this checklist consist of simple Yes/No questions, based on the checklists by Deniese Pierotti [Pie04], and Lonny Chu [Chu06].

The heuristic evaluation was performed by one user with some usability concepts knowledge that explored the various systems and answered the checklist's questions.

After having evaluated all the systems the results were analyzed. For this purpose it was used a severity rating for each problem detected. This rating is based on the recommended rating by Jakob Nielsen [Nie08] that consists of assigning each detected problem a severity degree. The severity degree of a usability problem is a combination of three factors: **frequency** with which the problem occurs; **impact** of the problem; and the **persistency** of the problem.

The severity scale is defined in the following way.

- **0** = I do not agree that this is a usability problem at all
- **1** = Cosmetic problem only: need not be fixed unless extra time is available on project
- **2** = Minor usability problem: fixing this should be given low priority
- **3** = Major usability problem: important to fix, so should be given high priority
- **4**= Usability catastrophe: imperative to fix

5.3.3.2 Usability Testing

This evaluation technique is described earlier on Evaluation on HCI section and the followed approach was based on the recommended by Usability.gov [Usa08c].

The purpose of these usability tests was to assess the usability and ease of navigation of Google Earth, Virtual Earth, Transporlis, and Itinerarium. The main goal was to determine what is or is not working well on the applications from the users' perspective. During the tests information such as the following was analyzed:

- Do users complete each task successfully?
- What paths do they take?
- Do those paths seem efficient to them?
- What words or paths are they looking for which are not in the system?
- Where do users get confuse?

The facilitator's role, present in all tests, was fundamental to their success as he encouraged users to express their feelings and opinions towards the systems as well as some suggestions about what could be improved. It was included a discussion period after each session where users were able to share their thoughts on any aspect of the tested application and the test itself.

On the beginning and end of each test users had to complete a small survey. The first was a demographic survey to trace the user's profile with information like grade level, age group and experience using the web, online maps and journey planners (see Appendix B, section B.1). The second survey, made at the end of sessions, is based on System Usability Scale (SUS) by John Brooke [Bro]. Is a 10 item questionnaire that gives an overview of user's satisfaction with the software (see Appendix B, section B.2).

Because the objective was to compare Google Earth and Virtual Earth, and also Transporlis and Itinerarium, usability tests for Google Earth and Virtual Earth were similar, as it were also for Transporlis and Itinerarium. By similar it is meant the same kind of scenarios and user tasks.

After conducting the tests, the results were analyzed, the user's profile traced and the SUS score calculated. The SUS score has a particular way of being calculated. Each item has a score contribution that ranges from 0 to 4. For items 1, 3, 5, 7 and 9 the score contribution is the scale position minus 1, and for item 2, 4, 6, 8 an 10 the scores contribution is 5 minus the scale position. The sum of each score contribution multiplied by 2,5 gives the SUS score. The score goes from 0 to 100.

5.3.4 Results Analysis

5.3.4.1 Heuristic Evaluation

Regarding this evaluation, like it was previously said, all systems were evaluated in the same way, against the same heuristics and rated according to the same scale. By analyzing the obtained results it is possible to know which are the systems’ major usability problems, considering each evaluation aspect (heuristic).

5.3.4.1.1 Google Earth

Regarding Google Earth the results can be seen on the chart on Figure 5.6. On this chart it is possible to see for each heuristic the quantity of problems found.

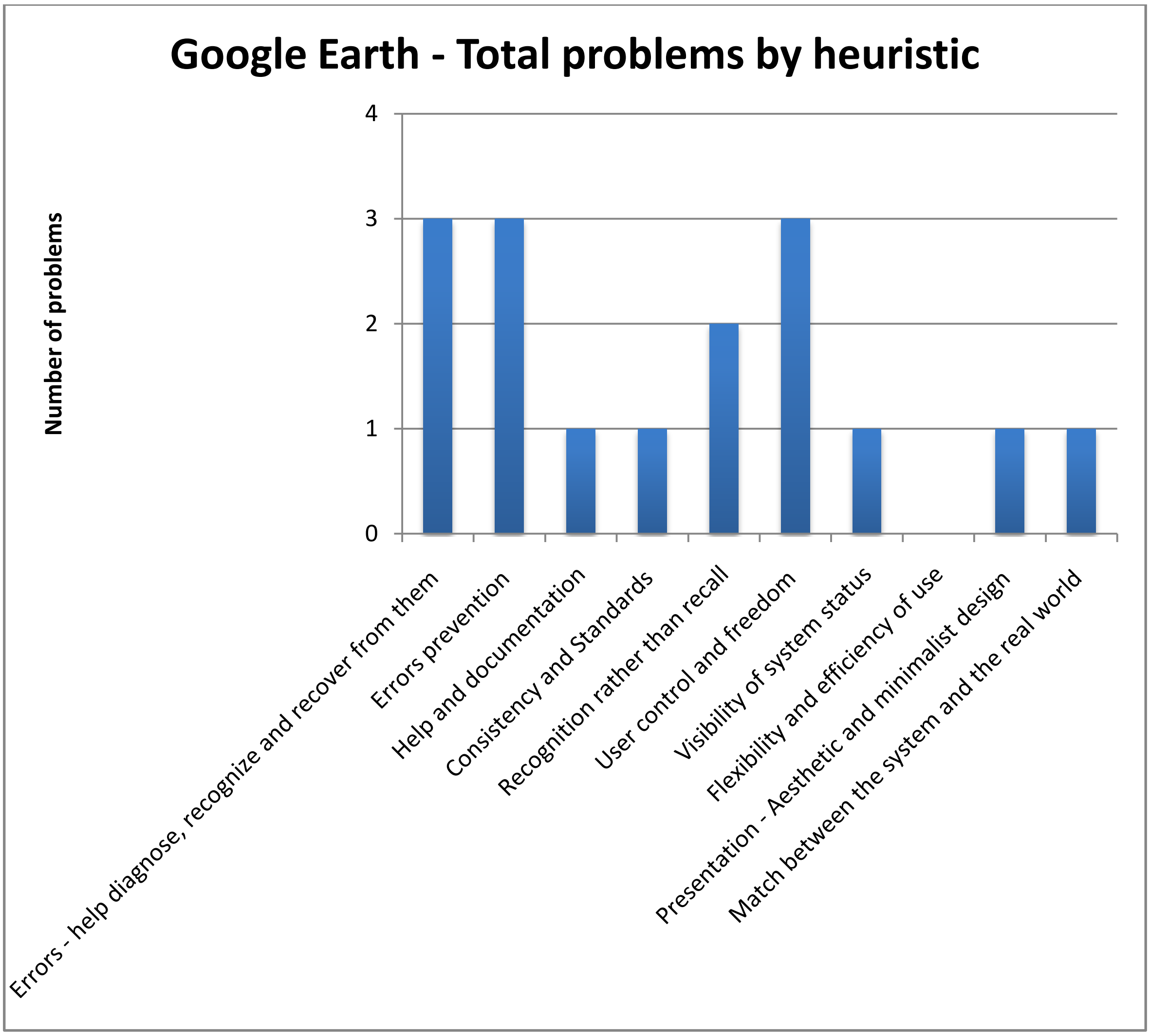
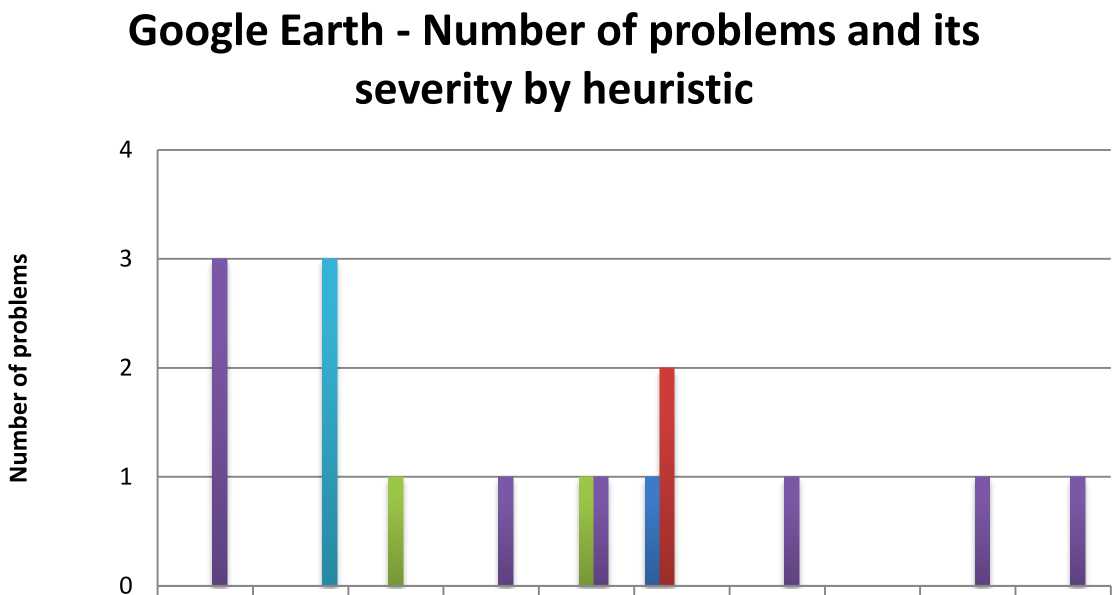


Figure 5.6: Google Earth - Total problems by heuristic

Observing the chart it is possible to highlight 4 heuristics that have more problems. They are:

- Errors - help diagnose, recognize and recover from them
- Errors prevention
- Recognition rather than recall
- User control and freedom

But once the problems were rated according to a severity scale not all of them are major problems or problems at all. So on the chart on Figure 5.7 it is possible to see the problems found on Google Earth divided by severity degree and heuristics.



	Errors - help diagnose, recognize and recover from them	Errors prevention	Help and documentation	Consistency and Standards	Recognition rather than recall	User control and freedom	Visibility of system status	Flexibility and efficiency of use	Presentation - Aesthetic and minimalist design	Match between the system and the real world
Severity 0	0	0	0	0	0	1	0	0	0	0
Severity 1	0	0	0	0	0	2	0	0	0	0
Severity 2	0	0	1	0	1	0	0	0	0	0
Severity 3	3	0	0	1	1	0	1	0	1	1
Severity 4	0	3	0	0	0	0	0	0	0	0

Figure 5.7: Google Earth - Number of problems and its severity by heuristic

On this chart it is possible to see that the problems related to the “User control and freedom” heuristic have only severity 0 and 1, therefore this heuristic it is not a critical one. On the other hand the other heuristics referred above have problems with a high severity degree, namely the “Error prevention” heuristic which problems have all a severity degree of 4. In fact Google Earth does not pay much attention to this aspect. The system is not able to recognize potential errors and warn users about them. The other heuristic, “Errors - help diagnose, recognize and recover from them” has also major problems. This evaluation detected that error messages are not very useful (do not suggest the error cause) and do not provide contact details to the user, also the system does not provide a way to contact support (e-mail or web form).

The system also has some serious problems related to other heuristics. For example the system does not provide a legend for the used colour codes (Consistency and Standards), inactive menu items are not greyed out or omitted (Recognition rather than recall), the user is not kept informed of the system progress (Visibility of system status), the field labels for buttons and textboxes do not exist (Presentation - Aesthetic and minimalist design) and some icons, namely the ones on the toolbar, are not concrete and familiar and therefore their function not clearly understood (Match between the system and the real world).

The chart below on Figure 5.8 shows the problems divided by severity degree. It is possible to see that 50% of the problems have a severity rate of 3, and 19% a severity rate of 4, making a total of 69% of serious and critical usability problems for Google Earth among the 16 problems found.

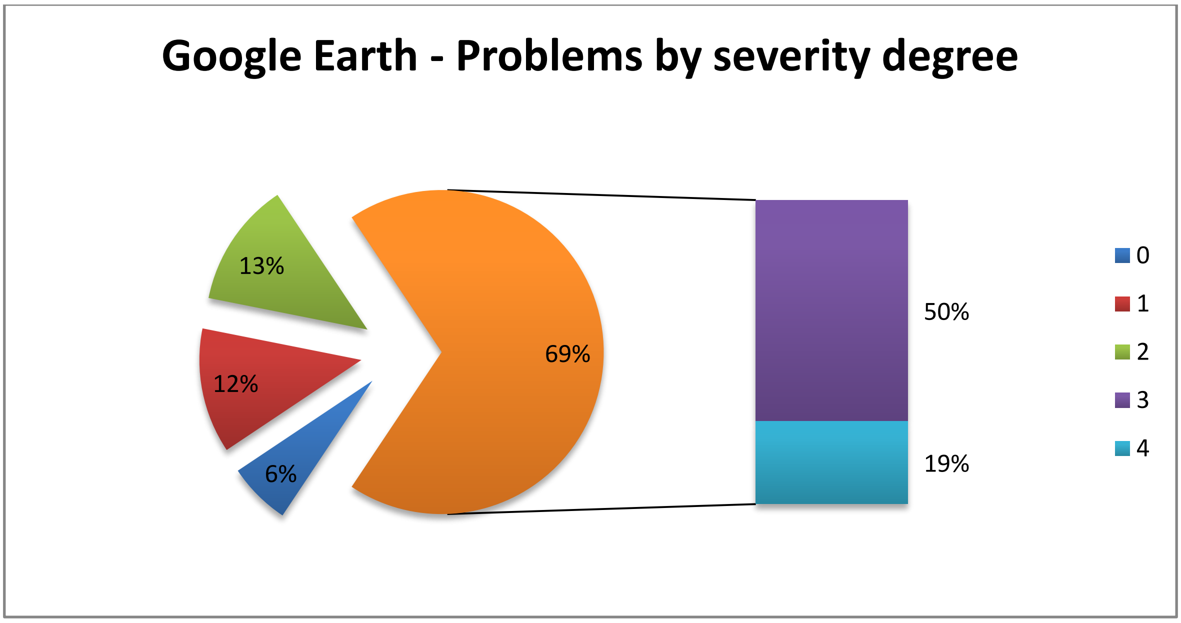


Figure 5.8: Google Earth - Problems by severity degree

5.3.4.1.2 Virtual Earth

For Virtual Earth, as can be seen on the chart on Figure 5.9, problems divide themselves mainly among the following heuristics:

- Errors prevention
- User control and freedom
- Visibility of system status

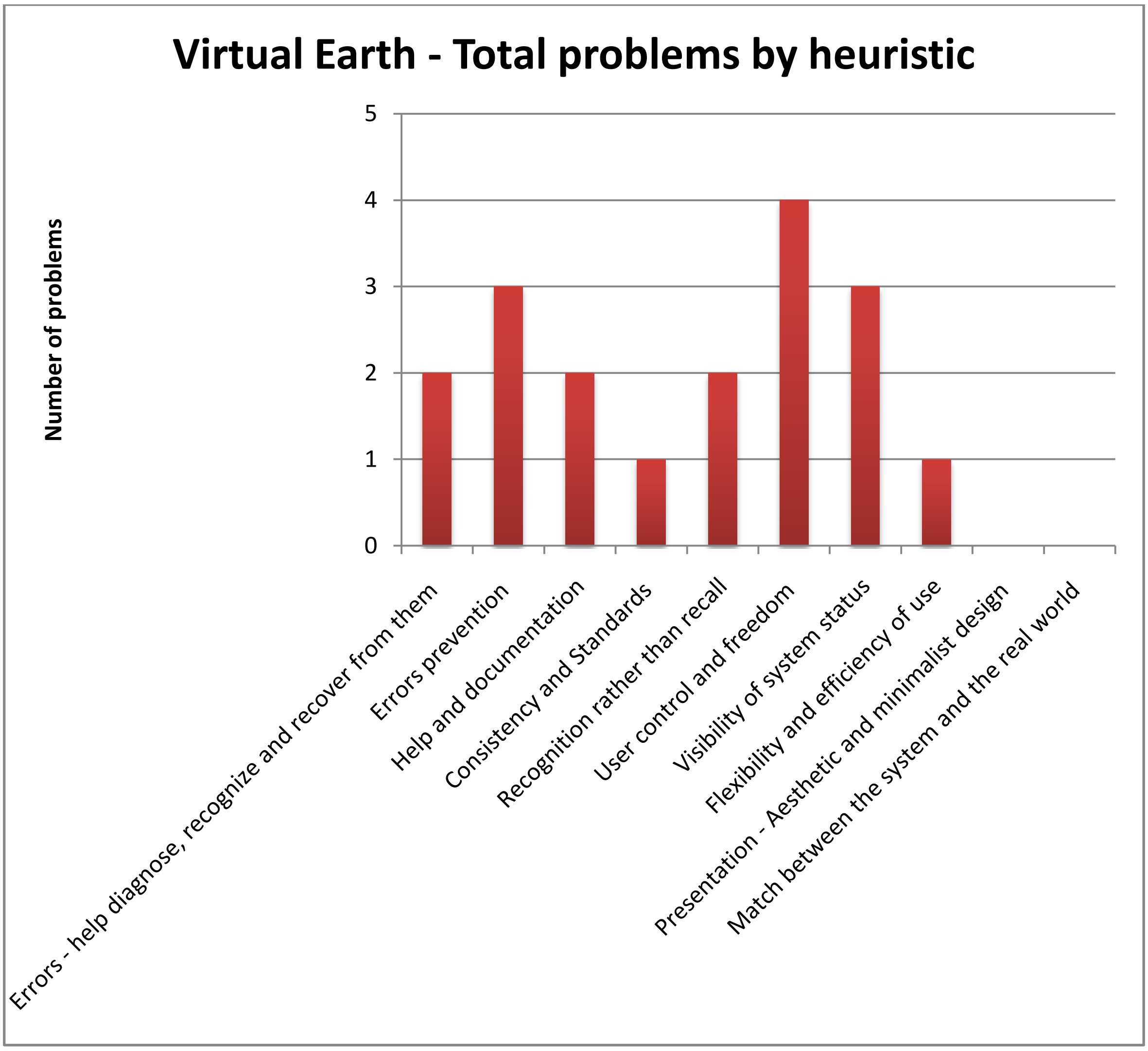
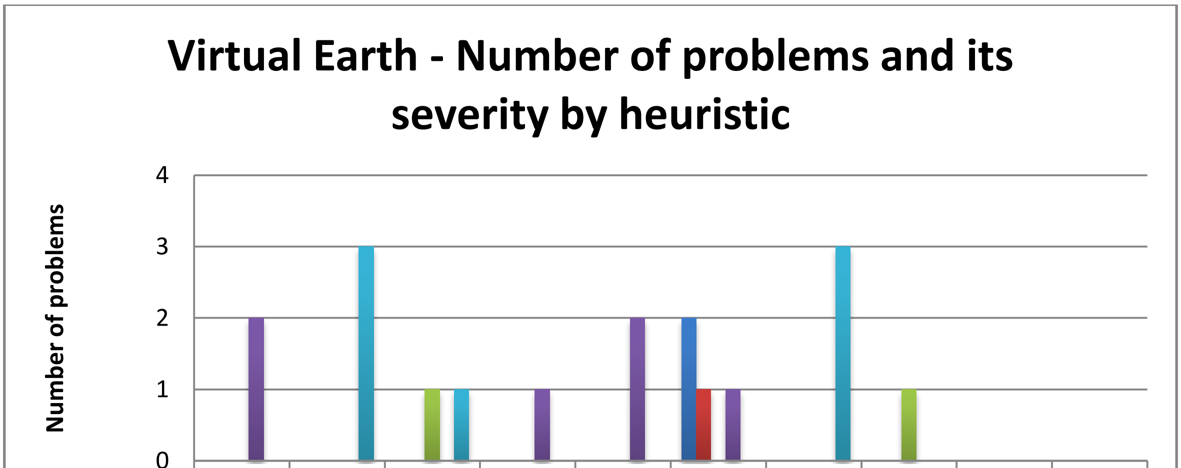


Figure 5.9: Virtual Earth - Total problems by heuristic

Among these heuristics the chart on Figure 5.10 shows that the "Errors prevention" and "Visibility of system status" heuristics are critical ones, having all the detected problems a severity degree of 4. Regarding the "Errors prevention" heuristic, it happens the same thing as with Google Earth: the system is not able to recognize potential errors and warn users about them. With "Visibility of system status" heuristic problems relate mainly with the shown information not matching what the user was expecting, the menu items not providing visual feedback about what is selectable, not selectable and what is already selected, and, like happened with Google Earth, user is not kept informed about the system's progress.

On the same chart it can also be seen that "Help and Documentation" heuristic has a problem with a severity degree of 4. This problem is related with the fact that Virtual Earth does not provide users any type of help document to support them while navigating in the application.

Other Virtual Earth major problems are related with the users not being able to contact support because it is not provided any kind of contact information or way of contacting support (Errors - help diagnose, recognize and recover from them), like in Google Earth, a legend for colour codes is not provided (Consistency and Standards), inactive menu items are not greyed out or omitted and the available options are not always clearly presented, much because the lack of visual feedback referred above, (Recognition rather than recall), finally the menu's navigation mechanism is very confuse, sometimes blocking the user to go back to a previous menu (User control and freedom).



	Errors - help diagnose, recognize and recover from them	Errors prevention	Help and documentation	Consistency and Standards	Recognition rather than recall	User control and freedom	Visibility of system status	Flexibility and efficiency of use	Presentation - Aesthetic and minimalist design	Match between the system and the real world
Severity 0	0	0	0	0	0	2	0	0	0	0
Severity 1	0	0	0	0	0	1	0	0	0	0
Severity 2	0	0	1	0	0	0	0	1	0	0
Severity 3	2	0	0	1	2	1	0	0	0	0
Severity 4	0	3	1	0	0	0	3	0	0	0

Figure 5.10: Virtual Earth - Number of problems and its severity by heuristic

Similar to what happened with Google Earth, it is possible to see on chart from Figure 5.11 below that 72% of problems are mainly distributed along severity degrees 3 and 4, among a total of 18 problems. It is important to refer that from this 72%, more than 50% of the problems have a severity degree of 4.

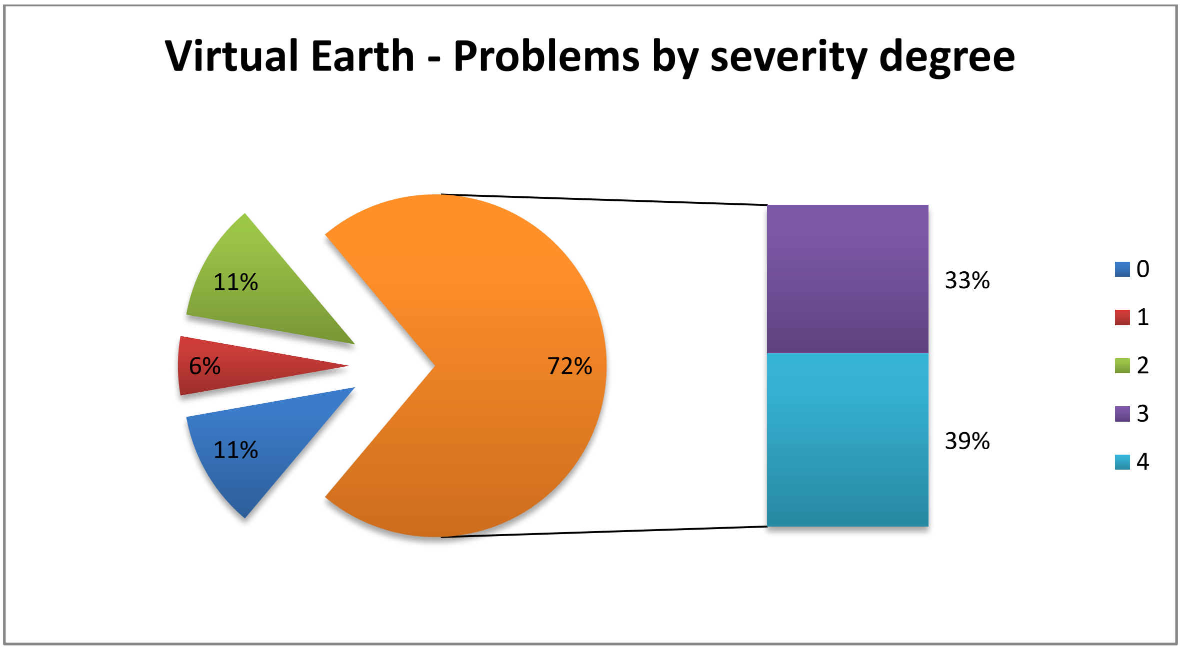


Figure 5.11: Virtual Earth: Problems by severity degree

5.3.4.1.3 Transporlis

Transporlis is an application with a lot of usability problems. As can be seen on charts on Figure 5.12 and Figure 5.13 the heuristics with more problems are:

- Errors - help diagnose, recognize and recover from them
- Errors prevention
- Help and documentation
- User control and freedom
- Visibility of system status

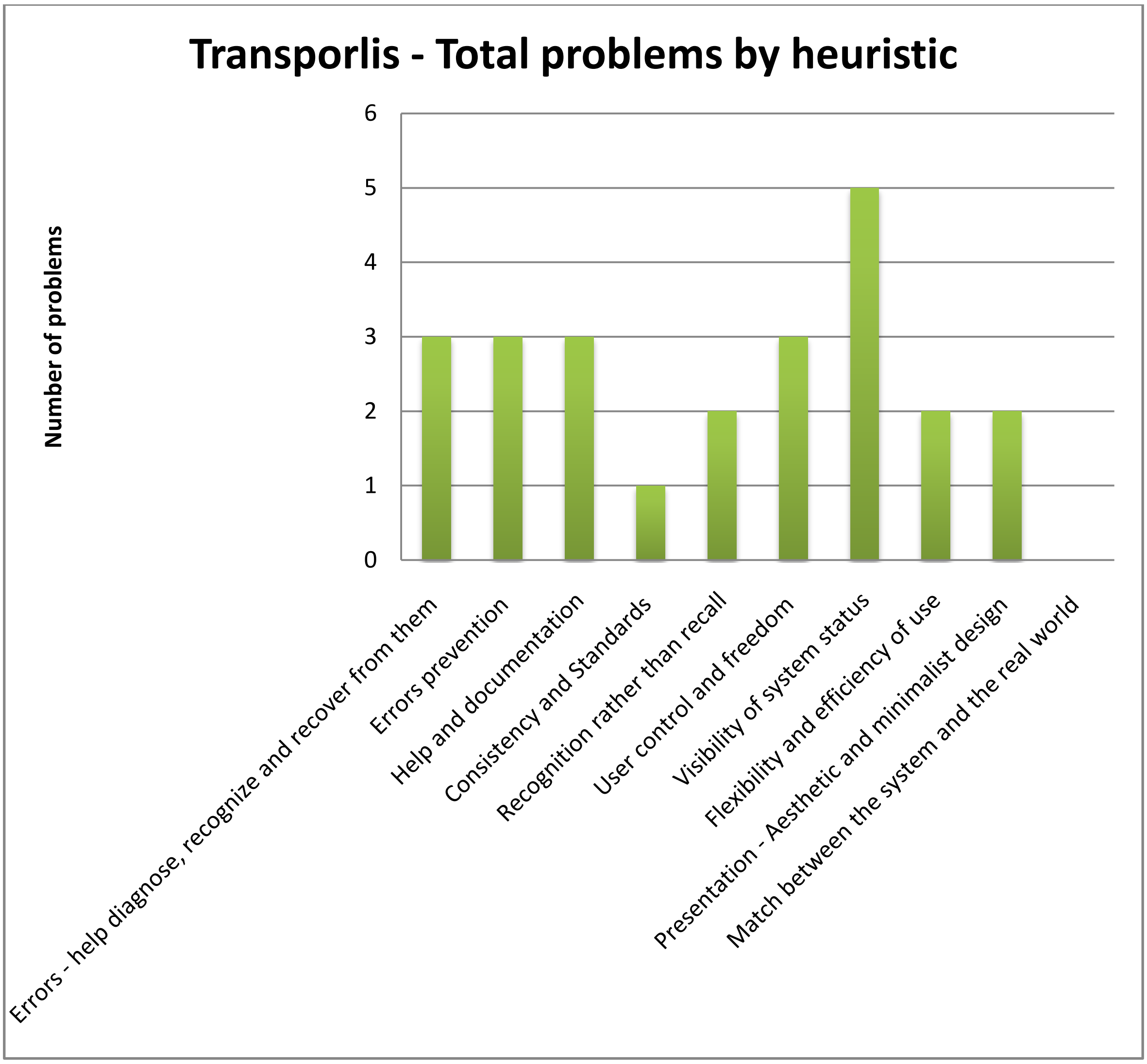
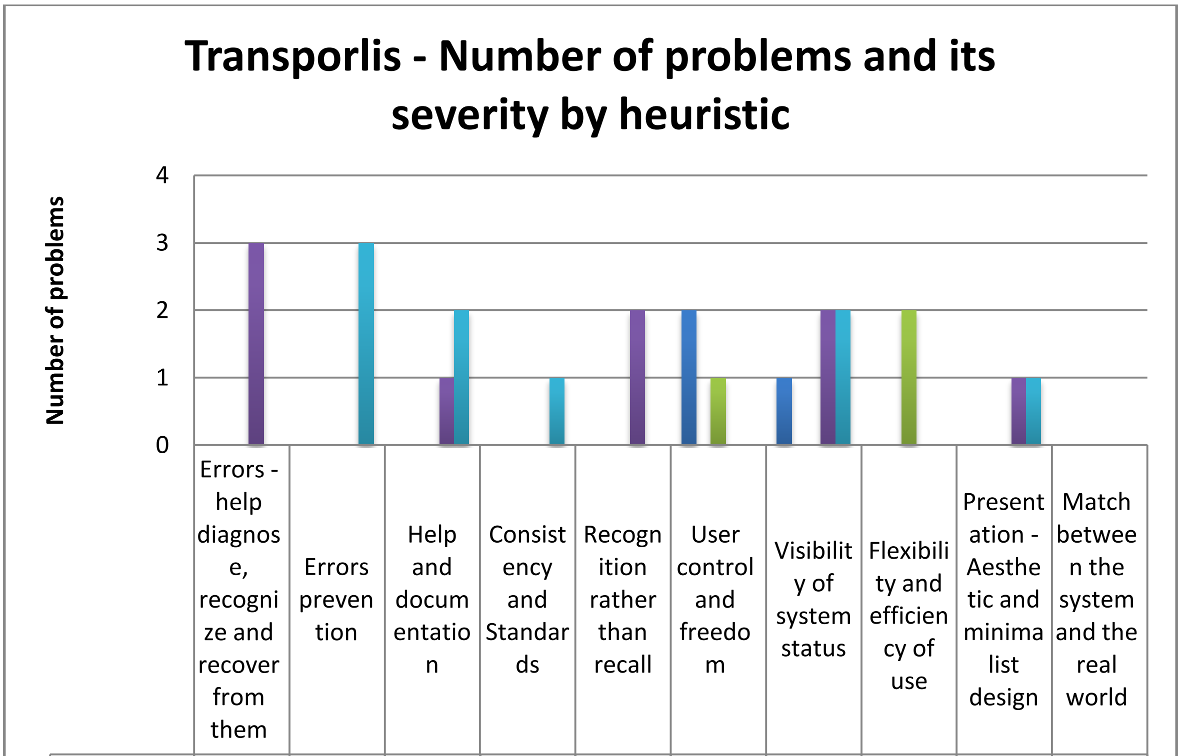


Figure 5.12: Transporlis - Total problems by heuristic

From the observation of the chart on Figure 5.13 it is possible to see the "User control and freedom" heuristic is not a critical one once it has problems with low security degree. The other referred heuristics plus "Consistency and standards", "Recognition rather than recall" and "Presentation - Aesthetic and minimalist design" are critical ones. Major problems are:

- Error messages are not clear and the system does not provide the means to user contact details for assistance neither means to contact support (Errors - help diagnose, recognize and recover from them);
- The system does not recognize errors, neither prevents or warns users about them (Errors prevention);
- There is no online help available (Help and documentation);
- The system does not follow conventions and user expectations, namely the map interface (Consistency and standards);

- The information regarding links and available options is not clearly presented (Recognition rather than recall);
- The system does not provide visual feedback for every action and it is not clear what information is available at the current location (Visibility of system status)
- The interface is confuse, too complex and not aesthetically pleasing (Presentation - Aesthetic and minimalist design).



	Errors - help diagnose, recognize and recover from them	Errors prevention	Help and documentation	Consistency and Standards	Recognition rather than recall	User control and freedom	Visibility of system status	Flexibility and efficiency of use	Presentation - Aesthetic and minimalist design	Match between the system and the real world
Severity 0	0	0	0	0	0	2	1	0	0	0
Severity 1	0	0	0	0	0	0	0	0	0	0
Severity 2	0	0	0	0	0	1	0	2	0	0
Severity 3	3	0	1	0	2	0	2	0	1	0
Severity 4	0	3	2	1	0	0	2	0	1	0

Figure 5.13: Transporlis - Number of problems and its severity by heuristic

Considering the severity of the found problems, it is important to refer that 75% of the problems, among 24, have a severity degree of 3 and 4. It is also important to refer that 50% of this 75% are problems of a severity degree of 4. The Figure 5.14 illustrates the case.

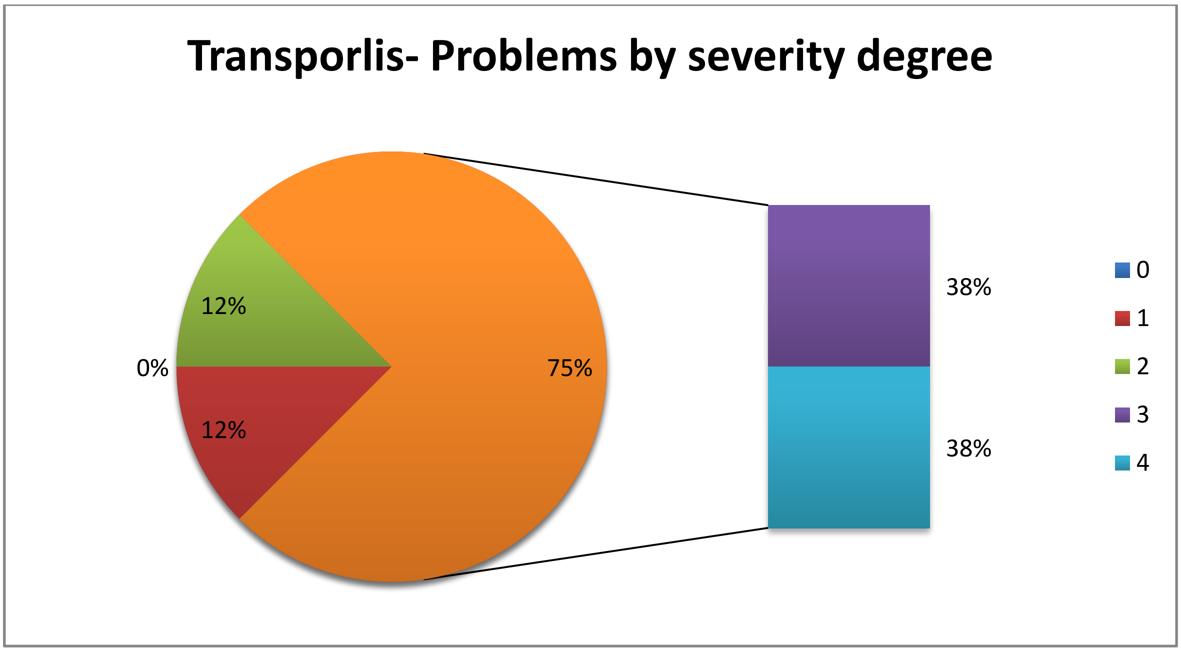


Figure 5.14: Transporlis - Problems by severity degree

5.3.4.1.4 Itinerarium

Itinerarium follows the same path as Transporlis, having been identified some serious problems. From the chart on Figure 5.15 it is possible to see that problems are distributed mainly by the first three heuristics:

- Errors - help diagnose, recognize and recover from them
- Errors prevention
- Help and documentation

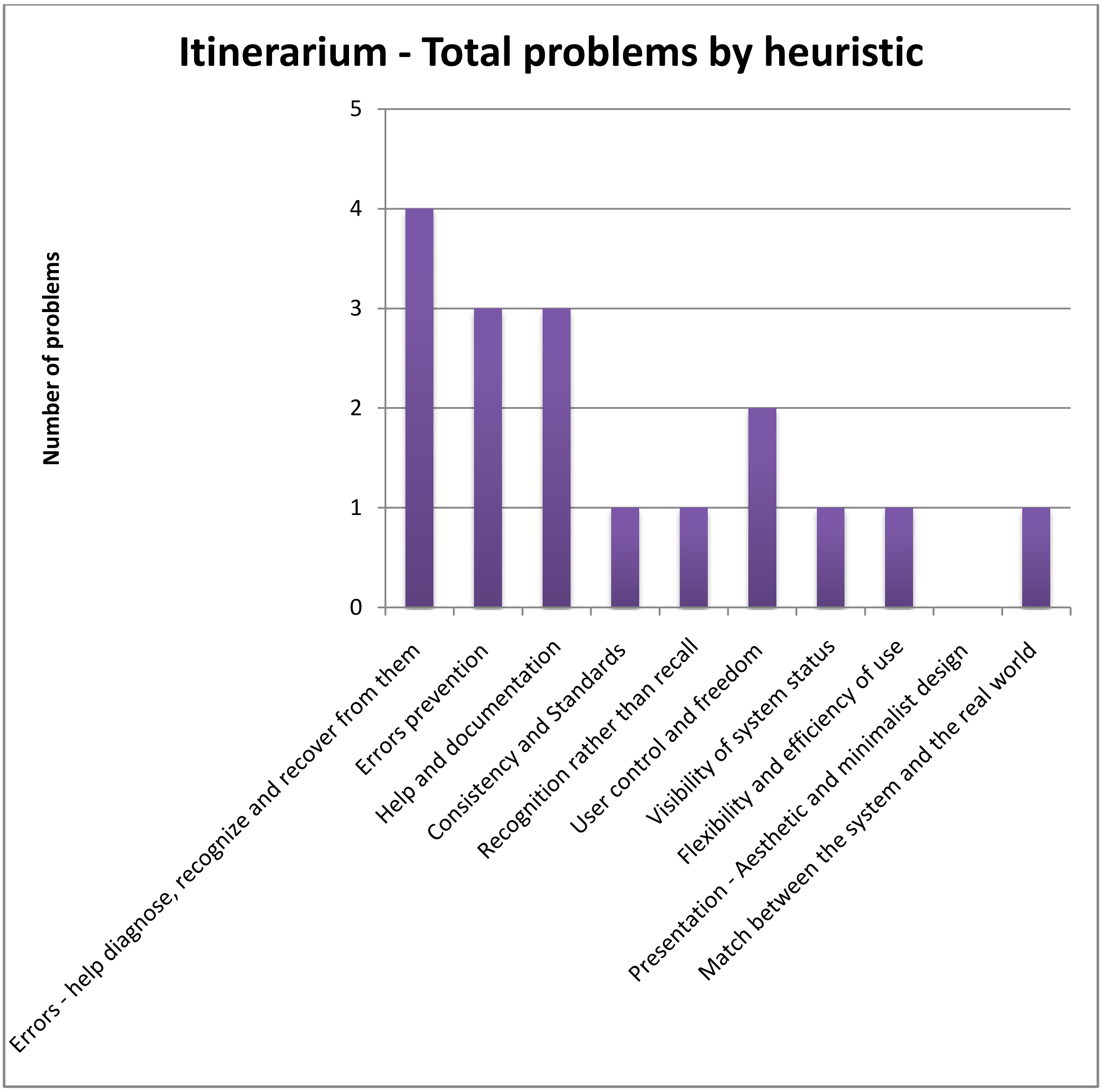
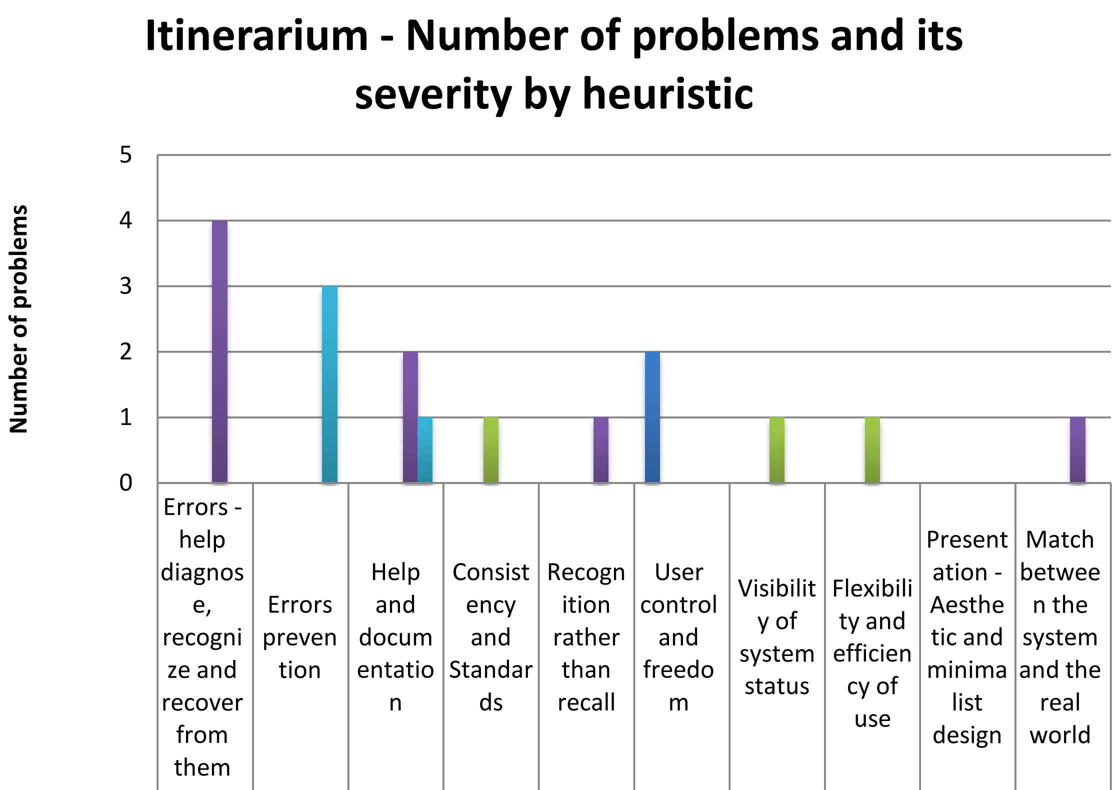


Figure 5.15: Itinerarium - Total problems by heuristic

Analyzing the chart on Figure 5.16 it is possible to see that the most critical heuristics are “Errors prevention” and “Help and documentation”.

Associated with the first heuristic are problems associated with the fact that the system is not able to recognize potential errors, and prevent and warn users about them. The problems associated with the “Help and documentation” heuristic exist simply because there is not available any type of help documentation.



	Errors - help diagnose, recognize and recover from them	Errors prevention	Help and documentation	Consistency and Standards	Recognition rather than recall	User control and freedom	Visibility of system status	Flexibility and efficiency of use	Presentation - Aesthetic and minimalist design	Match between the system and the real world
Severity 0	0	0	0	0	0	2	0	0	0	0
Severity 1	0	0	0	0	0	0	0	0	0	0
Severity 2	0	0	0	1	0	0	1	1	0	0
Severity 3	4	0	2	0	1	0	0	0	0	1
Severity 4	0	3	1	0	0	0	0	0	0	0

Figure 5.16: Itinerarium - Number of problems and its severity by heuristic

Regarding other heuristics, there are also some associated problems. For example, the lack of information about support contacts and ways to contact support, and error messages are also considered not being clear (Errors - help diagnose, recognize and recover from them), inactive menu items are not omitted or greyed out (Recognition rather than recall) and the used icons are not very familiar (Match between the system and the real world).

About problem's severity of Itinerarium it follows the same line as for the other applications. About 70% problems, among 17, are of severity 3 and 4. This case is illustrated on the chart on Figure 5.17.

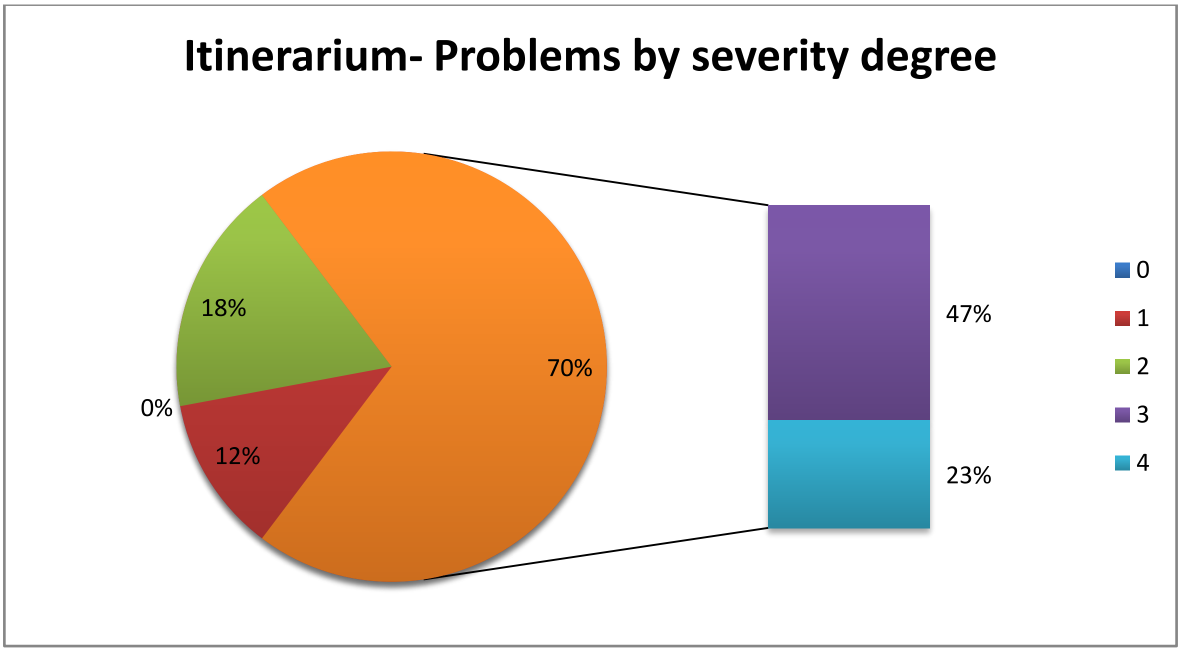


Figure 5.17: Itinerarium - Problems by severity degree

5.3.4.2 Usability Tests

On this section, the obtained results from the usability tests conducted on each application will be analyzed. First the users' profile will be analyzed, then the major problems identified in each application will be shown, regarding each scenario, the users' frustration level will be analyzed, and finally the SUS score will also be analyzed.

5.3.4.2.1 Users Profile

Like it was previously said on the beginning of each test users had to fill a demographic survey. This survey had the goal of helping tracing the profile of the users. The total of users that participated on the usability tests were 5.

Table 5.1: Results from the demographic survey

	User 1	**User 2**	**User 3**	**User 4**	**User 5**
Grade Level	College	College	College	College	College
Age Group	25-34	18-24	25-34	25-34	18-24
Gender	Male	Male	Male	Male	Male
Years using the web	11	7	10	10	10
How often do you use the Internet?	Daily	Daily	Daily	Daily	Daily
Have you ever used an online map or a journey planner?	Yes	Yes	Yes	Yes	Yes

With the aid of Table 5.1 it is possible to trace the following users' profile:

- All the users were males;
- All the users have a college degree;
- 60% of the users have an age between 25-34 years and 40% between 18-24;
- The Web is no strange for all of them, being the average of years using the Web 9,6;
- All of them had already used some kind of online map or journey planner.

It is also important to notice that 3 users were computer engineers, 1 was a designer and 1 an economist.

5.3.4.2.2 Google Earth

The major problems users identified on Google Earth were the following:

1. Placemarks are not selectable on “Directions” dropdown lists (“from” and “to”)
2. Route information it is not visible
3. It is not possible to insert points on the middle of the route
4. Poor graphics quality
5. It is not intuitive to add a placemark. (it is not possible to right click the place with the mouse)
6. Layers menu is not visible
7. Layers information is not well organized (lack of information)
8. Function of buttons on the toolbar above the map is not understood
9. Map does not correspond to the reality (obsolete information)
10. It is only possible to move placemarks while they are being edited
11. It is difficult to find the wanted layer on the layer menu
12. It is a an application that you must install on your PC

Obviously not all users identified all the problems, some of them were more frequent than others. On Table 5.2 it is possible to see the problems, the users who identified them and the related scenario. Some problems are not related to any scenario as were problems that were referred on discussing the system with the users.

Table 5.2: Google Earth - Problems found by user and scenario

Problem	User 1	User 2	User 3	User 4	User 5	Scenario	Tasks
1	x	x				1	1.1; 1.2
2	x	x			x	1	1.3
3	x	x	x	x	x	1	2
4		x	x			-	-
5		x				1	1.1; 1.2
6		x		x		2	1
7		x	x	x		2	1
8		x	x	x		-	-
9			x			-	-
10				x		1	1.1; 1.2
11			x	x		-	-
12					x	-	-

On the chart from Figure 5.18 it is possible to see the problems frequency in a more friendly way.

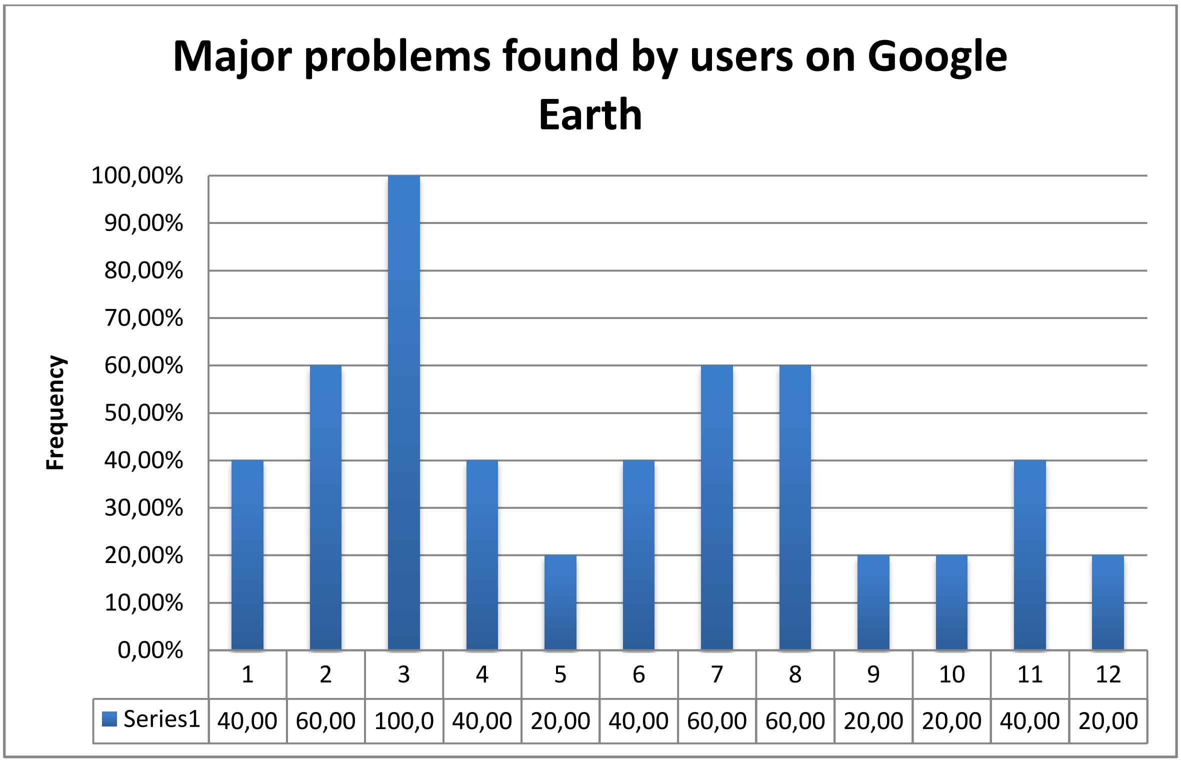


Figure 5.18: Google Earth - Major problems found by users

Analyzing both the chart and the table it is possible to see that all users identified one problem: the problem of not being possible to insert a point on the middle of a route. This task is present on scenario 1, task 2 where users had to find the route from their homes to Barcelona passing by Valencia. The users found this task extremely difficult because they were not able to move the route or insert a middle point on it. Ironically Google Maps allows doing this. To do this task, users had to search for two routes. One from home to Valencia and another from Valencia to Barcelona, then, on the left sidebar, they had to fill the checkboxes of each route to view the route on the map. However it is not possible to see the route total information (number of Km and estimated travel time).

There are also other problems that were unveiled during usability testing. Namely 60% of users claimed that route information was not visible. In fact, this information was displayed at the end of the route description. If it was a long route it was necessary to scroll down to view the route information. Users did not found that route information was placed correctly and argued that it should be highlighted putting it on the top of the route description or in the map, above the route line.

60% of users also argued that the layers menu was not well organized. Layers are organized in a tree and it is not always clear what each parent leaf means, also most of the information users needed was all under one parent leaf, the “Places of Interest” leaf, which is a very general term. Problem number 11 (“It is difficult to find the wanted layer on the layer menu”) is related to this problem too. Also related to the layers menu is problem number 6 (“Layers menu is not visible”). Sometimes users found it was difficult to find the layers menu on the sidebar. That happened because the route description menu got bigger and the other menu below got smaller, becoming sometimes so small that it was difficult to find it.

Another problem was related with the toolbar placed above the map. Users did not find it useful and the functions of some buttons were not understood also.

Placemarks raised also an issue. Users normally added a placemark for their start and end points, and then they went to the “directions” tab, and on the textboxes “From” and “To” inserted the names of the placemarks they just created, and clicked on the “search” button. After this users received an error message explaining them that the “search did not return any results”. What happened was that Google Earth does not use the name of placemarks if the route search is performed in the explained way. Only works if the placemark is right-clicked and then the options “Directions from here” or “Directions to here” selected. Users did not like the fact that the way they performed the search did not work and claimed that the system should recognize the placemarks' names on the search textboxes.

The quality of the satellite pictures was also a point users claimed. Some areas of the map had poor quality pictures and they claimed that it was bad because they couldn't see the area in more detail.

One point that is important to notice is that a user claimed that the fact that Google Earth is an application that must be installed on your PC is a limitation. It is not possible to access all the functionalities that the system provides anywhere, at any time, which raises accessibility issues.

These problems are related to the user frustration level registered for each scenario task. Analyzing the chart on Figure 5.19 and comparing it to Table 5.2 and the chart on Figure 5.18 it is possible to see that they are related. The problems that registered more frequency, relating them with the scenario task where they appeared, are the scenario tasks that register a higher user frustration level. For example, as we can see on Figure 5.18 problem 3 has a frequency of 100%. On Table 5.2 it is possible to see that this problem is related to scenario 1 task 2. On the chart from Figure 5.19 we can see that on this scenario and task users registered the highest frustration level.

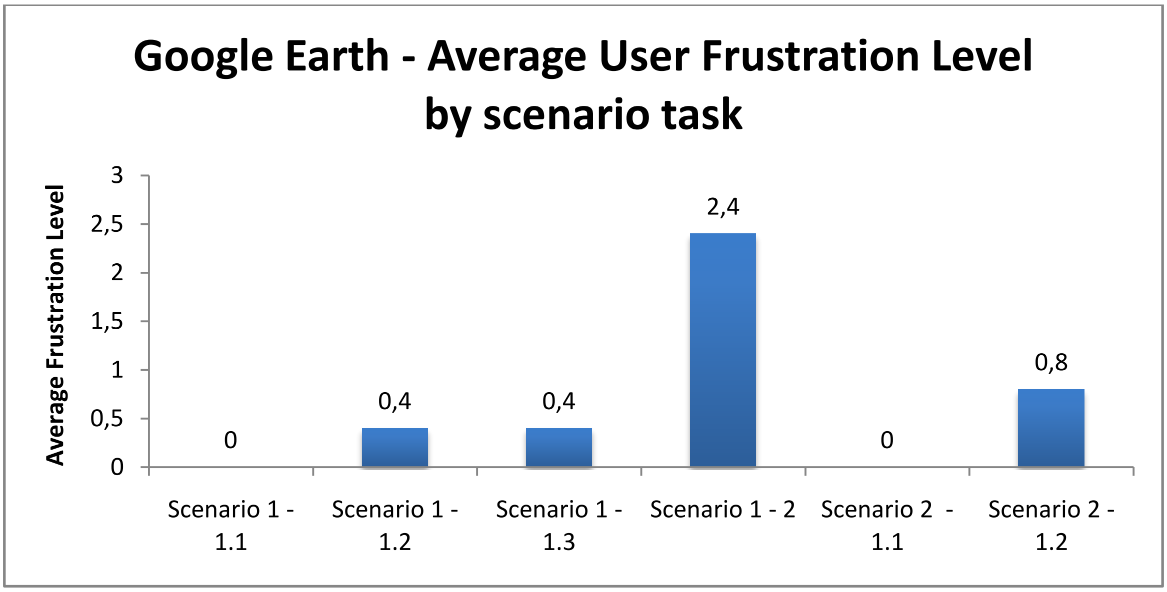


Figure 5.19: Google Earth - Average user frustration level by scenario task

At end users answered the System Usability Scale questionnaire. The obtained for each user is shown on Table 5.3.

Table 5.3: Google Earth - SUS Score by user

Users	SUS Score
User 1	82,5
User 2	80
User 3	70
User 4	82,5
User 5	62,5

All scores state that the overall user satisfaction with the system was pretty good. The average score is 75,5 which, considering that the maximum score is 100, reveals an overall very good user satisfaction with the system.

5.3.4.2.3 Virtual Earth

From the usability testing performed on Virtual Earth some interesting usability issues aroused. Some of the problems that appeared on Virtual Earth are very similar with some Google Earth problems. Namely problem number 4 is exactly the same as Google Earth's problem number 3. So the following usability problems aroused on Virtual Earth:

1. It is not possible to move a pushpin edit box
2. The task of adding a pushpin is confuse
3. It is not intuitive to change the distance units
4. It is not possible to add middle points on the route
5. Collections information is very poor
6. The search results are poor
7. The user is able to select unavailable services ("1-click directions")
8. After closing the sidebar it is not easy to put it back
9. System inconsistency (lose pushpins; poor user control; functionalities are not well integrated, system crashes)
10. It is difficult to find a specific category on the collections
11. Navigation with bird's eye is more difficult
12. The saved pushpins are not selectable on the directions search boxes
13. It is not easy to understand the Collections concept
14. It is not possible to save the routes

As can be seen on the chart from Figure 5.20 and on Table 5.4 there are some problems that stand out from the rest. That is the case of problems 4, 5, 6, 9 and 10.

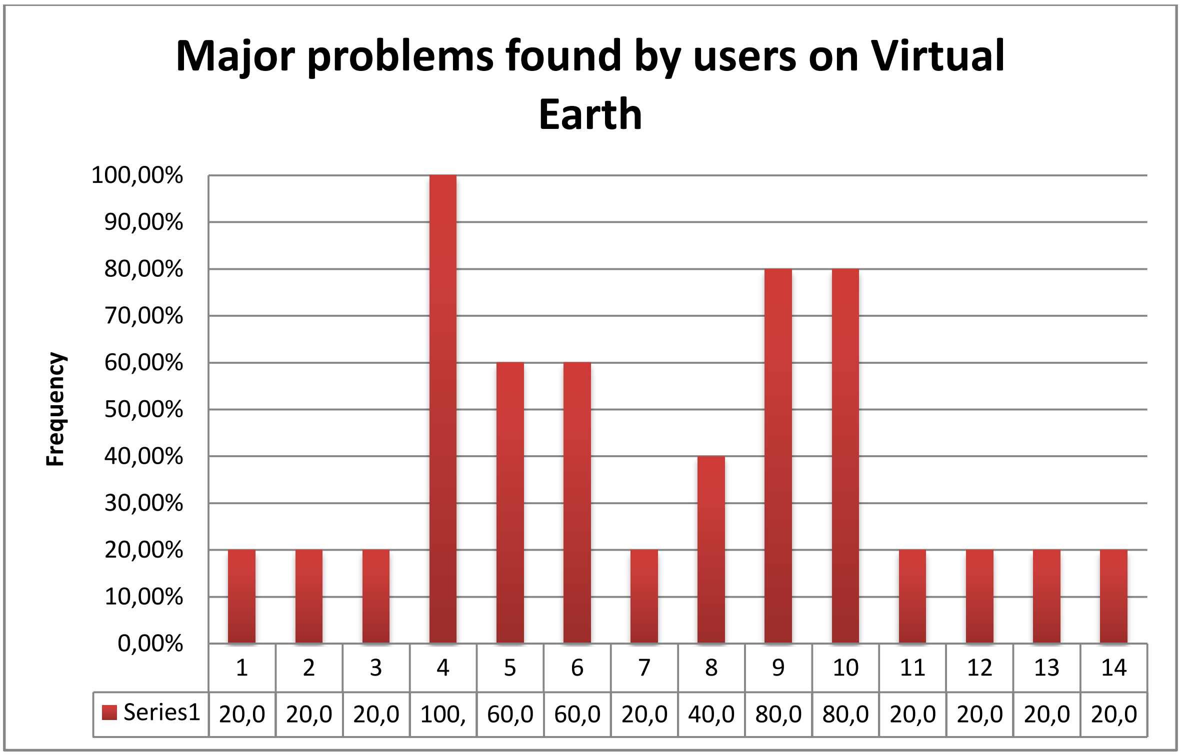


Figure 5.20: Virtual Earth - Major problems found by users

Table 5.4: Virtual Earth - Problems found by user and scenario

Problem	User 1	User 2	User 3	User 4	User 5	Scenario	Tasks
1	x					1	1.1; 1.2
2	x					1	1.1; 1.2
3	x					1	1.3
4	x	x	x	x	x	1	2
5	x			x	x	2	1.1; 1.2
6	x		x	x			
7		x					
8		x		x			
9		x	x	x	x		
10		x	x	x	x	2	1.1; 1.2
11		x					
12			x			1	1.3
13			x			2	1.1; 1.2
14				x		1	1.3

Once again users were not able to insert a middle point on the route (problem 4). Most of the users gave up this task feeling frustrated. In fact there is no way in Virtual Earth to insert a middle point on the route or edit the route. The only way to get through the problem is to calculate the route from home to Valencia and then another search from

Valencia to Barcelona. However this raises another problem as it is not possible to save a previously calculated route (problem 14).

Also related to the Collections some problems appeared. Collections save information about interesting places. They function in a similar way as the layers menu on Google Earth. Users claimed first that the term “Collections” does not explain well the concept behind it and that the information it contains is very poor in terms of content and organization, making it difficult to find a specific category.

During the tests the system was very unstable, occurring some system crashes where the user had to restart Virtual Earth, some pushpins were lost while the user was trying to calculate his route, also it was noticed a bad integration of functionalities. For example, sometimes on the directions textboxes users wrote as destination point “Barcelona, Spain”, then they right-clicked the pushpin that marked their home to set it as a start point, and the system cleaned the destination from the search textbox, so he had to write it again. Users claimed that these functionalities should be integrated so they would be able to perform the task as they tried.

It is also important to refer that sometimes users closed the left sidebar by accident and then they did not know how to put it back. The only way to restore it was to click, for example, on the “welcome” link, but then they lost the information and position they had before closing the sidebar.

It is also important to notice that 20% of users found the map navigation with bird’s eye a little confuse as they were only able to see one map area at a time, and the loading periods between map areas were very long.

Like in Google Earth, with Virtual Earth is also possible to establish a connection between the average user frustration level, visible on chart on Figure 5.21, and the problems’ frequency and corresponding scenario tasks visible on Table 5.4 and on the chart on Figure 5.20.

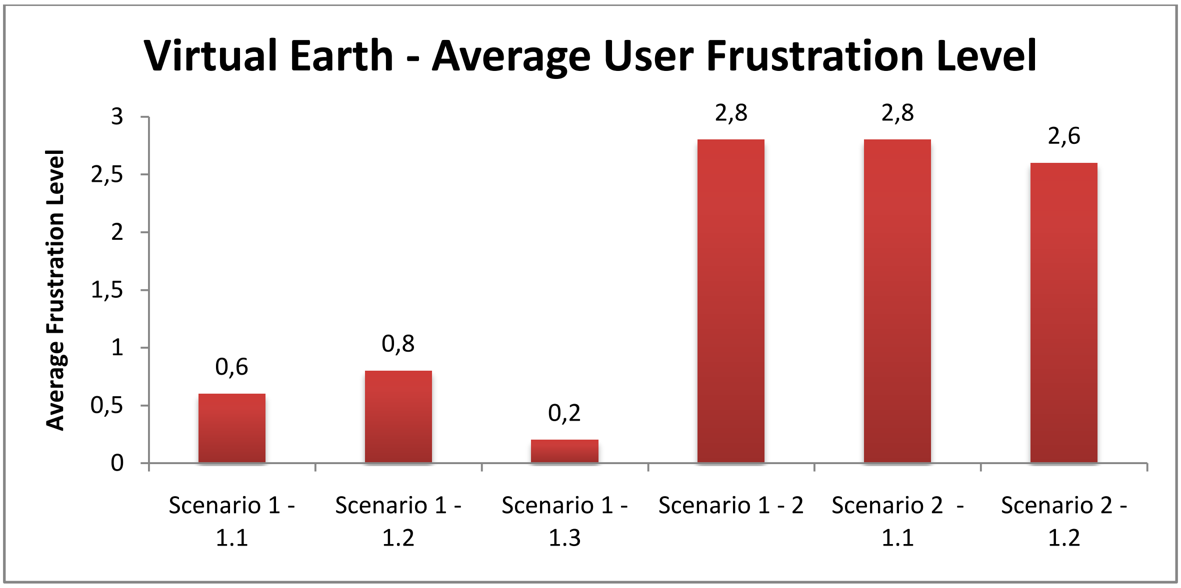


Figure 5.21: Virtual Earth - Average user frustration level

Regarding the SUS questionnaire, users answered at the end, Table 5.5 shows the results were good overall. In spite of having some bad scores, namely from users 1 and 3, the average SUS score of 61,5 shows a reasonable user satisfaction.

Table 5.5: Virtual Earth - SUS score by user

Users	SUS Score
User 1	45
User 2	72,5
User 3	35
User 4	87,5
User 5	67,5

5.3.4.2.4 Transporlis

On this system users had to find which buses to catch to go from one place to another, first without using the map and then only using the map. Distinguishing between these two types of searches allows knowing how well is the map functionality integrated with the rest of the system for one hand, and on the other hand how useful is that functionality for users.

From the usability tests performed it is possible to see that the application needs a usability improvement, especially on the map functionality. Users found this functionality very frustrating, in the few times it was available.

The obtained problems from the usability tests performed on Transporlis were the following:

1. The website's interface is confuse

2. The search results are not visible
3. Poor results feedback
4. Map unavailable
5. The time is shown in minutes
6. Letter size is too small
7. Is very slow to show the results
8. The map interface is very confuse
9. Map loadings are too slow
10. The map contents are poor
11. The search terms are confuse
12. The search results are not available in a print version

Observing Table 5.6 and Figure 5.22 it is important to notice that on 3 of the 5 tests performed the map service was unavailable (problem 4), not allowing users to perform their search on the map. Users did not like it, however they stated without using the map the task was easy, and the users who got to use the map said it was much easier the other way. This problem, from the facilitator's perspective, shows a weak availability of the service as the tests were conducted on different days at a different hour.

Table 5.6: Transporlis - problems found by user and scenario tasks

Problem	User 1	User 2	User 3	User 4	User 5	Tasks
1	x	x	x		x	-
2	x	x	x	x		1.1; 1.2
3	x	x	x		x	1.1; 1.2
4	x			x	x	1.2
5	x					1.3
6	x					-
7		x				1.1; 1.2
8		x	x			1.2
9		x	x			1.2
10			x			1.2
11				x		1.1
12					x	1.3

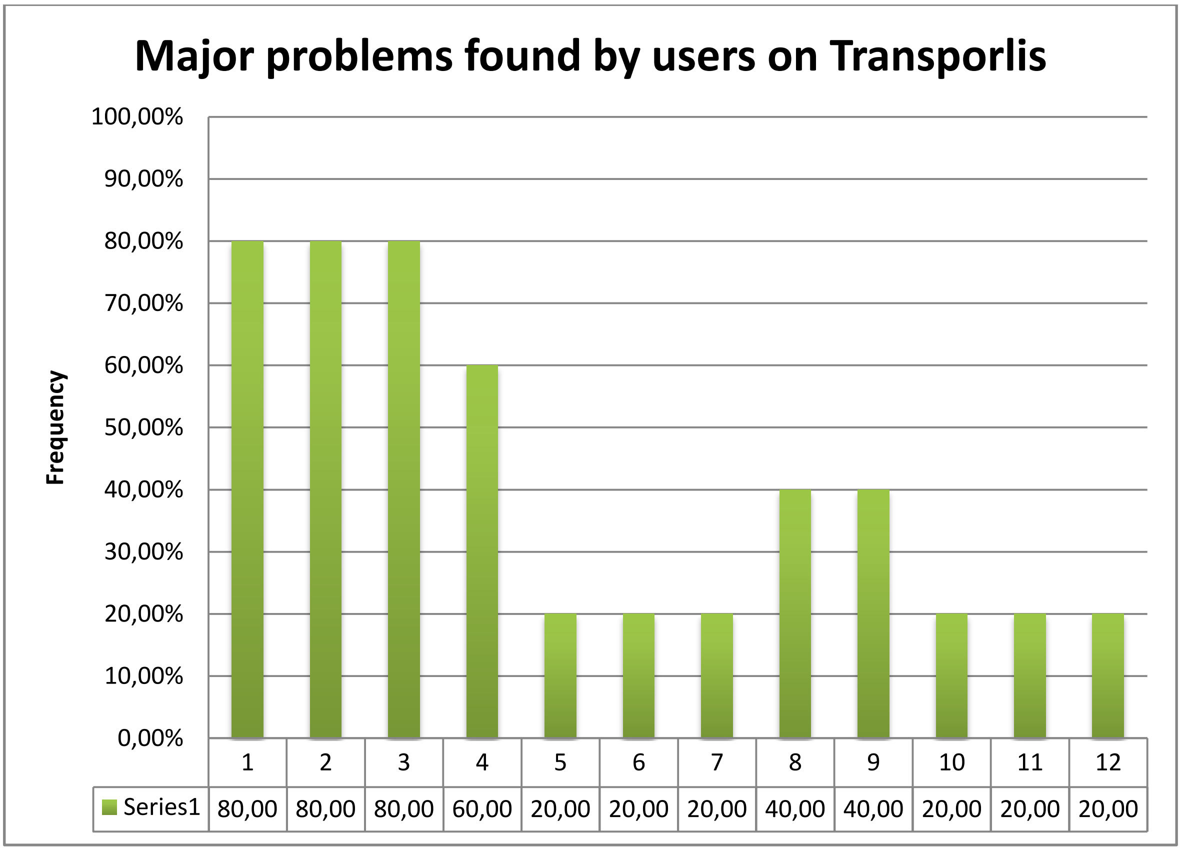


Figure 5.22: Transporlis - Major problems found by users

Other problems identified on Transporlis are related to the poor system feedback (problem 3) and the fact that the results of the search not being visible (problem 2). When users finished indicating their start and end points and clicked on the search button the system did not provided any feedback while calculating the results or when it finished. So, as the results appeared on the bottom of the page and it was necessary to scroll down to see them, users did not knew the system had already finished calculating the results, and thought the system was malfunctioning and tried again to perform the search. After losing some time, users discovered the search results and when they did, they felt frustrated because they lost time performing all over again when the information was already present. They claimed that it should be provided some visual feedback when the search ends and that the results should be put on a more visible place and highlighted.

Other identified problems on Transporlis were the interface and design of the site which users claimed it is confusing, the space is not being well used, and that the letter size is too small, making the system less appealing and accessible.

The map interfaced was also criticised as it did not follow the “normal way” (conventions), it was too small and slow on the loading periods.

Concerning the users’ frustration level, observing the chart on Figure 5.23 it is possible to see that the critical point of the system is related to task 1.2 which is about the map service. Once again it demonstrates that the map is a major problem on Transporlis and its value to the system should be re-evaluated.

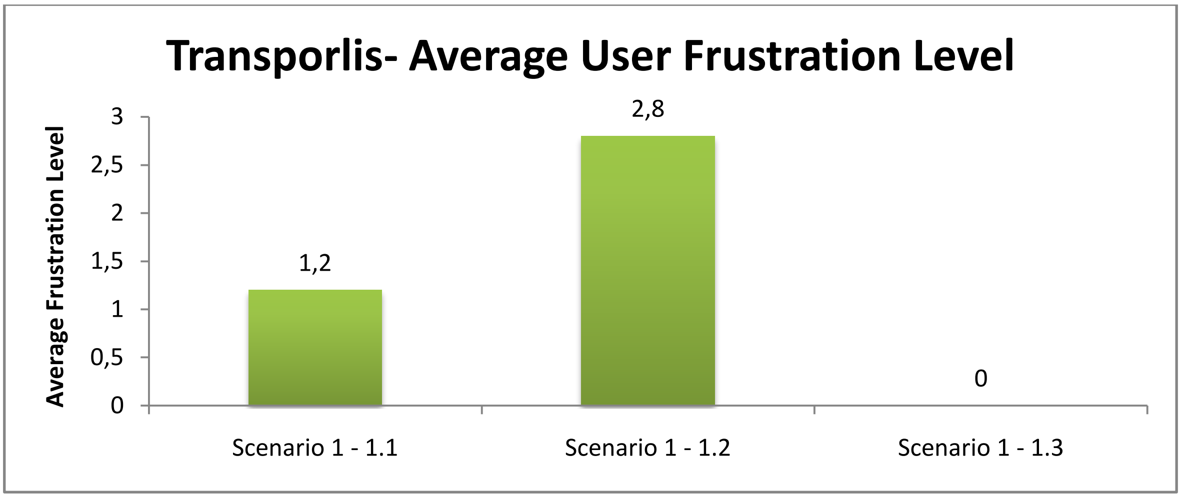


Figure 5.23: Transporlis - Average user frustration level

Regarding the SUS score, as can be seen on Table 5.7 some users were much more satisfied then others. Curiously the users who were less satisfied with the system were the ones that tried performing their search using only the map. For the others the map service was unavailable. Overall the user satisfaction was reasonable, being the average SUS score 57.

Table 5.7: Transporlis - SUS score by user

Users	SUS Score
User 1	77,5
User 2	37,5
User 3	40
User 4	80
User 5	50

5.3.4.2.5 Itinerarium

The usability tests conducted on Itinerarium were very similar to the Transporlis tests, only the end and start points were altered to fit the city they applied to. So on Itinerarium users had also to perform their searches using only the search boxes and then only using the map. Once again the search using the map showed to be more difficult than the other type which led users to raise questions about its value to the system.

The problems identified by users were the following:

1. The map is too small
2. It is difficult to navigate on the map
3. The search results are not well distributed

4. The letter size is small
5. The website's design is not very good
6. Map loadings are slow
7. Map interface is confuse
8. Map is unavailable
9. The website interface has many underused spaces
10. It is difficult to read the search results
11. It is not provided obvious feedback when the user selects the point on the map

Reading this list and observing Table 5.8, it is possible to see that on Itinerarium 50% of the identified problems are related to the map. Also from the chart on Figure 5.24 it is possible to see that some of these problems occur at higher frequencies.

Table 5.8: Itinerarium – problems found by user and scenario tasks

Problem	User 1	User 2	User 3	User 4	User 5	Tasks
1	x		x			1.2
2	x			x	x	1.2
3	x		x			1.3
4	x					
5	x					
6	x	x	x	x	x	1.2
7		x	x	x	x	1.2
8		x				1.2
9		x	x			
10			x			1.3
11	x		x		x	1.2

The more critical problems with the map are the fact that he is too small (problem 1), and users would like to have a more wide view of the map without having to zoom in or out or scrolling, actions that led to the problem of the slow loading times (problem 6). Other problems with the map service are about its interface being confuse (problem 7) which make it more difficult to navigate (problem 2). Also when users selected the point they wanted on the map it was not obvious that the point stayed selected, because the moment users clicked on the point of the map, the window was closed automatically, and on the site appeared written, in normal letters and colour, that the point was chosen on the map. What happened was that users stayed confused not knowing what happened and took some time finding the information that the point was selected on the page (problem 11).

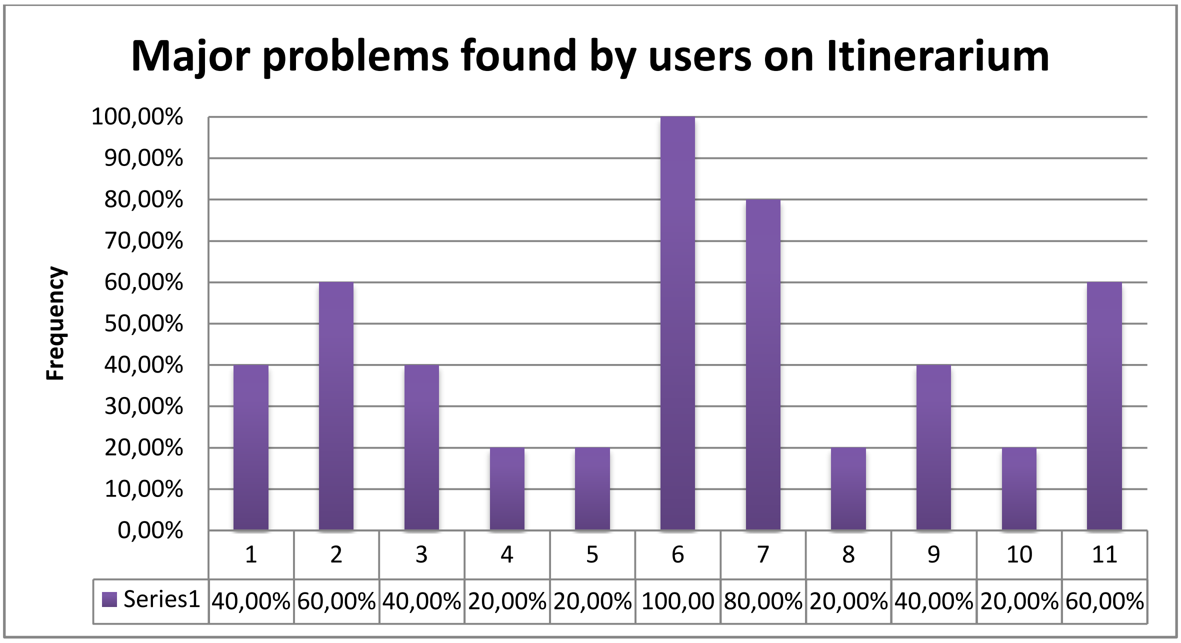


Figure 5.24: Itinerarium - major problems found by users

Although there are many problems with the map service the problem all the users raised was about the website's design (problem 5). Users claimed that there were many underused spaces (problem 9), the letter size was too small and it was difficult to read the search results (problem 10) because the background colour was to dark and the letters were dark too. Also users found it difficult to read because the information was too compressed (problem 3). Users argued that the different parts of the results should be differentiated and highlighted in different ways.

Regarding the users' frustration level, as can be seen on chart from Figure 5.25 the critical point is clearly on task 1.2, which was where users had to perform their search using only the map. Once again the results show that the map service only complicates the system, not adding it any value.

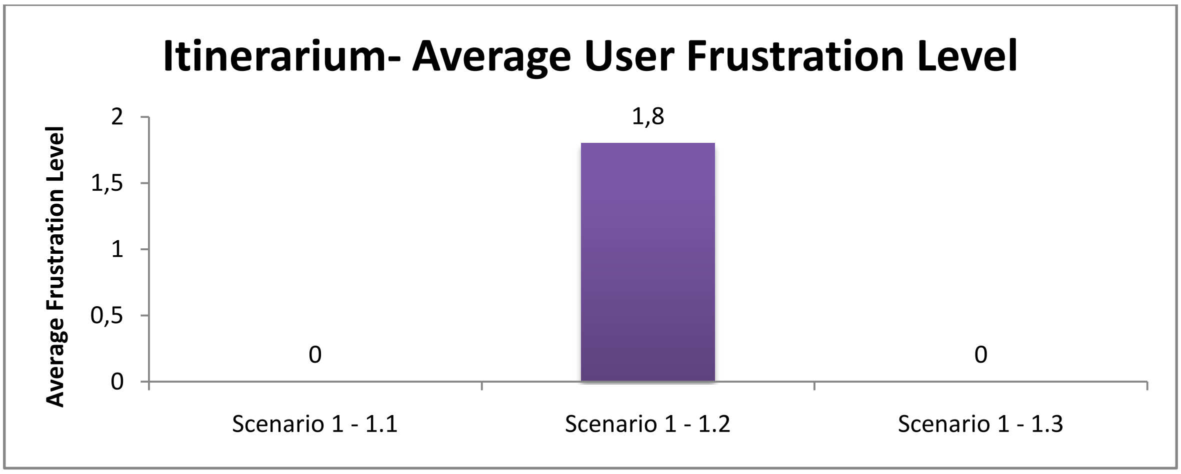


Figure 5.25: Itinerarium - Average user frustration level

Concerning the SUS score, present on Table 5.9, the results were very good having the average user satisfaction the value of 79.

Table 5.9: Itinerarium - SUS score by user

Users	SUS Score
User 1	75
User 2	90
User 3	77,5
User 4	75
User 5	77,5

5.3.4.3 Google Earth vs. Virtual Earth

From the comparison of Google Earth and Virtual was possible to see what system satisfied users most. Also by comparing the usability problems detected on both of them allowed to have a better understanding of their strong and weak points and how to avoid them.

Concerning the heuristic evaluation, on the chart from Figure 5.26 it is possible to see for each heuristic which was the system that behaved better. For this purpose to each heuristic was given a weight, equal to the sum of problems of that heuristic multiplied each one by its severity degree. So the system with less problem weight was the one that behaved better.

However from observing Figure 5.26 it is not possible to say that one system it is better than the other. There are points where Google Earth is better than Virtual Earth and vice versa. For example on the “Presentation – Aesthetic and minimalist design” and “Match between the system and the real world” heuristics Virtual Earth is clearly better. In fact, Virtual Earth had a simple and familiar interface while on Google Earth there was the toolbar above the map whose icons were not very familiar and thereby their function not understood. Virtual Earth also had better results on the “Errors – help diagnose, recognize and recover from them” heuristic where Google Earth looses because of the lack of usefulness of the information present on error messages.

Except for the “Errors prevention” heuristic where both systems have the same problems, on the rest of the heuristics Google Earth had an overall better performance. On the “visibility of system status” heuristic Google Earth had a much better performance than Virtual Earth. Virtual Earth looses because it does not provide any visual feedback concerning what is already selected and what is not, and because information at the current location does not match the expected. These flaws were considered to be level 4 on the severity scale.

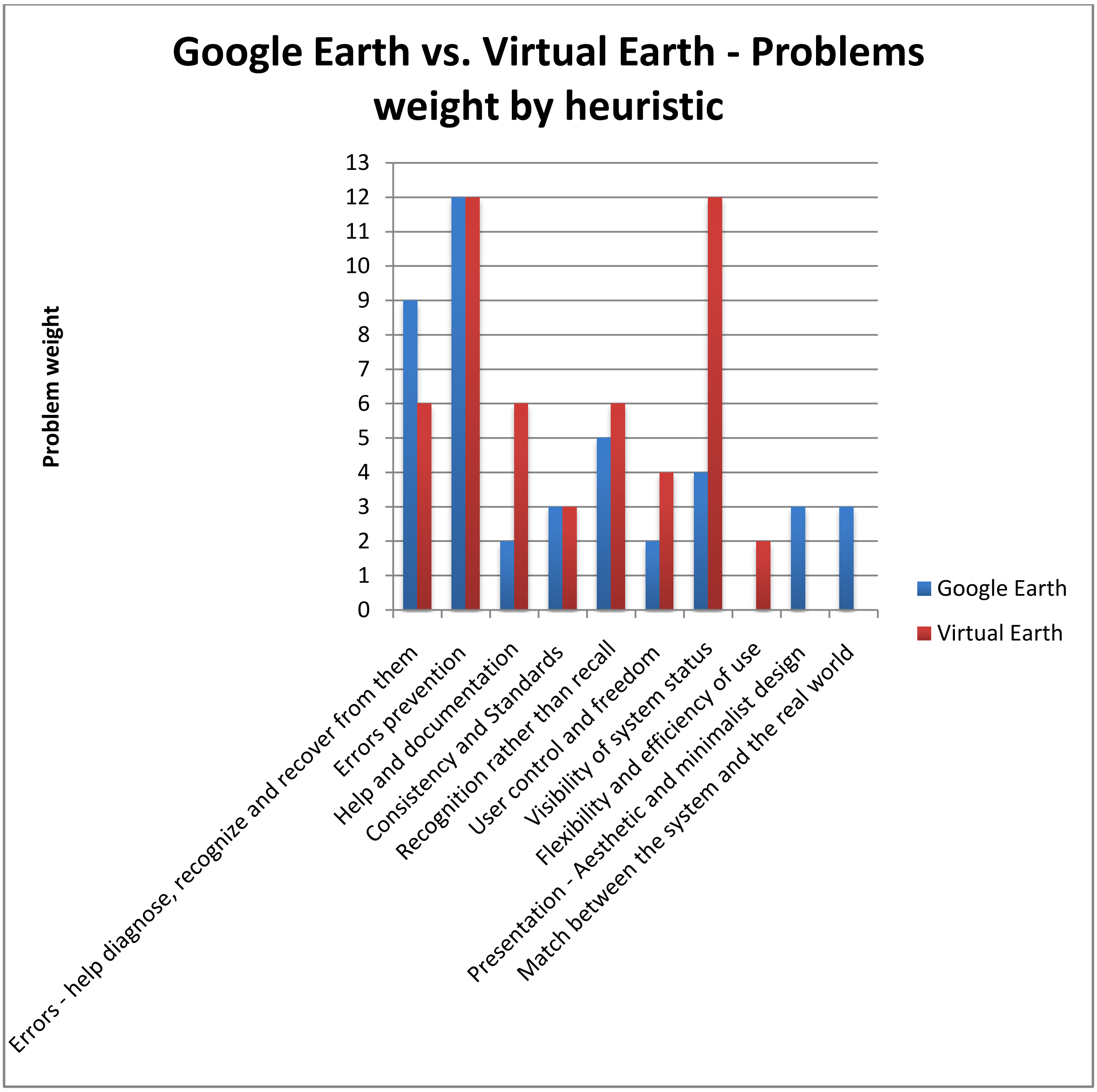


Figure 5.26: Google vs. Virtual Earth - Problems weight by heuristic

On the chart from Figure 5.27 it is possible to see the results from Google Earth and Virtual Earth concerning the detected users' frustration level divided by tasks.

Overall Google Earth caused less frustration on users than Virtual Earth, especially on tasks 1.1 and 1.2 from scenario 2 (Appendix B), where users had to find hotels and interesting places to visit on Barcelona. On Virtual Earth this task was done using the "Collections" menu. Like it was previously said this concept was not well understood by users and the menu suffers from lack of information and organization.

On tasks 1.1 and 1.2 from scenario 1 the difference between the two systems it is not very high, however Google Earth had better results. This can be explained by the fact that Virtual Earth had some inconsistencies, being one of them the loss of pushpins which users used to mark their start and end points. But on task 1.3 from scenario 1, users found Virtual

Earth less frustrating than Google Earth. On this task users had to found the route information. One of the problems indentified on Google Earth was that this information was not visible, being placed at the end of the route description. On Virtual Earth this information it is placed at the beginning of the route description, thereby being discovered faster by users.

The task 2 of scenario 1 has similar results on both systems. In fact many users got very frustrated because the systems did not allow inserting a middle point on the route, having some of them given up of performing the task claiming it was impossible.

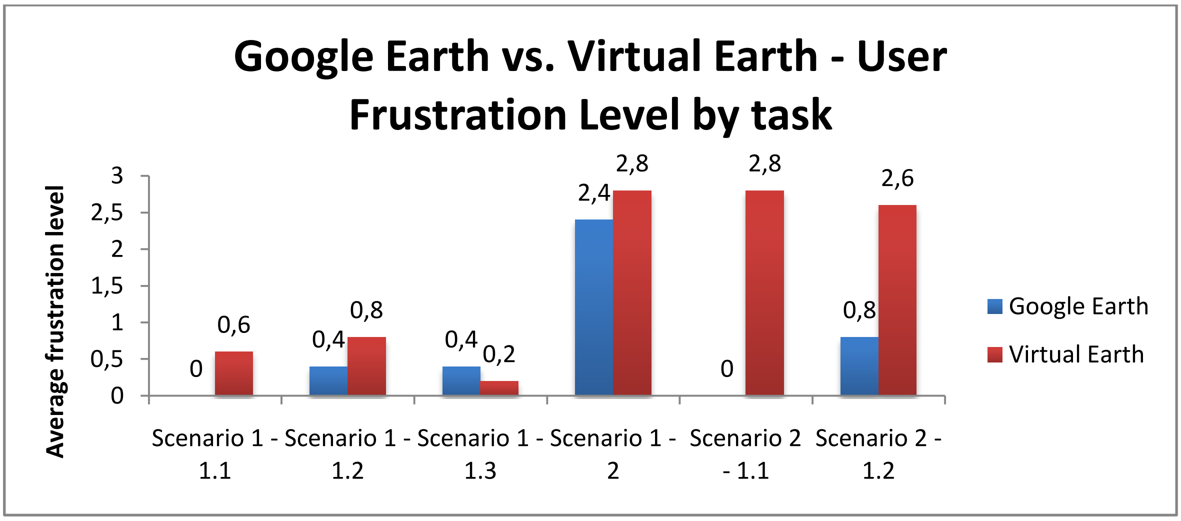


Figure 5.27: Google Earth vs. Virtual Earth - User frustration level by scenario task

Regarding the SUS score comparison, it shows that overall users got more satisfied with Google Earth than with Virtual Earth. As can be seen on chart from Figure 5.28 the score is favourable to Google Earth except for users 4 and 5 who got more satisfied using Virtual Earth. Also by comparing the average SUS score from the two system it is possible to see the same thing: Google Earth got a score of 75,5 and Virtual Earth a score of 61,5.

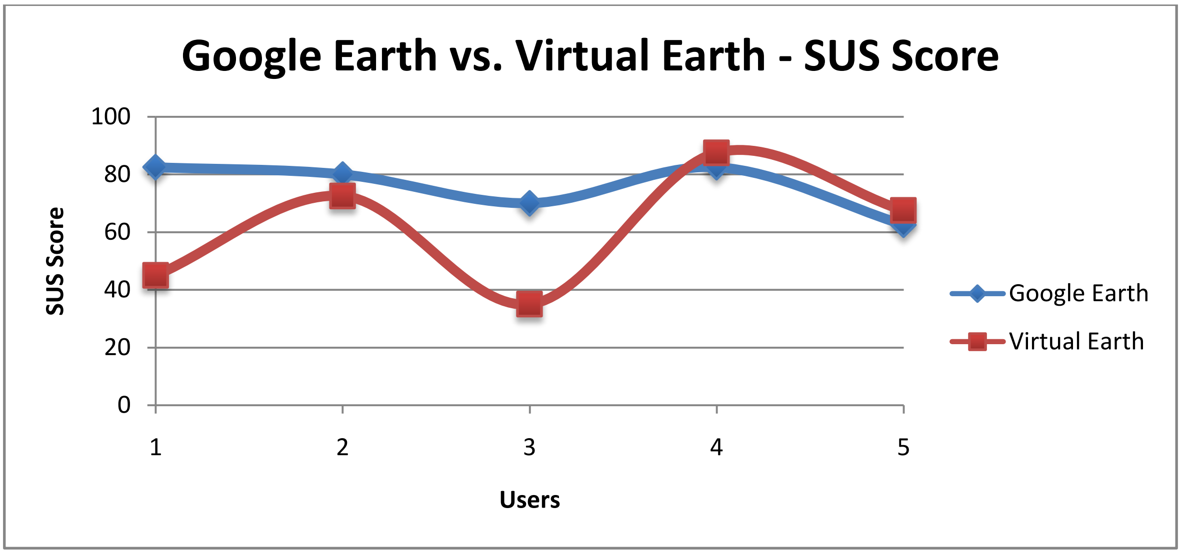


Figure 5.28: Google Earth vs. Virtual Earth - SUS score

5.3.4.4 Transporlis vs. Itinerarium

By comparing Transporlis and Itinerarium it is possible to see their weak and strong points, what could be improved and also to see with which system users got more satisfied.

By analyzing the chart on Figure 5.29 it is possible to see that there is no better system. There are points where Transporlis is better than Itinerarium and vice versa. Overall Itinerarium had better results than Transporlis except on “Errors – help diagnose, recognize and recover from them” and “match between the system and the real world” heuristics where Itinerarium needs some work on putting error messages better, and more familiar icons on the interface.

On the rest of the heuristics Itinerarium has a better performance than Transporlis. This last one looses mainly because it lacks on providing visual feedback to users (visibility of system status) and on its confusing interface (presentation – aesthetic and minimalist design).

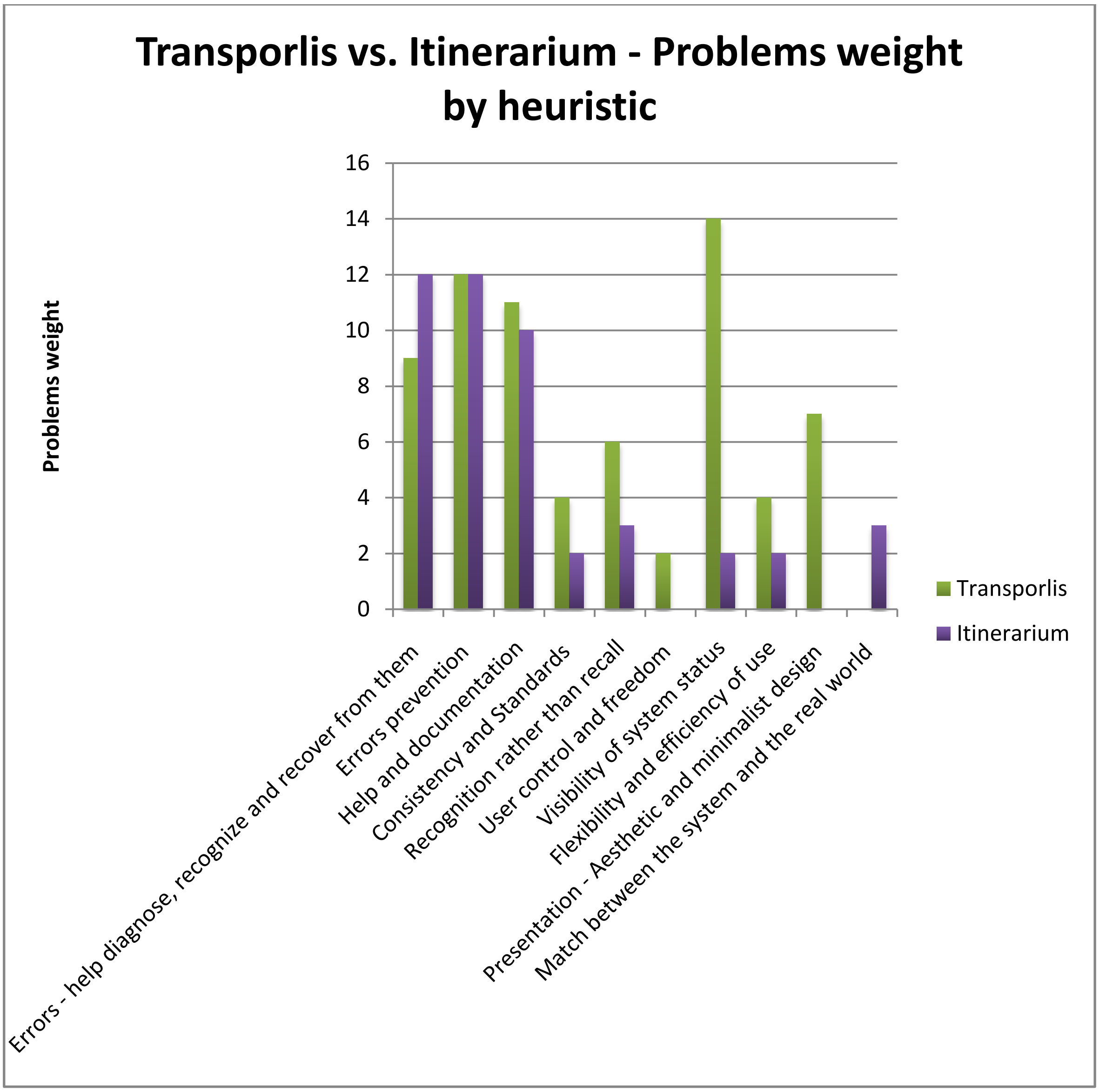


Figure 5.29: Transporlis vs. Itinerarium - Problems weight by heuristic

On the chart from Figure 5.30 it is possible to see the average user frustration level on each task from Transporlis and Itinerarium scenarios (Appendix B). The critical point is clearly on task 1.2 where users had to perform their search using the map. In fact most of the problems detected by users reside on the map service which users found it was very poor on both systems.

Also on task 1.1 users got a little frustrated with Transporlis because they found the interface confuse.

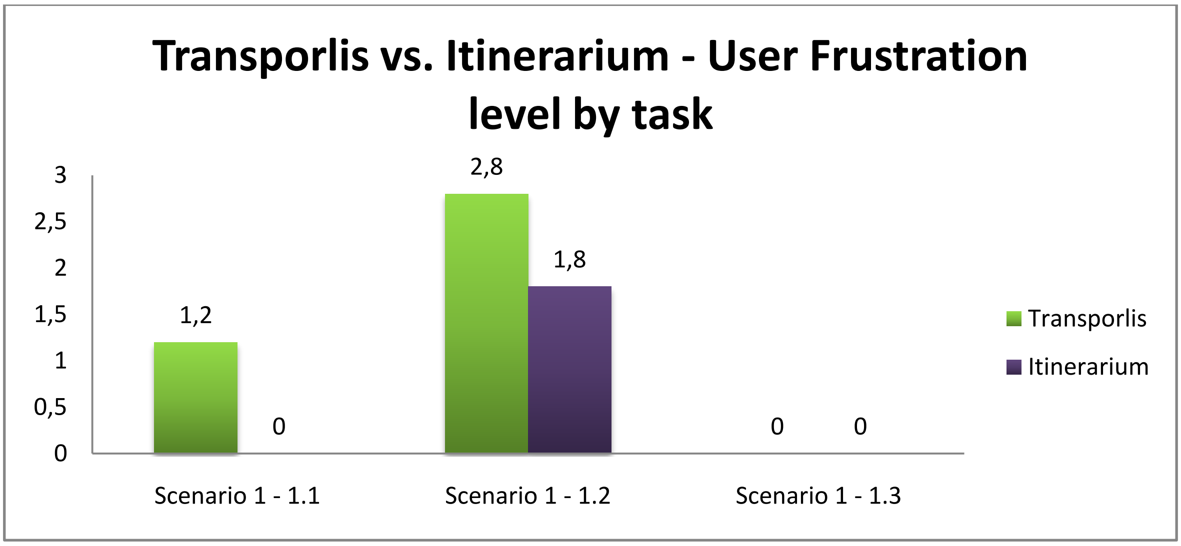


Figure 5.30: Transporlis vs. Itinerarium - User frustration level by task

Regarding the SUS score results, on Figure 5.31, it is possible to see that overall users got more satisfied with Itinerarium than with Transporlis. One exception is user 4 who liked more Transporlis.

The average results of the SUS Score of 57, to Transporlis, and 79, to Itinerarium, show the same.

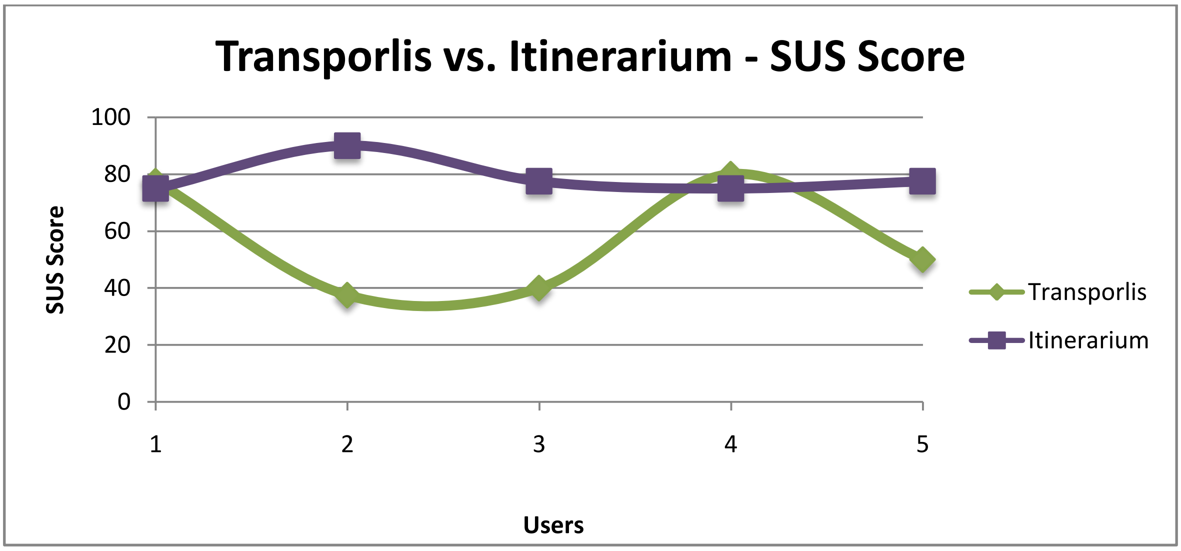


Figure 5.31: Transporlis vs. Itinerarium - SUS score

5.4 Summary and Discussion

The HCI concepts play an important role on GIS. As a system that deals with large amounts of data, it is important to display them to users in an efficient and pleasant way.

Here is where HCI is able to play is role by enabling GIS to better satisfy user needs, providing them the efficiency, satisfaction they expect. To know what users expect when interacting with a GIS interface it is necessary to make a psychological study of human and spatial data perception.

It is possible to say that humans capture spatial information during their everyday lives through their senses. There are three types of spatial information: declarative, procedural, and configurational. This information may come from three sources: haptic, pictorial, and transperceptual sources. Studying the spatial information types and its sources it is possible to understand some cognitive aspects of geo-spatial visualization and try to predict users' expectations and workflows.

Other important step to understand the connection between HCI and GIS is to study its usability problems. During this research some interesting results were found. On the case study analysis, the main problems were related to the lack or confuse information on the error messages, the difficulty of dealing with the system, the confuse interface and, the poor feedback. The conducted evaluation on the generalist applications, Google Earth and Virtual Earth, revealed also problems with error messages, with the interface and with, the visibility of the system status. The specific applications, Transporlis and Itinerarium, revealed problems mainly on the map service that, due to its complexity, users questioned its utility to the system.

Through the analysis of the importance HCI has on GIS the cognitive aspects of geo-spatial visualization, and crossing them with the results obtained from the problems research and evaluation, it is possible to see that little attention is given to usability on GIS. To improve GIS interfaces it is necessary to incorporate usability into their development, as part of their creation.

Chapter 6

A user-centred methodology for the development of GIS

Having analyzed the usability problems of some GIS it is possible to say that something is wrong in the way GIS are made. On this chapter, considering the nature of the identified problems, a user-centred methodology for the development of GIS, will be proposed. This methodology will have into account several aspects of software development processes, usability techniques and user involvement on the software process.

6.1 The Base Methodology

For one hand we have the traditional plan-driven methodologies of software development that “promise predictability, stability, and high assurance” [Boe03]. On the other hand we have agile methodologies that “promise higher customer satisfaction, lower defect rates, faster development times and a solution to rapidly changing requirements” [Boe03]. However both approaches have their shortcomings that if not addressed may lead to project failure. On Table 6.1 it is possible to see the application, management, technical and personnel characteristics of both agile and plan-driven methods. Although agile and plan-driven methods may be defined on their pure form, on reality these extremes are rarely populated. It is possible to say that there is a relationship between the methods’ home grounds, the project type and environment [Boe03]. The challenge here is to find the break point between those variables so that the project will most likely succeed.

So where is the break point for the development of a Geographical Information System?

Table 6.1: Agile and plan-driven methods home grounds [Boe03]

Characteristics	**Agile**	**Plan-driven**
Application		
Primary Goals	Rapid value; responding to change	predictability, stability, high assurance
Size	Smaller teams and projects	Larger teams and projects
Environment	Turbulent; high change; project-focused	stable; low-change; project/organization focused
Management		
Customer Relations	Dedicated on-site customers; focused on prioritized increments	As-needed customer interactions; focused on contract provisions
Planning and Control	Internalized plans; qualitative control	Documented plans, quantitative control
Communications	Tacit interpersonal knowledge	Explicit documented knowledge
Technical		
Requirements	Prioritized informal stories and test cases; undergoing unforeseeable change	Formalized project, capability, interface, quality, foreseeable evolution requirements
Development	Simple design; short increments; refactoring assumed inexpensive	Extensive design; longer increments; refactoring assumed expensive
Test	Executable test cases define requirements, testing	Documented test plans and procedures
Personnel		
Customers	Dedicated, collocated CRACK[9] performers	CRACK performers, not always collocated
Developers	At least 30% full-time Level 2 and 3 experts; no level 1B or -1 personnel (see Table 6.2)	50% Level 3s early; 10% throughout; 30% Level 1Bs workable; no Level -1s (see Table 6.2)
Culture	Comfort and empowerment via many degrees of freedom (thriving on chaos)	Comfort and empowerment via framework of policies and procedures (thriving on order)

[9] Collaborative, Representative, Authorized, Committed, Knowledgeable

With the aid of the information on Table 6.1, authors [Boe03] have identified five critical decision factors associated with agile and plan-driven home grounds, and represented them graphically on Figure 6.1. These five factors are:

1. **Personnel**: measures the percentage of people with level 1B on one side and on the other side the percentage of people that is Level 2 and 3 (see Table 6.2).
2. **Dynamism**: rate of change. Normally measured as percentage of requirements change per month.
3. **Culture**: measures the freedom and diversity of the development team. The more high values of freedom and diversity more is the project culture "thriving on chaos".
4. **Size**: number of people involved on the project.
5. **Criticality**: measures the project loss due to impact of defects.

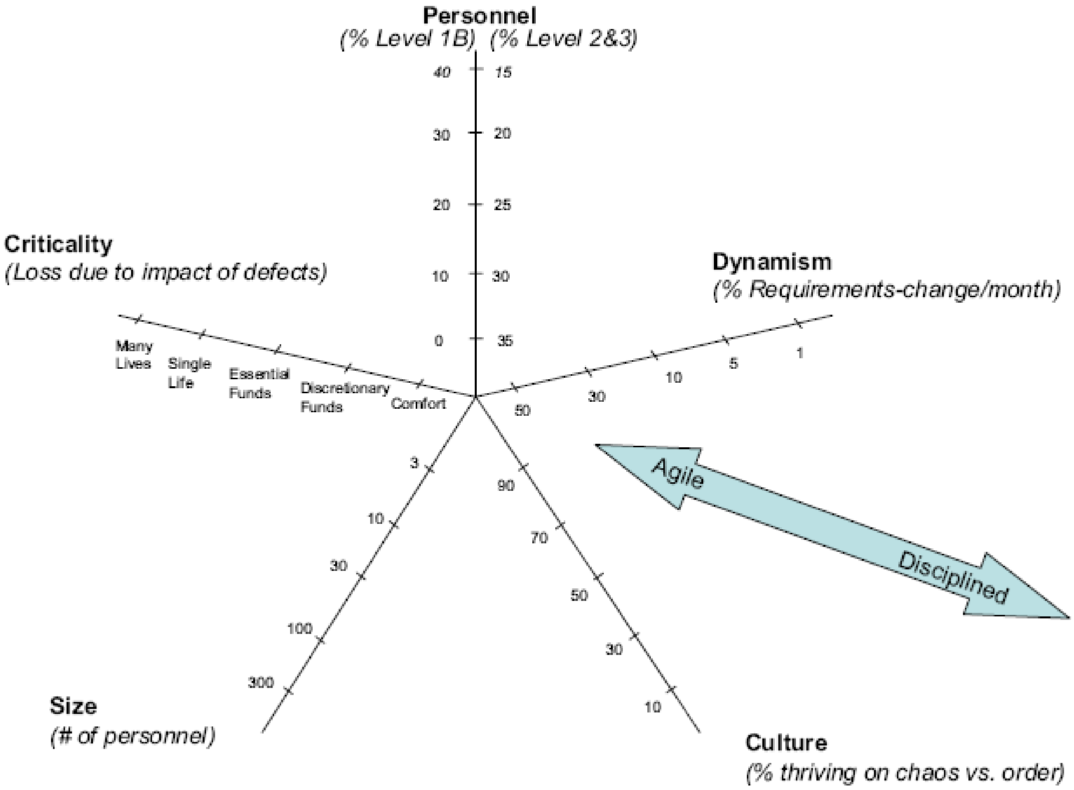


Figure 6.1: Dimensions affecting method selection [Boe03]

The chart on Figure 6.1 allows rating a software development project, along the five axes, and visually evaluating its home ground relationships. High values of Criticality and Size indicate that plan-driven methods will succeed better than agile. If a project has a high Criticality is necessary to ensure that he is predictable, and stable. And the same goes if the team is big: the bigger the team is more difficult is to manage it agilely. The Culture axis reflects that agile methods are more likely to succeed in a culture that “thrives on chaos” than in one that “thrives on order”. The opposite happens with plan-driven methods. For Dynamism, agile methods cope well with both high and low rates of change, but plan-driven methods deal better with low rates of change. Regarding the Personnel factor, plan-driven methods work well with high and low skill levels, but agile methods require a richer mix of higher level (2 and 3) skills (see Table 6.2). So if all the ratings are near the centre, agile methods work better. But otherwise, if they are at the periphery, projects will best succeed with a disciplined approach.

Table 6.2: Levels of software method understanding and use (based on [Coc00] and [Boe03])

Level	Characteristics
3	Able to revise a method (break its rules) to fit an unprecedented new situation.
2	Can function well in managing a small, precedent agile or disciplined project but need the guidance of Level 3 people on a large or unprecedented project. Some Level 2s have the capability to become Level 3s with experience.
1A	Can function well on agile or disciplined teams if there are enough Level 2 people to guide them. With experience can become Level 2.
1B	Can function well in performing straightforward software development in a stable situation. But they are able to slow down an agile team trying to cope with rapid change, particularly if they form a majority of the team. They can form a well-performing majority of a stable, well-structured disciplined team. With experience can master some Level 1A skills.
-1	May have technical skills, but are unable or unwilling to collaborate of follow shared methods.

The development of a GIS is, like in any other software project, unique. Each one has its own characteristics. So it is not possible to define a methodology that can cope with all the unique aspects each GIS project has. All the five factors described above have to be evaluated for each project and then the best practices chosen. And best practices are referred not methodologies because most of the time if one specific method is followed rigidly it is probable that some things go wrong. So authors [Boe03] say “Build your method up – do not tailor it down” meaning with this that using “a barely sufficient process” [Hru05] is enough. A barely sufficient process can be seen as a process that fits the needs of the project. This process may be hybrid, adopting best practices of plan-driven for some things and best practices of agile methods for other things. The important here is to lead the project to success.

6.2 Integrating Usability Techniques into the Software Development Process

According to ISO 13407 [ISO99] there are four activities that need to be done iteratively during all stages of the project until the system meets the users' expectations and requirements. These activities are:

1. understand and specify the context of use
2. specify the user and organizational requirements
3. produce design solutions
4. Evaluate designs against requirements.

The iterative nature of these steps is illustrated on Figure 6.2.

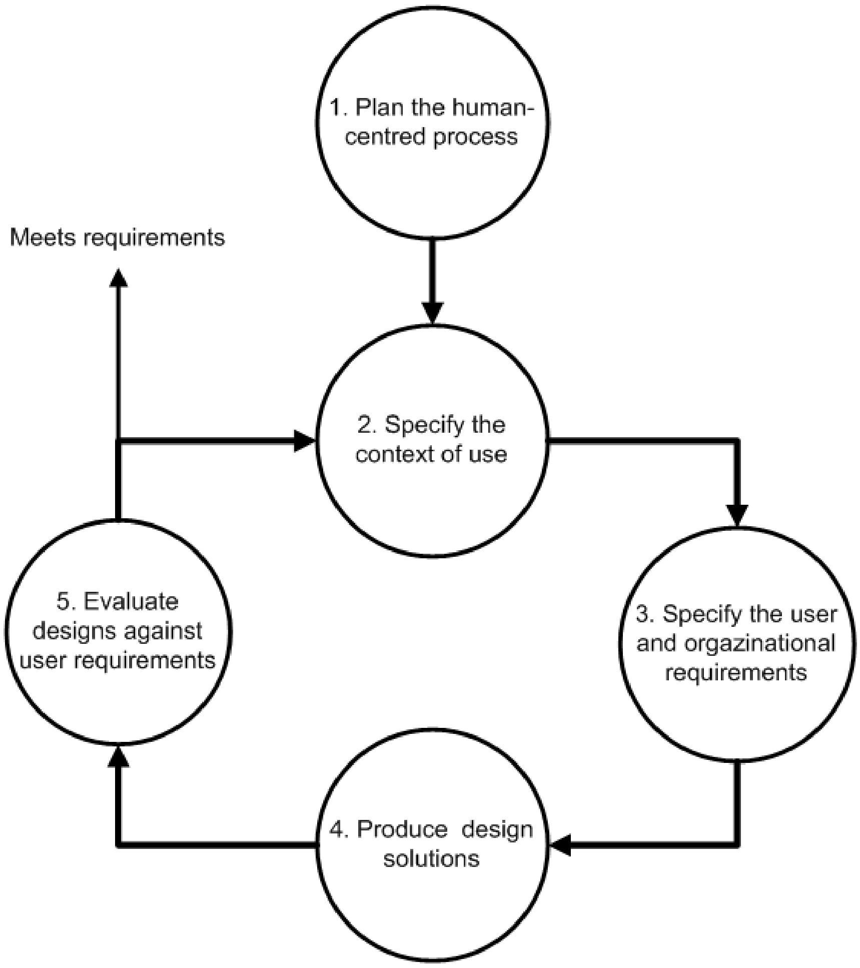


Figure 6.2: The interdependence of usability activities (based on [Bev97])

These four activities are related to software development phases and usability activities. On this section, from these four activities some usability activities will be derived, and then a connection will be established between these last and software development activities. In the end usability techniques will be mapped to software development activities.

Based on the four activities defined above, and on the literature [Fer02] a list of usability activities grouped according to the kind of development activity they belong was made. On Figure 6.3 it is possible how the usability activities were divided.

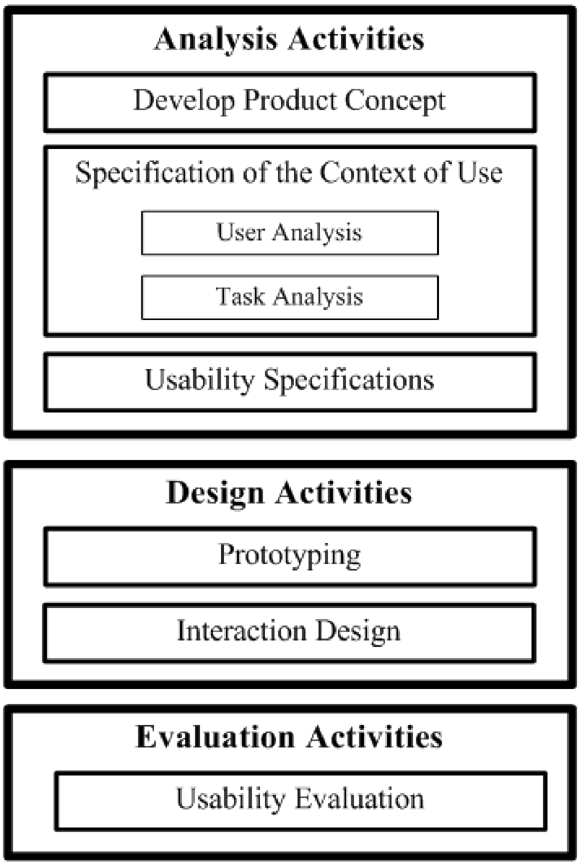


Figure 6.3: Usability activities grouped according to the generic development activity (based on [Fer02])

To better integrate usability techniques into the development process is to relate them with the software development activities. So on Figure 6.4 it is possible to see the mapping between usability activities (on the left side) and the software development activities (on the right side) that are affected by those usability activities.

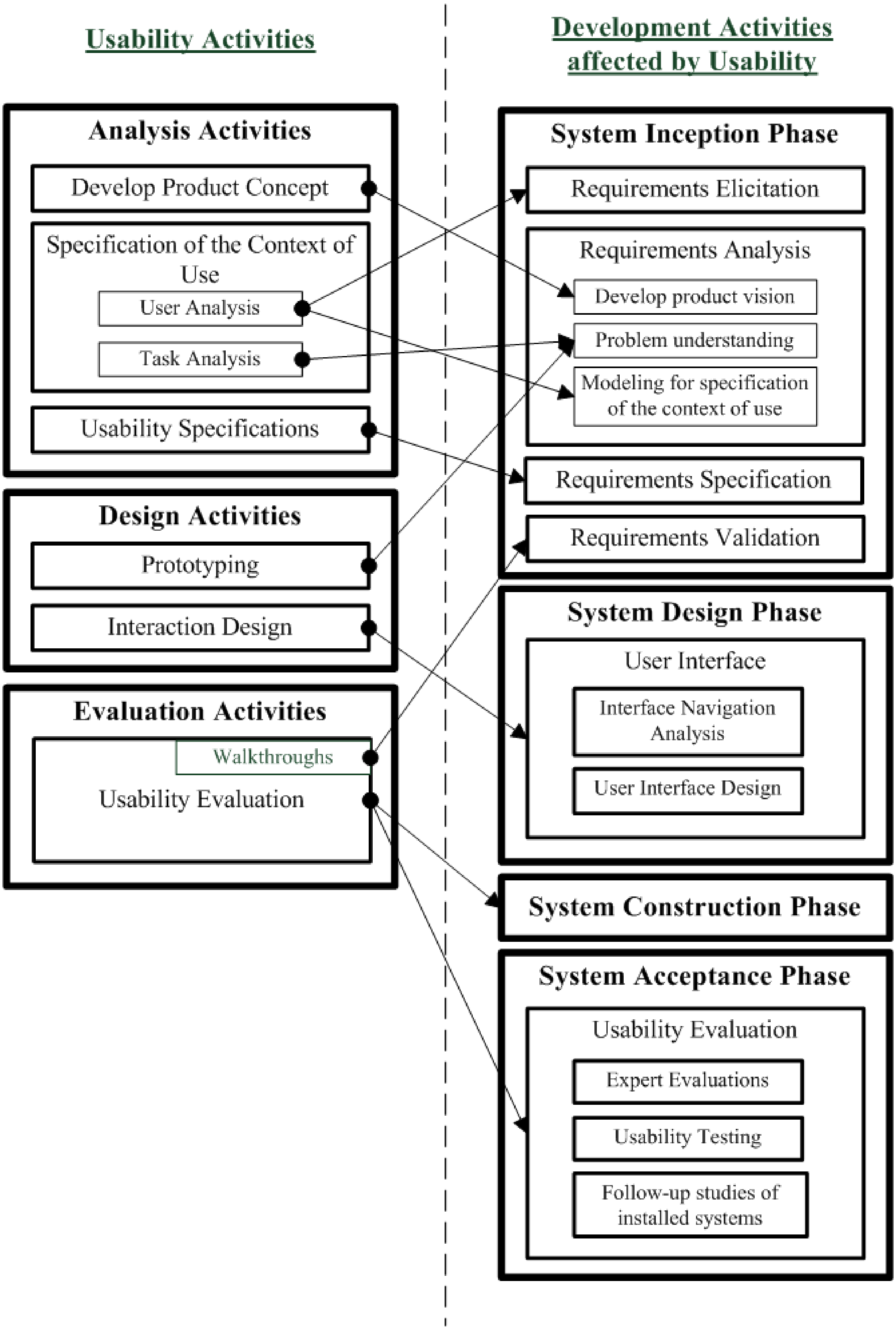


Figure 6.4: Mapping of usability activities to software development activities (based on [Fer02])

Not all software development phases are relevant for the purposes of this thesis. Among the relevant phases there are:

- System Inception Phase, where the requirements engineering activities are allocated. The requirements engineering activities include: requirements elicitation, requirements analysis, requirements specification and requirements validation. The requirements elicitation phase requires a deep user analysis, as the main goal of this phase is to understand their needs. The requirements analysis phase also requires a deep user analysis to contextualize their activities, and also a task analysis accompanied by prototyping for a better problem understanding. The product vision "helps assure that everyone working on the project is working toward a single objective" [Lef03]. On the usability area the product concept is about knowing who the users and competitors are, and building a product overview accessible to everyone. These two activities are related due to their common goals. "Walkthroughs are a kind of evaluation activity that can be performed on analysis products" [Fer02] so they are linked to requirements validation activity on Figure 6.4.
- System Design Phase, where among other important activities is included the user interface design. These activities include first an analysis of the navigational structure of the interface and then its design. On these activities it is important the interaction design role whose main goal is, as said on section 2.5, "about creating user experiences that enhance and extend the way people work, communicate and interact" [Pre94].
- System Production Phase, where the main activity is coding. In spite of this phase is handled most by developers, it is important to that the system is evaluated regularly so that on the end changes are minimal.
- System Acceptance Phase, where the system is evaluated against the established requirements to see if it meets the users' expectations. Among the evaluation activities it is the usability evaluation which, due to its complexity, was divided into three types: Expert Evaluation, Usability Testing and Follow-up studies of installed systems.

Having mapped the usability activities to software development activities, it is now possible to match usability techniques to these last activities.

The usability techniques collected from the literature ([Lef03], [Fer02] and [Soa07]) were allocated to development techniques. Figure 6.5 shows the allocation made.

The techniques are linked to the development activity by an arrow. Some techniques may be applied in more than one activity, like Prototyping which is used for Problem understanding and Requirements Validation.

For the allocation of usability activities to the development activities it was compared the objective of each technique with the definition and goals of each development activity.

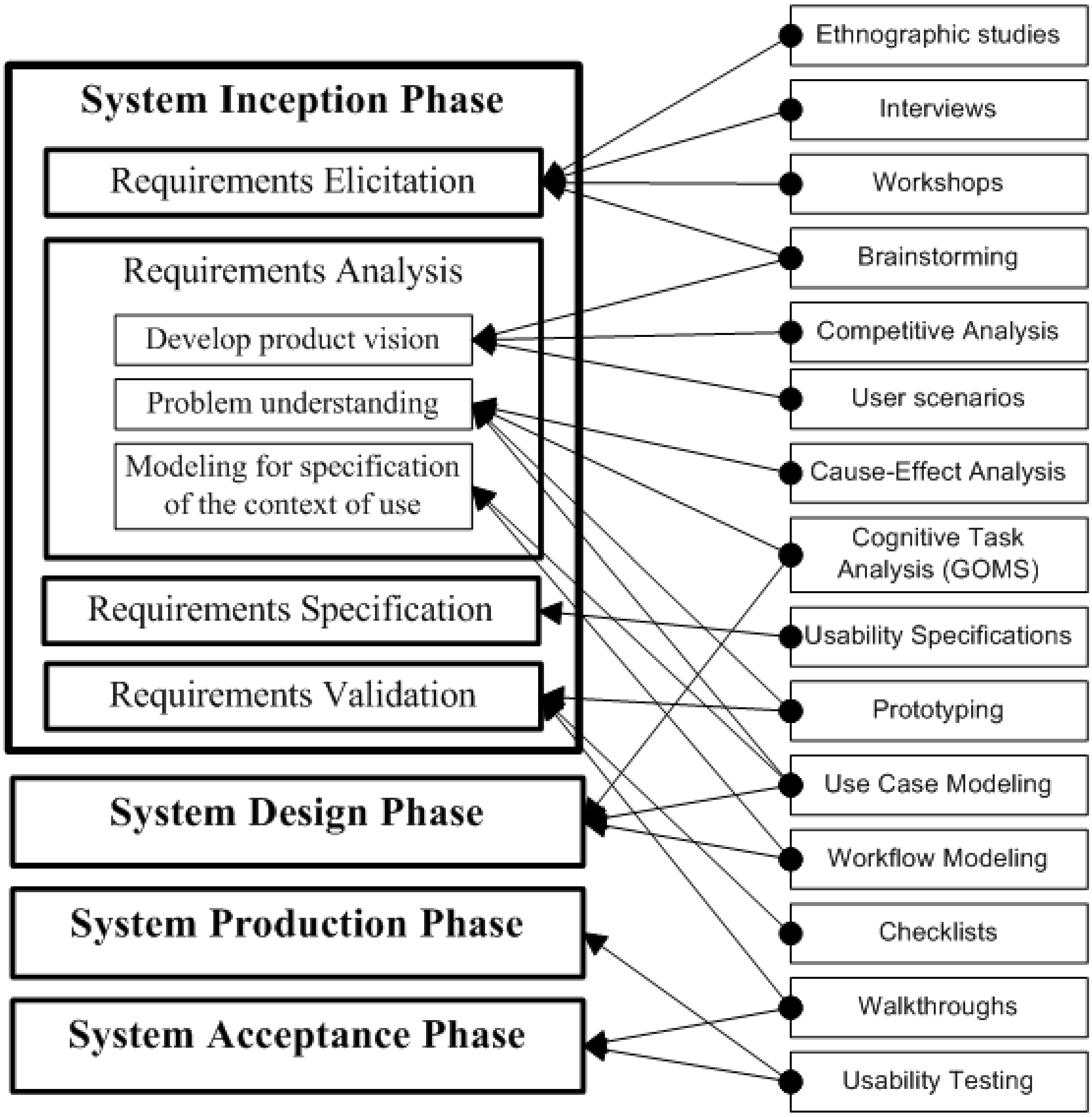


Figure 6.5: Allocation of usability techniques to development activities (based on [Fer02])

Integrating usability techniques on the development of Geographical Information Systems is very important. From the obtained results of the heuristic evaluation and usability testing it is possible to see that there are still many problems to resolve. For example, on Transporlis and Itinerarium, the map service it is not contributing nothing or almost nothing to the system. In fact he is interfering with the overall satisfaction users have with it. If the users were confronted with the service early on the development process through walkthroughs or prototypes and the problems detected, maybe the service would be better now or even wouldn't make part of the system. Other big problem of the evaluated system was the map interface and the integration of the various functionalities. With the aid of usability techniques like Cognitive Task Analysis, Use Case and Workflow Modelling the way users interact with the system and how they expect it to function would be better understood.

6.3 Involving Users into the GIS Software Development Process

An important part of integrating usability techniques into the GIS software development process is involving users on their execution. Users can be involved in a more passive way being information providers, or in a more active way, participating in decision-making activities.

The most common user involvement is a passive one where throughout all iterations of the development process users provide insight to the project team. On this type of involvement, normally there is a usability team with defined roles responsible for implementing usability techniques that allows them to gather effective user information. The usability roles present on a usability team are [And01]:

- Usability Engineer: the usability engineer has the responsibility of gathering and analyzing user requirements, as well as studying the system's users. This role's main goal is to capture the user's mental models of their work.
- User Interface Designer: this role's goal is to express the user's mental model as closely as possible within the constraints of the data and technical architecture. The UI (User Interface) Designer must be versed in usability principles and employ these principles while working.
- Usability Evaluator: has responsibility for testing the product design, analyzing and documenting the results, and presenting them to the development team.

Other variant of this technique is to introduce a Product Analyst [Neb05]. The Product Analysts are domain experts with long time experience in their field of work and incorporate their knowledge about the users' workflow and the organizational settings users operate in. They protect the users' interests during the project and gather information about users in an adequate way. These experts are always readily available to the team. Working together with the Product Analysts and the development is the Concept Team [Neb05]. This team consists of software designers and usability engineers, and is responsible for translating analysis results into concepts and subsequently into user interface designs.

Both these approaches to user involvement do not require that users have some type of responsibility during the project. However they are key to the product success by providing information for requirements definition and user interface designing. They also play an important role on the evaluation of the user interface.

Other not so common type of user involvement is the active one. This type of involvement requires a deep user involvement and a commitment to the project. The users assume responsibilities and participate on decision making activities. One technique for active user involvement is to put the users managing requirements [Cla98]. Users participate in monitoring the project progress and controlling the requirements management process. They cooperate with the development team in an attempt to lead to positive results.

However, when trying to involve users whether passively or actively, there are "a number of organizational and psychological barriers preventing companies from embracing user input" [van07]. The most frequently heard reasons for not involving users are the following ([van07] , [Iiv04]):

- "Involving users will only lengthen development timelines and time to market"
- "Usage scenarios and usability testing just add to the already sky-high number of requirements we're dealing with."
- "We already have enough trouble managing our product development process – adding users into the mix will make the process even more chaotic."
- "It is problematic to get money and the permission from the projects to do this, it is not easy to get permission to spend money on doing usability"

Dealing with these barriers it is not easy, and they are there because development teams do not know how to involve users and how best to manage them. To deal with these barriers it is necessary to plan with advance the user involvement and see what degree of involvement the project requires. If the product to be developed is a standard off-the-shelf product the type and degree of user involvement needed is different if it was a specific product for a specific customer. So to manage user involvement it is not a straightforward method that is applied the same way on every project. Some variables need to be taken into account. These variables can be:

- <u>Project type</u>: is the project for a specific customer or a standard off-the shelf product?
- <u>Diversity of users</u>: how many types of users the system has to deal with?
- <u>Development team organizational culture</u>: what are the values of the software company the development team is integrated on?
- <u>Customer and users availability</u>: is the costumer and/or users willing to participate or provide the means to user involvement?

All these variables are related, and limit the amount and type of user involvement. If the product is, like Google Earth and Virtual Earth, a standard off-the-shelf product, for no specific customer, than perhaps the best way of involving users is the passive way, with the introduction of a Product Analysts who knows the business very well or a Usability Team to ensure that usability principles are applied. If the product is for a specific customer or type of users, like Transporlis or Itinerarium, than is necessary to see the other variables. If there is a high diversity of users putting them on the decision making process it would be very complicated and unproductive. So once again following the passive way would be better. On the other hand, if the users are well defined, it should be seen if users are willing to participate [Cla98], whether actively or just as information providers, and usability testers.

Other important factor for user involvement is the organizational culture of the development team. According to the literature [Iiv04], organizational cultural factors have a direct impact on the way users are involved on the software development process. To better understand the importance of this factor the case study illustrated on the literature [Iiv04] will be shown.

Table 6.3: Cultural Assumptions indentified on the case units

	Unit A	Unit B
Who are we and what we do?	We're a product development unit, part of a large global corporation, producing functionally correct software within the schedules.	We're a product development unit, part of a small-to-medium-sized company, staying in the bleeding edge of technological development, a pioneer.
How do we carry out our work?	Control mechanisms, rules, tools and processes are in place and useful.	Adhocratic ways of working, no control of work, taking initiative experimenting with new things.
How do we relate to each other?	"We are all valued workers", good social relationships important	Competent, technical people respected

On Table 6.3 the case study units are described regarding their cultural backgrounds. It is possible to see that while unit A has a more rule and control-based culture, unit B is a more flexible and innovative company. This can be related to the fact that unit A is part of a large global corporation while unit B is part of a small-to-medium-sized company.

The results obtained from the case study show that although there are similarities in the way user involvement is treated on both companies, there are also some differences. These differences are related to the reason why to involve users and the way they involve users.

Table 6.4: Two approaches to user involvement

	Unit A	Unit B
Approaches to user involvement	"Quality and control oriented engineering approach"	"Business and collaboration oriented sneaking in approach"
Why	Capitalist orientation; money saving	Capitalist orientation; money making
How	Design a structured engineering process, usability specialists in consultative role	Design a creative, communicative process, usability specialists in consensus role
Strategy	Controlling strategy	'Sneaking in' strategy

"The 'quality and control oriented engineering approach' tries to facilitate user involvement by controlling, measuring and monitoring that is argued to resemble 'normal project work' in the unit. The 'business and collaboration oriented sneaking in approach', on the other hand, tries to sneak in, in secret and is careful of not commanding people to do things against their will, since the personnel is used to 'do what they want', 'people are trusted' and they are 'allowed to take initiative'" [Iiv04].

Although both units adopted a passive user involvement, unit B was more collaborative with usability specialists than unit A, who only used them in a consultative role. Unit A and B also have different perspectives on why to involve users. While unit A sees the user involvement as a money saving activity, unit B puts more value on it seeing it as a money making activity.

From the case study presented it is possible to see how organizational culture can affect the way users are involved on software projects.

6.4 Summary and Discussion

Defining a process for the development of GIS product it is not linear. Each project has its characteristics as it is necessary to consider the following variables before choosing a process. Those variables are:

- Personnel,
- Dynamism,
- Culture,
- Size, and
- Criticality.

Studying how these variables can influence the software project allows choosing the best guidelines to follow for the software development process.

Integrating usability techniques into the development process is not also linear. It is necessary first to study the existent usability activities and fit them on the development process phases, and then analyze which usability techniques are adequate for those phases.

Finally, it is also important to consider the way users are involved on the development process. Users can be involved in two ways, a passive way where they are information providers for the project team, and an active way where they collaborate actively with the project team and participate on decision-making activities. Choosing the best way to involve them passes through the analysis of the following variables:

- Project type,
- Diversity of users,
- Development team organizational culture, and
- Customer and users availability.

Having explored the paths that lead to the creation of a user-centred methodology for the development of Geographical Information Systems it is possible to see that there is no recipe that works well on all situations. The best approach is to choose the best methodology, usability techniques and type of user involvement that fits the project's needs. The important here is not to ignore what was presented on this chapter.

Chapter 7

Return on Investment Analysis

On the previous chapters some GIS usability problems were identified and some best practices to cope with those problems were suggested. Now it is necessary to analyze how the proposed practises can benefit GIS projects. To do this a Return on Investment Analysis (ROI) will be made, not with numbers but with potential benefits that integrating usability techniques and involving users should bring to the project.

7.1 Why Projects Fail?

Researches from literature [The01] show a not very famous project resolution history. Figure 7.1 shows the resolution of 30.000 application projects in large, medium, and small cross-industry U.S. companies tested by The Standish Group since 1994. The authors classified the projects in three types:

- Successful: the project is completed on time and on budget, and has all specified features.
- Challenged: the project is complete and operational, but over-budget, out of time and with fewer features than specified.
- Failed: the project is cancelled before completion or never implemented.

As can be seen most of the projects are challenged or even failed. But why this situation happens? What are the root causes?

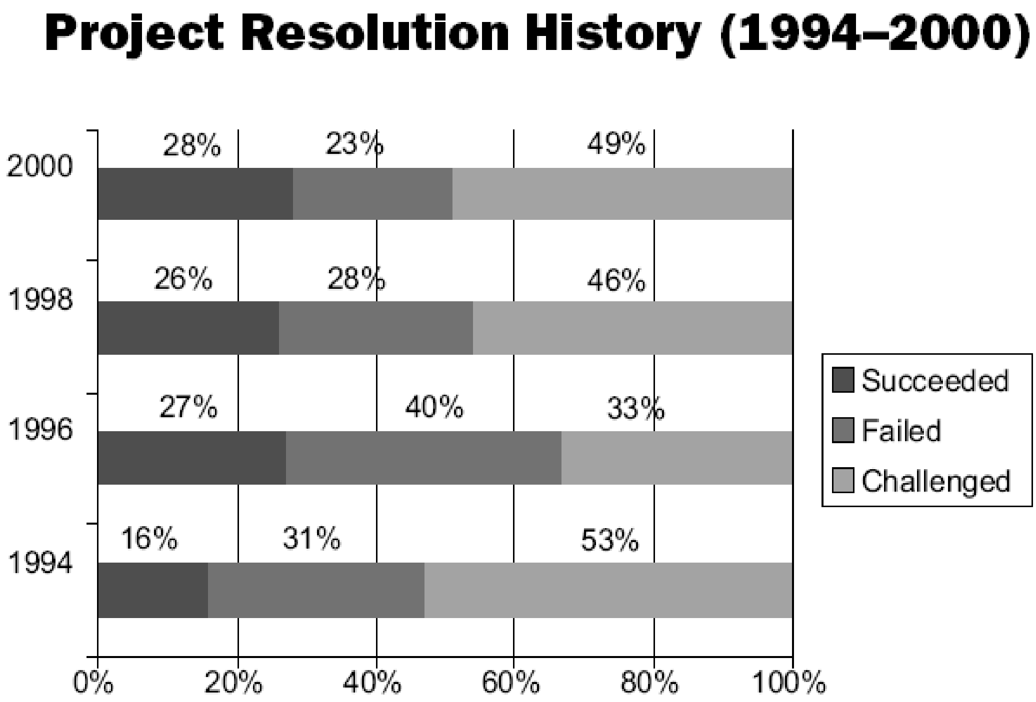


Figure 7.1: Project Resolution History (1994-2000) [The01]

Another study from European Software Process Improvement Training Initiative [ESP95] showed the main reasons that cause projects to fail or to be challenged. Figure 7.2 shows the main findings of the study. Results show that the two major problems are:

- Requirements specifications, and
- Managing customer requirements.

Errors on requirements management and specification propagate throughout the project phases and by the time they are discovered, the development team will have invested time and effort in building a design from those erroneous requirements. As a result, the design will probably have to be thrown away or reworked. This implies more effort, time, and costs.

It seems clear now that requirements management is a critical point on software projects and deserves extra attention.

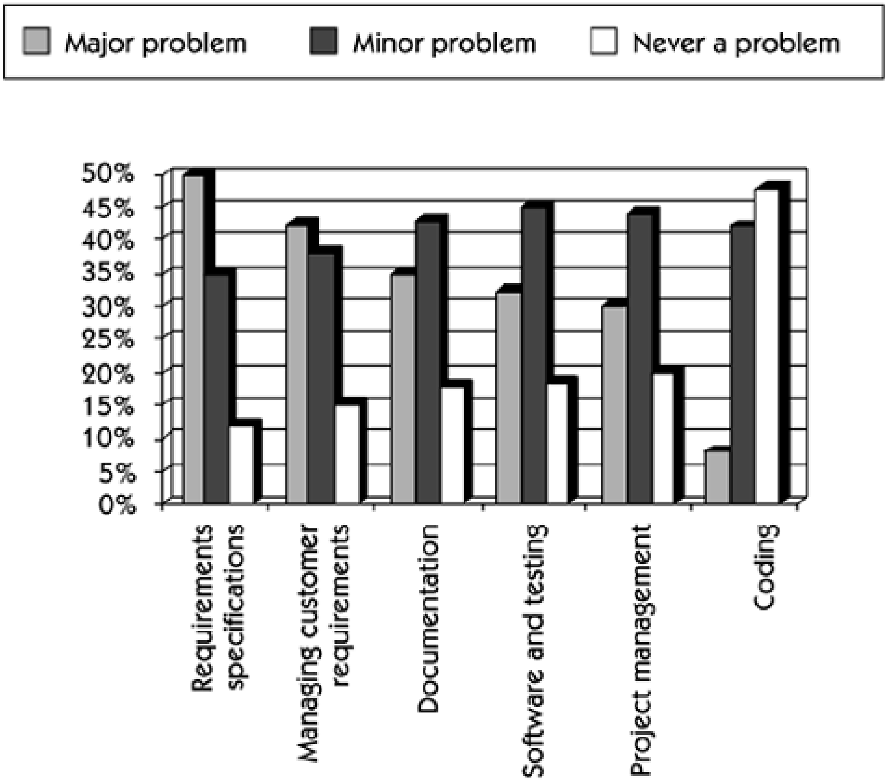


Figure 7.2: Largest software development problems by category

7.2 Achieving Project Success

Considering the statistics mentioned above one might think that achieving project success is very difficult. However achieving success is only a case of adopting best practises. On the same study from the Standish Group [The01] it were identified some success factors obtained from successful projects. So according to the study, the three most important factors are:

- User involvement: 16 percent of all successful projects
- Executive management support: 14 percent of all successful projects
- Clear statement of requirements: 12 percent of all successful projects

From the results it is possible to see that involving users on the software process it is the most important success factor, because "even when delivered on time and on budget, a project can fail if it does not meet user's needs or expectations" [The01]. A clear state of requirements is also a very important factor for achieving success.

However simply involving user it is not enough. They have to be involved on something and that something is usability.

On the developed methodology was described how to use usability techniques on some phases of the development process, and how to involve users. As integrating usability techniques imply user involvement the benefits brought by both cannot be separated.

Studies from the literature ([Mar02], [Usa08b]) show that many benefits can arise from integrating usability on the development process. Those benefits may be divided into the following categories [Usa08b]:

- Development Costs;
- User effectiveness;
- Revenue.

Regarding the development costs integrating usability techniques can be very beneficial. Results show that it helps saving development time and, subsequently, development costs by detecting problems earlier on the inception and design phase. Also due to this, maintenance costs are also reduced.

The user effectiveness is also improved. Results show that user productivity and job satisfaction increased, while customer support and training needs decreased. This happens because "when users feel more effective with their work, rates of absenteeism and employee turnover are lowered" [Mar02]. The systems' ease of use and learning also increased, making users more satisfied with the system and their success rate higher (fewer errors).

But usability not only brings cost savings and customer satisfaction to the company. It also brings profit because "when customers find one [system] that "works", they tend to repeat business and gain trust in the organization. Usable products also lead to good product reviews. Publications devote space just to this one factor, and good reviews lead to increased sales" [Mar02]. Investing on usability also brings the company competitive advantage as it delivers the customer a product with increased value for him.

7.3 Summary and Discussion

The history shows us that software project's resolution has not been very successful, being the first causes of project failure the poor requirements specification and management. Studies present user involvement and a clear requirements statement has key factors for changing the situation and therefore achieving success. The main benefits they bring are related to:

- Reducing development costs,
- Reducing development time,
- Reducing maintenance costs,
- Increasing user effectiveness,
- Increasing user satisfaction,
- Reducing customer support and training,
- Increasing user success,
- Increasing the system's learnability,
- Increasing customer loyalty,
- Increasing the product sales, and
- Achieving a competitive advantage.

As it is possible to see involving users and usability into the software development process has many benefits and it is key to project success. So the implementation of the proposed methodology to a GIS project has all the conditions to be successful once all the variables involved are taken into account and analyzed.

Chapter 8

Critical Analysis and Conclusions

The integration of usability on Geographical Information Systems is crucial for their success. As the GIS user approaches the common user, leaving behind the idea that these type of systems are only for experts, GIS interfaces have to be more appealing in order to satisfy the users' needs and wants. Another challenging point GIS face is their availability to other types of devices. In spite of the work developed on this thesis focus on the GIS interfaces for computers, it is important to refer that GIS are gaining popularity among mobile devices, like Global Positioning Systems (GPS) and PDAs, which require even more attention with the user interface.

As it was referred early, not only GIS face usability problems, all software products suffer the same. The lack of usability is a problem of all software products and is pointed out as the main cause for software products lack of success. The developed work contributes to change the situation of GIS, and also of other types of systems.

To achieve this goal a research of the three main areas involved, Human-Computer Interaction, Software Development Processes, and Geographical Information Systems was made, learning with this more about the state of the art of these areas and how are they evolving. Then, to learn how is the current GIS usability, it was a made a literature research, and a heuristic evaluation and usability tests on some GIS. The obtained results show that GIS user interfaces' need more attention regarding their usability and the experience they offer to users. Problems like, uninformative error messages, confuse user interfaces, mainly with the map, were common on the evaluated systems.

Having reached the conclusion that usability was missing on GIS, and of the benefits it could bring, a set of guidelines that incorporate best practises from Software Development Processes and Human-Computer Interaction, was developed. These guidelines follow the principle that software projects are all different and the best approach is to choose the practises that fit the projects' needs.

Choosing the best practises depends on a set of variables like the project size, diversity of users, among others referred on Chapter 6 . These variables need to be analyzed and then how to apply those practices needs to be planned. It is important to refer that simply applying practices to a project, without a previous analysis of its variables, may be harmful and even cause project failure.

The viability of the developed guidelines was analyzed through an analysis of some case studies where usability and users are incorporated on the development process. The analyzed case studies show very positive results, like the reduction of the projects' cost and time, the increasing user satisfaction, and even an increasing of the products sales, demonstrating that the developed guidelines are viable and may be a great contribution to the projects' success.

These guidelines not only apply to GIS but also to the development of other types of software products. This may be seen as an advantage but also as problem, because the guidelines are not very GIS specific. However a GIS project can be seen as a common software project that plays by the same rules, only having different development characteristics. The developed guidelines are prepared to deal with the specific characteristics of GIS projects as the enumerated variables are common to every software projects.

The developed work followed the established goals. However there is still work to be done and other areas that would be interesting to explore. On the next chapter it is possible to see some further work notes.

Chapter 9

Further Work

As further work the next step is to apply these guidelines to real GIS projects and analyze the results. The ideal situation is to apply them in a professional scope on about 3 to 5 development teams and compare the results making usability tests to assess the user satisfaction with the systems. This field study would be very important as it would allow identifying problems with the methodology and improving it.

Studying more deeply the GIS development would also be important as it would allow making a GIS specific variant of the developed guidelines. This would provide more efficient means of dealing with the specific GIS problems.

Another important field of study would be the GIS security vs. GIS usability. And by security it is meant not only the security of spatial information but also the security of users. For example, users operate with GPS while driving, so it is important to guarantee that GPS offer a secure user experience so that users do not risk their lives operating with it. As security and usability are very hard to put together it would be a very interesting study and it would add more value to the developed work.

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Appendix A

Heuristic Evaluation Checklist

Errors - help diagnose, recognize and recover from them

- Are error messages clear and in plain language?
- Are error messages useful (suggest the cause of the error)?
- Do error messages provide a clear exit point?
- Do error messages provide contact details for assistance?
- It is easy to contact support through e-mail or a web form?

Errors prevention

- Are potential errors recognized before becoming a problem?
- Does the system prevent users from making errors whenever possible?
- Does the system warn users if they are about to make a potentially serious error?

Help and documentation

- Is there online help?
- Is the available help useful?
- A site map or other navigational assistance is always readily available?
- Is the available documentation too large?
- If it exists, is the help information accurate, complete and understandable

Consistency and Standards

- Does the system follow conventions and expectations?
- Is a legend provided if colour codes are numerous or not obvious in meaning?
- Are commands used the same way and do they mean the same thing in all parts of the system?

Recognition rather than recall

- Have items been grouped into logical zones, and have headings been used to distinguish between zones?
- Is colour coding consistent throughout the system?
- Are inactive menu items greyed out or omitted?
- Are available options always clearly presented?
- Are labels and links described clearly?

User control and freedom

- When a user's task is complete, does the system waits for a signal from the user before processing?
- Is there an “undo” function at the level of a single action, a data entry, and a complete group of actions?
- Can users cancel out operations in progress?
- Are menus broad (many menu items) rather than deep (many menu levels)?
- If the system has multiple menu levels, is there a mechanism that allows users to go back to previous menus?

Visibility of system status

- Is it clear what information is available at the current location?
- The current information matches the expected?
- Is it clear where you can go from the current location?
- Is it always clear what is happening from each action you perform?
- Do menu instructions, prompts, and error messages appear in the same place(s) on each page?
- Is there some form of system feedback for every operator action?
- Is there visual feedback in menus or dialogue boxes about which choices are selectable?
- Is there visual feedback in menus or dialogue boxes about which choice the cursor is on mow?
- If multiple options can be selected in a menu or dialogue box is there visual feedback about which options are already selected?
- If there are observable delays (greater than 15s) is the system's response time, is the user kept informed of the system's progress?

Flexibility and efficiency of use

- Does the system allows novice users to enter the simplest, most common form of each command, and allows expert users to add parameters?
- If the system uses a pointing device, do users have the option of either clicking on fields or using a keyboard shortcut?

- On menus, do users have the option of either clicking directly on a dialogue box option or using a keyboard shortcut?

Presentation - Aesthetic and minimalist design

- Is the site structure simple and clean?
- Do colour choices allow for easy readability?
- Is the site aesthetically pleasing?
- Are field labels brief, familiar and descriptive?
- Are menu titles brief, yet long enough to communicate?

Match between the system and the real world

- Are icons concrete and familiar?
- Are menu choices ordered in the most logical way?
- Do the selected colours correspond to common expectations about colour codes?
- Are input data codes meaningful?
- Is the vocabulary appropriate for the intended audience?

Appendix B

Usability Tests Definitions

B.1 Demographic Information Questionnaire

1. **Name**: ____

2. **Grade Level**: Elementary Middle School High School College

3. **Years Using the Web**: _______________

4. **Age Group**: 5-10 11-13 14-17 18-24 25-34 35-44 45-55 over 55

5. **Gender**: Female Male

6. **How often do you use the internet?**
   Daily Weekly Monthly Occasionally Never

7. **Have you ever used an online map or a journey planner?**
   Yes No

8. **May we contact you about your input at a later date?**
   If so, please provide your e-mail address. _______________________________

B.2 System Usability Scale (SUS) Questionnaire

The System Usability Scale (SUS) is a simple, ten-item scale, created by John Brooke [Bro] giving a global view of subjective assessments of usability. Is a Likert scale, where a statement is made and the respondent then indicates the degree of agreement or disagreement with the statement on a 5 (or 7) point scale. This questionnaire is composed of the 10 following statements, being possible to rate each one from 1 to 5:

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

B.3 User Frustration Scale

For each task the users' frustration level was measured on the following way:

- ☺ 0 = User completed task with zero difficulty. (Zero Frustration)
- 😐 1 = User completed task with only minor problem(s). (Little Frustration)
- ☹ 2 = User completed task, but it required more effort/time/dead-ends than the user expected. (Medium/High Frustration)
- 💣 3 = User did not complete task. (Point of Failure)

This scale is based on the sample scale from University of Texas [Uni07].

B.4 Usability Test Scenarios

B.4.1 Google Earth and Virtual Earth

Test Scenario 1 – Plan your journey

1. You're planning your next summer vacations in Barcelona and you want to know how you get there by car. You're looking for information such as roads to take, estimated travel time and number of km. So to complete this task you will:

   1.1. Find your house and mark it as the travel start point.

   1.2. Find the city centre and mark it as your destination point.

   1.3. Get the directions between your start point and destination point.

      1.3.1. What is the estimated travel time?

      1.3.2. How many Km do you have to drive?

2. But before you go to Barcelona you want to stop at Valencia, Spain to visit some friends. Now you want to know the directions of your home to Barcelona passing by Valencia.

   Try to change your route so that it passes by Valencia.

Test Scenario 2 - Visit the city

1. Now that you know how to go to Barcelona you want to gather information about the place. You want to know:
   1.1. Places where you can stay. Try to find detailed information about the place you want to stay, like the rating and contact information.
   1.2. Interesting places to visit.

B.4.2 Transporlis

Test Scenario 1 – Know how to go from one place to another

1. After a long journey you finally arrived at Oriente station at Lisbon. Now you want to know how to go to Tagus Park by public transportation.

   Go to Transporlis and try to know which bus, metro, etc. you have to catch using:
   1.1. The search form to find the start and end points.
   1.2. The map to find the start and end points.
   1.3. Try to know more details about your journey.
      1.3.1. How much money will you be paying?
      1.3.2. What's the estimated travel time?
      1.3.3. How much time will you have to wait?
      1.3.4. How many transhipments will you have to make?
      1.3.5. How much will you have to walk to get to the bus stops or stations?

B.4.3 Itinerarium

Test Scenario 1 – Know how to go from one place to another

1. After a long journey you finally arrived at Campanhã station at Oporto. Now you want to know how to go to Rosa Mota Pavillion by public transportation.

   Go to Transporlis and try to know which bus, metro, etc. you have to catch using:
   1.1. The search form to find the start and end points.
   1.2. The map to find the start and end points.
   1.3. Try to know more details about your journey.
      1.3.1. How much money will you be paying?
      1.3.2. What's the estimated travel time?
      1.3.3. How much time will you have to wait?
      1.3.4. How many transhipments will you have to make?
      1.3.5. How much will you have to walk to get to the bus stops or stations?

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