GEOGRAPHIC INFORMATION MANAGEMENT SYSTEM FOR REVIEW AND REPORTING OF ECOLOGICAL RISKS TO THE ENVIRONMENT

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Abstract: This paper outlines the progression of the Geographic Information Management System (GIMS) project that is currently implemented in the Republic of Srpska (Bosnia and Herzegovina) for the review and reporting of ecological risks to the environment. The project has been implemented under the name REeko. The primary role of REeko is improving systems for reporting, monitoring and managing ecological risks. It is particularly concerned with the illegal disposal of waste that poses a large environmental threat in Bosnia and Herzegovina. REeko is an organizational and informational system. In the organizational sense, the project includes the public institutions: The Environmental Protection and Energy Efficiency Fund of the Republic of Srpska (the central institution of the REeko system) and the municipalities of the Republic of Srpska (the final institution involved in the REeko system). In the informational sense, REeko is developed as a centralized WEB platform that allows for a simple and efficient means of use. The general public and authorized institutions are the two predominant users of the REeko system. REeko assists the public by providing an easy means for reporting ecological risks within their local environment. It also assists authorized institutions in monitoring and managing these risks.

Key Words: GIS, GIMS, REeko, environment, ecological risk, Republic of Srpska.

Introduction

The use of information and communication technology (ICT) has an immense impact on the environment. In today's technological, economically and socially progressive world, environmental data collection, risk management, decision making and reporting would not be possible without the use of ICT. The evolution of ICT has lead to the emergence of informational systems (IS) that are customized for environmental management, referred to as Environmental management information systems (EMIS). EMIS can be defined as an "organizational technological system for the systematic collection, processing and distribution of relevant information about the environment " (El-Gayar & Fritz 2006).

In recent times a lot of attention has been focused on the use of geographic information systems (GIS) in the field of environmental management. GIS can be defined as an informational system designed for collection, distribution, processing, analysis, management and presentation of geographic information (Foote & Lynch 1995). Environmental management is in large part a local operation (Berry 1999). In addition to determining the phisical, chemical or biological properties of the phenomnon which are observed in the enviroment, it is also vital to establish the location of the described and observed occurance during the management processes. The collection, processing, analysis and distribution of spatial information regarding envirmontal developments is essential in the process of environmental management as it allows for grater managment efficency. It promotes timely and relevant decision making concerning the improvement and conservation of the enviroment. In the area of enviromental management, GIS technolgy has shown to be a powerful tool. The significance of GIS and its practical models of application in enviromental managment are described in a large number of recent reports (Brown et al. 2002, Kubásek 2013, Morita & Takagishi 2002, Tasaki et al. 2007, Kubásek & Hřebíček 2013).

Although it is not yet defined in scientific works, the use of the term Geographic Informational Management System (GIMS) has emerged in recent times.

It has arisen from basic characteristics and definitions of Management Information Systems (MIS), such as:

- MIS is an information system that improves management by providing reports in appropriate and systematic manner (Kroneke & Hatch 1994).
- MIS is a system that supports management in functional fields (Brown 2002).
- MIS is often used in place of the term System for Decision Support (Veljković 2008).
- MIS can be defined as an information system that provides information for users with similar needs. The main purpose of the Management Information Systems is to provide managers with the information they need to make decisions and solve problems. Management Information Systems are supported by corporate databases, which include data generated by transaction processing (Alcamí & Carañana 2012).

Hence, taking into account the basic properties of GIS, the term GIMS can be characterized as:

- A system that manipulates spatial information.

- A system that is improving processes of management and decision-making in areas concerned with research, use and protection of resources that have physical signs.
- The Information-Communicational set of procedures is used for the collection, storage, processing, analysis and distribution of spatial information. It shouldprovide analysts, managers and institutions accesses to relevant decision making information in a fast, understandable and consistent way. It should also provide information regarding predictions in the field of management and the use and conservation of spatial recourses.

It can be concluded that the term GIMS can be used to emphasize the role of GIS in the management and decision-making processes.

It is appropriate to apply GIMS to the environmental field. The effectiveness of monitoring and management of the environment is in a large part dependent on the availability and quality of information used in the management and decision-making process. Thus GIMS can provide efficient collection of and rapid access to relevant information.

This paper presents a review of the GIMS, which is intended for the centralized collection of information on environmental risks (illegal waste dumps, illegal wastewater discharge and natural hazard such as landslides etc.). This is done in the form of public reports and the forwarding of this information to relevant departments. The GIMS discussed in this report is has been implemented as a pilot project but it should become the official system for collecting information regarding environmental risks in the Republic of Srpska. (*the administrative-territorial organization of Bosnia and Herzegovina consists of Republic of Srpska, the Federation of Bosnia and Herzegovina and the district of Brcko*).

Bosnia and Herzegovina is confronted with a large number of environmental risks. Primarily, a large number of illegal waste dumps of various sorts (construction, industrial, organic, household waste, etc.). Preliminary research (creating a GIS database and mapping polluters along the Vrbas river- http://gis.pmfbl.org/vrbas/) found a large number of potential high-risk locations. Specifically, along the 235 km stretch of the Vrbas River, 307 high-risk locations were identified; of which 115 were illegal waste dumps and 192 were illegal waste water discharge locations. The intensity and type of waste that has been observed as well as the emergence of new 'hot-spots' indicates a significant environmental risk. This poses considerable degrading effects on the environment in the Republic of Srpska and Bosnia and Herzegovina. Addressing the identified problem is a priority. Finding a solution to this issue would result in environmental improvements as well as generate potential for the use of recycled waste as a resource.

The factors that lead to environmental risk locations in Bosnia and Herzegovina include: poor municipal collection systems and waste disposal, poor financial state of the local council in charge of waste management, a lack of control over inspectional organizations, a lack of awareness among the population about the need for proper waste disposal, a lack of recycling systems etc. These issues are in part due to the absence of a system for reviewing, reporting and monitoring environmental risks. As previously outlined, REeko is a system within the GIMS that is concerned with reviewing and

reporting ecological risks in the environment (REeko). REeko has developed from the Environmental Protection and Energy Efficiency Fund of the Republic of Srpska (EPEEF). The system was developed as a pilot project and is currently in a test phase. It is a unique system as it is fully adapted to monitor and manage environmental risks. The development of the REeko system was launched in early 2013 and implemented in early 2014 when the website was established (http://reeko.ekofondrs.org).

Method

The development of the REeko system is based on the general developmental methodology of IS. The 'Waterfall' model of the 'Life Cycle' methodology is utilized (Isaias & Issa 2015). Figure 1 displays the initial developmental steps of IS based on the 'Waterfall' model. This model provides a step-by-step analysis of IS development, from the identification of needs to the implementation of solutions.

Figure 1. Life Cycle - Waterfall model development of IS
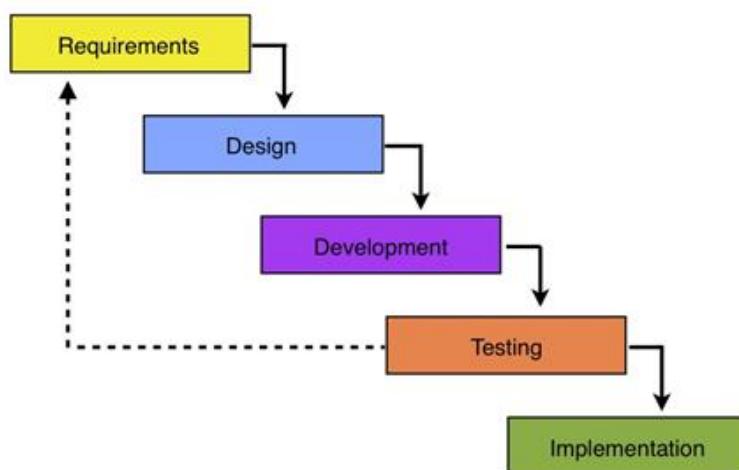
The first step of the development of the REeko system was ***problem identification*** (Fig. 1). As previously outlined in preliminary research, the illegal waste disposal and water discharge by citizens has been a major problem in Bosnia and Herzegovina. On the other hand, interviews have been conducted with representatives of relevant authority organizations involved in the environmental field (EPEEF, mayors, inspection services and municipal utilities). The interviews identified a need for establishing a more efficient system for reporting, reviewing and monitoring ecological risks to the environment. Thus it was concluded that the relevant municipal departments do not have an effective system of identifying ecological-risk areas in the environment. The problem is particularly concerning due to the vapidly escalating emergence of new ecological risk location. The interviews have resulted in an agreement to launch the development of GIMS for the review and reporting of environmental risks.

The second step (Fig. 1) involved ***designing*** the REeko GIMS by defining its structure. The users of the system were first identified. REeko has two groups of users, the public and administrative institutions. REeko provides the public with an easy method of reporting and reviewing ecological risk in the environment and offers them feedback in response to their complaints from relevant services

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(EPEEF, municipal services). REeko provides administrative services with an inventory of ecological risk locations, allowing them to monitor the dynamics of their formation. This enables a timely response to and elimination of the problem. The administrative sector is divided into two sections, the central institution (EPEEF) and the municipalities. The REeko system is primarily designed for citizens and local services in order to enable environmental improvement within their communities. Due to the large number of municipalities, it would be organizationally complex and economically unjustified to develop GIMS in them all. Therefor, EPEEF is legally responsible for environmental data collection in the Republic of Srpska. In occurrence with the reasons listed above, the decision was made to improve the development of a centralized GIMS, with EPEEF acting as the central institution and the municipality acting as the final authority in the process.

Following the identification of system users, the next step is determining the functions of the system that are necessary in order to satisfy the needs of the users. It was established that the REeko system is required to fulfill the following needs:

- Provide the public with a simple means for reporting ecological risk in the environment via the Internet and mobile applications.
- Provide the public with a simple investigation and review ,with the possibility of monitoring the status of each application, in terms of activity and the level of implementation by the relevant services.
- Enable relevant departments to efficiently analyze and processes reports via specially designed administrative tools.
- Allows relevant departments to easily locate registered areas.
- Enable reports to be collected in a centralized database.
- Due to the large number of users, the system should be based on the WEB in order to allow easy access and use.

The system structure has been designed based on the identified users and functions of the REeko system. REeko is defined as an organizational-informational system, which means that is it has an organizational and informational structure.

In an organizational sense the users of the system are; the central institution (the 'heart' of the system) that receives and forwards reports and the relevant municipal services that react to these reports and forwards them to the central system (Fig. 2). In organizational sense there is an established and precisely defined procedure that is used for processing all reports. This is done in order maintain the competence of all segments within the organizational system.

All reports that are made by the public are reviewed by administrators within the central institution (EPEEF). If a report is validated, it is then forwarded to a relevant municipality. After reports are forwarded from the central institution, they become visible on the administrative interfaces in the areas where the applications were sent. The administrators are then required to print the reports and forward them to appropriate environmental services (inspection and utility services). The services that receive the reports are required to visit the area in question, establish facts and initiate proceedings that

aimed at resolving the issue. Following this, municipal authorities return the report to the administrators in the municipality who then input the information into the REeko system.

Figure 2. The organizational structure of the REeko system
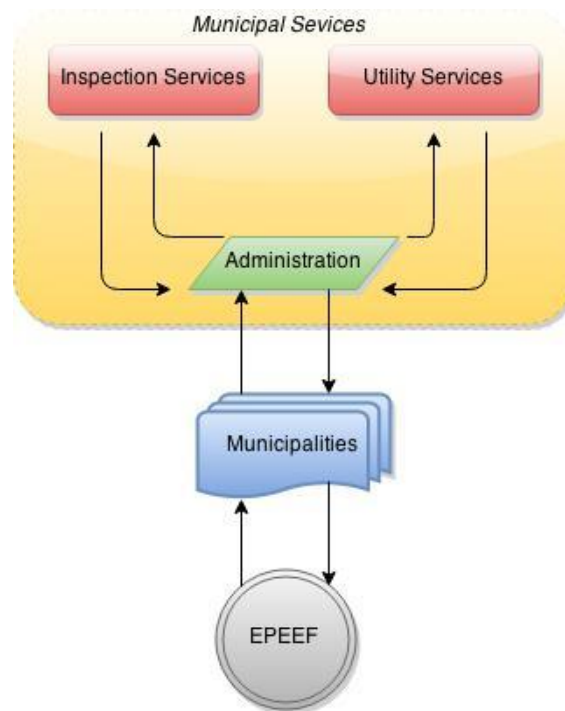
The informational structure (Fig. 3) is designed in accordance with the defined organizational structure and the necessary functions of the system. In regards to the ICT, REeko is fully developed as a web platform that also has the support of mobile devices such as native Android applications. ICTs focus on WEB and mobile application provides the public and relevant institutions with a simple and functional means of use. The WEB based structure of the system enables the development of a centralized system, which was an initial aim. The complete system has been developed on a separate server in EPEEF.

The informational structure of the REeko system has caracter 2-tier architecture (Fig. 3) that consists of: *database layer* and *application layer.*

The ***database layer*** is designed to enable the implementation of all the defined functions of the system. This layer consists of six separate entities/tables (Reports, Spatial Information, Security, Users, Administration and News), connected to a single database via the Database Management System (DBMS).

Public reports are stored in the *Reports* table. For each report, the following data is generated: Type (the type of ecological risk - waste dumps, waste water, other), Photo (Photograph of location) Description (Description of perceived risk), Date (date of report), Municipality (Municipality of the registered location), Geometry (the geographic coordinates of the registered location), Status (the status of the report – in process, verified, forwarded, completed) and Remark (notices regarding the processing of reports). Type, Photo and Description are forms that are filled out by public users. Date,

Municipality and Geometry are automatically generated. Status and Remark are forms that are filled out or altered by administrators depending on the status of the report.

Figure 3. The informational structure of the REeko system
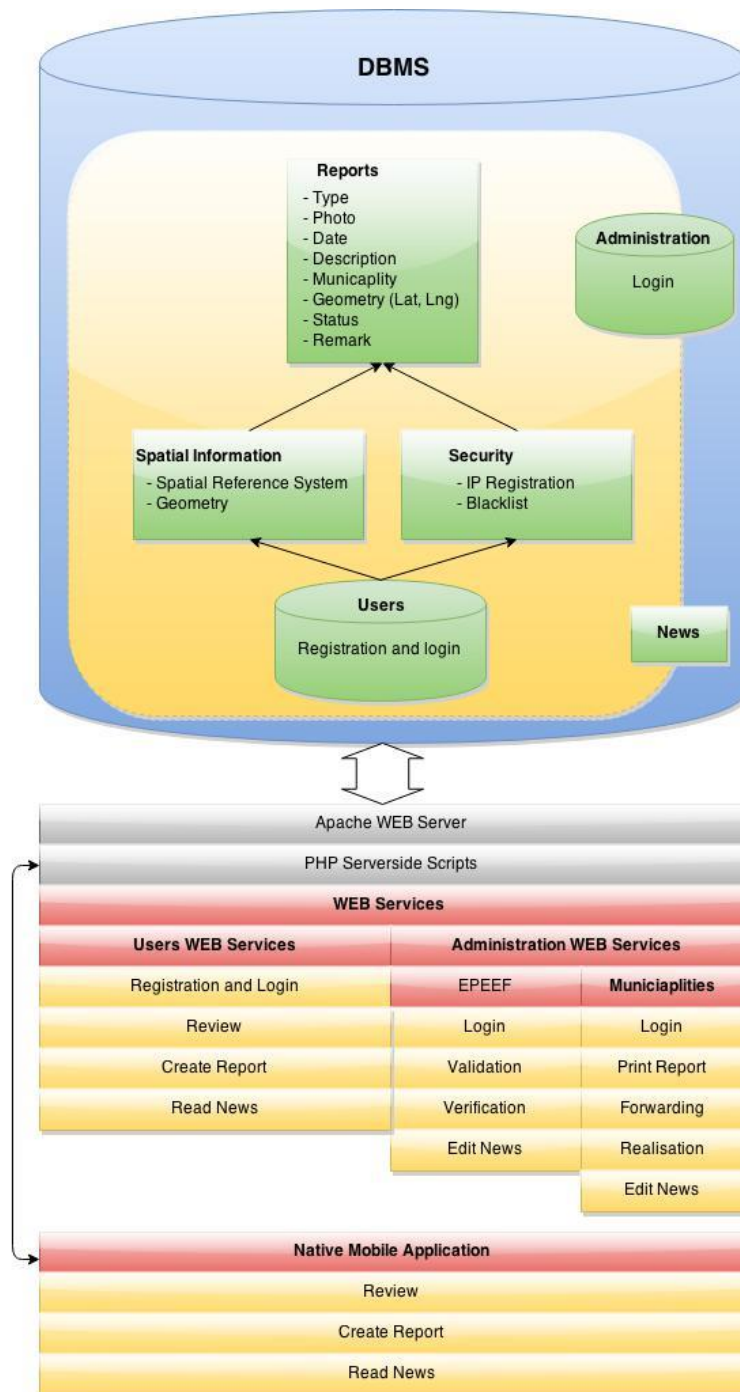
Spatial information tables contain the borders of municipalities in the REeko system, stored in the form of geometric data types (multipolygon). The function of this table is two-fold. It prevents reports from areas that are not included in the REeko system. It alsoenables the identification of reported locations and determines the municipality to which they belong.

The *application level* generates data regarding the location from which all WEB and mobile reports are sent. The application then sends this information to the Spatial Information table, which determines the municipality that corresponds with the location from which the report was sent. This is done by means of "point in polygon". If the report is received from within borders covered by the REeko system, it is then sent to the Report table, where on the basis of prior identification (belonging to a given polygon/municipality) the municipality to which the report location belongs is automatically generated.

The *Security* component of DBMS is involved in anti-SPAM protection systems and blocking unauthorized accounts from which fraudulent reports could be sent.

Users and *Administration* are separate databases where information about user reports and their authenticity are stored.

News is an entity that records news and information related to the REeko system.

The application layer consists of two parts that are dependent on the type of application: WEB services or mobile applications (Native Android Application). The user level is divided into: user service and administrator service. Administrator services can be differentiated by: Administrator services in the central institution and administrator services that are used by municipalities. Each of mentioned services are tailored to the specific needs of individual user groups.

The third step (Fig. 2) initiates the *development* of GIMS. In the developmental stage, two actions are carried out: configuring the database and writing the code for the application section of the system. The complete REeko system was developed on open-source tools as well as on the Linux distribution open-source operating system (Debian - https://www.debian.org/). The software support used for the development of DBSM is based on the MySQL underlying database (https://www.mysql.com/). The Apache system is used as the WEB server software (http://www.apache.org/). The communication service application layer and the database layer are coded in PHP programming language (http://php.net/). The application layer is developed in the following programming languages: Javascript, JQuery, CSS, HTML.

Following the implementation of the previously mentioned steps, the REeko system *testing* processes begins. Tests were conducted on all system components such as the organizational and informational systems. Since there were no significant deficiencies observed, the *implementation* and public promotion of the REeko system was initiated.

Results and discussions

An organization-information system was developed based on the described methodology. This system enables the collection, recording, storage, transfer and analysis of information. It also enables monitoring and management of ecological risks in the environment. Conceptually, REeko is based on the principles of the geographic information systems. Determining all spatial information that enters the REeko system resulted in the initiation of all software applications that are in accordance with GIS

principals. Given the purpose and functions of the system as well as its base in GIS, this developed system can be characterized as a GIMS.

The overall results that have emerged from the development of the REeko system are:

- An improved system for the collection of information on environmental risks;
- An improved system for monitoring and managing environmental risks;
- An efficient method of raising public awareness regarding the consequences that irresponsible behavior can have on the environment;
- A centralized database for ecological risks.

Specific results that have been derived from the implantation of the REeko system can be dived into the applicative nature of desktop and mobile applications.

Desktop applications

Following the launch of the REecko desktop application, five basic options are provided: review and report, analytical maps, Administration, REeko and REekoAndroid (http://reeko.ekofondrs.org/).

'Review and report' are a groups of tools available to all users of the system that serve to review and report ecological risks in the environment. In order to utilize all functions of the REeko system available to the public, it is necessary for users to register an account on the system. Notifications are sent to users upon registration. Five options are given to users following their registration: Map, All reports, My Reports, Instructions and News. The '*Map*' option allows users to review existing reports and create new ones. Right clicking on the marker (reports in the database) provides users with basic information about a particular report. The 'find location' option allows users to locate areas on the map, which is a necessary step when filling a new report. Right clicking on a location opens a report form. All required areas must ben filled out in the report. These include: a short description of the problem, the type of problem and a photograph of the location. The '*All Reports*' option provides an overview table of all reports in the REeko database. Reports can be filtered by: ID, municipality, status and type. Filtering criteria can also be combined. The 'show on map' option displays the map location of the selected report. The '*My Reports*' option provides an overview of the logged on users own reports and allows users to monitor their status and progress. The '*Instructions*' option provides basic instruction on how to use the REeko system. The '*News*' option provides recent news regarding the Reeko system.

The '*Analitical map*' is a WEB-GIS application that provides a more advanced review and analysis of information in the REeko system. By combining established layers (roads, land use, relief, satellite imagery, reported location, roads and streets, waterways, location border, municipal borders, toponyms) maps can be established that suit the users needs. This can be used to determine the basic spatial elements near the identified site and analyze the effects that individual locations have on the environment. Under the option 'Analytical map' several analytical tools are developed. The most important of these tools are: a multi-functional tool used for searching for and creating inquiries and

also the tools used for downloading selected reports. The multi-functional tool allows users to make several various inquiries (using SQL operator). This enables the data analyses of reports to be combined with other layers of data in the application. Inquiry results can be downloaded to a desktop computer in a variety of formats (Excel, Shapefile etc.). The other tools in the toolbar are common and suggestively indicate their purpose. The tools listed under the '*Administration*' group are exclusively intended for the use of administrators in the relevant departments of the REeko system. Selecting the '*Administration*' option opens the option to select the administrator type (EPEFF, municipality). Logging into the EPEEF administrator opens an application that contains six options: New report, Verified, Forwarded, Completed, All reports, News. The 'New reports' option displays all new reports that are being processed. All reports under the 'New reports' option must be reviewed by a person in charge of the EPEEF then verified and forwarded to the relevant municipality. The 'Verified', 'Forwarded' and 'Completed' options contain all reports that have been given those corresponding statuses. The 'All reports' option contains all reports in every status category within the REeko system. These reports can be located by their set criteria. The 'News'options provides an overview of current news and editing options (erasing, write new). EPEEF administrators have the ability to edit any report within any option. Logging into the municipal administrator interface opens an application with five options that include: New reports, Forwarded, Completed, All reports and News. The 'New reports' option contains new reports that have a 'verified' status. This option contains all reports that have been verified and forwarded by an EPEEF administrator. All reports within this option must be reviewed by a municipal administrator, printed and forwarded to the relevant municipal services. The options 'Forwarded' and 'Completed' contain all reports that have been given these statuses under municipal jurisdiction. The 'All reports' option contains all reports in the REekosystem; reports of all statuses given under municipal jurisdiction and that can be located by their set criteria. The 'News' option provides an overview of existing news and allows editing (erasing, writing new).

The **'REeko'** option contains the central information regarding the REeko system. Alternatively the '**REeko Android'** option contains central information concerning android applications and download links.

REeko Mobile

REeko mobile is a native android application (https://play.google.com/store/apps/details?id=org.ekofondrs.reeko) that is a part of the REeko informational system. It has been developed for the Android 4+ platform through the use of Java ADT. It has been optimized for a 4+ inch diagonal screen but due to its customizable user interface, the application can run seamlessly on smaller diagonals. The application assists the public to submit reports ands also aids inspectional services to locate identified areas. Entering the report location ID into the search system of the application simplifies area identification by displaying the search location as well as the current location of the user.

Upon starting the application, the user is provided with a map of their current location. The color of the pins signifies the type of ecological risk and the label on the pin identifies the status of the risk. User

interactions and applications are found under 'options' at the top of the window and in side sliding menu. Touching the pin on the map provides users with a detailed overview of the situation of that location. While the map is opened location services are activated. These services are deactivated when the user exits the screens that require these services. This is a means of energy conservation. The application is configured to seek out all information that is needed in order to precisely determine user locations (3G networks, WiFi signals and GPS locations).

In addition to viewing the ecological risks on the map, it is also possible to review the list of reports. Information that is displayed is automatically updated. Every row on the list represents a report with all relevant data (date of report, Individual Identification number, locality, status, type, description and a photograph).

Users can add new reports at any time as long as there location services are activated. The application notifies the users if their location service is turned off. The processes of adding a new report involves tapping the corresponding button on the screen, which then opens the form that is required to be filled out. The form requires users to first identify the type of ecological risk on the reported location. Selecting the type of environmental risk also changes the color of the send button. Users are then required to enter a short text description of the risk (up to 255 characters) and provide a photograph of the location. Reports are sent via 3G or WiFi networks. If Internet connections are not available the transfers will be made as soon as possible in the order in which they were sent. Location data is directly linked to the image and the report. Therefor it is not possible to submit a report on one location and provide a photograph of another. After a report has been sent, photos can not be accessed, added to or replaced. Each image has a digital signature. Information on the location, date, time and user as well as the electronic signature of images is stored along with the senders 'Device ID'. The mobile application offers the ability to search for reports based on different criteria such as: municipality, ID, status and type. In addition to these functions, the mobile application also offers options such as: my reports, review of news and general information about the application and the REeko system.

Conclusions

There are a large number of evident ecological risks across the territory of Bosnia and Herzegovina. Illegal waste dumps and water discharges are of particular concern. The problems are to some extent due to insufficient development and capacity of institutions, a lack of organizational efficiency of particular initiations responsible for the environment and a generally chronic lack of funds and investments into the environment. This problem is further accentuated by the lack of a centralized database as well as the lack of an efficient system for reporting, reviewing and monitoring environmental risks.

Based on the identified problems, a geographic information management system (GIMS) for reporting and reviewing environmental risks was created. This system called REeko was created within the Environmental Protection and Energy Efficiency Fund of the Republic of Srpska. The system aimed to create a centralized data collection system on a nation level and simultaneously increase the efficiency

of response of utility services at a local level. This system is of particular value as it allows for the direct communication between the public and relevant institutions and services and thus speeds up the reporting and responding processes. The practical value of the REeko system is evident in the simple method of reviewing, reporting and monitoring of ecological risks and thus creating the prerequisites for improving the overall state of the environment. Whether citizens submit reports due to feelings of personal threat or an increased awareness of environmental risks, they automatically become contributors to the system. Feelings of satisfaction and acceptance encourage members of the public to use the system. This can further broaden environmental awareness within the social groups of users.

The implementation of the GIMS REeko will be of great use to institutions and environmental services as it allows for the simple processing and analysis of completed reports. It will be of particular use to local inspectors and utility services. In addition to the direct beneficiaries of the REeko system, researches can also benefit by using the information provided regarding environmental risks in order to produce scientific papers, studies and analysis. The results of such studies can directly or indirectly influence the environmental field.

The introduction of the GIMS Reko system in institutions at local and higher levels may initiate incentives for the development of GIMS in other areas (eg. the management of communal infrastructure).

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