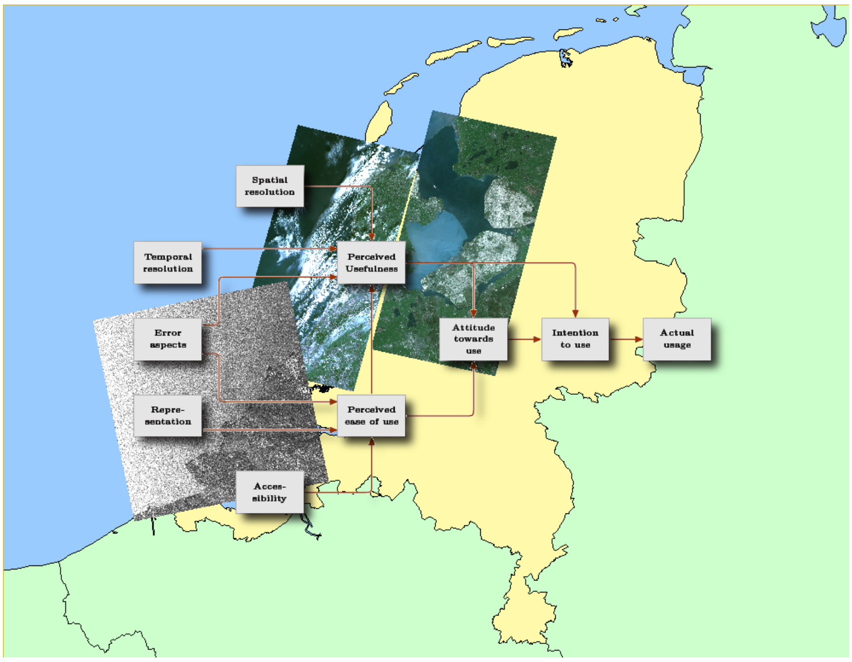
Earth observation acceptance by GIS users

Dissertation



Edwin Wisse

Submitted in part fulfilment of the requirements for the degree of Master of Science in Geographical Information Systems (UNIGIS), Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam
The Netherlands, August 2006

Abstract

Over the last decades the acceptance of Earth observation information has lagged behind expectation. Market forecasts have predicted a large market for Earth observation imagery. Particularly the adoption outside the research community has been much slower than anticipated. A number of possible reasons have been hypothesised. It was assumed that either the spatial resolution was too low for users, that data was not acquired often enough, or that they simply were not able to find information and were thus not familiar with its possibilities.

In this study an attempt is made to identify and quantify the different factors which might form an obstacle for a specific group of users: users of GIS information. In GIS many data sources are used. It is one of the fields were a great future for Earth observation information was predicted. From a literature study and an analysis the following factors were identified: *spatial resolution* (how accurate is the data?), *temporal resolution* (how often is the data acquired?), *error aspects* (how good is the data?), *representation* (how is it delivered?) and *accessibility* (where can I get the data?).

In order to test the relative importance of these parameters a methodology used in informatics was used: the technology acceptance model (TAM). This model uses the constructs *perceived usefulness* and *perceived ease of use* to quantify the acceptance by users. For this a standard scale (a list of questions) was developed. A modified version of TAM was made to test a model for Earth observation acceptance. A new scale was developed and a test session was organised.

The test session involved a group of subjects who were all GIS users, but were not particularly using Earth observation. A questionnaire was taken in a controlled environment where the subjects first listened to presentations about different aspects of Earth observation information and visited the NLR mobile ground station. The test was carried out in an interactive session in which the subjects could explore Earth observation information during the session.

The test results did not support the assumptions made in the modified model. A number of possible reasons can be identified, the test group was small (25 persons) and the number of measured relations and parameters comparatively large. A number of conclusions could be drawn from the results despite the fact that the modified model did not seem to apply. GIS users need high resolution data, current acquisition intervals (of about half a year between image acquisitions) is no problem for them. GIS users prefer accurate to complete information. They prefer in incomplete (but error free) map to a complete map in which some of the information may be erroneous. This is an important find since error in Earth observation information is always present. Ways must be found to visualise and communicate error to make Earth observation imagery and derived products more useful to GIS users.

Finally a number of recommendations are made for further study. It is worthwhile to reformulate the Earth observation TAM with less parameters and less parameters. When this model is used with a larger group of test subjects a true quantification of the affect of the different acceptance parameters should be possible.

Contents

Preface

This report is the result from my graduation study for the Unigis postgraduate course in geo-information. A number of years ago I started the Unigis course to better understand the practices and needs of GIS users. GIS is seen as an important market for Earth observation data, and I wanted to see how people work in that field, what their data needs are. I have received plenty of encouragement and tips to further investigate the GIS users in his or her natural environment and the study has brought me far away from the certainties that engineers prefer. I am pleased that the result of these years in an investigation into the problem that started me with Unigis in the first place.

The results presented in this dissertation are based on my own research at the Vrije Universiteit Amsterdam. All assistance received from other individuals and organisations has been acknowledged and full reference is made to all published and unpublished sources used.
This thesis has not been submitted previously for a degree at any Institution.

Signed:
Steenwijkerwold, 21–8–2006

Edwin Wisse

Acknowledgements

During this study I have been fortunate to get help and advise from a large number of people. Without them this study would not have been possible.

First of all I would like to thank Eduardo Dias for his feedback and help in my exploration of a (for me) completely new field of study: researching actual human users and their needs.

Furthermore I would like to thank Henk Scholten for pointing me into uncharted territory. Being an engineer I proposed a technical subject. By suggesting a *softer* user study in which users would be the focus my graduation study became a very interesting one.

Rob Dekker from TNO kindly provided me with very useful classified images including reliability information. These maps were the result from his own Unigis Msc study. His maps provide excellent examples to the subjects of the user study.

The ArcGIS user group (thanks Hans, Frans, Hedwig, Erik, Juliette and Jeroen) provided me with an excellent group of test subjects when they asked me to organise a user day for their user group at NLR. Without them I would never have found such an appropriate group of subjects for this study and a classroom session would not have been possible.

Finally I would like to thank my colleagues at NLR who have provided me with some constructive criticism on the question scale. I would especially like to thank Bob Moll, Hans Roefs, Mark van Persie and Rob van Swol for the presentations they prepared and gave for the ArcGIS user day, and Peter Koster for the preparation of the ArcGIS user day at NLR.

Thank you all, without your work and your comments it would not have been possible, or at least a lot less fun to do.

Chapter 1 Introduction

Despite the technological developments and the increase in Earth observation satellite missions it has failed to evolve into a mature and self-sustainable operational or commercial activity (Achache, 2003a). A number of possible reasons have been proposed over the years. The emergence of for example high resolution satellite imagery has indeed lead to new applications but still operational application has not met expectations.

It has been noted that Earth observation is very much technology driven. The users are found mostly in areas where adoption of new technology is the norm, like universities and laboratories. The predicted wide user base for Earth observation has clearly not emerged. A number of reasons for the apparent lack of adoption of Earth observation has been proposed.

In this project I hope to find an answer from potential users themselves. There are many users of geographic information who (in my opinion) would benefit from using Earth observation information but who are not making the transition. Using methodology which has been used to study user acceptance in other fields (discussed in chapter 2) I plan to find out what these users actually need.

The problem can be formulated in the following question (1.1):

> *What factors are decisive in user acceptance of Earth observation information by* GIS *users?*

Question 1.1 The problem for this study

There are several ways of identifying the needs of users. The simplest, deriving user requirements from interviews often leads to ambiguous results. It is difficult for users to envisage how new technology or, in this case, data sources will affect the way they work. This problem has been addressed in the field of information systems. As a result, tried and tested methodologies exist to find the factors in user acceptance.

In chapter 2 the technology acceptance model is discussed. The technology acceptance model (TAM) has been defined to test acceptance of information systems (or rather software tools) by computer users. It involves an extension of theories from the field of psychology. The key feature is that it defines two constructs as underlying basis of user acceptance: perceived usefulness and perceived ease of use. These two determine attitude towards technology, which determines the users' intention to use. TAM has been applied both in information technology and in other fields. The model has been extended in order to be applied in those fields.

The research problem in this study involves acceptance of Earth observation information. As I will explain in chapter 3, there are a number of parameters which have been identified as possible hurdles in the acceptance. The different parameters are spatial and temporal resolution, the error aspects of Earth observation information, its representation and its accessibility.
In chapter 4 the modified Earth observation TAM will be presented. Based on the original TAM and the parameters defined in chapter 3, the model was extended with a number of external parameters. The affect of the parameters on the constructs are defined in a number of hypotheses. These hypotheses will be tested using the response data from a questionnaire. The scale (list of questions) of the modified Earth observation TAM is defined. Some of these questions are based on the original TAM scale, most are added to test the hypotheses. A test group of GIS users participated in a test session consisting of a questionnaire combined with a presentation on Earth observation as an information source. An online presentation client was available allowing the participants to inspect and compare different Earth observation data products.
Chapter 5 describes the classroom sessions. The classroom sessions involved presentation of the questions defined in chapter 4 to the subjects group. The subjects received a presentation on Earth observation in which the questions were integrated. They could interact with a (limited) number of data layers illustrating the different aspects of Earth observation information. The group of subjects were all GIS users who were mostly not daily users of Earth observation information. this made them ideal as a target user group.
In chapter 6 the results from the questionnaire are presented. Using statistical techniques, the reliability of the responses was computed. The affect of the parameters on the constructs follows from the correlations between the different parameters and constructs. The results are matched to the hypotheses which were defined in chapter 4.
Chapter 7 contains the conclusions. Despite the limited group size some interesting conclusions can be drawn from the responses of the test group. Finally a number of recommendations are made for further study. These recommendations involve both modifications on the model and recommendations which may improve acceptance of Earth observation information by GIS users, which was the objective of this study.

Chapter 2 User acceptance of technology

2.1 Introduction

The acceptance of new technology by users is of great importance, it is also difficult. The history of technology shows many examples of products which failed in the market despite expectations and planned efforts to meet user requirements. On the other hand the popularity of some products have caught most by surprise. Well known examples of a surprise successes are e-mail and the short message service of mobile telephones. Both products are by products of technology, computer networks and mobile phones respectively, and both have turned out to be driving factors behind the acceptance of that technology.
One example of technology which has not met its expectations is Earth observation imagery. Despite a long development, which has lead to mature technology and acceptance in scientific fields, the acceptance of Earth observation imagery as a commercial data source has not met expectations. Market studies for Earth observation are often projections based on the market for geographical data. Whether Earth observation offers a better solution to the users' problems than traditional data acquisition remains an open question.
In order to test the acceptance of software products methodology has been developed. The technology acceptance model represents a well-established methodology to test whether a software tool offers advantages to users and thus whether they will accept the tool and incorporate it into their work.

2.2 The technology acceptance model

The technology acceptance model (TAM) was developed to test the acceptance of information systems (IS). TAM was first described and applied by Davis (Davis, 1989). It is founded on the theory of reasoned action (TRA). The theory of reasoned action states that a person forms an attitude about a situation (or object or action) based on beliefs. TRA is based on two hypotheses, that intention positively affects usage, and that attitude positively affects intention. On the basis of attitude an intention is formed to handle the situation. This intention completely determines the actual behaviour.
The theory of reasoned action is a well researched model that has been proven successful in predicting and explaining user behaviour across a wide range of domains. According to TRA a person's behaviour is determined by her or his behavioural intention. Intention is determined both by the person's attitude and and subjective norm concerning the behaviour. Here intention is a measure of the strength of a person's intention to perform specific behaviour. The attitude is defined as a person's positive or negative feelings about performing that behaviour

and the subjective norm refers to "the person's perception that most people who are important to her or him think she or he should (or should not) perform that behaviour". TRA is a general model which is not specific to a given domain or technology type. As a result it is not particularly suited for specific domain either and requires careful adjustments to fit a study area. The beliefs that underlie behaviour for a specific case must be explicitly specified by researchers (Davis et al., 1989).

Davis introduced TAM as a specific adaption of TRA aimed at testing acceptance of information systems. TAM uses TRA as a theoretical basis for the definition of the links between its two basic constructs and attitude, intention and actual adoption behaviour.

The technology acceptance model proposes that the acceptance of (information) technology depends on two constructs (independent parameters), *perceived usefulness* (PU) and *perceived ease of use* (PEU), and on the causal chain from the theory of reasoned action: attitude, ntention, and finally (computer) usage behaviour. The perceived usefulness is defined as *the degree to which a person believes that using a particular system would enhance his or her job performance* (Davis, 1989). It is a measure of whether (possible) users think that the technology will help them perform their job better. The perceived ease of use is defined as *the degree to which a person believes that using a particular system would be free of effort* (Davis, 1989). Even if a person believes a technology is useful she may still reject it if she thinks performance benefits are outweighed by the effort to use or introduce the technology.

The relevance of perceived ease of use is based on research on self-efficacy , defined as "judgements of how well one can execute courses of action to deal with prospective situations". Self-efficacy beliefs (or perceived self-efficacy) are regarded as determinants of behaviour. In this case, the introduction of new technology, it deals with how users build expectations of usability and usefulness of that technology. The definition of perceived usability is based on self-efficacy.

The cost-benefit paradigm is also relevant to perceived usefulness and ease of use. It states that the choices users make among various decision-making strategies are made with a tradeoff between the effort required and the benefits they offer. Cost-benefit research has been using mainly objective measures of accuracy and effort.

So the ideas behind TAM are based on accepted ideas from cognitive psychology and management theory.

A schematic view of the theory of reasoned action combined with the technology acceptance model is included as figure 2.1. The relations on which the model is based are indicated by arrows. he first relations are based on the theory of reasoned action: intention determines usage (H_1) and attitude determines intention (H_2). The parameters which affects these are defined within the technology acceptance model: perceived usefulness affects both intention (H_3) and attitude

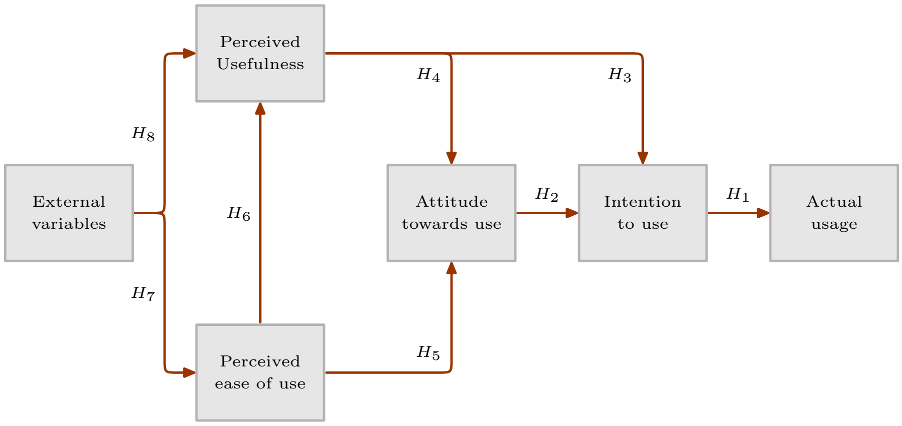


Fig. 2-1 The standard technology acceptance model as introduced by Davis (Davis, 1989). TAM is based on two constructs: perceived ease of use and perceived usefulness. These (and only these) determine attitude and intention. Intention determines actual usage. The relations are numbered and indicated by arrows. These relations are discussed on page 4.

(H_4), whereas perceived ease of use affects attitude (H_5) and perceived usefulness (H_6). Perceived usefulness does not affect perceived ease of use. For users, ease of use does make a product more usable, but the opposite is of course not the case. Increased usefulness (unfortunately) does not make it easier to use.
The relations between external variables and the perceived usefulness and ease of use (H_7 and H_8) depend on the field of study. Using the standard TAM these relations are out of scope since only the constructs are addressed in the questions. Nevertheless they are included in the Davis' model.
The data collection is generally done using a questionnaire. The study subjects (or users) acquaint themselves with the test subject matter and answer a series of questions afterwards. The resulting data can then be used to draw conclusions on what factors contribute the most to the acceptance by the subjects. The questions on the questionnaire allow users to select between 5 alternative answers ranging from *completely disagree* to *completely agree*. These questions must be formulated carefully to allow distinction between the factors one tries to measure.
The model was intended for information technology. Because the model proved to be useful, it has been adapted for (and applied) in other technologies as well. Mainly it has been used to rate the acceptance potential of information, communication and consumer products. Several authors have applied simplified models in which ease of use and usability affect usage directly. Intention to use and attitude are ignored in these models. In the case proposed here intention and attitude seem to be important factors (page 4).

According to Davis the perceived usefulness is a major determinant of people's intention to use a tool whereas perceived ease of use is a (significant) secondary determinant of intention.
The emphasis in studies using TAM lies on the perceived usefulness and perceived ease of use constructs and on the parameters which affect these. However, it is important to use the other elements, derived from the theory of reasoned action, as well. The influence of attitude deserves some further attention. Yang shows shows that a better understanding of the role of attitude can enhance the models predictability (Yang and Yoo, 2004). Davis found the affect of attitude to be modest. By using a more precise definition of attitude its influence can be quantified more reliably. Attitude can be defined to consist of two components: affective attitude refers to how much the person likes the object of thought, while the cognitive attitude refers to an individuals specific beliefs related to the object. In this case it can be argued that attitude is particularly important, even as an independent parameter, due to the public's attitude toward space technology. Space technology is seen as *difficult*, high-technology. An attitude which can possibly hamper its adoption in applications.

2.2.1 Scale

The scale is the list of questions (or scale items in TAM terminology) used in a TAM questionnaire. The purpose of the model lies in the quantification of the relations between the different constructs defined in the model. The questions must be selected to match the relations between the constructs.
Davis' research had resulted in a standard set of questions which can be used in standard TAM studies. The Davis' scale was aimed at testing acceptance of a new tool by users. The scale items (the questions) were pretested by asking a group of subjects to rank the questions against the definitions of the variables and eliminating questions which receive a low ranking. By asking the subjects to rate similarity of scale items those with excess coverage of a construct were removed and others where added where inadequate coverage is indicated.
Table 2.1 shows the standard Davis' scale. The strength of the model lies in well chosen questions. Questions should be able to cover the hypothesised relations. Otherwise no conclusion can be drawn from the responses. Note that all questions refer either to PU or PEU. No questions are included to measure the affect of the construct on Intention. This is because it is hypothesised that attitude and thus intention are completely determined by the constructs.
The standard Davis scale has been adapted for a wide range of TAM studies. The Davis' scale has been developed with software tools in mind, so when applying it to other technology the scale items should be reconsidered. Also, researchers have added other constructs, naturally these require a redesigned scale.

Table 2-1 The original questions (scale items) as formulated by Davis refering to a hypthetical software tool called *TestTool*.

Using *TestTool* in my job would enable me to accomplish tasks more quickly	PU
Using *TestTool* would improve my job performance	PU
Using *TestTool* in my job would increase my productivity	PU
Using *TestTool* would enhance my effectiveness on the job	PU
Using *TestTool* would make it easier to do my job	PU
I would find *TestTool* useful in my job	PU
Learning to operate *TestTool* would be easy to me	PEU
I would find it easy to get *TestTool* to do what I want to do	PEU
My interaction with *TestTool* would be clear and understandable	PEU
I would find *TestTool* to be flexible to interact with	PEU
It would be easy for me to become skilful at using *TestTool*	PEU
I would find *TestTool* easy to use	PEU

2.2.2 Extensions to the model

Depending on the applications, modified versions of the model have been formulated and applied by a number of authors. One example is the inclusion of perceived attractiveness . Perceived attractiveness is defined *the degree to which a person believes that the systems interface is aesthetically pleasing* (van der Heijden, 2003). The perceived attractiveness fits into TAM as an extra construct next to PU and PEU. For a study on acceptance of a portal website the model was extended with *perceived enjoyment*. The perceived enjoyment is relevant in recreational or game-based learning environments (van der Heijden, 2003, Venkatesh, 1999) where fun is an incentive for adopting and using a system. The enjoyment is relevant in cases where technology is used in a recreational sense. For a study in e-learning acceptance (Ong et al., 2004)the parameter *perceived credibiliy* was introduced on the basis of the assumption that the users (computer-savvy engineers) needed to be convinced that e-learning offers advantages over their normal practice of learning new techniques on their own. As already mentioned in section 2.2.1 the newly introduced constructs require a new scale. In both cases questions were added for the new constructs, and some questions were omitted to limit the total number of questions.

TAM has also been used as a basis for an extended model in combination with other models like the task-technology fit model (Junglas, 2003). The latter model describes the degree to which a technology assists an individual in performing a portfolio of tasks. More specifically, it reflects the correspondence between task requirements, individual abilities, and the functionality of the technology.

In general, external parameters are used to adapt the technology acceptance model for different fields. The new parameters can be constructs or can be external variables. In a study on the acceptance for e-learning systems a number of independent system characteristics like *functionality*, *interactivity* and *response* are introduced (Pituch and kuei Lee, 2004). Venkatesh introduced another extension to TAM by introducing social influences like *subjective norm*, *volitariness* etc. on the constructs (Venkatesh and Davis, 2000).
Extension of TAM depends strongly on the study subject and the personal preference of the researcher. The subjective aspect of studies like these cannot be avoided but should be taken into account.
The introduction of new constructs and parameters should be avoided when possible. The attractiveness of the original TAM lies partly in the fact that it reduces the complexity of the research problem to two independent parameters. Adding new constructs introduces the risk that these parameters may be correlated to perceived ease of use or perceived usefulness. Extending the model with other models also makes the model too complex. The simplicity of TAM is useful to reduce a subjective and complicated subject to a quantifiable study.
One aspect of the e-learning and recreational website studies does apply to other study: in a learning environment a playful, recreational approach can improve perceived ease of use (Venkatesh, 1999). Since using TAM to test new technology will usually involve instruction the influence of perceived enjoyment can be important.
Lederer gives a brief overview of these alternative models in his paper on web usage (Lederer et al., 2000).

2.2.3 Influence of culture

The technology acceptance model has been applied mainly in North America. Since it is based on assumptions about motivations and intentions of users there could be an influence of culture. In other cultures the relation between attitude and intention may be less pronounced or be influenced strongly by other factors. The applicability of the model in other cultures has been studied (Straub et al., 1997), one of the conclusions was that the model holds in a European context as well. It sould be noted that TAM has been used with apparent success in Asian countries as well, despite one of the conclusions from the aforementioned study. Since we are dealing with a European environment in this study the applicability in Asian cultures is less relevant.

2.3 Concluding

Perceived usefulness refers to the benefit a technology can bring and perceived ease of use refers to the effort it takes. In the technology acceptance model these two parameters determine whether a new technology will be adopted by the user. The technology acceptance model was designed explicitly for information systems and more specific adoption of computer applications in the workplace it has been applied for a wide range of applications such as mail tools, word processors etc. After the model proved to be successful, it was applied to a much wider range of technology. In studies the acceptance of web-based information tools both for work and for pleasure was tested, expanding the applicability of TAM beyond the workplace. TAM has been extended both with new constructs and external parameters.

In the following section I will discuss a new information source for GIS users: Earth observation. A number of problems can be identified in the acceptance of Earth observation. The goal is to formulate these problems such that they can be incorporated as parameters into a modified TAM.

Chapter 3 Earth observation

3.1 Introduction

The term Earth observation covers all techniques used to get information about Earth from satellites in space. A wide range of sensors are used to measure reflectance, gravity, magnetism and other parameters. The remote sensing tutorial (NASA, 2005)offers an introduction to the wide field of remote sensing.
Earth observation has found wide use particularly in areas which were not covered by traditional means of collecting geo-information. In developing countries it is often preferable to produce an up to date map on satellite imagery due to remoteness of the study areas. Also, using Earth observation a new view on Earth can be acquired by using new instruments.

3.1.1 About terms

The term remote sensing is used for all data acquisition using sensors to observe a subject in another location. These sensors can be satellite or aircraft based, or even located near the ground on an elevated platform. The term *Earth observation* is generally used when referring to *satellite based* remote sensing. Therefore the term *Earth observation* is used in this document.

3.1.2 A (very) brief history

In the beginning of space development the possibility to monitor the Earth from space was already seen as one of the important applications of this new technology. The first astronauts were the first to have a large scale view of Earth and brought hand-held cameras to show the view to the world. The first imaging satellites were launched soon after. Obviously, during the Cold War, military surveillance and reconnaissance was the first application using remote sensing extensively. The first dedicated, civilian remote sensing satellite was Landsat-1 (then called the Earth Resources Technology Satellite, ERTS), launched on the 23rd of July, 1972. Landsat proved to be a pioneering mission, showing how agriculture and the environment on Earth could be observed from space. Since Landsat a wide range of satellites carrying an even wider range of sensors has been orbiting Earth. Earth observation satellites have been developed and operated by most space agencies. In Europe the French Spot series of satellites is well known and has contributed greatly to the routine scanning of Earth.
Modern Earth observation satellites carry high resolution optical sensors, allowing objects of about a square metre to be discerned. Others image the Earth using other sensors like radar, allowing the to see through clouds and to make very precise height measurements.

The first decades of Earth observation the satellites were mainly scientific satellites. These satellites were aimed at studying the Earth with new and improving sensors. The last years have seen more and more commercial companies exploiting and even launching its own Earth observation satellites. The commercial satellites carry high resolution sensors aimed at new non-scientific users. This commercial development marks a new phase in Earth observation. Presently we are in a transition from a scientific to operational and commercial use of Earth observation.

3.1.3 Satellites and sensors

There are two, fundamentally different, types of sensors: passive and active sensors. The passive sensors detect radiation which is reflected or emitted by Earth itself. The reflected radiation comes ultimately form the Sun. The Sun emits radiation in a wide frequency range, with a peak around yellow visible light. The frequencies which can be used for passive Earth observation depend on the absorption by the atmosphere. Visible light and infrared reach the surface almost unattenuated, but high frequency radiation like ultra-violet (UV) radiation is almost completely absorbed. It is a fortunate coincidence that the atmosphere is quite transparent to electromagnetic radiation in the region of peak emission from the Sun.

Optical instruments are the best known example of passive instruments. These sensors make imagery which is familiar to users since they imagery corresponds to photos of the Earth, only taken from a higher altitude. Infra-red (IR) sensors give information about vegetation and vegetation health.

Dust, smoke, aerosols, and condensed water vapour (clouds) can scatter and block visible light. The fact that visible and infra-red radiation is blocked by clouds hampers image acquisition in some areas on Earth. Over the Netherlands cloud cover strongly limits the number of images which can be recorded.

A passive sensor may measure the reflectance in a single frequency band. This is called a panchromatic sensor. A panchromatic sensor produces gray-scale (black/white) images. A multi-spectral sensor measures the reflectance in a number of frequency bands. Images from the different bands can be combined into false colour images highlighting features on the ground or they can be combined to produce true colour images. Most Earth observation satellites carry both panchromatic and multi-spectral sensors.

The atmosphere is transparent to long-wavelength radiation as well. Radio and radar waves can therefore also be used for Earth observation. However, since the Sun does not emit strong radiation at these frequencies passive sensors cannot be used. So called active sensors have been developed which transmit radiation themselves, the reflectance by Earth is then measured.

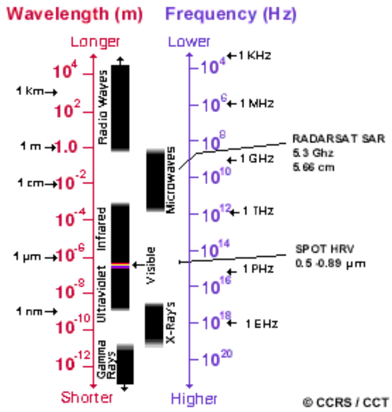


Fig. 3-1 The electromagnetic spectrum. From (Canada Centre for Remote Sensing, 2004)

Active sensors use radar frequencies. Radar sensors transmit radar pulses to Earth, the return pulses are detected by the instrument. The strength of the return pulse depends on the reflectivity and geometry on the ground. The advantage lies in the fact that these input is known and that the frequency of the instrument can be chosen. Radar instruments can be designed to be weather independent, they can see *through* clouds.

Radar instruments are the best known examples of active sensors. Presently laser based instruments are being introduced in Earth observation but are presently only used experimentally.

Almost all earth observation satellites follow orbits over the poles, which causes almost the whole Earth to pass under them. Satellite orbits cannot be changed practically after launch so the choice of orbit is important. Most Earth observation satellites follow sun-synchronous orbits, this means the pass (almost) over the poles and that the orbit's orientation stays the same with respect to the Sun. As a result Earth observation satellites pass over the same area on Earth in the morning or in the afternoon/evening.

3.2 Strengths and weaknesses

To the early space technology developers the advantages of remote sensing from space were obvious: the possibility to monitor the whole planet on an unprecedented scale. It has found wide application in environment monitoring. Satellites allow regular observations in places where none were feasible before. However, Earth observation has not been applied as widely as predicted in the traditional geo-information community.

To explain the lagging market development a number of possible reasons have been proposed These perceived shortfalls will be discussed in the following sections.

3.2.1 Spatial resolution

Earth observation imagery offers synoptic data. Synoptic means that it has a global scope. The fact that a single sensors circles the whole Earth for years results in a dataset which is consistent both geographically as well as temporal. This allows different regions to be compared, or the same region in different years. The extent of a single image gives a user an overview which is simply unattainable with sensors closer to Earth. This comes at a price. The smallest elements in an image are the called pixels . The size on the ground of these pixels determine the spatial resolution of the images. For a typical image of the traditional Earth observations satellites such as Landsat or the SPOT series the resolution is in the order of ten(s) of meters.

Tables 3.1 and 3.2 list the resolutions of a number of prominent optical and radar satellites (ESA, 2004). The optical sensors in table 3.1 show the characteristics of the multi-spectral sensors[1] of the satellites. Often they have a panchromatic sensor[2] as well with a better resolution. The table shows a number of sensors with a limited number of bands optimised for high resolution and a number with a large number of bands with lower resolution.

The relatively low spatial resolution of the standard optical sensors was obviously no problem for the main application fields for which the data was used. This imagery was (and is) mainly applied for scientific studies involving large areas, for example assessment of vegetation growth over a large area or studies on the impact erosion or studies on (large scale) urban development. For analysis of, for example, developments and changes within an urban environment at building level their resolution is insufficient. Also detailed analysis of agriculture is not possible using the relative coarse traditional optical imagery.

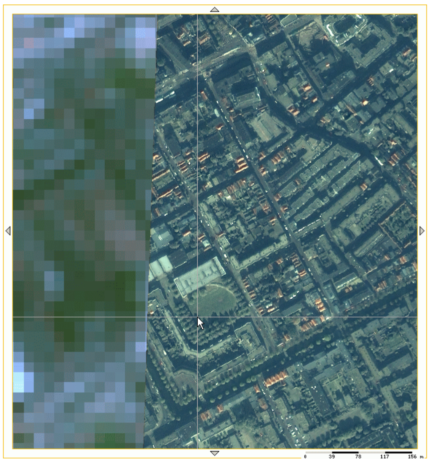
The need for higher resolutions has led to the development of a new generation of satellites. These are the commercial satellites Ikonos and Quickbird. These satellites offer imagery with resolutions in the order of a meter (Ryan et al., 2003). Imagery from these satellites is slowly finding acceptance to monitor urban environments (Ganas et al., 2002, Lee et al., 2003)where many features of interest have scales just below the resolution threshold of the traditional Earth observation sensors. The resolution of the imagery from these high resolution sensors is still considerably more coarse than aerial photography.

Figure 3.2 shows the difference between standard optical imagery and high resolution imagery and radar imagery. The difference between standard optical and high resolution are large.

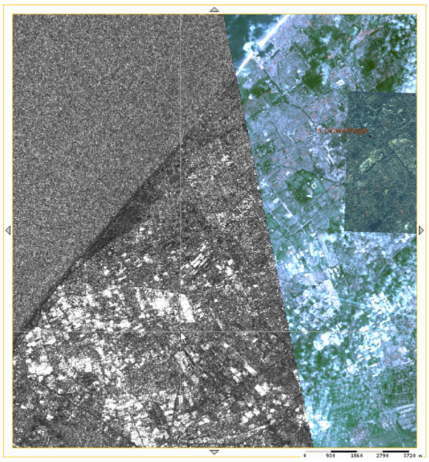
As can be seen in the list of radar sensors (table 3.2) radar images tend to have a lower resolution than the optical satellites although future high resolution radar

[1] a multi-spectral sensor measures reflectance in a number of bands which can be combined into colour images

[2] panchromatic sensors measure reflectance in a single band, resulting in a gray scale image



optical and high resolution



optical and radar

Fig. 3-2 Two overlays showing different data types side by side.

Table 3-1 Characteristics of a number of optical Earth observation satellites. Landsat and SPOT are well known satellites with standard sensors. Envisat and Terra carry multispectral sensors with much more bands. The commercial Ikonos and Quickbird satellites offer high resolution, but less bands. The quoted revisit times of Ikonos, Quickbird and Cartosat are achieved by pointing the sensor off-track. The satellites themselves have revisit times in the order of a month.

satellite (sensor)	bands	resolution (m)	swath (km)	revisit time (days)
Landsat 4,5	7	30	180	16
Landsat 7	7	30	180	16
SPOT 2,4	3/4	20	$2 * 60$	26
SPOT 5	4	10	$2 * 60$	26
Envisat (MERIS)	15	260	1050	35
Terra (ASTER)	3	15	60	16
Terra (MODIS)	36	250	2330	16
Quickbird 2	4	2.4	16.5	
Ikonos 2	4	4	13	1.5
Cartosat 1	1	5.8	70	1 to 4 days

sensors are planned to be launched within the near future. The main advantages of radar sensors lie in the fact that they are not hampered by cloud cover and that the nature of radar measurements allows for very different information to be derived from the raw radar data. Radar data allows vertical soil movement to be tracked accurately, some vegetation types can be distinguished and roughness of water surfaces can be measured. In this study we will only consider imagery

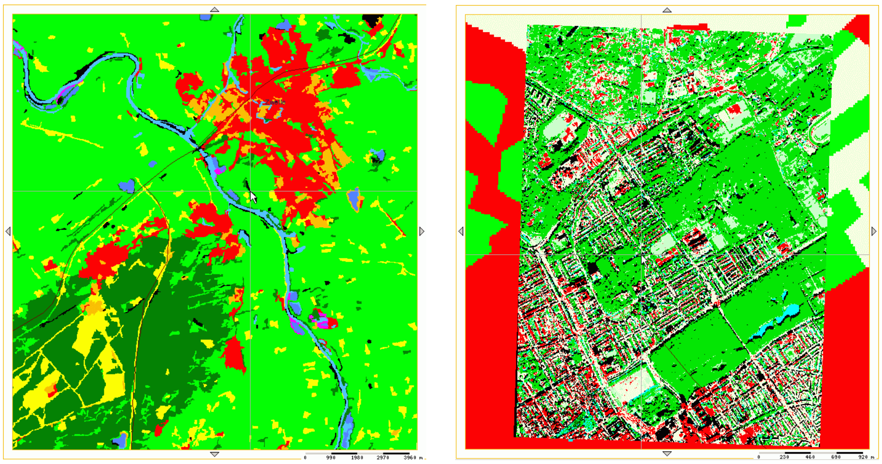
Table 3-2 Characteristics of a number of radar Earth observation satellites. Terrasar is planned constellation of two different radar satellites.

satellite	resolution (m)	swath (km)	revisit time (days)
ERS 1,2	25	100	35
Envisat (ASAR)	30	60-100	35
Radarsat 1	8-100	50-500	24
Radarsat 2	3-28-100	20-100-500	24
TerraSAR	1-30	20-200	11

derived from radar data but one should keep in mind that its versatile technology allows much more to be observed and measured than just the imagery aspects. Since radar satellites measure the reflectance of a radar pulse transmitted by the satellite radar images are always grey scale. Radar images show the reflectance of radar waves by the Earth.
In table 3.2 there are several figures for the resolution for a number of radar satellites (Radarsat and TerraSAR). The resolution of the sensors on these radar satellites depends on the mode they use to acquire the image. A radar satellite can be set to spot beam mode or wide beam mode (or several modes in between).

3.2.2 Temporal resolution

Earth observation sensors are carried by satellites. The orbit geometry in combination with the viewing angle results in the fact that satellites can only provide a limited number of images over a given time. The revisit time is defined as the time between (possible) acquisitions of a satellite image of a given area. The revisit time determines the temporal resolution of a data product. In the above definition I used the word *possible* because the minimum revisit time is by no means the actual revisit time. Optical sensors are useless when the area of interest is covered by clouds. This is particularly common for areas in the mid-latitudes on Earth, which happen to be relatively densely populated and thus are important areas to monitor. Radar imagery (SAR) does not suffer from this problem, but the characteristics of a radar image are very different from an optical image.
Revisit times are reduced by programming the satellites to repeat observations during subsequent passes. However, this carries a considerable price tag. The satellite will have to be programmed to acquire imagery whenever it passes near the area of interest. Typical revisit times range from a couple of days to several weeks or even months. Tables 3.1 and 3.2 list the revisit times of a number of the most prominent Earth observation satellites.
One of the proposed reasons why Earth observation is not used more widely is based on these limited revisit times. A data provider who can guarantee regular



optical high-resolution

Fig. 3-3 Classified images from optical data and high resolution optical respectively.

will have to use a number of identical satellites. This is called a (satellite) constellation . A constellation of radar satellites is proposed as a commercial viable opportunity (Krischke et al., 2000). No satellite constellation has been implemented. Therefore it is still an open question whether a improved revisit time addresses the needs of prospective Earth observation data users.

3.2.3 Error aspects

In present GIS implementations error is not prominently represented. Data is essentially treated as if it were error free (Goodchild, 1998, Worboys, 1998). The fact that this leads to discrepancies when bringing Earth observation data into a GIS has been noted (Gahegan and Ehlers, 2000). Knowledge of the errors present in Earth observation data is essential for users. Presently the largest user group consists of scientific users.

Errors in Earth observation data can mean both the spatial error (or rather uncertainty) resulting from the spatial resolution and classification error . The spatial uncertainty was discussed in section 3.2.1, classification will be introduced in section 3.2.4. Apart from the spatial resolution there may be a spatial error (due to pointing errors in the satellite sensor). As stated in section 3.2.4 a considerable error (up to 100 metres) in the location of the pixels may be present in the raw imagery. If a user buys an image from a specialised company these errors may have been corrected.

The classification error is partly due the theories and models used to derive information from Earth observation data and partly due to the size of the individual pixels. When a pixel covers an area containing several different features the spectrum of the pixel will show aspects of all features present on the ground. Classification of this pixel to one single feature type will unavoidably result in the elimination of the other possible feature classes in this location.

Table 3-3 Overview of land use classification experiments. Maps were used to improve the classification. This table was taken over from (Dekker, 2003). PHARUS is not a satellite based sensor, but was used in the study since it compares well to planned satellite based radar sensors.

sensor	bands	resolution	map	scale	method	PCC	kappa
Landsat 5 TM	6	30 m	VMap1	250K	fuzzy	82.9%	59.6
ERS 1	1	30 m	VMap1	250K	NN	52.1%	36.3
Ikonos	4	4 m	TOP10	10K	NN	42.4%	26.8
PHARUS	1	4 m	TOP10	10K	NN	48.3%	29.4

Classification errors depends strongly on the classification type and sensor characteristics. The number of bands can improve classification reliability considerably. Single band radar images are more difficult to turn onto classified maps than multi-channel optical images.
Table 3.3 shows the results found in a comparative study of classification using advanced techniques for a number of different sensors (Dekker, 2003, 2004). In this study classification results using either (multi-spectral optical) or radar data were compared. The best results were achieved using multi-spectral,medium resolution Landsat data. Even in this best case the percentage correctly classified (PCC) was only 83 %. For high resolution sensors the PCC is significantly lower. For radar satellites the PCC is lower, but the results suggest it does not drop significantly with increasing resolution.
Another discrepancy between the GIS and Earth observation user communities lies in the standard used to represent accuracy. The GIS definition is scale . Scale is based on the cartographic meaning of scale: the ratio of the length of a distance unit on a map and that distance unit. This ratio has no dimension. In Earth observation the unit for map accuracy is the resolution, the smallest size of an object represented in the map. When we want to bring digital Earth observation data into a GIS environment this discrepancy must be taken into account (Goodchild, 2001).
Over the last few years the problem of error handling and representation in a GIS environment has received increasing attention. Dealing with uncertainty in classification is not unique to Earth observation derived information. It can be addressed by using logical constructs formulated to deal with uncertain information in general (Duckham et al., 2001). It is seen as a problem of representation (Ehlschlaeger, 2000). This is a general development in GIS and goes well beyond the scope of this study.

3.2.4 (Re)presentation

Earth observation data differs in one important aspect from traditional geographic information, Earth observation data is represented as a raster of (pixel) values. Traditional GIS data tend to be represented as vector information, as a series of points, lines and polygons plus their meta-data. In the GIS community a distinction is made between raster and vector oriented data. Software packages are even divided between raster and vector type packages. Most GIS users use vector data. Raster data is generally regarded as *raw* data which must be converted to a vector format.

Earth observation imagery as it is delivered by the satellite operators needs a number of operations to make it useable. If the image is delivered within a projection system there can be a considerable error in the locations of the pixels. A pixel may be as much as 100 metres from its indicated position[3]. Also the image will need to be processed to adjust its colour and brightness parameters (stretching). A raw Earth observation image is affected by the changing lighting conditions and uses standard exposures, unlike a normal camera. Images are therefore too light or dark by default.

Raw Earth observation data contains a wealth of information, but it requires expert knowledge to extract it from the data. By carrying out a classification meaningful information can be extracted from the images. The resulting classified image will show where, for example, certain vegetation types grow or show different types of buildings or soil type. A classified image shows information which is much more useful for the user than the *visual representation* of the image. Classification requires knowledge about how different types of vegetation, building or soil are represented in the raw imagery as intensities in the different bands.

Using modern software packages this data extraction can be carried out routinely. Some of these packages export the information as vector layers to standard GIS file formats. One example is Ecognition , which extracts vector information from the data rasters and then treats the segments as objects in the classification (Benz et al., 2004). This yields a classified map in a standard GIS vector format.

3.2.5 Data accessibility

First and foremost prospective users have to be able to find the data they need. They must know the data providers and must be able to distinguish the differences between data products and which data product corresponds to their needs best. There is a wide range of data products with different parameters and different levels of quality and accuracy.

Each of the different data products is offered through its own channel. There are a number of providers satellite imagery and each has its own sales channel. Currently, companies and institutes offering Earth observation data have online web

[3] This is due to the fact that the location information is derived from the known position and pointing of the sensor, which is only known with a limited accuracy

a b

Fig. 3-4 An Earth observation image (a) and a vector representation (b) showing the result of the segmentation and classification operations. From (Benz et al., 2004)

interfaces allowing users to search, select and order data. Each of the satellite operators have their own interface. This makes data ordering cumbersome for users. As a result a number of small companies act as intermediates between the data providers and users. Alternatively there are small service providers on the market offering services like search requests and other data services. These service providers search for data taking the users' requirements into account. Their business is largely based on their contacts with the satellite imagery providers. There is presently no single point of contact where users can search, compare and order Earth observation data.

A spatial data infrastructure (SDI) offers users and providers of data a way to offer, find and retrieve data and information. Within Europe a number of initiatives have been initiated to build a European or national spatial data infrastructure. These initiatives were based on the idea that there were many users looking for different and better data sources but were unable to find what was available. Search facilities are an important part of the data infrastructure designs. There is a wide range of raw data products (from infrared to optical to SAR) and an even wider range of processed products based on this raw data. As a consequence a user has to use a complicated search tool in order to find data.

Data formats are another data accessibility issue. It is possible that for GIS users the data is simply delivered in the wrong format. Earth observation images are rarely delivered in the formats used in standard GIS packages. Some packages allow this kind of data to be imported easily, but nevertheless this means that importing and handling Earth observation imagery is a special operation within a GIS.

Within the technology acceptance model data accessibility is a factor which influences perceived ease of use (PEU) rather than perceived usability.

3.3 Concluding

Table 3.4 lists the different problems a GIS user may face when she wants to start using Earth observation data. In the following chapter we will see how these fit into the technology acceptance model.

Table 3-4 Identified factors in the (lack of) adoption of Earth observation data by GIS users

Accessibility	Where can I get Earth observation data?
Representation	How is it delivered?
Spatial resolution	Is the data (spatially) accurate?
Temporal resolution	Can data be acquired when needed?
Error	How good is it?

Chapter 4 Earth observation and TAM

4.1 Introduction

In the previous chapter I have introduced the technology acceptance model and discussed the different possible reasons for the lack of acceptance of Earth observation. This resulted in the definition of five parameters which can be used to test the acceptance of Earth observation. In this section I will discuss how TAM can be used to test acceptance of Earth observation information.

4.2 Testing Earth observation use

The objective of this study is to identify what parameters decide the acceptance and use of Earth observation data by users of geo-information. In terms of the technology acceptance model these parameters influence the perceived ease of use and the perceived usability.

Since the TAM model does not incorporate external factors affecting the constructs the relations of the parameters to the constructs must be hypothesised. The resulting hypotheses can then be tested in a similar way to the TAM hypotheses.

There are a few notable differences between testing acceptance of a software product and an information source like Earth observation. TAM is generally used to test a software tool which is new to users. In this case I will test an information source to which the subjects have already been exposed. Most will know Earth observation information from trade magazines, presentations at conferences or from specialised companies. Some may already use Earth observation data.

This study is not aimed at a specific user group. Rather, it tries to find to requirements of a very diffuse group of (possible) users. Therefore the users will have very different work procedures and very different needs. It is important that the questions used are relevant to the whole user group.

4.2.1 Components analysis

The first objective of this study was formulated in question 1.1 on page 1. The objective is to identify the factors which have limited the remote sensing market development. A number of possible shortcomings of Earth observation information was discussed in chapter 3. Assuming that these parameters are the most important ones we can formulate the first hypothesis (4.1).

So we postulate that the external parameters mentioned in the original TAM (Davis et al., 1989)are the parameters from the Earth observation weaknesses analysis. How strong the parameters affect the different constructs now becomes one of the objectives of this study.

The identified shortcomings of Earth observation as a data source influence the perceived usefulness and perceived ease of use in the acceptance of Earth observation as a data source.

Hypothesis 4.1 Parameters affect PU and PEU

When we look again at the research problem for this study (question 1.1) we see it refers to the parameters influencing usage, rather than usage itself. Before using the TAM to model user acceptance we should determine how these parameters affect the PU and PEU.

4.2.2 Parameters in the technology acceptance model

Over the years, the technology acceptance model has been applied to a wide range of fields. For many studies the standard TAM constructs were deemed to be insufficient to model some aspects of the study field.

In section 2.2.2 we have seen that the model has been extended and tested with a number of extra constructs and parameters. The practice of extending the model to fit a specific field of study is well established and has been documented well. For different fields a strongly different set of extra constructs can be used to test the parameters which affect perceived usefulness and ease of use. This gives researchers a means to interpret the influences affecting acceptance. The fact that such different parameters and constructs are defined for different studies is a recognition of the fact that very different factors determine acceptance in different fields.

In section 3 we have identified a number of parameters which (according to hypothesis 4.1) affect the perceived ease of use and perceived usefulness. The difference between these parameters and the constructs as applied in a modified TAMis the fact that the parameters refer not to perception by users, but instead they refer to physical characteristics of Earth observation information. The parameters are independent of the constructs in the sense that they affect the constructs, but they are not affected by the constructs or by other parameters. This is a fundamental difference between this study and other studies using an extended TAM.

Figure 4.1 shows the Earth observation modified TAM. Five parameters are introduced to reflect the factors identified in chapter 3. Not all parameters affect both PU and PEU constructs. The introduction of the new parameters results in a number of hypotheses.

The spatial resolution is a quantifiable parameter. Therefore its affect on the dependent variable PU can be measured. For this reason the term *degree of spatial resolution* is used. Ideally it would be possible to find out at what resolution

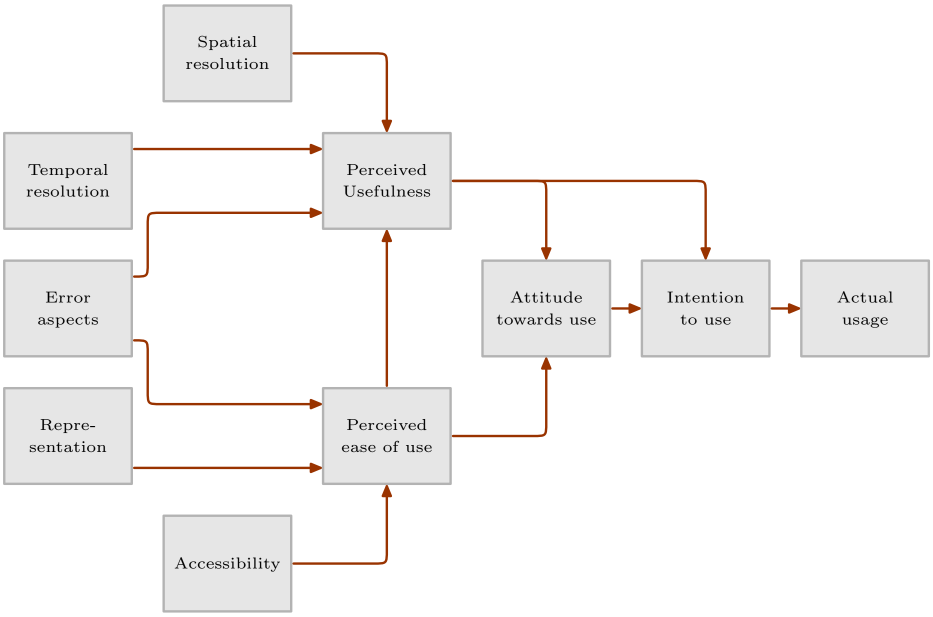


Fig. 4-1 The modified Earth observation TAM *model. The focus lies on the characteristics which influence the perceived usefulness and perceived ease of use.*

The degree of spatial resolution positively influences PU.

Hypothesis 4.2 Spatial resolution affects PU

Earth observation information becomes useful for users. Figure 4.2 shows the presumed relationship between spatial resolution and PU. The usefulness is perceived as low when the resolution is low after which it increases until it reaches a maximum again.

The degree of temporal resolution positively influences PU.

Hypothesis 4.3 Temporal resolution affects PU

The temporal resolution is similar to the spatial resolution, both are quantifiable parameters. Therefore it can be assumed that there is a relation between the *degree of temporal resolution* and usefulness similar to the relation between spatial resolution and usefulness. This depends greatly on the temporal resolution needed by possible users.
A relation between spatial and temporal resolution on PEU is not assumed. It proved to be very difficult to define scale items which test this relation (see section 2.2.1). After all, PEU refers to ease of use, and there is little influence of the

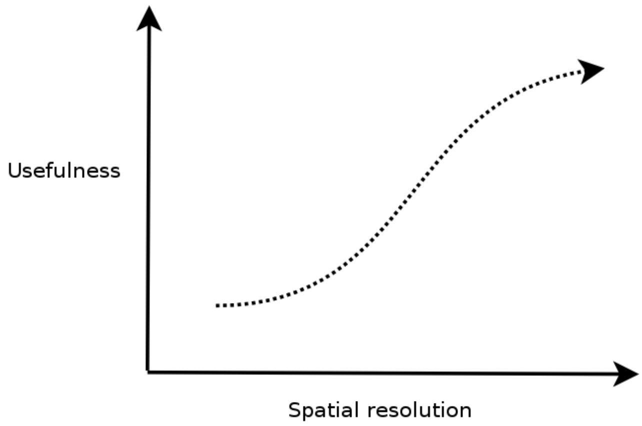


Fig. 4-2 Possible relation between spatial resolution and usefulness.

degree of resolution on this. This can be seen when we consider two copies of the same series of images, when we degrade spatial resolution (by sub-sampling for example) or the temporal resolution (by omitting images from the series) this does not affect ease of use in any way. Only the fact that Earth observation images are (generally) delivered as raster data can have an affect on ease of use. However, in this study the raster nature of the data is represented by the introduction of the representation parameter.

The error aspects influence both PU *and* PEU*.*

Hypothesis 4.4 Error affects PU and PEU

Error aspects are less easy to quantify. There are a number of error parameters which are combined into the single parameter. Both the geo-referencing error and the classification error are error aspects. To be able to quantify them they should be treated as separate parameters, along with other error aspects. It is decided to treat different error aspects as a single parameter to limit the number of questions. Error itself is hard to quantify, quantifying the relation between the different error parameters and the PU and PEU constructs is even more problematic. Error aspects affect both the ease of use and usefulness. It affects ease of use since it may require action from the user. It affects usefulness since it puts limits on the usability of the information.

Accessibility positively affects PEU*.*

Hypothesis 4.5 Accessibility affects PEU

Accessibility is a measure of how easy a user can find relevant information. A prospective user needs to overcome a hurdle in finding access to data sources. Once she or he has established how to find data, the operation of searching and ordering will be known. How easy-to-use and useful an interface for searching and ordering data is, could be the subject of a TAM study in its own right. The study of the acceptance of a user interface for searching data is out of the scope for this study. Given the present development towards a geospatial data infrastructure this can be a useful study when such an infrastructure comes available.

Representation positively affects only PEU.

Hypothesis 4.6 Representation affects PEU

Representation indicates whether the information is delivered in a form which is directly usable in a GIS environment. This suggests it affects ease of use only. How usable the interface for importing the information into a GIS is, depends on the user interface of the GIS used by the subject. As such it is out of scope for this study. This leaves the ease of use. When subjects are presented with information about representation (the file format used, preprocessing aspects) she or he can form an opinion about how easy it is to import this information regardless of the interface implemented in the GIS.

Both accessibility and representation affect only the perceived ease of use since neither offers any advantages in terms of job performance, which is modelled as the perceived usefulness. Part of the ease of use aspects of the parameters are out of scope since they affect the ease of use of external interfaces.

One of the differences between this study and TAM studies in general is the fact that we are testing an information source rather than a software tool. In TAM studies, the ease of use questions refer to how easy it is for a user to adopt and use new technology. The type of questions used in the standard scale clearly reflect this. The ease of use is a valid construct for Earth observation information but as already noted in the discussion of hypotheses 4.2, 4.3 and 4.4, it is assumed that these three independent parameters influence mostly PU. This leads to the formulation of the final hypothesis.

The PU *construct in the modified Earth observation* TAM *model is a stronger construct than* PEU.

Hypothesis 4.7 PU is stronger than PEU

As a result, we can expect a stronger affect of PU on intention to use. It is likely the affect of the parameters on PU will also be more pronounced.

4.2.3 Scale

The questions as formulated by Davis (see table 2.1 on page 7) are intended to be applied in a traditional TAM study. As stated before there are a few notable differences to be taken into account. First of all we are not testing a tool, but an information source. This means that the usefulness (PU) can be tested more straight forward than the ease of use (PEU). The ease of use is relevant to the user interfaces of the tools used to find, order and import data rather than the Earth observation information itself. Nevertheless, the information has ease of use aspects which can be tested. Care should be taken that ease of use questions refer to Earth observation as an information source, rather than to the tool which will be used to search, process and visualise the data.

Table 4-1 Non-TAM questions included to identify the background of the test group.

number	question
1	What kind of organisation do you work for?
2	How many people work in your organisation?
3	Do you have experience with Earth observation information?

The questions used in this study differ from those defined in the standard TAM as defined by Davis (Davis, 1989). Modified and new constructs have been used in a number of studies to apply the TAM to different study areas. Adding constructs requires a new scale to be developed. In one example discussed previously, the new constructs *perceived attractiveness* and *perceived enjoyment* were introduced as additional constructs and the number of questions was limited to 3 per construct (van der Heijden, 2003).

In this study I formulated new scales since the constructs from Davis were not applicable in this case and the number of constructs had to be limited due to the large number of variables to be tested.

Based on the parameters mentioned in section 3.3 and the hypotheses 4.2 to 4.6 we can now formulate a number of questions.

First the subjects are asked about their background. Since a very heterogeneous group of users was expected, it is important to find out how acquainted they already are with Earth observation. These initial questions are listed in table 4.1. The most important question is of course whether the subject has already used Earth observation information. The other questions are added to determine in what kind of organisation the subjects work.

For the first question (about their organisation) the subjects can choose between five options: government, utility company, consultancy, research or education or finally other. For the organisation size subjects can choose between 1 to 10 employees, 11 to 50 employees, 51 to 100 employees, 101 to 500 employees or 500 or

Table 4-2 Questions based on the identified Earth observation weaknesses. There are questions refering to specific data products (optical/high resolution optical or radar) and others refering to Earth observation information in general. These questions can be divided into *usefulness* and *ease of use* categories. Note that most questions refer to PU.

number	**question**	**construct**	**parameter**
4	The spatial resolution of optical images is sufficient for my needs	PU	spatial
5	Optical images are acquired often enough for my needs	PU	temporal
6	The spatial resolution of high resolution images is sufficient for my needs	PU	spatial
7	High resolution images are acquired often enough for my needs	PU	temporal
8	The spatial resolution of radar images is sufficient for my needs	PU	spatial
9	Radar images are acquired often enough for my needs	PU	temporal
10	Thematical maps (classified images) with a classification error are usable for me	PU	error
11	An error-free, but incomplete, thematical map or classified image is useful for me	PU	error
12	Images with a (standard) georeferencing error are acceptable for me	PU	error
13	I would not find it difficult to correct a georeferencing error	PEU	error, representation
14	Visualisation of the uncertainties in classification and georeferencing would improve usability for me	PU	error
15	Importing Earth observation imagery and information into my GIS environment is easy for me	PEU	representation
16	I know how to find and order the Earth observation images I need	PEU	accessibility

more employees. For the question about previous experience, subjects can choose

Table 4-3 Questionnaire questions based on the original TAM. These were taken from Davis' standard scale (See table 2.1 on page 7) and refer directly to the PU and PEU constructs.

number	question	construct
17	Using Earth observation in my job would enable me to accomplish tasks more quickly	PU
18	Using Earth observation information would increase my job performance	PU
19	Learning to use Earth observation would be easy for me	PEU
20	I would find Earth observation information easy to use	PEU

Table 4-4 These questions are to determine the affect of PU on intention

number	**question**	**construct**
21	I am going to investigate the usability of Earth observation information for my job	Intention
22	I am going to use Earth observation information in my job in the near future	Intention

between: never, a single time, a number of times, regularly or daily.
The questions relating to the different independent parameters are listed in table 4.2. The number of independent parameters has resulted in a considerable number of questions. A number of questions refer to Earth observation in general, while others apply to the different types of Earth observation data identified in section 3: low resolution optical, high resolution optical and radar images. The questions are grouped per data type rather than per parameter.
Table 4.3 lists the questions derived from Davis' standard scale. Since there are already a considerable number of questions covering the parameters the number of questions from the original TAM were limited. A similar approach was taken by van der Heijden, who introduced extra constructs and therefore limited the number of questions per construct (van der Heijden, 2003). In Davis' scale the questions refer to job performance, productivity increase and job effectiveness. The similarity between these questions is intentional and improves the reliability of the results. In this case the number of tested parameters imposes an upper limit to the number of questions and thus the reliability of the result.
Finally table 4.4 lists two final questions referring to the *intention to use* construct from the original TAM. These allow a comparison between actual use (last question in table 4.2) and the intention to use. It will also allow to test the affect of the PU and PEU constructs on the actual intention. This will give an indication how well the theory of reasoned action, and therefore TAM, applies in this study.

Subjects can answer questions 4 to 22 on a 5 point scale, the options are: completely agree, somewhat agree, maybe yes/no, somewhat disagree, completely disagree. The first three questions also have five options, but these differ per question. Questions 4 to 22 have a quantifiable scale, while the questions referring to the subjects' background have a qualitative scale.

4.3 Pretest sessions

The questions are evaluated by a group of experts in the area of remote sensing and GIS. These pretest sessions are meant to find weaknesses in the questions. A pretest sessions was held both with a TAM expert and a group of Earth observation specialists at NLR. As a result the Davis' scale questions were added. The presented questions are the result.

4.4 Concluding

The TAM can be applied well to the question posed in this study (question 1.1 at page 1) introducing a minimal number of extra parameters. The parameters identified in chapter 3 can be incorporated into the model without problem. Their relations to the PU and PEU constructs can be formulated clearly, leading to a manageable testable hypotheses.
Most questions in the scale of the modified model are new and refer to the relations between the parameters and constructs. A limited number of questions were included from Davis' scale to test how well the modified model still matches Davis'. In order to test the internal relations of the modified model, two questions measuring intention to use were included as well.
The perceived usefulness is a more well-defined construct than the perceived ease of use in the modified model. Care was taken to formulate ease of use questions which refer to Earth observation information as a data source rather than the tools used to handle that information.

Chapter 5 The testing session

5.1 Introduction

In the previous chapter, the Earth observation acceptance model was introduced and a scale was defined. In this chapter, the test sessions are described.

5.2 Study method

When using TAM, the method and conditions under which it is used must be defined. The group of test subjects must be chosen to reflect the intended target user group. The environment in which the questionnaire is administered must be defined. Care must be taken that either the a priori knowledge of the subject is known and that all subject have access to the same infomarmation during the session. These factors can bias the research results.

5.2.1 Environment

The environment encompasses the conditions under which the questionnaire is carried out. One can either chose an uncontrolled or a controlled environment. A controlled environment means that the researcher determines the course of the session and has made decisions on the information the subjects receive. A controlled environment has the advantage that a researcher can prepare the subjects to ensure that they make their decisions on provided information and less on preconceived ideas.
In this study the aim is to carry out the test sessions and data collection place in an artificial, controlled environment. A so called laboratory setting is the most controlled environment.
In a laboratory setting the subjects get information and give their answers to the questionnaire under controlled conditions. This means that:

- the researcher determines use cases presented to the subjects
- subjects react within a framework defined by the researcher

The researcher can thus select the information presented to the subjects, this information should be relevant to individual parameters. This should allow the affect of individual parameters to be determined.
For Earth observation the choice for a laboratory setting is important especially because subjects *will* have a priori opinions about the applicability of Earth observation for their job. As stated before subjects will have read about and seen Earth observation imagery in trade magazines, congresses or even on the evening news. Their opinions can very well be based on biased or outdated information. The development of for example high resolution sensors is fairly recent.

5.2.2 Time dimension

A research study can either be carried out on a single point in time, a cross-sectional study, or can consist of several sessions over a longer time interval, a longitudinal study. A longitudinal study has the advantage that it allows the influence of single parameters to be studied as the introduction of new technology influence the separate parameters. However, this excludes a controlled environment approach. The developments in technology are well outside the control of the researcher.
A cross-sectional approach is used here. Primarily because a longitudinal study requires a long time period and considerable effort. The same user group has to be available for the consecutive sessions. In this case this is not practical, nor does it add extra information to the study.

5.3 Test session options

A controlled test environment can be implemented in a number of ways. A traditional questionnaire consists of a paper form which subject fill out. Internet technology allows questionnaires to be distributed to large user groups. A questionnaire on the web can be turned into a controlled environment. Interactive elements and explanations can be added to the questionnaire providing the subjects with a *story*. Thus the researcher can control the information given to the subjects.
A classroom session allows the researcher to control the conditions of the test much better, despite the advances in web technology. The subjects can be presented with targeted information. It allows the subjects to pose questions to help clarify key concepts.
In recent studies e-mail surveys and web-based questionnaires have been used for data acquisition. In an e-mail survey a large number of users can be approached by simply sending them a questionnaire. The disadvantage is the low response rate. Response has been fond to be as low as 5% (Lederer et al., 2000). In a web based survey users are invited to visit a website on which an interactive survey is implemented. It allows an even large audience to be approached easily. When the invitation is posted on a web forum or newsgroup the response rate cannot be measured, since it is generally not known how many users see the invitation. Technically the response rate can be measured if the invitation is added to a popular website. The user then sees a pop-up and can decide to participate in the questionnaire. This approach is used for commercial questionnaires. However, in this case there is no particular website which is popular over the whole width of the target user group.
The target user for this study consists of GIS users who are not (yet) Earth observation data users. The target user group works in municipalities and provinces and in a range of commercial companies who use geospatial data for various

tasks[4]. Since this group of users is limited in size it will be difficult to approach them using a web based survey and the low response rate of an e-mail survey will probably result in a too small test group. To ensure the reliability of the study, the test group should be large enough to be able to be used statistically.
Because of the limited response rate of web-based surveys and the fact that there was no access to a popular web portal to address a large user group it was decided to organise a group session rather than a remote web-based session. A group session allows aspects of Earth observation to be presented in a classroom type setting and administer the questions. Feedback from the subjects can be answered.

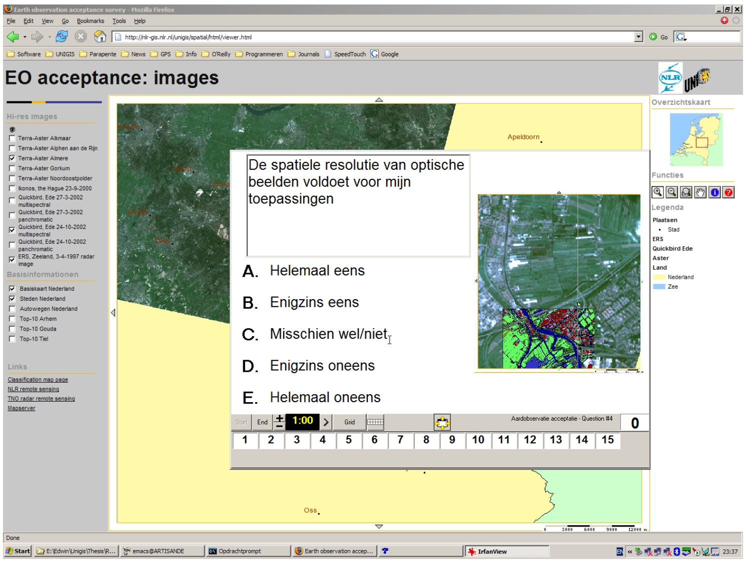
5.4 The classroom session

A number of options for a classroom session with an appropriate group of subjects were considered. Unigis students would constitute a good target group. However, since Unigis is a distance learning course, organising a classroom session proved to be difficult. An asynchronous distance questionnaire was considered. For reasons stated in the previous section this was not considered an optimal solution.
An opportunity to organise a classroom session for a specific user group arose when the Dutch ArcGIS user group asked whether NLR would consider to host its *gebruikersdag*, which the user group organises each year. The ArcGIS user group has members from a wide range of GIS-oriented institutes and companies, the common factor being the use of ESRI software products. The user day is, of course, aimed at GIS users, a considerable part of these users are potential Earth observation users. This makes this group an ideal subject group for this study.
It can be assumed that the subjects will be familiar with Earth observation as a data source, even when they have never used it themselves. They will generally have read about it in trade magazines, heard presentations at conferences and have seen Earth observation imagery used in the media. Some of them may already be using it as a data source. Therefore it is not necessary to introduce Earth observation to them. An introduction of the data types and parameters will suffice before the questionnaire is presented. The fact that the participants have registered to participate for a user day on the theme of Earth observation indicates some familiarity and interest in the subject.
The classroom session was designed to consist of a presentation of various aspects of Earth observation in which an interactive element was introduced. The questions listed in section 2.2.1 were posed to the subjects during the presentation.

5.4.1 Questionnaire implementation

In the group sessions, an interactive voting system was used to collect the responses. The questions were presented after each of the presentation parts. The

[4] One possible task is monitoring pipelines, the use of Earth observation data is studied for that particular application but it is not used operationally



Question window

Hand-held voting unit

Fig. 5-1 The classroom voting system. At the bottom of the question window 15 boxes denote which subjects have responded.

voting system consists of a central unit and a number of hand-held voting units. The central unit consists of a computer with voting software and a receiver. The hand-held units are similar to remote controls.

The voting system allows interactive operation by an operator. The operator selects a question, which is then presented along with a number of answer options to the subjects. Figure 5.1 shows an example screen of the voting system interface and a voting handheld unit. Using the handheld voting units the subjects can then enter an answer on a scale from *A* to *E*. The voting status, showing how many of the subjects had answered the question, is indicated in the bottom of the voting window. The voting status ensured that all subjects had voted before moving on the next question or explanation.

At the end of the session the results can be presented graphically. Some initial results were shown and discussed very briefly with the subjects.

5.4.2 The GIS environment

The subjects should acquaint themselves with different types of Earth observation data to be able to form an opinion during the questions sessions. The interactive GIS environment was a standard off-the-shelf web mapping server package together with a simple client. A number of images were presented in this environment.

The GIS environment only allows the most basic GIS operations like zooming, panning, and overlaying layers. Users can carry out a limited number of tasks relating to the questions.
The number of operations was limited. For more complicated operations on the data users will normally use a GIS package they are familiar with. In section 4 it was already mentioned that care must be taken to test Earth observation information, rather than the tools users would normally use to handle that information.
In order to illustrate the problems referred to in the questions, a number of Earth observation images were available as demonstration layers through the GIS environment. The available Earth observations layers were:

- A standard resolution image showing a familiar area of the Netherlands including an urban environment. For this option we can choose between optical and radar based imagery. Optical low resolution sensors have one advantage of their high resolution alternatives: they offer more bands and thus allow form a better classification. A series of ASTER images of the coast and the central part of the Netherlands were available.
- High resolution images of an urban environment. High resolution imagery is presently only available with a limited number of bands. High resolution imagery is available only as optical imagery. Images form Ikonos (the Hague) and Quickbird (Ede) were available.
- A radar image, including part of an urban environment. Radar imagery is only available in relatively coarse resolutions. An ERS image of the Hague and the surrounding Westland area was included.
- A low reliability classified image from high resolution data. Studies on classification reliability have shown that high resolution, limited bandwidth imagery results in a less reliable classification. The image shows a part of the Hague. For comparison a high resolution image of the same area is also available.
- A high reliability classified image from low resolution and wide bandwidth data. This classified image shows an area near Zwolle in the Netherlands. Some different types of vegetation are indicated (see figure 5.3).

Summarising, a number of images show areas within or covering the Hague. The low resolution classified image shows an agricultural area near Zwolle. Finally, an alternative urban area around Ede is available for browsing.
As noted before, the information and questions sessions should be kept short to motivate users to answer all questions in a serious manner. The planned questionnaire session was to be carried out after a number of presentations, it was taken into account that subjects would be distracted during long presentations.
A session must not become a condensed course on Earth observation, therefore the number of proposed images and the length of the explanations are restricted.
Care was taken to illustrate different parameters using these few images.

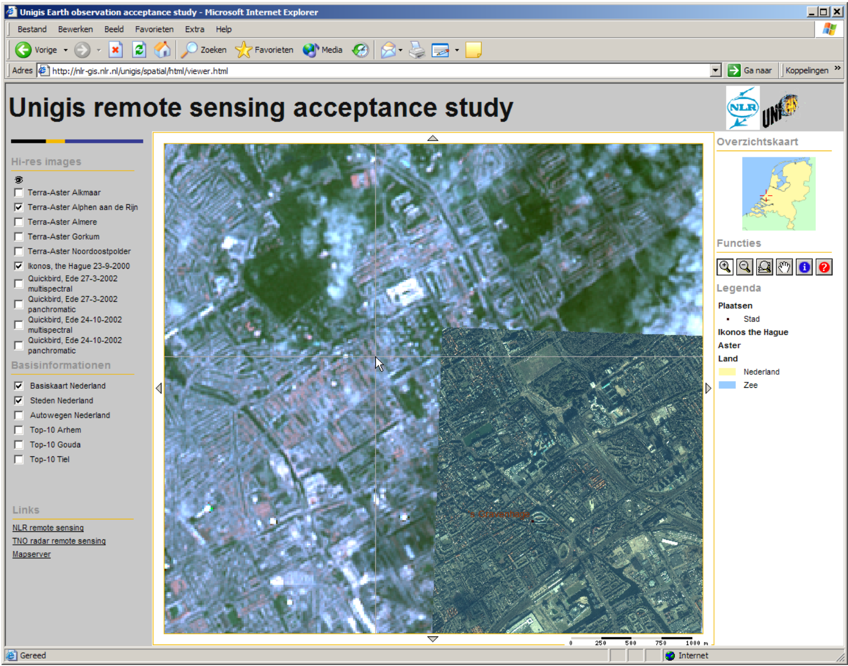


Fig. 5-2 Web-based GIS environment for remote sensing imagery showing a low and high resolution image side by side.

Among the questions, listed in table 4.2 at page 29, there are a number of questions which refer to all Earth observation layers simultaneously. Others refer to each layer individually. For example, the questions about spatial resolution and classification error should be asked after all different layers have been presented. A number of additional data layers are presented as reference layers:

- A vector layer showing building and streets. A demonstration dataset of the TOP-10 layer was available.
- A coarse vector layer showing the coastline and main roads. This layer was included for orientation.

The vector layer allows users to compare the images to the ground truth . Ground truth is defined as the actual state of the features in the satellite image. The help layers were included to illustrate the uncertainties resulting from the spatial resolution of the different images.
Comparison of the Earth observation layers and the additional layers allow users to experience resolution and error aspects of Earth observation data. The accessibility, another parameter affecting perceived ease of use, cannot be easily implemented in a task in the GIS environment. To experience the impact of this parameter subjects should search for data. However, a task in which the subjects perform an actual search is too time-intensive to be carried out within a session. Instead the various options for searching and ordering data were presented.

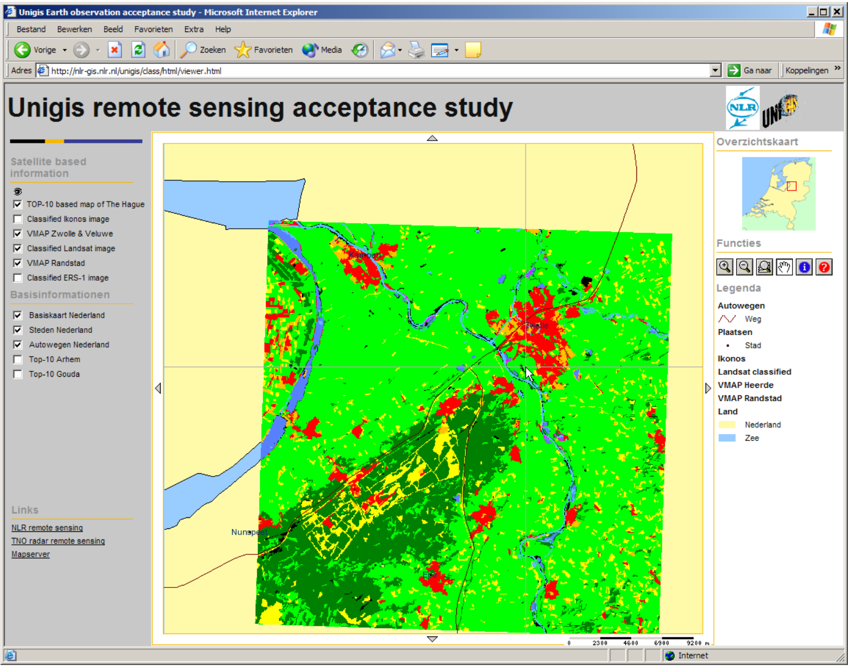


Fig. 5-3 Web-based GIS environment for the classified remote sensing imagery

The different images were installed on a web mapping server, the open source Minnesota web mapping server was implemented on an internet server. A web interface implemented on the server was used to present the images in a GIS like environment, a web client environment was obtained from a German GIS company (Geografische Datenverarbeitung GmbH)[5]. The client was designed to interface with the Minnesota web server and is available free of charge. A small number of laptop computers were installed and had access to the server. These laptop computers were available to the subjects. They could select images from an area of interest and zoom in and compare the images.
The subjects could interact with the data layers using the four laptop computers. Figure 5.4 shows the test setup. One presentation laptop was used to show the questions and the GIS environment on a projection screen. The four other networked laptops were available for the subjects. All laptops had access to a central web mapping server (not visible) which served the data layers and the interface. Only a standard web browser was installed on the laptops. The data entry device of the classroom voting system is visible in front of the presentation laptop.
The tools used for questionnaire and GIS implementation are listed in Appendix A at page 67.

[5] More information about the used software tools is included in appendix A

Table 5-1 Program of the ArcGIS user day

12:00 - 13:00	Reception, lunch
13:00 - 13:10	Welcome, announcements AGGN, announcements ESRI Nederland
13:10 - 13:30	Introduction NLR by Hans Roefs
13:30 - 13:50	Presentation "Rapids mobile grondstation: Data reception" by Bob Moll
13:50 - 14:10	Presentation "NLR and GIS" by Mark van Persie
14:10 - 14:30	Presentation "Remote sensing and the Geospatial Data Infrastructure" by Rob van Swol
14:30 - 15:00	Coffee break
15:00 - 15:20	Presentation "Beheer van Remote Sensing Data in ArcSDE" by Arjan van der Pluim
15:20 - 16:20	Paralel visit to Rapids, project room and user questionnaire session "Acceptance of Earth observation information by GIS users" by Edwin Wisse
16:20 - 17:00	Close

5.5 ArcGIS user day

The subjects group consisted of participants of a "ArcGIS gebruikersdag" (ArcGIS user day) held at NLR on June $15^t h$. This is a bi-yearly event in which the Dutch ArcGIS user group offers its members an afternoon of presentations and demonstrations on a GIS related topic. The user day is held at the premises of an organisation active in geographic information. The ArcGIS user group unites the users of the ArcGIS GIS software package from the ESRI corporation. ArcGIS is widely used in the Netherlands in government and commerce. Provinces and municipalities, as well as consulting firms and utility companies use ArcGIS and send representatives to the user days. This makes it a very attractive group of subjects for this study. The subjects' background range from a wide range of organisations, and as yet they are using little Earth observation information but are interested enough to hear more about it.

The ArcGIS user day usually involves a number of presentations from the hosting organisation and AGGN and ESRI. This is normally followed by an visit to a relevant facility. NLR has a mobile ground-station which can receive optical and radar data. Furthermore some examples of projects were demonstrated in the project room. The participants could see what is involved in receiving and processing a satellite image.

A program was drawn up (table 5.1) highlighting the Earth observation activities of NLR and introducing a number of key terms. During the presentation, key features like spatial resolution, different data types and the problems of searching and finding data were discussed.

Fig. 5-4 The questionnaire session setup. Four laptop computers with access to the GIS-like environment were available to the subjects.

5.6 Group sessions

The complete group consisted of 28 persons. After the presentations the participants were divided into two groups. The first group visited the Rapids ground-station and project room first and then participated in the user session. The other group did the user session first and visited Rapids and the project room afterwards.

By dividing the group into two smaller groups the groups were small enough to allow interaction during the session. Also, the group size allowd the participants the laptops interactively to explore the example images and data layers.

During the session, areas of interest were shown interactively on the projection screen using the web interface to the mapping server but the subject were free to explore the data themselves. They did so enthusiastically to the point where the server started to have problems coping with the repeated requests.

A number of images were shown in the question window of the classroom voting system as well, thereby linking the questiosn to the example images. Some of the images were included in this report as figures 3.2 (page 15) and 3.3 (page 17) in section 3.

The full text of the explanations in the test sessions is included as Appendix B. The text of the sessions is written out in full to ensure that different groups get the same information. The protocol text was presented to both subject groups. The text was read from paper to ensure that both groups received the same information. Feedback from the subjects was encouraged.

An introduction was read leading into each set of questions. The questions and accompanying data layers are highlighted in yellow in the protocol text.
Some feedback and questions were asked but all after the introduction was presented and the users were free to interact with the data layers.

5.7 Concluding

A classroom session has several advantages over a web based or e-mail survey. Therefore a classroom session was the preferred data collection event.
The ArcGIS user day was an ideal event to carry out the user questionnaire. The attendees where all GIS users who were interested enough in GIS to register and attend an afternoon of presentations and demonstrations. Feedback from the subjects concerning the setup of the questionnaire was favourable.
In the next section the results of the questionnaire will be presented and discussed.

Chapter 6 Questionnaire results

6.1 Introduction

The outcomes from the classroom session were analysed in order to find indications of their reliability and to see whether the results support the hypotheses that were introduced in section 3.3. A number of standard measures and methods are used to process and evaluate questionnaires like the one used in this study. These measures and methods are introduced briefly in the following sections.

6.2 The group

First we consider the backgrounds of the test user group. A total number of 28 persons participated in the user questionnaire. The subjects reacted favourably to the used setup. When a questionnaire was announced in the program some expected “another paper to fill out”, feedback from the subjects indicated that they found the used setup with classroom type questions and an interactive hands-on environment enjoyable.

Figure 6.1 shows the background of the subjects. Most are from various governmental organisations and have a little to some experience with Earth observation information. According to the list of participants there where people from ministries and provinces and a few from a local municipality among those from governmental organisations. Most were either from very small organisations (1-10 persons) or from large to very large organisations (100 or more). The governmental organisations are generally large organisations (see figure 6.2).

Most had some to little experience with Earth observation information. This indicates that the subject group matches the target group well. Only two indicated that they use Earth observation on a daily basis, five more used it on a regular basis. That leaves 26 non-daily users.

One of the subjects did not finish the questionnaire. This brings the total number of cases to 25.

6.3 Data processing

The results were exported from the classroom system and imported into SPSS. The responses were inverted. In the classroom system a value of 1 denoted “completely agree” and 5 denoted “completely disagree”. The responses were remapped so that a *high* response stood for high agreement. This was done since it will make the eventual bar charts easier to interpret.

As stated before (also see figure 6.1) two of the respondents answered that they had *daily experience* with Earth observation information. These test subjects

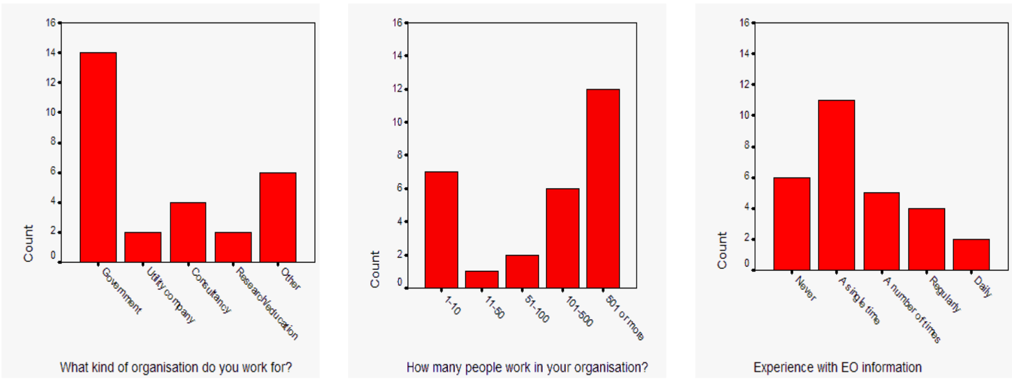


Fig. 6-1 Background of the subjects. To what organisations did they belong, how many people work in these organisations and how much experience did they have with Earth observation. Most are from various governmental organisations. Most have little to some experience with Earth observation information.

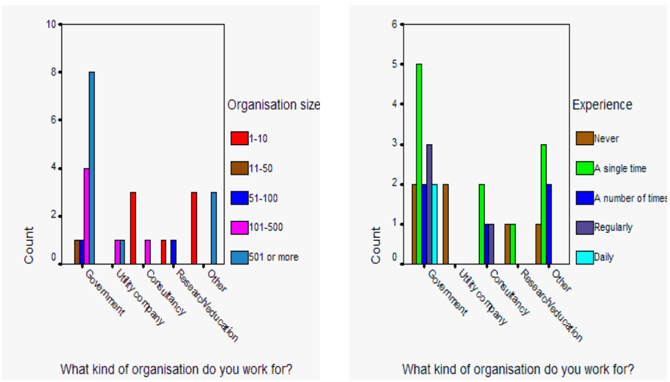


Fig. 6-2 Background per organisation type

did not match the intended user group so they should be removed from the cases. The responses were filtered on this question, in the further analysis the two cases were omitted.

One of the participants left the session before the end and did not answer all questions. The responses from this subject were also filtered from the result data set.

Values for PU, PEU and Intention were computed from the responses. The scores for these constructs are based on the average of the corresponding questions' responses. Additionally two alternative PU and PEU constructs were computed: Davis' PU and Davis' PEU constructs. In the Earth observation modified TAM scale, four questions were included from the original Davis' scale (see table 4.3). The Davis' constructs' scores are based on these questions. They were included because they allow comparison between the original TAM and the modified version. The Davis' constructs should not be influenced by the parameters. But we should find some similarity between the construct from the Davis' scale and the modified scale.

Reliability was computed for the constructs and the correlation between selected parameters and constructs.

6.4 Reliability

When measuring aspects of human ideas or attitudes the reliability of the test requires attention. Measurement of reliability is achieved by making sure that several questions measure the same construct. On the other hand, this should not lead to duplication by making the questions too similar.
The reliability of a test can be estimated by computing the correlation between the answers to questions that measure the same construct. A high correlation indicates that the subjects answer questions referring to the same construct consistently.
The inter-item correlation consists of the average of all possible pairs of questions referring to the same construct. A high inter-item correlation indicates highly consistent answers between similar questions and thus high reliability.
In split-half reliability we randomly divide all questions belonging to the same construct into two sets. The split-half reliability estimate is simply the correlation between these two total scores.

6.4.1 Cronbach's alpha

In TAM studies Cronbach's alpha (A) is often used as a measure of reliability. That is, the relevance of the questions of a survey to the constructs used in the model. A is the mean value of all split-half reliability values. Since this is cumbersome to compute there is a standardised formula. The formula for the standardised A is:

$$\mathrm{A} = N\overline{r}/(1 + (N - 1)\overline{r})$$

Here N is the number of questions and $\overline{r}$ is the correlation between the questions. So as the number of questions increases, so does A. A high correlation between questions results in a high A.
The A can be computed over all questions, by summation of all possible split-set correlations. It can also be computed over either the PU or PEU questions.
As discussed in the preceding section there are other, simpler measures of reliability. Since A is used widely in TAM studies it is used in this case as well. This gives us a measure to compare the results with those of other TAM studies.
A test is considered reliable when the A is 0.7 or higher. The actual threshold value depends on the study field of the test.

6.4.2 Reliability indicators' reliability

It should be kept in mind that all measures of reliability are affected not only by the consistency of the questionnaire, but by the consistency of the test subjects as well. A perfectly uniform group of test subjects with similar backgrounds and

Table 6-1 Reliability indicators for the constructs. $n = 25$

construct	**items**	α
perceived usefulness	12	0.3486
perceived ease of use	5	0.4916
Davis' perceived usefulness	2	0.7985
Davis' perceived ease of use	2	0.4270
intention to use	2	0.7255

according work situations and requirements will result in high value for the reliability indicators as well.
However, since the group of test subjects in this study is heterogeneous by nature ("GIS users not (yet) using Earth observation information" being a rather vague group of test subjects) the reliability indicators themselves do not correlate highly with the questions themselves.

6.4.3 Reliability of the results

Table 6.1 shows the reliability indicators (Cronbach's α) for the different constructs. Again, values for the constructs of both the modified model and the Davis' part of the model are included. The reliability of the construct including the parameter related questions is low.
The reliability for PU and PEU appears to be extremely low. However, we must keep in mind that this reliability indicator was computed over *all* scale items referring to PU and PEU respectively. In traditional TAM studies a standard scale is used in which a number of similar questions is specifically designed to clarify the subjects' attitude to usefulness and ease of use. In this case, a new scale was designed to measure the affect of a number of parameters on the TAM constructs. Since questions were included to test all parameter relations to the constructs the questions were very diverse. This results in diverse responses which suggest a low reliability.
For both PU and PEU two questions were included from the original Davis' scale. The reliability of these constructs based on these questions were computed as well. Davis' PU shows a high α. The value is larger then 0.7, which indicates that the test was reliable for this construct. The responses to the two questions included for PU apparently match well. Interestingly the α of Davis' PEU is lower than the questionnaire PEU. The questions used refer to *learning to use* and *using* Earth observation respectively. These might be different enough for the subjects to yield very diverse responses and thus a low α value.
The reliability of the test for the intention to use is also high. Again the test was based on two questions. Even though this is a small number of questions they appear to match well.

Table 6-2 Reliability indicators for the parameters. $n = 25$

parameter	**items**	α
spatial resolution	3	0.3328
temporal resolution	3	0.1668
error aspects	5	0.5248
representation	2	0.6007
availability	1	-

Table 6.2 shows the reliability indicators for the different parameters. Since only a single question referred to the availability parameter no α could be computed for this parameter. Again, the fact that different questions referring to a parameter refer to different data types result in a low α. This becomes clear when we compare the α of error aspects and availability to the α of the spatial and temporal resolution. The low α value for the resolution parameters therefore does not indicate a low reliability of the questionnaire results. It does indicate that more (similar) questions could improve the reliability.

6.5 Statistics of the test results

Having measured the reliability we can draw conclusions from the results. There are a number of statistical properties of a response set we can use to draw conclusions from the results.

6.5.1 Mean and σ

The mean $\bar{x}$ and variance σ per question yield some useful information. Intuitively the variance to a well-formulated question should be low, but it should be kept in mind that this depends also on the test subjects' backgrounds.

6.5.2 χ^2 distribution

The chi-square distribution, or χ^2 distribution, is one of the theoretical probability distributions most widely used in statistical significance tests. It is useful because, under reasonable assumptions, easily calculated quantities can be proved to have distributions that approximate to the chi-square distribution if the null hypothesis is true.

The best-known situations in which the chi-square distribution is used are the common chi-square tests for goodness of fit of an observed distribution to a theoretical one.

By carrying out a χ^2 test, we can test how well the answers to a question match a chance distribution. Given a large enough group of subjects the answers will follow such a distribution. The asymptotic significance of the χ^2 test gives a direct indication whether the assumption that the answers follow a chance distribution should be rejected. The test is an effective way to pre-screen the results.

6.5.3 Correlation

The correlation between two variables reflects the degree to which the variables are related. The correlation of between a parameter and a construct gives a quantative indication of the strength of the affect of the parameter on the construct. The most common measure of correlation is the Pearson's correlation (called Pearson Product Moment Correlation in full). When measured in a population the Pearson Product Moment correlation is designated by the Greek letter ρ. When computed in a sample, it is designated by the letter r and is sometimes called *Pearson's r*. Pearson's correlation reflects the degree of linear relationship between two variables. It ranges from +1 to -1. A correlation of +1 means that there is a perfect positive linear relationship between variables.

6.5.4 Regression

An alternative way to find a relation between two parameters is regression analysis . We assume a linear trend between two variables x and y. When try to fit a linear trend

$$y = \alpha + \beta x$$

between the variables (using a least squares solution for example) we can use statistics to quantify how well the linear trend fits. The β coefficient is a measure for the linearity of the relation between the parameters. The β coefficient is normalised A random relation between the parameters will result in a β value of zero, a β close to one indicates a strong linear relation.

6.6 Response on the test

From the responses to the different questions we can draw a number of conclusions. In this section we look at the mean responses and at the distribution of the responses on a number of questions

6.6.1 Mean and variances of the responses

Some basic statistics of the responses are listed in table 6.3. The mean score and variance (σ) are based on the rescaled five point responses where 1 corresponds with *completely disagree* and 5 corresponds to *completely agree*. The response matching the mean value (rounded to the nearest integer) is included to illustrate the meaning of the mean value. As can be expected the mean values fall in the *somewhat disagree* to *somewhat agree* range.
A χ^2 test was carried out on the responses to identify which response did not match a chance distribution. The last column, the asymptotic significance indicates the probability of the χ^2 value. A low value means the hypothesis that the response do *not* match a chance distribution must be rejected. In other words a low value indicates an answer distribution matching the expected distribution. Most of the responses are distributed according to a chance distribution, with two

Table 6-3 Some basic statistics of the responses based on the cases which remained after filtering. ($n = 25$)

number	mean	mean response	std. dev.	χ^2	asymp. sig.
4	3.00	Maybe yes/no	1.080	13.2	0.010
5	3.52	Somewhat agree	1.194	6.4	0.171
6	3.76	Somewhat agree	0.970	16.4	0.003
7	3.84	Somewhat agree	1.143	14.8	0.005
8	2.20	Somewhat disagree	1.080	10.8	0.029
9	3.40	Maybe yes/no	1.258	9.2	0.056
10	2.20	Somewhat disagree	1.258	8.8	0.066
11	3.12	Maybe yes/no	1.236	6.8	0.147
12	1.92	Somewhat disagree	1.038	16.8	0.002
13	3.04	Maybe yes/no	1.485	1.2	0.878
14	4.40	Somewhat agree	0.957	33.8	0.000
15	3.84	Somewhat agree	1.313	10.8	0.029
16	3.84	Somewhat agree	1.143	16.4	0.003
17	3.24	Maybe yes/no	1.012	14.4	0.006
18	3.20	Maybe yes/no	1.041	11.2	0.024
19	4.08	Somewhat agree	0.909	15.2	0.004
20	3.84	Somewhat agree	0.898	14.4	0.006
21	3.72	Somewhat agree	1.100	8.0	0.092
22	3.28	Maybe yes/no	1.061	10.8	0.029

exceptions. Questions 11 ("An error-free, but incomplete, thematical map or classified image is useful for me") but especially 13 ("I would not find it difficult to correct a geo-referencing error") deviate significantly from a chance distribution. The responses to the questions also showed a relatively high σ, indicating a wider distribution of answers than for the other questions.
Question 13 is a typical ease of use question. As already stated these questions are prone to refer to the tools subjects use to handle data rather than the data itself. For this question this seems to be the case. Inexperienced users find the correction of the geo-referencing error difficult on one hand, and the experienced users (for whom the task poses no problem) on the other hand.

6.6.2 The responses

Figures 6.3 and 6.4 show the frequency bar charts for the spatial and temporal questions respectively.

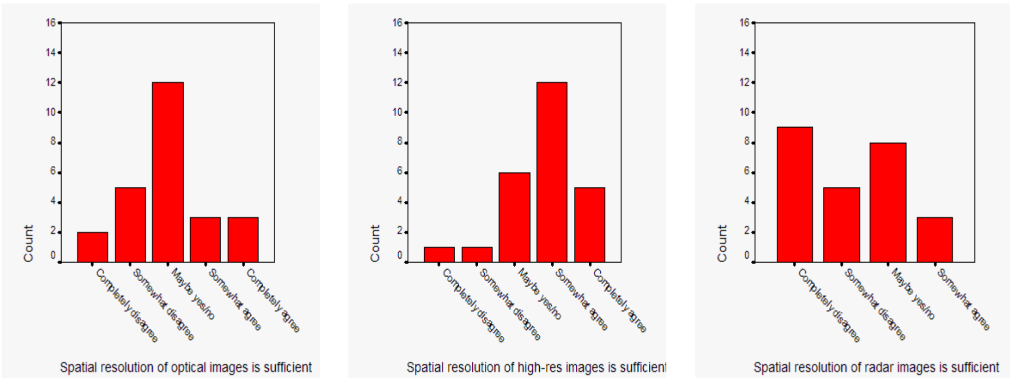


Fig. 6-3 Bar charts of the responses to the spatial resolution questions (in table 4.2 as questions 4, 6 and 8).

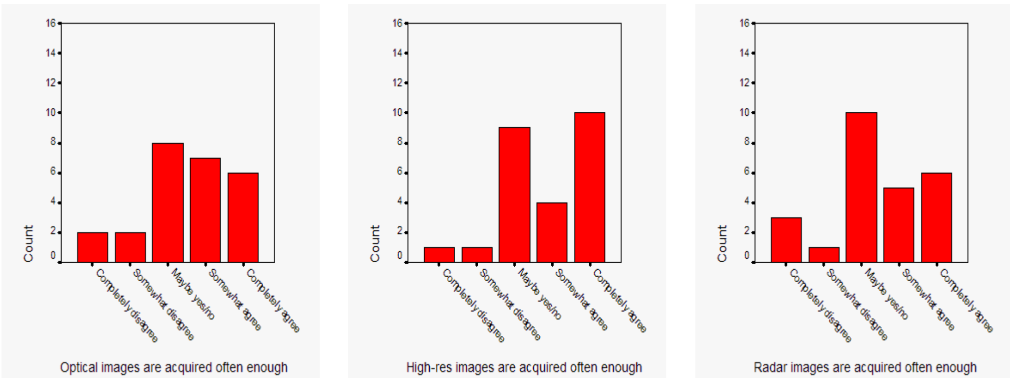


Fig. 6-4 Bar charts of the responses to the temporal resolution questions (in table 4.2 as questions 5, 7 and 9).

In the questionnaire session three data types were presented to the subjects. Of these, radar had the lowest resolution and high-resolution optical the highest resolution. Subjects could compare the data types as different layers in the desktop environment. The responses shows a clear preference towards metre-resolution imagery acquired by the high resolution sensors. For radar the response is clearly negative, with most responses in the *completely disagree* bar. For radar data there is not a single *completely agree* response. The response to standard optical imagery is more or less neutral. The response on the high resolution imagery is clearly more positive, although, even here, few subjects indicate that the spatial resolution fits their needs completely.
From the temporal resolution questions, we can conclude that the subjects have no problem with the acquisition frequencies of current imagery sources. Almost all answers are neutral to positive. Interestingly, radar imagery shows more neutral response than optical imagery even though it was stated during the questionnaire session that the acquisition interval for radar is comparable to optical in this respect with the difference that it is not hampered by cloud cover and can thus be acquired more often than optical data. Presumably, the subjects' slightly negative

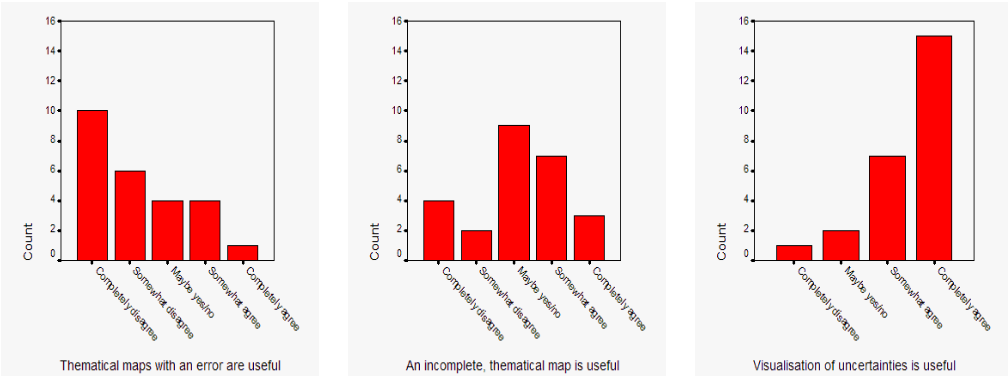


Fig. 6-5 Bar charts of the responses to the error aspects questions (in table 4.2 as questions 10, 11 and 14).

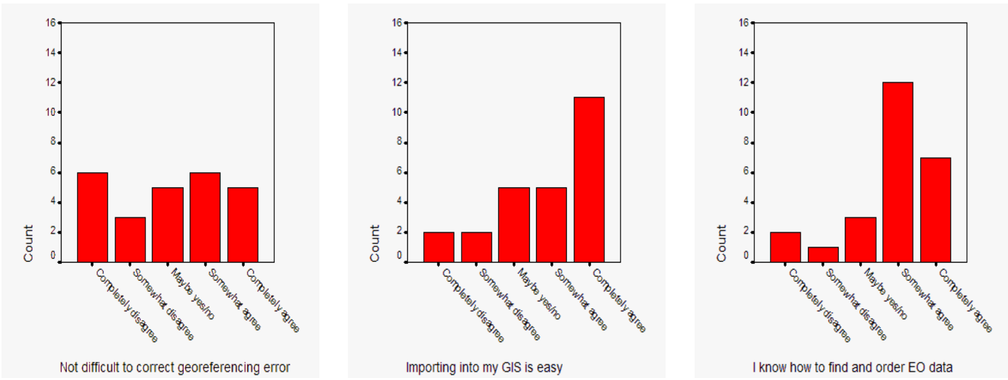


Fig. 6-6 Bar charts of ease of use related questions (in table 4.2 as questions 13, 15 and 16).

attitude towards radar data (see the spatial resolution response) was carried over to the other radar related question.
Figure 6.5 shows the responses to the three error related questions. Classification maps from Earth observation typically contains erroneous pixels. Two questions were introduced in the scale to find out what users would find more useful: a map with some erroneous features, but showing all available features or a map with only the certain features which would not be complete. For the GIS users an incomplete map is apparently more useful than one with erroneous features. The visualisation of the errors and uncertainties in the classified image would be useful for most of the subjects.
In the parameter related questions of the Earth observation modified TAM three questions related to the ease of use. Figure 6.6 shows the responses to these questions. The response to the question about correcting georefencing error is neutral with a large spread, see the standard deviation ($\sigma = 1.427$) in table 6.3. Also note that this was one of the two questions which deviates significantly from the chance distribution with an asymptotic significance of 0.790 in the χ^2 test. It shows by far the largest deviation from the standard distribution. Because of this

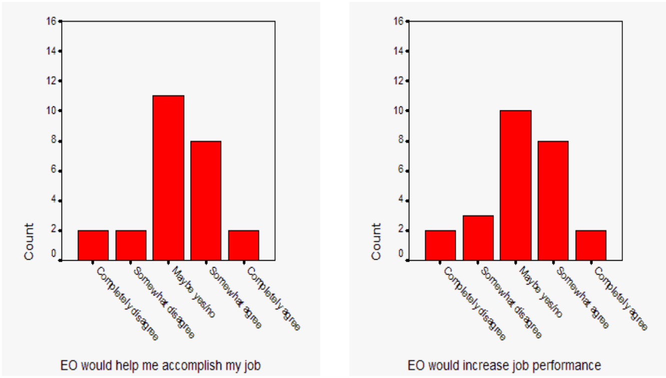


Fig. 6-7 Bar charts of the Davis' usefulness related questions (in table 4.3 as questions 17 and 18).

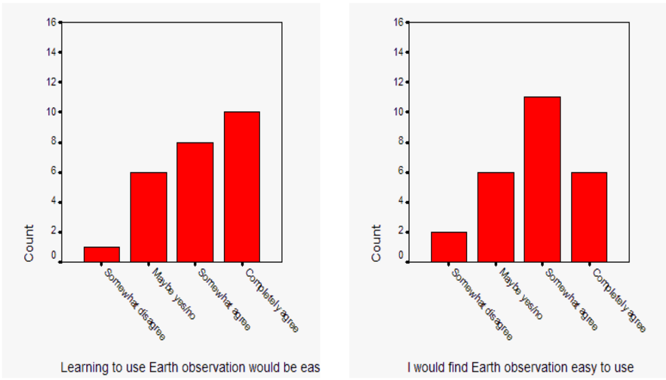


Fig. 6-8 Bar charts of the Davis' ease of use related questions (in table 4.3 as questions 19 and 20).

we should not draw conclusions from this question. Presumably, the concept of correcting geo-referencing error was not entirely clear to the subjects.
Both other questions show a positive response. Most subjects experience little problem find, ordering and importing their data. Since all test subjects were experienced ArcGIS users, their response to the question on data importing could be expected. It is, after all, just raster data an thus very similar to for example aerial photos some might already use. The response to the question on finding and ordering shows a less positive response.
Figure 6.7 shows the response to the Davis' usefulness related questions. The response to both questions is moderate to positive. Both show the same distribution. Recall that the reliability was very high for this construct, indicating that the subjects responded similar to both questions.
Figure 6.8 shows the response to the Davis' ease of use related questions. The ease of use related questions also show a moderate to positive distribution.
Figure 6.9 shows the answers to the *intention* related questions. As can be expected, given the theme of the user day, the intention to learn more about Earth observation is neutral to very positive. After all, the subjects participated in the

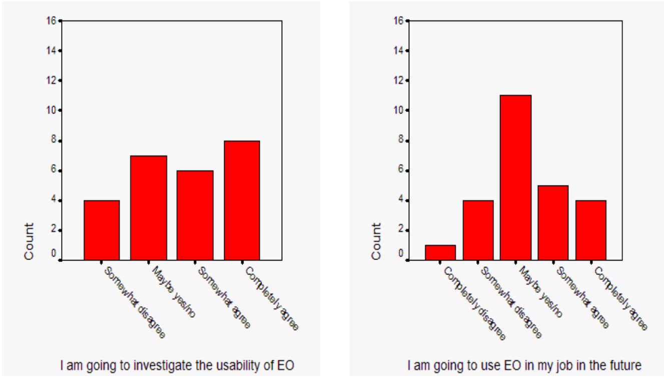


Fig. 6-9 Bar charts of the intention related questions (in table 4.4 as questions 21 and 22).

user day specifically to learn more about Earth observation. Their answer to the actual intention to use is overwhelmingly neutral, with a slight bias towards the positive side. Only a single subject indicated no intention to use Earth observation information at all. Interestingly this particular subject was among the moderate users (the previous experience answer was "a number of times"). The subject might have intended to indicate no intention to use *more* Earth observation information beyond current use or the latter answer might indicate no foreseen use in the current work environment.

6.7 Correlations of the test

The correlation between variables gives an indication of a relationship between the two. In the following section the correlation between parameters and constructs will be discussed.

6.7.1 Correlation between constructs and usage

Table 6.4 lists the correlations between the constructs from the modified Earth observation TAM. Correlation between current use and perceived usefulness is very weak. There is a weak correlation between current use and perceived ease of use. Correlation of both usefulness and ease of use with intention to use almost zero. The correlation between the constructs and current use shows no correlation between perceived usefulness and current use. Correlation with ease of use is higher, but still not significant. It indicates that experienced users grade the ease of use high and that less experienced users grade the ease of use lower. This suggest that (the lack of) ease of use is a hurdle which is overcome through experience. Correlation between current use and Davis' usefulness is high, although not significant. Experienced users apparently grade the overall usefulness of Earth observation high. It is interesting that the correlation of intention to use with perceived usefulness from the modified model is close to zero. This suggests that perception of the importance of the parameters from the modified model is *not* affected by

Table 6-4 Pearsons correlation between PU and PEU contructs and the current usage and the intention to use. There is no significant correlation between the intention, current use and the constructs.

	Current use	**Intention to use**
Usefulness	-0.221	0.084
Ease of use	0.287	-0.116
Davis' usefulness	0.349	0.336
Davis' ease of use	0.266	-0.056

Table 6-5 Pearsons correlation between the complete PU and PEU and Davis' PU and PEU. Red means correlation is significant at the 0.01 level (2-tailed).

	Usefulness	**Ease of use**
Davis' usefulness	0.153	-0.312
Davis' ease of use	-0.241	0.506

the rate of experience, even though the perceived (Davis') usefulness apparently *is*.

Especially the zero, and even negative, correlations between the constructs and intention are surprising. These would indicate that a positive or negative change in perceived usability would not affect intention. A possible explanation lies in the fact that the event on which the questionnaire was carried out was an afternoon dedicated to Earth observation. All participants had willingly registered for the event, most likely out of interest in the subject. The zero correlation indicates that even though they say they intent to use Earth observation, they nevertheless indicated that for them there are still some significant hurdles.

The a relatively high correlation between Davis' usefulness and intention supports the original TAM. The much lower correlation between usefulness (from the modified model) and intention indicates that the introduction of the parameters has not improved the TRA part of the model. The affect of the constructs from the modified model on attitude and thus on intention is less strong in the modified model.

Table 6.5 shows the correlations between the complete and Davis' constructs. Only the correlation between Usefulness and Davis' Usefulness and the correlation between ease of use and Davis' ease of use are of interest. Both correlations are positive. The correlation between the ease of use and Davis' ease of use is significant.

Table 6-6 Pearsons correlation between the parameters and PU and PEU. Note that the PU and PEU constructs and the parameters are partly based on the same questions and are therefore not independent. Red means correlation is significant at the 0.01 level (2-tailed), orange means correlation is significant at the 0.05 level (2-tailed).

	Perceived usefulness	**Perceived ease of use**
Spatial resolution	0.639	-0.207
Temporal resolution	0.526	0.078
Error aspects	0.501	0.303
Representation	0.323	0.587
Accessibility	-0.116	0.580

Table 6-7 Pearsons correlation between the parameters and Davis' PU and PEU.

	Davis' PU	**Davis' PEU**
Spatial resolution	-0.018	-0.111
Temporal resolution	-0.220	-0.059
Error aspects	-0.350	-0.315
Representation	-0.126	-0.043
Accessibility	-0.057	-0.092

6.7.2 Correlation between parameters and constructs

The correlations between both the complete PU and PEU constructs and the parameters and the Davis' constructs and the parameters were computed. It must be remembered that the complete constructs and the parameters are not independent. Therefore part of the found correlations are due to the fact that they are based on the same questions.

Table 6.6 lists the correlations between the parameters and the usefulness and ease of use constructs[6]. Especially the correlations of spatial resolution and error aspects with perceived usefulness appear significant. Temporal resolution shows a slightly weaker, but still significant correlation with usefulness. Correlations of both spatial and temporal resolution parameters with ease of use are much lower. These numbers seem to support hypotheses 4.2 (at page 25) and 4.3 well.

The error aspects parameter correlates significantly with usefulness. Correlation with perceived ease of use is weak. This corresponds with hypothesis 4.4 (page 26) to some extent. It was hypothesised that the error aspects would correlate with both constructs. However, it fits well with hypothesis 4.7 (page 27). It was

[6] The PU and PEU constructs and the parameters are partly based on the same questions. They are therefore not independent and a correlation van be expected.

Table 6-8 Pearsons correlation between the responses on *spatial resolution* related questions.

	Optical imagery	High resolution	Radar imagery
Optical		0.199	0.286
High-resolution	0.199		-0.072
Radar imagery	0.286	-0.072	

Table 6-9 Pearsons correlation between the responses on *temporal resolution* related questions.

	Optical imagery	High resolution	Radar imagery
Optical		-0.059	0.327
High-resolution	-0.059		-0.098
Radar imagery	0.327	-0.098	

hypothesised that perceived usefulness would be a stronger construct than the perceived ease of use. The difference in correlation of the error aspects parameter fits well with these two hypotheses.

The representation and accessibility parameters both show a significant correlation with the perceived ease of use. Representation also shows a weak, not significant, correlation with usefulness. The strong correlations with ease of use support hypothesis 4.6 (page 27) and hypothesis 4.5 (page 26)

The Davis' PU and PEU constructs are based on questions which are completely independent of the questions referring to the parameters. These correlations are listed in table 6.7. None of the parameters show a significant correlation with any of the Davis' constructs. This, together with the significant correlation of Davis' perceived usefulness with intention to use suggest that the Earth observation modified TAM model consists of two separate parts. It has relations between the parameters and constructs as hypothesised on one side, on the other side the Davis' scale constructs affect the intention to use. The weakness of the affect of Davis' perceived ease of use fits well with hypothesis 4.7.

6.7.3 Correlation between data types

A number of questions refer to the same parameter, but for different data types. Two of the presented data products are similar in resolution: radar and (standard) optical imagery. Table 6.8 shows the correlations between the responses in resolution related questions. There is some (not significant) correlation between the radar and standard optical responses.

Table 6.9 shows the correlation between the same data types but this time for the temporal resolution. For this parameter there is also some correlation between optical and radar imagery.

Table 6-10 Regression analysis for the relations between parameters and constructs. ANOVA

dependent	variables	R^2	adjusted R^2	significance
Davis' PU	spatial, temporal, error, representation, accessibility	0.214	0.007	0.427
Davis' PEU	spatial, temporal, error, representation, accessibility	0.164	-0.055	0.598
Davis' PU	4, 6, 8 (spatial questions)	0.104	-0.024	0.501
Davis' PU	5, 7, 9 (temporal questions)	0.204	0.090	0.108
Davis' PU	10, 11, 12, 13, 14 (error questions)	0.244	0.045	0.336
Davis' PEU	10, 11, 12, 13, 14 (error questions)	0.228	0.025	0.383
Davis' PEU	13, 15 (representation questions)	0.069	-0.016	0.457
Davis' PEU	16 (accessibility question)	0.026	-0.017	0.445
Davis' PU	Intention	0.130	0.092	0.077

Table 6-11 Coefficients of the regression analysis of the parameters and Davis' perceived usefulness.

parameter	β	std error	standardised β	t	significance
spatial	0.115	0.292	0.084	0.395	0.697
temporal	-0.331	0.290	-0.260	-1.141	0.268
error	-0.551	0.298	-0.419	-1.851	0.080

This indicates that users have answered these similar questions accordingly. The correlation between the temporal resolution optical and radar is even almost the same as the correlation between the two for spatial resolution. It must be noted that the repeat period between acquisitions is much better for radar than for optical data. Possibly the negative attitude towards the spatial resolution of radar imagery has carried over to the question about temporal resolution. This is likely because the questions during the session were grouped per data type. The three data types and the corresponding questions were presented consecutively.

6.7.4 Regression analysis

We have not found a significant relation between the parameters and the Davis' constructs using Pearson's correlations. Regression analysis offers an alternative way to find a linear trend between two variables. Tables 6.10 to 6.13 shows the results of a regression analysis. Only those parameters and constructs which have a hypothetical connection according to the modified TAM are investigated.

Table 6-12 Coefficients of the regression analysis of the parameters and Davis' perceived ease of use.

parameter	β	std error	standardised β	t	significance
error	-0.341	0.236	-0.336	-1.443	0.165
representation	0.270	0.228	0.364	1.183	0.251
accessibility	-0.221	0.171	-0.350	-1.291	0.212

Table 6-13 Coefficients of the regression analysis of the parameters and Davis' perceived ease of use.

parameter	β	std error	standardised β	t	significance
intention	0.368	0.199	0.360	1.852	0.077

Table 6.10 shows how well the regression analysis assumptions apply, an ANOVA analysis was carried out. The R^2 is the proportion of variance in the dependent variable which can be predicted from the independent variable. The significance in the last column indicates the significance of the test.
Tables 6.11 and 6.12 show the results of the least squares fit and its significance. The significance in this table indicates the significance of the β coefficient, a value of 0.05 or lower indicates a significant relation. None of the relations are significant. In the Usefulness table we see an almost significant relation between Davis PU and the error parameter. The β coefficient has a negative value. This indicates a negative relation between the two variables. Care was taken to formulate the questions positive. However, the parameter itself is a negative parameter. The questions were formulated as "images with a (geocoding, classification) error are acceptable to me" (see table 4.1 on page 28). A high error is a negative parameter for the acceptance, in contrast to the resolution parameters for example.
Table 6.13 shows the results of the regression analysis between the Davis' PU construct and the intention to use construct. The relation is not significant, but it is very close. This matches the original TAM model. In table 6.4 (page 54) these constructs also showed the highest (but not significant) correlation.
The results of the regression analysis match the results from the correlation tests. The given dataset does not support the hypothesised relations between the parameters and the constructs. These is a relation between the Davis' usefulness and the intention to use. This is matches the original TAM, this is not straightforward since in this case the analysis is based on a much smaller number of questions than in the original model.

6.8 A second look at experience

In order to estimate the influence of experience of the users we have a look at the responses of the test subjects on the experience question in relation to the perceived usefulness and ease of use. In this case the experience is compared to the

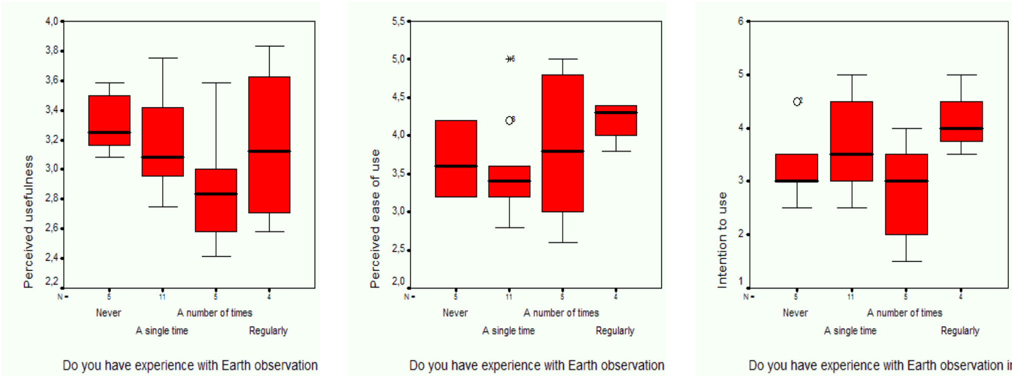


Fig. 6-10 Stem and leaf plots of experience against the PU, PEU *and intention constructs.*

complete PU and PEU, rather than the Davis' PU and PEU. This is justified since both are independent.

Figure 6.10 shows stem and leaf diagrams of the constructs PU, PEU and intention of the Earth observation modified TAM as a function of current use (or experience).

The first plot in figure 6.10 shows that perceived usefulness is highest for experienced subjects who use Earth observation *regularly*, the most experienced users (who use it *daily*) were filtered from the result data set. Interestingly it is lowest for subjects who have some experience, whereas subjects with little or no experience show a higher perceived usefulness.

The ease of use diagram shows, as expected, that regular users rate the ease of use high, while the casual or non-users are neutral. The experienced users are acquainted with methods of finding and importing information and do not experience it as difficult. This suggests that the casual users rate unfamiliarity with Earth observation information rather than its ease of use.

The last plot in figure 6.10 shows the intention to use against the experience. The experienced subjects show a slightly positive intention. Subjects who have used Earth observation information *a number of times* show the highest intention, but also the largest spread in their responses.

When we compare the plots of usefulness against experience to the intention against experience we see that the two figures show an almost opposite trend. Especially for subjects with moderate experience. They show the highest intention to use, but the lowest perceived usefulness.

6.9 Concluding

The reliability appears to be low at first sight. We must remember that the Earth observation modified TAM differs from TAM in the number of parameters and relations. The modified TAM contains five extra parameters and six more relations. As a result the number of questions referring to a construct or to a parameter is

considerably lower than in the original TAM studies. Therefore it is not surprising that the reliability indicators have low values.
There are significant correlations between the PU construct and the spatial and temporal resolution and error parameters and between the PEU construct and the representation and accessibility parameters. However, the constructs are not independent of the the parameters because both are partly based on the same questions. A number of questions from the original Davis' scale were included in the modified scale. These questions do not refer to any of the parameters and are therefore independent of the parameters. Based on these questions we can compute the correlations between the constructs and the parameters, but these show no significant correlation.
Therefore the hypotheses concerning the relations between the parameters and constructs are not supported by the results. There are a number of possible reasons.
First of all the group size is limited. After eliminating the users with daily experience with Earth observation information (2 subjects) 25 subjects remained. This limited number is largely due to the chosen setup of the questionnaire. The questionnaire was carried out as a part of a full afternoon in which the subjects were familiarised with the subject in a number of presentations. A visit to the ground station at NLR was also included. This meant that the subjects had to dedicate a full day to the program. The organising ArcGIS user group reaches a large number of people, but the turnout depends on whether people can free the time to participate. This said the turnout was sufficient for the questionnaire, even though the results cannot support the modified model.
The questions refer to a limited number of constructs in the original TAM. Having several questions measuring the same parameter or construct increases the reliability of the test. In this case a limited number of questions referred to five different parameters. Two of these parameters (spatial and temporal resolution) even referred to different data types with different characteristics. Per parameter there were about two or three questions. The only relation for which a positive relation was found using the regression analysis is the relation between the error parameter and the Davis' PU, five questions referred to the error parameter. That is more than any other parameter. The correlation between the error parameter and Davis' PU was high, but not significant.
As stated above the questions did not refer only refer to the parameters, but to different characteristics within the parameter. For example the questions referring to spatial resolutions referred to high and low resolution data. Subjects generally found high resolution data more usable than low resolution data. That is an interesting result in itself, but it muddles the relation between the spatial resolution
One hypothesis 4.7 (on page 27) *is* supported by the results. In the modified TAM the perceived usefulness is a much stronger construct than the perceived ease of

use. As can be seen from the plots of the constructs against current use the experienced users rate ease of use high, whereas other users are mote neutral. This suggests that they have graded familiarity with Earth observation information rather than ease of use.

Chapter 7 Conclusions

7.1 About the Earth observation modified TAM

In order to make a division between the parameters and constructs the scale included questions referring to the parameters and separate questions taken from the original Davis' scale. The PU and PEU constructs can be based either on the whole scale, or in the original Davis' scale. The latter are referred to as Davis' PU and Davis' PEU.

The hypotheses introduced in chapter 4 are not supported by the results of the questionnaire. There are no significant correlations between the parameters and the PU and PEU constructs based on Davis' scale (see table 6.7). There are significant correlations between the PU and PEU constructs based on all questions and the parameters (see table 6.6). These correlations are partly due by the fact that the parameters and the constructs are partly based on the same questions. Therefore they are not completely independent.

There are a number of possible reasons for the low reliability (α) and weak correlations between the parameters and the constructs. These are:

- Limited group size. After eliminating the experienced users the analysis was based on 25 persons. This is a rather small test group. The size of the test group was partly due to the chosen test session with an all-day program including presentations and an excursion to the NLR ground station. A larger test group would have been difficult to accommodate.
- Weak link between the questions and the hypotheses. The number of questions was kept to a limit. Since I wanted to test a large number of relations between parameters and constructs this meant that only 2 or 3 questions are used to test a hypothesis.
- Grouping of questions. Even when questions refer to the same parameter-construct relation they can refer to different data types. For example for spatial and temporal resolution the questions referred to low and high resolution optical imagery and radar images respectively. This allowed analysis of the test subjects' attitudes to different data types but it weakened the relation between the questions and the hypotheses further.

The ease of use construct is relatively weak in the modified model. In the original TAM study Davis already concluded that perceived usefulness is a major determinant of intention whereas perceived ease of use is only a secondary determinant of intention (to use computers) (Davis et al., 1989). The difference in the constructs is even more pronounced in the modified Earth observation TAM model used here.

The results suggest the the Earth observation TAM consists of two separate models. Significant correlations were found between the parameters and the constructs of the modified TAM. A significant correlation was also found between Davis' perceived usefulness and the intention to use. Since ease of use is a much weaker construct in this model no significant correlation of ease of use was found with intention.
Incorporating questions measuring *intention to use*, proved to be very useful in order to test the applicability of a modified model. The correlations between the constructs and intention support the questions from the original TAM scale.
The main conclusion is that I tried to test too many relations with a limited number of questions and a group size which proved to be too small to test the hypotheses of the modified TAM. The questionnaire did make some conclusions about the perception of the GIS users of Earth observation possible. This will be discussed in the following section.

7.2 Weaknesses and strengths of Earth observation

The subjects clearly prefer high resolution imagery. Response to traditional optical (and radar) imagery was neutral, it was more positive to high resolution images. High resolution imagery comes close to the imagery data which subjects are perhaps more familiar with: aerial photographs.
The subjects were neutral to the temporal resolution issue. This indicates that present acquisition intervals do not hamper acceptance. In the presentation it was specifically mentioned that optical images can be acquired as rare as twice a year due to cloud cover. Despite this the response to all questions relating to temporal resolution was moderate to positive, only few indicated that these acquisition frequencies makes the information less useful.
The error aspects questions showed a number of interesting results. For the classified maps, GIS users accept an incomplete map rather than a complete map with erroneous features. Visualisation of the errors in a layer would make Earth observation apparently more useful to the subjects.
Both the representation and accessibility aspects were hypothesised to affect ease of use. The subjects have no problem with raster data even though most of the information in their GIS will probably be vector data. Importing information and finding and ordering data are not seen as problematic by the subjects. However, it is very much open to debate whether the given subjects could give a response based on facts on the accessibility question. Given the fact that they range from non-users to casual users means that they have probably not had to look for data often. A session with more seasoned users could give a better indication about the weight of this parameter.

7.3 Further study

Despite the fact that this study has provided me with some answers, it has left me with even more questions. I would like to conclude this report with a number of recommendations.

The first recommendation would be to carry out additional tests using the current model. The reliability indicators have a low value. It is likely further tests on larger user groups would result in a higher reliability.

The Earth observation modified TAM should be evaluated. The perceived ease of use is a weak construct and the parameters affect it weakly. Formulating the questions matching ease of use proved to be difficult. When testing for ease of use in this context one should take care that one does not test the ease of use of the software tools which are used to deal with the Earth observation information. The importance of the ease of use construct is illustrated by the comparison with experience. The ease of use issues are seen as a problem mainly by the less experienced subjects whereas experienced subjects indicate they have little problems with the practical ease of use issues. This indicates that ease of use of a significant hurdle for people when they want to adopt Earth observation information. The questions referring to ease of use should be evaluated in order make the affects on the construct clearer. Since it proved to be difficult to phrase questions from the parameters it should be considered to include more ease of use questions from Davis' scale.

The affect of error aspects on usefulness deserves a study in itself. It was incorporated into the model as a single parameter even though different error types were identified. It was found that the error aspects parameter consists of several (georeferencing, classification, etc.) which affect the different constructs differently. Splitting the error aspects parameter did carry to far for this study, but it might be interesting to investigate how users grade the effect and affect of the different error aspects.

Appendix A Questionnaire and GIS

For the GIS environment the map server from the University of Minnesota is used in combination with a web client from a german company: GDV.

A.1 Interactive questionnaire

The interactive questionnaire consisted of a presentation, questions were presented to the subjects after each parameter was presented. A computer with a receiver unit and handheld remote control units was used to implement questions and response collection. The subjects used remote control units to submit their responses.

The protocol for the interactive questionnaire is included as Appendix B.

A.2 The GIS environment

The GIS implementation was intended as a support for the sessions. The necessary functionality is limited to a number of essential functions. A participant was able to select layers, to zoom in and out. The GIS environment shows the layers list, the main layer panel and a legenda.

Open source components were selected for the GIS environment. First of all these are cost effective, secondly the rapid development of web-based GIS is implemented early in open source projects. Effective open source components were available both for the server and client components.

A.2.1 Server

The server side must be able to serve both raster layers (the satellite imagery) and vector layers (for reference) over the internet. In the Open Geospatial Consortium a number of specifications have been established for web-based GIS operations and data delivery. A web mapping server (WMS) offers basic raster map server functionality.

In this case the selected server application is the Minnesota University mapserver (see the website at mapserver.gis.umn.edu). The mapserver offers basic web mapping like a WMS server but offers a number of extra features. It allows both scalebars and legends to be plotted. These are associated with the selected layers.

A.2.2 Client

For the client side a number of packages are available. Standard mapserver clients use a scripting language implemented on the web site in combination with a number of simple client elements.

A simple client without server side components is offered free of charge by a German company, Geografische Datenverarbeitung GmbH. This client was developped specifically for the Minnesota mapserver and uses only client-side javascript in combination with standard HTML. It offers a number of standard functions allowing the user to zoom and pan the map image and to select layers. The client

also shows an overview window and a legend area. The overview area shows the location of the current map window in an overview map of the whole study area. The legend area shows the legends of the selected layers. The standard client set-up can be found on www.gdv-gis.de/mapserv.
A number of pages were made for satellite imagery and classified imagery respectively. Two screenshots are included in the report as figures 5.2 (page 38) and 5.3 (page 39).

Appendix B Test session protocol

The protocol is the text of the users sessions' presentation and questionnaire. The text was presented in Dutch. The presentation lasted about 20 minutes. During the session subjects were encouraged to use a computer to select and compare Earth observation imagery layers and to react on the presentation.
The texts in the boxes indicate an action from the researcher: showing example data layers or presenting the questions to the subjects.
Goedemiddag,
U heeft vandaag een aantal presentaties gezien over aardobservatie bij het NLR. We hebben vooral laten zien hoe het ontvangen wordt en beschikbaar wordt gemaakt. In deze sessie willen we U graag een enquete voorleggen om uw mening over Aardobservatie te peilen.
Mogelijk werkt U al met aardobservatiebeelden of bent U van plan ze te gebruiken. We hebben gemerkt dat GIS gebruikers geïnterresseerd zijn in aardobservatiedata maar het vaak nog niet zelf actief gebruiken. Blijkbaar zijn er een aantal factoren die acceptatie (nog) tegenhouden. In deze enquete hebben we een aantal van deze factoren op een rij gezet en willen met name kijken hoe deze factoren volgens U invloed hebben op bruikbaarheid en gebruikersgemak van aardobservatie. We presenteren U een twintigtal multiple choice vragen waarmee U kunt antwoorden met de afstandsbediening die U gekregen heeft.
Allereerst willen we graag weten wat voor gebruiker U bent. Uw antwoorden zijn in principe anoniem. We willen U vragen voor wat voor organisatie U werkt, hoe groot die organisatie is en of U misschien al met aardobservatie werkt.

Presentatie over de algemene vragen over de gebruikers:
Voor wat voor organisatie werkt U?
Hoeveel mensen werken in Uw organisatie?
Heeft U ervaring met aardobservatie in Uw werk?

De eerste mogelijke factoren zijn de resolutie van Aardobservatiedata en de frequentie waarmee beelden opgenomen worden. We gaan naar een drietal types aardobservatiedata kijken: normale optische beelden, hoge resolutie beelden en radarbeelden.

Toon pagina met ASTER beelden en TOP-10 van Nederland.

Allereerst kijken we naar "traditionele", optische aardobservatiebeelden. Satellieten Landsat en SPOT beelden zijn inmiddels al ruime tijd in gebruik. Eerst vooral voor onderzoek, later steeds meer voor commercieele toepassingen. De resolutie ligt in de orde van 10 meter, voor Landsat is het wat grover (30 meter), voor

SPOT fijner (10 meter). De beelden worden voornamelijk gebruikt voor landbouwtoepassingen en voor milieuonderzoeken. De resolutie is niet voldoende om stedelijk gebied goed in kaart te brengen maar het feit dat de sensoren meer kanalen hebben betekent dat er extra informatie uit deze beelden te halen is. De kaart die U zie laat MODIS beelden zien met een resolutie van 15 meter. Beelden kunnen worden ongeveer 1 keer per week hetzelfde gebied laten zien, maar doordat Nederland nogal eens bewolkt is is dat in de praktijk een stuk minder vaak. Een satelliet kan meestal slechts 2 tot 4 wolkenvrije opnamen per jaar maken. Doordat er meer satellieten in gebruik zijn ligt dit tegenwoordig gunstiger (een opname per maand gemiddeld) maar in sommige jaargetijden krijgt men geen wolkenvrije beelden.

Presenteer vragen over traditionele aardobservatiebeelden:
De spatiele resolutie van optische beelden voldoet voor mijn toepassingen
Optische beelden worden vaak genoeg opgenomen voor mijn toepassingen

Toon pagina met Ikonos en Quickbird van Ede en Den Haag

Sinds enige jaren is data van een nieuwe generatie satellieten beschikbaar. Dit zijn commercieele satellieten met een hogere resolutie dan de Landsat en SPOTserie. De resoluties van Quickbird en Ikonos data is ongeveer 1 meter. Hiermee worden details als huizen en straten in steden zichtbaar. Door de bedrijven worden kortere tijden tussen twee opnamen geclaimed, dit wordt bereikt door ook onder een grote hoek nog opnamen te maken wanneer de satelliet niet precies over het doel gaat. Verder wordt het aantal opneembare beelden natuurlijk ook beperkt door bewolking. Tegenwoordig is een opname per maand haalbaar.

Presenteer vragen over hoge resolutiebeelden:
De spatieele resolutie van hoge-resolutiebeelden is voldoende voor mijn toepassingen
Hoge-resolutiebeelden worden vaak genoeg opgenomen voor mijn eisen

Toon pagina met ERS beeld

Het derde datatype is radar. Radar heeft als voordeel dat het dwars door bewolking heenkijkt. De resolutie ligt in dezelfde ordegrootte als voor traditionele optische data. Radarbeelden verschillen vooral omdat ze niet gereflecteerd zonlicht laten zien maar gereflecteerde radarpulsen. Objecten gemaakt door mensen worden duidelijk zichtbaar. Omdat radar niet door bewolking gehinderd wordt kunnen in ieder jaargetijde opnamen worden gemaakt. Dus bij iedere passage over Nederland wordt een bruikbare opname gemaakt.

Presenteer vragen over radarbeelden:
De spatiele resolutie van radarbeelden is voldoende voor mijn toepassingen
Radarbeelden worden vaak genoeg opgenomen voor mijn toepassingen

Toon pagina met geclassificeerde beelden

We hebben tot nu naar ruwe beelden gekeken. Veel gebruikers willen echter de informatie hebben die *in* de beelden zit. Experts kunnen thematische kaarten van satellietbeelden maken, dit proces is bekend als classificatie. De kaart op de volgende webpagina laat een aantal geclassificeerde beelden zien voor Den Haag (gebaseerd op Ikonos) en de omgeving van Zwolle (gebaseerd op Landsat). Classificatie is niet zonder fouten. Volgens een studie varieert het percentage correcte pixels van 80% voor Landsat tot slechts 40% voor Ikonos.

Presenteer vragen over geclassificeerde beelden:
Thematische kaarten (geclassificeerde beelden) met een classificatiefout zijn bruikbaar voor mij
Een foutvrije, maar incomplete thematische kaart of geclassificeerd beeld is bruikbaar voor mij

Wanneer U een aardobservatiebeeld ontvangt is dit nog niet direct bruikbaar om met andere data te combineren. Er worden voorlopige coordinaten berekend voor de hoekpunten. De nauwkeurigheid hiervan is meestal slechter dan de resolutie, dus beelden zijn verschoven. Wanneer de beelden met andere data-lagen gebruikt worden moet dit gecorrigeerd worden.

Presenteer vragen over ruimtelijke nauwkeurigheid:
Beelden met een (standaard) geocoderingsfout zijn bruikbaar voor mij
Ik zou het niet moeilijk vinden met de geocoderingsfout te corrigeren
Visualisatie van de onzekerheden in classificatie en geocodering zou de bruikbaarheid voor mij verbeteren

Om data te kunnen toepassen moet het natuurlijk gevonden worden en in een GIS systeem worden ingevoerd. Wij willen U allereerst vragen of U weet hoe U aardobservatiebeelden in moet brengen in een GIS systeem. Ten tweede willen we U vragen of weet hoe U aan aardobservatiebeelden kunt komen, hetzijn extern of via Uw eigen organisatie.

Presenteer vragen over vinden en importeren van informatie:
Het importeren van aardobservatiedata in mijn GIS *omgeving is eenvoudig voor mij*
Ik weet hoe ik de aardobservatiebeelden die ik nodig heb kan vinden en bestellen

Tot slot willen we U een paar vragen stellen over uw algemene indruk van bruikbaarheid en gebruikersgemak van aardobservatie.

Presenteer TAM *vragen:*
Gebruik van aardobservatieinformatie in mijn GIS omgeving zou mij helpen mijn taken sneller uit te voeren
Gebruik van aardobservatieinformatie zou mijn efficientie in het werk verbeteren
Het leren omgaan met aardobservatie zou gemakkelijk voor mij zijn
Ik zou aardobservatiedata gemakkelijk in het gebruik vinden

Tot slot hebben we nog twee vragen voor U:

Ik ga de bruikbaarheid van aardobservatie voor mijn werk verder onderzoeken
Ik ga aardobservatie gebruiken in mijn werk in de nabije toekomst

We zullen de resultaten van dit onderzoek beschikbaar maken. Dank voor Uw medewerking.

Index

Acronym list

AGGN	ArcGIS gebruikersgroep Nederland
ANOVA	Analysis of variance
ASAR	Advanced Synthetic Aperture Radar
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ERS	European Remote Sensing Satellite
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
HTML	Hypertext Markup Language
IR	Infra-Red
IS	Information Systems
MERIS	MEdium Resolution Imaging Spectrometer Instrument
MODIS	MODerate resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NLR	National Aerospace Laboratory
PCC	Percentage Correctly Classified
PEU	Perceived Ease of Use
PU	Perceived Usefulness
SAR	Synthetic Aperture Radar
SDI	Spatial Data Infrastructure
SPOT	Systeme Pour l'observation de la Terre
TAM	Technology Acceptance Model
TNO	Technisch Natuurkundig Onderzoek
TRA	Theory of Reasoned Action
UV	Ultra-Violet
WMS	Web Mapping Server

Figures, tables and hypotheses

Figures

Tables

Hypotheses

References

1 ESA, (2004). *Earth observation handbook*. Committee on Earth Observation Satellites. online at www.eohandbook.com.

2 NASA, (2005). The remote sensing tutorial. website. rst.gsfc.nasa.gov.

3 Achache, J. (2003a). A new persepctive for Earth observation: The oxygen (0_2) project. *ESA Bulletin* (116), pages 22–33.

4 Benz, U. C., Hofmann, P., Willhauck, G., Lingenfelder, I. and Heynen, M. (2004). Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS Journal of Photogrammetry & Remote Sensing* (58), pages 239–258.

5 Canada Centre for Remote Sensing, (2004). Fundamentals of remote sensing. website. online at www.ccrs.nrcan.gc.ca.

6 Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 3 (13), pages 319–340.

7 Davis, F. D., Bagozzi, R. P. and Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management science*, 35 (8), pages 982–1003.

8 Dekker, R. J. (2003). Object-based updating of land-use maps of urban areas using satellite remote sensing. Master's thesis, Unigis/Free University Amsterdam.

9 Dekker, R. J. (2004). *Object-based updating of land-use maps of urban areas using satellite remote sensing*. Gävle, Sweden.

10 Duckham, M., Mason, K., Stell, J. and Worboys, M. (2001). A formal approach to imperfection in geographic information. *Computers, Environment and Urban Systems* (25), pages 89–103.

11 Ehlschlaeger, C. R. (2000). Representing uncertainty of area class maps with a correlated inter-map cell swapping heuristic. *Computers, Environment and Urban Systems* (24).

12 Gahegan, M. and Ehlers, M. (2000). A framework for the modelling of uncertainty between remote sensing and geographic information systems. *ISPRS Journal of Photogrammetry & Remote Sensing* (55), pages 176–188.

13 Ganas, A., Lagios, E. and Tzannetos, N. (2002). An investigation into the spatial accuracy of the Ikonos 2 orthoimagery within an urban environment. *Int. Journal of Remote Sensing*, 23 (17), pages 3513–3519.

14 Goodchild, M. F. (1998). Uncertainty: The achilles heel of GIS?. *Geospatial Solutions*, 8 (11), pages 50–53.

15 Goodchild, M. F. (2001). Metrics of scale in remote sensing and GIS. *International Journal of Applied Earth Observation and Geoinformation*, 3 (2), pages 114–120.

16 Junglas, I. (2003). *U-Comerce: An Expertimental Investigation Of Ubiquity And Uniqueness*. PhD thesis, University of Georgia, Athens, Georgia.

17 Krischke, D. M., Niemeyer, W. and Scherer, S. (2000). Rapideye satellite based geo-information system. *Acta Astronautica*, 46 (2-6), pages 307–312.

18 Lederer, A. L., Maupin, D. J., Sena, M. P. and Zhuang, Y. (2000). The technology acceptance model and the world wide web. *Decision Support Systems* (29), pages 269–282.

19 Lee, D. S., Shan, J. and Bethel, J. S. (2003). Class-guided building extraction from Ikonos imagery. *Photogrammetric Engineering & Remote Sensing*, 69 (2), pages 143–150.

20 Ong, C.-S., Lai, J.-Y. and Wang, Y.-S. (2004). Factors affecting engineers acceptance of asynchronous e-learning systems in high-tech companies. *Information & Management* (41), pages 795–804.

21 Pituch, K. A. and kuei Lee, Y. (2004). The influence of system characteristics on e-learning use. *Computer and education* . In press.

22 Ryan, R., Baldridge, B., Schowengerdt, R. A., Choi, T., Helder, D. L. and Blonski, S. (2003). Ikonos spatial resolution and image interpretability characterization. *Remote Sensing of Environment* (88), pages 37-652.

23 Straub, D., Keil, M. and Brenner, W. (1997). Testing the technology acceptance model across cultures: A three country study. *Information & Management* (33), pages 1-11.

24 van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in the netherlands. *Information & Management* (40), pages 541–549.

25 Venkatesh, V. (1999). Creation of favorable user perceptions: Exploring the role of intrinsic motivation. *MIS Quarterly*, 2 (23), pages 239–260.

26 Venkatesh, V. and Davis, F. D. (2000). A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management science*, 46 (2), pages 186–204.

27 Worboys, M. (1998). Imprecision in finite resolution spatial data. *GeoInformatica*, 2 (3), pages 257–279.

28 Yang, H. and Yoo, Y. (2004). It's all about attitude: revisiting the technology acceptance model. *Decision Support Systems* . Article in press, corrected proof.