Information system supporting spatial decision-making and its quality

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***Abstract*—**Decision-making is an important part of human's life. Information systems should highly support efficient decision making. Only well designed information systems with a high level of a quality can provide this kind of service. Approach to spatially-oriented information systems quality evaluation is described in the article. Next, a case study – evaluation of a quality of a Web-based intranet GIS application of a municipal authority, is described. In the end, obtained results and lessons learned from the evaluation are stated and commented.

***Keywords*—**Spatial decision-making, Spatial decision support systems, Web-based GIS, Intranet, Quality, Usability, Geographic information systems,.

I. Introduction

DECISION-MAKING is a very important part of our everyday lives. Organisations of all types need information to support decision-making in various levels of management in order to remain or become truly globally competitive [1]. Due to contemporary information overload, information systems play significant role as a supporting element of decision-making process. They should make the decision-making process more efficient. Because mankind lives in a space, the most of decisions must take it into account this dimension too. So, importance of spatial decision-making systems (SDSS) is rapidly increasing. Consequently, a strong attention has been paid to them, SDSS have been used in many different ways [2]-[4].

SDSS system can integrate database technology, expert system technology and spatial decision support system technology. It can consist of four components: a geographic information system (GIS), land use modules, a graphical user interface and land use planning tools [5].

Next significant advantage of contemporary Web applications is that they can provide adaptive user interface using many various technologies [6].

Decision-making process can be much better supported by an information system of a good quality. Quality of an IS can be defined in many various ways. From the user's point of view, quality means that product is able to provide him/her all expected functions and features, both explicit and implicit [7], [8]. High-quality software should meet all users' requirements on functions, it should be easily accessible and it should provide user-friendly environment. Concerning spatial data, interactive and easy access for end users, simple user interface with the limited number of functions and increasing number of end users resulted in a high popularity of Web-based geographic information systems (GIS) applications (in general Internet applications). These applications provide only several basic functions and they are simple. During last years Web-based GIS applications have become the most wide-spread GIS solutions [9]. If needed, they can provide many sophisticated functions, e.g. data editing, cartographic functions, and complex spatial analyses, so they can replace desktop applications. Of course, higher level of user's skills and knowledge is required in this case. This kind of application can be used as a tool for supporting spatial-oriented decision-making processes.

The article deals with a quality evaluation of a Web-based intranet application providing access to spatial information. Aim of the article is to propose a way how to evaluate quality of an intranet application of a medium size municipal authority. Number of users of evaluated application is limited so number of available respondents is limited as well. It means research will be conducted as a qualitative one. Web-based GIS application was chosen as an evaluated application. According to the proposed evaluation method selected Web-based GIS applications will be assessed and ways of their improvement will be proposed.

II. Information Systems' Quality

As it was mentioned, quality of information system can significantly influence its users. Attempts to objectively evaluate quality of information systems are old. Many definitions and quality models have been proposed to allow software quality evaluation. Some of them are discussed below.

A. Quality Models

The first widely recognized quality model was proposed by McCall in 1977. Next one, the Boehm model, followed in the next year. Because quality is a complex of many characteristics, these models use decompositional approach [10], [11]. Standard ISO/IEC 9126 defines a quality model applicable to every kind of software using six main

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characteristics to evaluate software quality [12]:

- Functionality – if there are all required (both implicit and explicit) functions available
- Reliability – if the software is reliable
- Efficiency – how efficient is the software
- Usability – if it is easy for users to use the software; the only characteristics dealing with users' point of view
- Maintainability – if it is easy to modify and maintain the software
- Portability – if it is easy to transfer the software to another platform.

In fact, each author can propose his or her own quality model to cover all important issues and to take aim of an evaluation into account [10].

B. Usability

According to ISO 9126 quality model, usability is the only quality characteristic of software dealing with a users' view on an evaluated application. In more detail, usability means that an application is useful, efficient, effective, learnable, accessible, and satisfying. Objective measurements of users' performance and subjective users' opinions are covered by the usability [13], [14].

Many usability evaluation methods have been proposed. All methods represent experimental methods. It means, they are either qualitative or quantitative methods. A suitable method must be proposed/selected for each study according to its defined aims. The following criteria were proposed by the authors to clarify choice of an appropriate method:

- Phase of the software development life cycle at which testing will be done
- Number of required test monitors/administrators (people who manage the whole testing)
- Number of evaluators (people who conduct the whole testing)
- Expertise level of test monitor/administrator (i.e. beginner, medium-skilled, expert)
- Number of required participants (people who evaluate the product) – usually representatives of real users
- Expertise level of participants (i.e. beginner, medium-skilled, expert)
- Level of interaction between test monitors and participants (i.e. high/medium/low or passive/interactive)
- Testing environment (special testing room, a testing room, the place of operation, anywhere)
- Procedure of the evaluation
- Orientation of the test (e.g. to the whole system, to its elements, etc.)
- Way of data logging/collection (i.e. manually, automatically by a software tool, video recording, sound recording)
- Investigation on a place of operation of the product
- Possibility of a remote evaluation
- Obtained output data (quantitative/qualitative; numeric/textual; subjective/objective)
- Fixed costs of the testing
- Costs per participant/test monitor/identified usability problems/the complete evaluation
- Number and type of identified usability problems.

III. Quality and Usability Evaluation

Many quality models and several ISO standards provide framework for quality evaluation. Some of them provide set of measurement metrics, some of them provide only set of characteristics.

At the first step, it is necessary to determine aim of the evaluation. Software *quality evaluation* can be done because of many different reasons and with many various aims [13]:

- To select the most suitable product from several alternatives
- To verify that the product has sufficient quality (so it can be sold, forwarded to the next process, etc)
- To find the problematic functions, tools or modules of the product
- To assess intermediate products
- To estimate/predict future values of an evaluated entity.

Software quality can be evaluated by [13]:

- Developers – usually as a part of testing of the software
- Acquirers – usually as a part of acquiring a new IS, e.g. selecting the most suitable software solution
- Independent evaluators – usually done in testing laboratories and independent organizations; this evaluation can be required by both developers and acquirers.

The whole quality evaluation system should consist of a suitable quality model, set of metrics, measurement tools, evaluation techniques, data management tools, computers (information and communication technologies), and evaluators and participants, if necessary [13].

Testing in general and *usability evaluation* should become an integral part of each phase of a live cycle because it take into account users of information systems and their needs. Measurement itself can be done according to one of many available quality models. In any case, complex evaluation of application by developers, management and users of the system is very important [15]. User's view is quite wide as it was determined by Wong and Jeffery [16] and as it is shown in the Fig. 1.

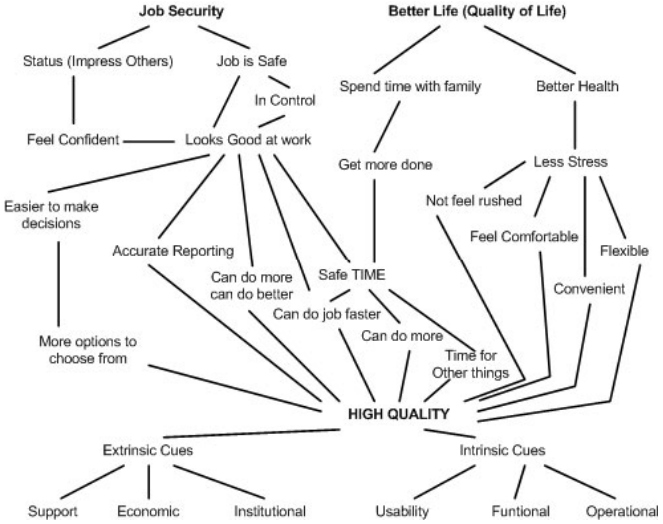

Fig. 1 – User's cognitive structure of software evaluation [16]

Different usability evaluation methods can be used in different phases of life cycle, e.g.:

Requirements analysis:

- Ethnographic observation
- Participating design
- Focus groups
- Inquiries
- Opened and closed card sorting

Design:

- Inquiries
- Opened and closed card sorting
- Paper prototyping
- Walkthrough
- Heuristic evaluation
- Usability user testing

Implementation:

- Heuristic evaluation
- Usability user testing

Maintenance and system operating:

- Follow-up studies

A very brief inquiry was run to find out if usability as term is known and usability evaluation methods are used in public administration authorities. Authorities at higher level of public administration were selected to ensure that they were using GIS and Web-based GIS applications. There were 29 answers available. Respondents were mostly information systems administrators. Usability itself is known term for 80 % of respondents. Geographic information systems are used by 90 % of respondents. From them, all 14 regional authorities use GIS solutions. Although usability seems to be a well-known term, usability evaluation is run only in 65 % of responding authorities. More general information systems are evaluated more often then GIS applications. The next difference between usability evaluation of general information systems and GIS is in the evaluation way. In the case of general systems, 25 % of evaluation is done by external companies and 60 % by internal employees (the rest is mixed). In the case of GIS, only 21 % of evaluation is done by external companies and 72 % by internal employees (the rest is mixed). The most often used usability evaluation methods are (ordered list; but only percentage share higher than 50 % is stated):

- Usability user testing (90 %)
- Feature inspection (63 %)
- Standards inspection (58 %)
- Questionnaires (52 %)
- Consistency checking
- Heuristic evaluation
- Cognitive walkthrough
- Card sorting
- Heuristic estimation
- Pluralistic walkthrough.

IV. Case Study: Quality and Usability of Web-Based Intranet GIS Application of Municipal Authority

All internal network devices and networks of a company are interconnected into one network, called Intranet, to provide network services to users. Usually, intranet uses the same technology as the Internet [17]. Its resources are available for employs only and it should improve communication and it should help to manage knowledge and its sharing within a company. It means that the network is private and resources are usually highly protected. [18]

Internet technologies (mostly Web technologies) are very often used by Intranet applications. Their typical architecture is client/server architecture. This architecture significantly supports scalability, maintainability, central data management and protection. Easy access to information and services and low costs per user are other benefits of the architecture. Client/server architecture is a very general model. It can be implemented in many various ways and by means of various technologies. Today, at least three layers are recognized: presentation layer (user inputs and outputs), application layer (implemented business logic for tasks/queries processing), and data layer (data storage and management) [19]. Used client application highly influences users perception of IS because it provides users interface to interact with IS. Web browser belongs to the most popular client applications. It is a general application, highly used by users so they usually do not need to learn how to use it.

Utilization of Web services belongs to the next recent development trends. Web-based GIS applications successfully use the technology of Web services because all necessary standards were adopted several years ago. Web services mashup (cascading) can increase functionality and richness of resulting application and it can assure higher quality of provided data – data are provided from their original sources. Additional advantage is that parameters of the cascaded services can be changed on-the-fly [20].

A. *Municipal Authority*

Municipal Authority Zamberk has in total 76 clerk employees including employees of the city information centre. All of them are potential users of the intranet application. Municipal authority offered access to the application to the local authorities within its administration boundaries. As a result, several independent user groups were created to grant an appropriate access to all users [21].

B. *Intranet Application and its Users*

Subject of the testing is intranet application of the Municipal Authority Zamberk. The *application* has been working more than 4 years. It is a commercial solution based on software named T-MapServer which is provided by T-MAPY spol. s r.o., Czech Rep. (http://www.tmapy.cz). The application is able to provide spatial information in a form of maps, graphical data, and database data [21]. An example of user interface of the application is shown in the Fig. 2. (Basic map project) and Fig. 3 (T-WIST REN). Available tool bar is in more detail shown in the Fig. 4.

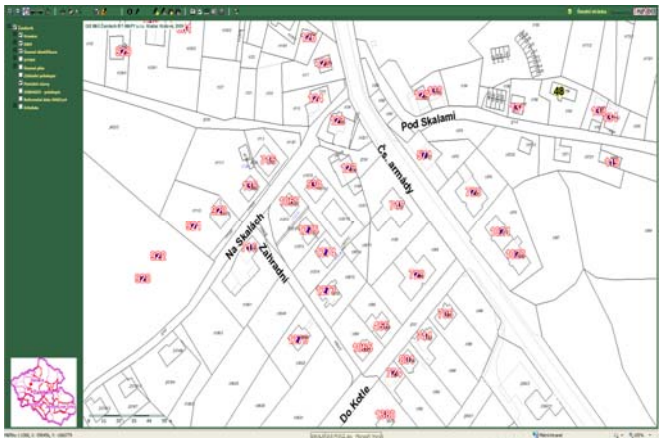

Fig. 2 - Example of user interface of the Web-based intranet application , Basic map project of the city (source: authors)

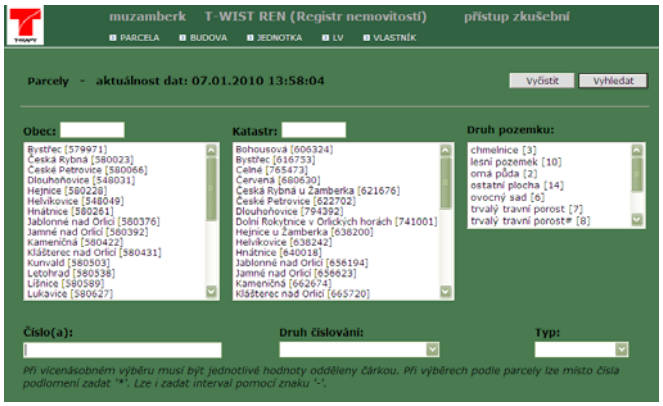

Fig. 3 - Example of user interface of the Web-based intranet application, T-WIST REN module (source: authors)

Fig. 4 – Toolbar of the Web-based intranet application (source: authors)

Technical parameters of the application [21]:

- Operating system: Linux CentOS 3.x (RedHat)
- Web server: Apache (version 2.0.46-44.ent.centos.2),
- Database: PostgreSQL, core of the T-WIST technology: PHP (version: 4.3.2-19.ent.twist.1)
- Mapserver: MapServer (former UMN MapServer - University of Minnesota), (version: 4.4.1-1)
- Client: MS Internet Explorer, Firefox.

Access for administrators is separated from access for the rest of the users. There are several different functions available for administrators. A special authority employee - GIS operator, uses the administrator rights to manage data and users rights.

Access to the most of the application is granted to the authorized users only using user names and passwords. Only a part of the application is publicly accessible, i.e. it is publicly available on the Internet. [21]

The application offers following modules (services) [21]:

- T-WIST REN (Land registry) – intranet
- ÚIR-ADR – Address searching – intranet
- Tourist regional information – publicly accessible
- Basic map project of the city – intranet
- Map project for the public – publicly accessible.

Basic map project of the city is linked up to T-WIST REN and ÚIR-ADR.

Target group of *users* of the application are municipal authority employees, city information centre employees, local authorities employees [21]. No GIS knowledge and skills are expected. High level of computer literacy cannot be expected as well. Users of the application are clerks and/or experts in different branches. Because of different origin of users, their equipment (software, hardware, and Internet connection) can vary but it can be influenced and it is known in advance. At least skills of users must be respected by design of the application, although users can undergo trainings how to use application. Their next advantage is that they use application regularly (at least some of them).

User groups of the application are as follows [21]:

- Municipal Authority Zamberk – 30 users
- Municipal Authority Letohrad – 11 users
- Municipal Police Letohrad – 4 users
- T-MAPY – 3 users
- Municipality Lukavice – 2 users
- Municipal Police Zamberk – 1 user
- Municipality Orlicky – 1 user.

Users have not undergone any training how to use the application. They can use application help or they can ask GIS operator how to use the application.

C. Aim and purpose of the evaluation

The main aim of the evaluation was to collect users' opinions and identify problems in quality, namely functionality and usability of the application so qualitative research methods were mostly used. The next reason for qualitative research was number of the participating users. It was limited to the number of the users of the application, i.e. to at maximum 52 users.

D. Evaluation Methodology and Results

In the case study, a simplified three-step mixed research was used, so both qualitative and quantitative research methods were used. The whole evaluation was split in the following steps [22]:

- Research questions definition
- Data collection
- Data processing and analyses

Written semi-structured questionnaire was used as a mixed research method to inquiry users and get required information. Semi-structured questionnaire consists of both opened and closed questions so users had possibility to write down their own opinions if they wanted or no proper answer was available. Closed questions can be answered faster and easier but they must provide all relevant answers otherwise they can provide incorrect results [22].

Respondents obtained the questionnaire printed on the paper and they were asked to return it within two weeks. Three various questionnaires were proposed to target survey precisely. In all cases it was supposed that users knew names of applications, tools and functions. Users were informed that in the case of necessity they could ask GIS operator for explanation but none of them did it. Survey 1 was aimed at potential users, survey 2 and 3 were aimed at current users of the application to let them evaluate the application [21].

All surveys were managed and run by GIS operator of the application who is employee of the Municipal Authority Zamberk.

1) Survey 1

This survey was focused on potential users, i.e. on employees who did not use the application. Aim of this survey was to identify employees who could become new users of the application. In the beginning, the application was briefly described. Attention was paid to services and data provided by the application. There were only two questions in this questionnaire. The first one asked about department and the second one about interest in the application utilization. Respondent was asked to explain reasons why he needs access to the application (for which operations access to the application is required).

In total, 17 respondents requested new access to the application. Obtained results (required operations, No. of answers, and proposed way of solution) [21]:

- Land identification (cadastre, addresses); required by 7 respondents; service is already available on intranet
- Searching for streets, addresses, and tourist information; required by 4 people; service is already publicly available on the Internet
- Land identification – property of citizens (cadastre, addresses); required by 3 respondents; interconnection with registry of citizens must be created; intranet access
- Identification of establishments; required by 1 respondent; interconnection with Trade Register; intranet access
- Access without any given reason was requested by 2 respondents

It can be concluded, that there were 1/3 of authority employees who have not heard about the application and its services although it could help them to do their work. It means information about the application is not spread adequately nad this process should be improved.

2) Survey 2

Users evaluated three main modules within this survey: T-WIST REN (Land registry), ÚIR-ADR – Address searching and Basic map project of the city. This questionnaire obtained all contemporary users, i.e. 30 respondents. Only 27 of them returned the questionnaire and 2 returned questionnaires empty. Utilization of the parts differs. Only 9 users use ÚIR-ADR, 18 users use Basic map project of the city and 20 users use T-WIST REN. Four users stated that they did not use the application at all.

Users of the application were then asked how to run particular functions and how to use particular tools in all three main modules. In general it can be concluded, that users of all three modules were able to use at least two tools (or run two particular functions). In all cases more than ½ of the users were able to use more than ½ of queried functions.

In more detailed view, 13 of 20 users of T-WIST REN can use more than one half of available functions, 5 of 9 users of ÚIR-ADR can use more than one half of functions and 15 of 18 users of Basic map project of the city can use more than one half of functions. All users were able to use at least 2 functions, no less.

This survey showed, that the most often used modules are T-WIST REN and Basic map project of the city, so attention should be preferably paid to them.

A special attention should be paid to users without knowledge of utilization of the application or with only a limited knowledge. Training of users could be possible solution.

Results of survey 2 were used as a basis for the following survey 3. According to the results, level of detail of the following questions was determined. [21]

3) Survey 3

Survey 3 was designed according to the results of the survey 2. This questionnaire contained 11 questions dealing with details about the application utilization, its usability, functionality, additional requirements (e.g. manual, training, etc.), and interest in remote access from outside the authority/office. In this case the closed questions was not only

single-choice, but also multiple-choice. In some answers respondents were requested to create a numerical order according to importance of given options, i.e. to decide what is the most important for them and what is less important.

All 52 contemporary users of the application, coming from all authorities using the application, obtained the questionnaire, 30 of them returned it. Some of the returned questionnaires were not filled completely – see Tab. 1. [21]

TABLE I
COMPLETENESS OF RETURNED QUESTIONNAIRES [21]

No. of Question	No. of Answers
1	30
2	30
3	30
4	28
5	28
6	4
7	24
8	28
9	23
10	19
11	0

Used questionnaire consisted of the following set of *questions* [21]:

Q. 1: How often do you use tools and functions of the application?

Q. 2: Is it easy and comfortable for you to use the application?

Q. 3: What would help you to improve your work with the application?

Q. 4: Would you utilize a remote access to the application outside the authority/your office?

Q. 5: Which of the following modules do you use? Sub-questions were dealing with particular tools and functions of the modules.

Q. 6: What do you miss in the application? Which additional functions, tools or modules would you like to use?

Q. 7: Which of the following data would you like to use?

Q. 8: Which additional functions/tools would you like to use in the Basic map project?

Q. 9: Which additional modules would you like to use?

Q. 10: Would you like to change or improve some parts of the current application? Which ones and how?

Q. 11: Do you have any other ideas, comments, requests, improvements (concerning content, design, organizational issues)?

Obtained results (for the total number of answers to each question see Tab. 1) [21]:

Q. 1: In total 14 users (it represents almost 50 %) use the application at least several times per week. On the other side, 9 users use application very rarely.

Q. 2: Twelve users use the application without any significant problems. Only 5 users stated that they were not able to use application because they did not know how to work with it.

Q. 3: Only 6 users do not want any additional training or manual, they are satisfied. On the other side, 14 users (almost 50 %) would like to pass training, and 8 users would like to get individual training.

Q. 4: In total 7 users would like to have a remote access from outside the authority/office. Solution of this problem was very simple – users were told a URL of the application and reminded to use their username and password.

Q. 5: There are 24 users using module T-WIST REN, they prefer to search according to the parcel numbers. The order of search tools in the application is different so it should be changed to meet user's requirements (see Fig. 5). 10 users use UIR-ADR module, only 2 user's use publicly accessible Tourist regional information, and 14 users use Basic map project of the city. The applications provides in total 22 tools (icons, see Fig. 4). There are only 2 users who use all the available tools. These users use application several times per week (Q. 1) and they do not have any problems with its utilization (Q. 2). All users, except for one, are able to use the following tools: zoom in, zoom out, and pan. One user uses only one tool – printing.

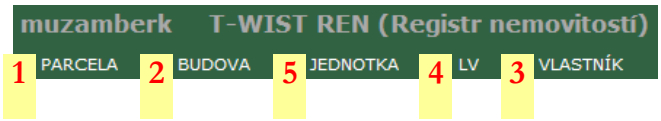

Fig. 5 – Actual and required order of searching criteria [21]

Q. 6: Users requested zoning plans, floodplain, and cadastral data.

Q. 7: Most of the users would like to use municipal zoning (territory) plans.

Q. 8: Users mostly require possibility to see complete list of neighboring parcels and their owners when they select a parcel (17 users).

Q. 9: Users mostly require access to the Registers of Economic Subjects.

Q. 10: There are only a few requests to change modules of the application: 1 respondent would like to change T-WIST REN, 3 users would like to change Basic map project of the city and 1 user would like to change Tourist regional information.

It was possible to find out that those 4 users, who almost do not use the application (Q. 1), are not able to use the application too (they do not know how to use it – Q. 2). Three of them would like to pass and individual training to be able to use the application.

It can be concluded, that users use the application although they are not forced to, so the application brings some benefits to them.

E. Lessons Learned

Functionality and usability evaluation should at least partly include real users or their representatives because their opinions and needs can differ from opinions of software developers and other experts.

Choice of quantitative or qualitative research methods depends on aim of the evaluation (e.g. choice of software, gathering users' requirements for software improvement, etc.).

Semi-structured questionnaire is a good choice. Closed questions can be answered quickly so respondents are not so disturbed by the questionnaire. On the other side, they must be designed properly (namely answers), otherwise they can provide incorrect results. Opened questions provide respondents certain freedom to express their opinions, so they are very useful within qualitative research but they are more time demanding so there are not so many respondents who answer opened questions. In this case, there was no answer at all to one question (see Tab. 1).

Several shorter questionnaires can increase successfulness of the survey (rate of return) because respondents do not need so much time to fill one questionnaire. After a short time period they can more easily fill another questionnaire.

Even in the case, when respondents fill questionnaire as a part of their work tasks, they do not answer questions carefully and completely. To obtain complete answers from all respondents, semi-structured interview should be used instead of questionnaire.

Training is a very important part of the software development life cycle. It can significantly improve users' ability to use software, so it can improve their productivity and satisfaction.

It was confirmed that most of the users need zooming and panning, i.e. the basic visualisation tools available in GIS applications.

Costs of the testing must be taken into account, some methods are time and material demanding so they can increase resulting price of the software. At least the following indicators should be taken into account:

- Consumed time for testing by designers, experts, evaluator and participants of evaluation and consequently salaries of the above stated people; time for data processing is included
- Costs of hardware necessary for testing
- Costs of other special equipment, e.g. video camera
- Costs of experimental laboratory (room rent, electricity, etc).

On the other side, there are many expected *benefits* which should result from the usability evaluation:

- Number of years of the project (application)
- Number of application users
- Decreasing number of users‘ mistakes
- Increasing work efficiency resulting to time savings (total number is dependent on number of users) and consequently money savings (users work faster so they are able to finish more tasks within a given time period)
- Decreasing time necessary for users training
- Increasing users' satisfaction
- Decreasing time necessary for system maintenance and service
- Improved communication
- Improved good name of the organization

The above given list of costs and benefits indicators is still not complete. Some of indicators are easily measurable, like number of users, number of mistakes, time necessary to complete a given task, time necessary for system maintenance; but some of them are difficult to measure, like users' satisfaction or improving good name of organization.

V. Conclusion

Evaluation of software quality should provide information if software meets users' requirements and if it can support productivity of the work and decision-making process. Importance of spatial DSS is rapidly increasing so attention should be paid to them as well.

Many quality models, metrics and methodologies have been proposed to objectively evaluate software quality. A particular evaluation procedure should be precisely proposed for each particular case to respect aims of the evaluation. A set of criteria for suitable method selection was proposed by the authors.

The described case study evaluated quality of Web-based intranet GIS application of a municipal authority with a focus on functionality and usability. At first, evaluation method had to be proposed. For this purpose semi-structured questionnaire was chosen as a method of the mixed research (i.e. both quantitative and qualitative research). To target surveys precisely and shorten necessary time for filling questionnaires, three separate questionnaires were created.

All obtained results and lessons learned from the survey are described in the article. Survey pointed out importance of users training and confirmed that even regular users of Web-based GIS most often use basic visualisation functions like zooming and panning.

For the future, it is planned to propose a suitable model for cost-benefit analysis because usability evaluation can significantly influence software development costs.

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