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Network-based system for acoustic mapping of urban areas

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Abstract

The paper presents both a general idea and basic assumptions of a research project, which was started a year ago at the Technical University of Silesia, Poland, and primarily was focused on the Region of Upper Silesia. At present, the project is prepared to cover other regions of the country.

In particular, the research area of this project comprises problems of preparing and utilizing the acoustic maps of towns that ought to be prepared in accordance with the EC directive com468 (2000). The main two assumptions of the project are as follows: 1) the maps will be prepared by means of advanced computer-based tools of the GIS and GPS classes, 2) both procedures of developing and utilizing the acoustic maps will be executed in the form of group-work using the PIONIER (Polish Optical Internet) NREN and Intranet tools for online collaboration and audiovisual communication with utilization of resources available at network and HPC centres across the country. It has been assumed that the system –primarily being developed for the needs of local scale mapping – thanks to the network approach will be adaptable also for larger (regional) scale enterprises.

The paper discusses briefly the current state of research in the mentioned field in Poland. The second part of the paper presents the timetable of further activities with a specification of expected results. Apart from the “technical” problems of acoustic mapping of urban areas, the paper also deals with some “non-technical” aspects in this field of activities. The final part of the paper introduces some perspectives of disseminating the results of the reported research within the process of European enlargement.

1. INTRODUCTION

The contemporary view of local and regional strategies and policies comprises – in a significantly increasing range – problems of managing the environment. These problems are clearly reflected in the activities of authorities, obliged both by law and by the pressure of the inhabitants' opinion to solve problems of a more and more complex nature.

In this paper the authors try to illustrate the statement formulated above on the example of a very specific pollution of the environment by acoustic noise. The problem of the exposition of humans to outdoor noise has become one of the most significant problems of our civilization. In compliance with WHO's information ("Guidelines for Community Noise", WHO, London, United Kingdom, April 1999) in 1999 about 40% of the population of the European Union was exposed to noise caused by transportation (mainly: road traffic) with an equivalent sound pressure level exceeding 55 dB(A) at daytime. Almost 20% of the people living in urban areas are exposed to levels exceeding 65 dB(A).

The same situation takes place in other countries. According to the results of investigations carried out by Building Research Institute in the 90's (Report: *Protection of environment before noise and vibrations. Current state and directions of activities*. By: J. Sadowski and others. Building Research Institute Warsaw 1992), more than 8 million inhabitants in Poland has been estimated to live in areas of "over normative" road-traffic noise (below 65 dB(A)) and 15 million in zones, where acoustic conditions are considered to be troublesome (between 55 dB(A) and 65 dB(A)).

Problems of outdoor noise may also be seen in law regulations. Let's mention here the international regulations and standards, like EC directive 2000/14/EC or COM 486 (2000), as well as national acts, like the new Polish "Law of Environmental Protection" (27.04.2001)

The number of exposed citizens in medium and large towns is constantly increasing. Investigations carried out in selected Polish cities have proved that the main source of exposure and most often source of hazard is first of all noise caused by road and railway and in several cities also by aircraft transport. Many research reports (for instance: *Report about state of investigations and acquired possessions in range of protection of environment against noise in Poland*, By: J. Sadowski and others, Building Research

Institute, Warsaw 1976; Report: *Noise and vibrations threat in Poland*. The Acoustics Committee of the Polish Academy of Sciences. By: Z. Engel and others. Warsaw 1984; Report: *State of environment in Poland (Chapter 12. Noise and vibrations)*, By: J. Sadowski for the State Inspectorate for Environmental Protection and the UNEP/GRID Centre Warsaw 1997) characterize the current state of the acoustic climate in selected parts of the country and give detailed analyse of the situation and main conclusions relating to necessary activities which should be undertaken in order to protect the inhabitants against the growing exposure to noise. Complex acoustic maps of cities belong to the important and effective tools for such activities.

Acoustic maps worked out in recent years, deliver information about the actual state of the acoustic climate in the investigated areas. The results are most interesting from the scientific point of view, but their usability for the needs of effective acoustic environment management is not satisfying for potential users: the local authorities..

On the one hand, the doubts concern the different degree of particularity and range of data, gained and processed in the variety of systems. On the other hand, the necessity is reported of elaborating some unified procedure of exploiting the acoustic map data by the personnel of local administration: people who are not acousticians at all.

2. “PIONIER-A-MAP” PROJECT: MAIN OBJECTIVES

Considering the aforesaid circumstances, at the Chair of Fundamentals of Technical Systems, Silesian Technical University in Zabrze, Poland, the idea of the realisation of a research project was taken up, focused on problems of preparing and exploiting acoustic maps of towns in accordance with the national and EC directives. The initial stage of research work was started two years ago. So far, an application of the research project “A-Map” has been forwarded to the Polish State Committee for Scientific Research suggesting an enterprise financed within the frame of the program PIONIER.

The main assumptions of the proposed project are:

1. A unique methodology of preparing acoustic maps of cities should be developed making use of the GIS technology as a modern tool, which would make it possible to join digital cartographic maps of grounds with databases, containing complete data for predicting, evaluating and estimating the acoustic climate on

the given ground. The use of these techniques will permit to take into account the acoustic hazards in spatial planning as well as the current environmental management in compliance with of the standards of PN-ISO 14000 series.

2. Aiming at a reduction of the costs of putting into practice this elaborated methodology, the choice of GIS platform will depend on preliminary questionnaire recognition of the software used at present in the respective local and regional units. The proper selection of the software platform ought to assure an effective transfer of data to the most often used systems in the country.
3. Project work will be focused on two autonomous layers:
 - **professional – utilitarian**, preparing a standardised counting, measuring and informatics procedure so that it might be applied by management of the cities,
 - **educational**, preparing qualified personnel to put into practice, exploitation and further development (including actualisation) of acoustic maps, and spreading information by the Internet.
4. Variety as well as the range of necessary research work requires the participation of several specialized investigative teams and institutions. Because in polish conditions the teams, potentially able to participate in the project, are located in different parts of the country (and also abroad), the cooperation has to be based on an effective and safe system of exchanging data. A warranted access to created as well as existing databases is needed both to read and actualise data. Such a geographical extensive undertaking makes it impossible to control the content of databases centrally. Therefore a natural solution of this problem appears to be the mechanisms of group work. In order to realise effectively all the tasks contained in the application of the project schedule both at the stage of working out the conception and assembling data the voice communication system is assumed to be used, as well as video conferences.

In order to realise this project, the consortium, consisting following four independent units, was formed:

- Technical University of Silesia, Faculty of Organization and Management (Zabrze/Poland)
- Wrocław University of Technology, Institute of Telecommunication and Acoustics (Wrocław/Poland)

- Academy of Mining and Metallurgy, Chair of Mechanics and Vibroacoustics (Kraków/Poland)
- Central Institute of Mining, Department of Technical Acoustics, Laser Technique and Radiometry (Katowice/Poland)

The experience and achievement of the consortium participants in the presented research area and also their formal relations with leading agencies of EU countries have made it possible from the very beginning of the realisation of this project to synchronise the research work, both by gathering information and by delivering own decisions and proposal. Basing on existing agreements and contracts of institutions participating in the consortium, and also the membership of the involved persons in specialised international organisations (Federation of Acoustic Societies of Europe - FASE, International Congress on Acoustics - ICA and others)

3. BASIC PROBLEMS CONCERNING THE CREATION AND EXPLOATATION OF ACOUSTIC MAPS

As a result of many discussions with future users of acoustic maps of towns it has been assumed that such maps should be treated as an integral part of a general GIS-based system of spatial planning. Such an approach makes it possible to utilise in the primary phase of the reported project the most “labour-consuming” element of the system, i.e. the preparation of digital maps of the area. In the phase of preparatory research work it was stated that for the needs of environment management with respect to the acoustic influence for large towns (with more than 100 thousand inhabitants) maps with a scale of 1:10 000 are the most useful solution. In the case of towns with more than 500 thousand inhabitants this factor is 1:50 000 or 1:100 000, respectively.

In Poland work, focussed on implementing GIS systems for the needs of spatial planning and management, concentrates on the preparation of detailed cadastral maps with scales of 1:50 000 and 1:100 000. Special attention is paid to marking in these maps the borders of building sites as well as allotments. The mapping of the communal infrastructure is of great importance, too.

If the map base is founded on a detailed raster map, which is next processed by means of vectorisation, there is no problem to get a map with a bigger scale. But in

many practical cases cadastral maps are “hand-made” on geodetic map graticules with a very limited presentation of those objects which essentially affect the form and distribution of the acoustic fields. Thus, the usability of cadastral maps for the mentioned purpose is very limited or even none.

In such a case it is necessary to undertake an uphill task of preparing autonomous map bases with the required scale and – after vectorisation – to adjust it with the cadastral map. The adjustment of prepared maps is very complicated and, in many cases, the final effect is not quite satisfying. Commercially available maps of larger Polish towns are also difficult to be harmonized with the cadastral maps. Therefore it is not easy to obtain a layer of the general GIS which not only adjusts other layers but also the real location of various objects in the represented area.

The practice of preparing acoustic maps allows to distinguish three main types of such maps (see **Fig.1.**):

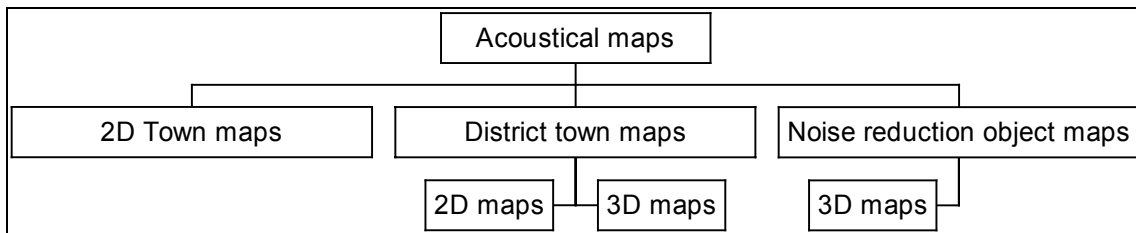


Fig. 1. Typology of acoustic maps

- Maps of whole towns, prepared first of all for the purpose of presenting the distribution of acoustic fields around the main roads and communication lines. There are mainly flat maps (Kompała J. *Mapa akustyczna gminy Bieruń*, Proceedings of XXIV Winter Acoustic School Ustroń/Poland 1996 (in Polish)), with the scales of 1:50 000 or 1:100 000. The values of acoustic parameters on these maps can be notified by means of a colour code. The map can contain a number of layers that represent successively distinguished objects, significantly affecting the acoustic climate of the town. For instance, one of the layers can represent noisy industrial plants, another one – communicational junctions, cross-roads etc. Modern GIS software makes it also possible to create transverse sections of transportation lines which enables us to visualise the range of the influence of noise.

- Maps of quarters or parts of towns with smaller scales (1:10 000, 1:5000 or even 1:1000). Such maps can contain many details, characteristic for the analysed area. The choice of these details can be accomplished by means of suitable links to other layers of the whole GIS system (see **Fig.2**)

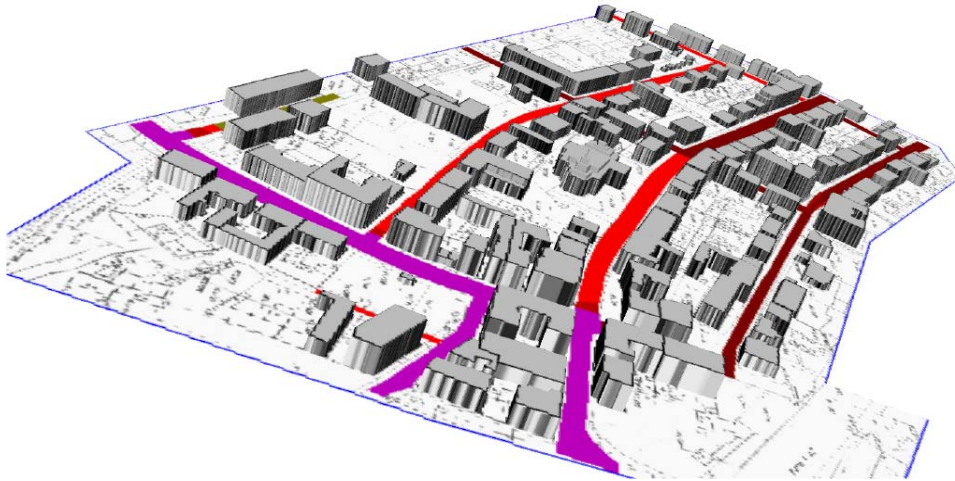


Fig. 2. Example of a 3D town district map

In recent years the procedures of the valuation of the parameters of acoustic climate of towns consider the links with demographic data, first of all the density of population in the represented area and the extent of the exposed population (Makarewicz R., *Mapa akustyczna miasta*, Proceedings of XXIX Winter Acoustic School, Wisła/Poland 2001 (in Polish); Maurin M., *Community noise impact indicators: a framework and examples*, Journal of Sound and Vibration, 79, 1991 V).

These values can be considered by means of links with digital data in a data-base or by a direct estimation of the elevation surfaces of buildings, close to the sources of noise. In the second case, 3D type maps can be utilised. The majority of modern GIS tools enables the users to create such maps.

- Maps of the object of “acoustic protection”, like acoustic screens, protecting green belts etc. The 3D technique of presentation makes it possible to present the spatial localisation of such objects in relation to the protected areas. It is also possible to add to the map a presentation of the distribution of acoustic fields, identified by

means of field measurements or modelling calculations. An example of a map of this type is shown in **Fig.3**.

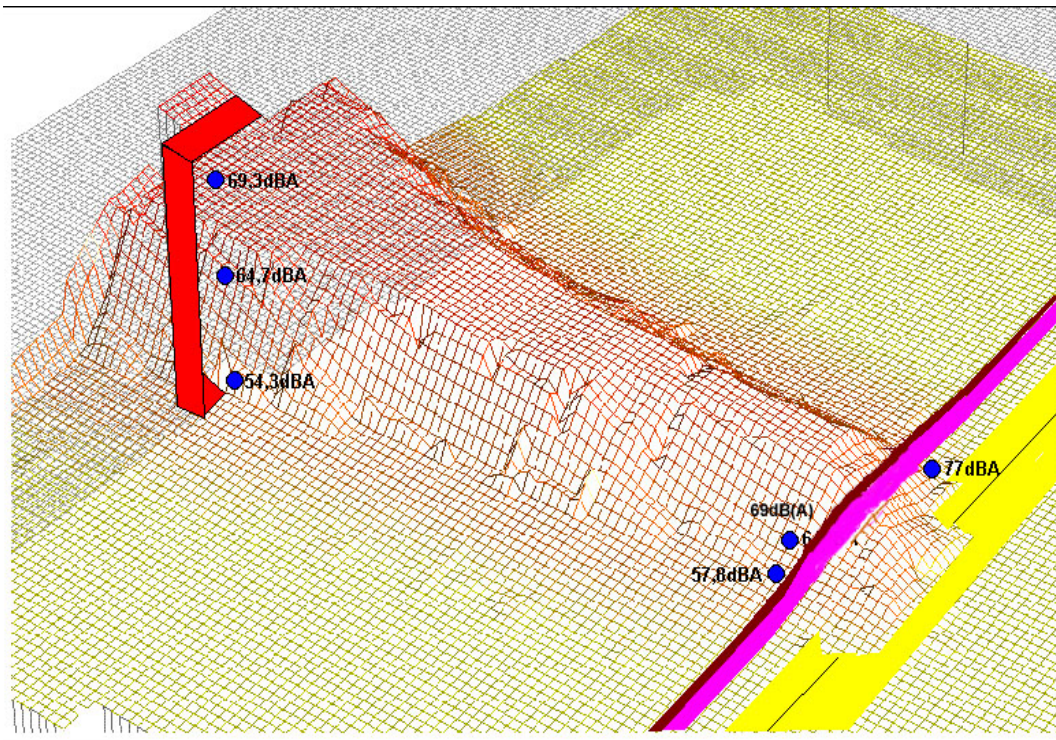


Fig. 3. Example of a 3D map of an acoustic field including road screen

The expected implementation of the conditions described by the EC COM468 directive makes it urgent to “polish up” the technology of creating acoustic maps, which would make it possible to adjust these maps with general systems of environment management in compliance with the standards of ISO 14000 series (Rabiega M, Rudno - Rudzińska B., Jaroch A., *Polityka hałasowa Unii Europejskiej*, Proceedings of XXIX Winter Acoustic School Wisła/Poland 2001 (in Polish)).

Our own experience has shown that acoustic maps, prepared by means of very advanced and specialised calculation software, based on most precise physical models of acoustic propagation, are not very popular because of their non-compatibility with recently developed and practically applied general GIS systems.

4. NETWORK-BASED ACTIVITIES: TECHNIQUES AND TOOLS

Both the procedures of developing and utilising the acoustic maps will be executed in the form of group-work using the PIONIER (Polish Optical Internet) NREN and Intranet tools for online collaboration and audiovisual communication utilising resources available in the network and HPC centres across the country.

We deal with three areas here. First is the challenge of introducing collected data into the system. In the offline mode devices will gather data onto their local storage and upload measurements into the database after connecting them to the network. Other devices working in the online mode will use leased lines, in case of a permanent monitoring station, to connect to the NREN node or wireless network, WiFi or GSM/UMTS based, to communicate with the database system across remote access systems provided by the NREN.

The second area is the coordination of groups working on various aspects of the project. There is no doubt the groups will consist of people from different institutions across Poland which will require frequent and efficient communication. On many occasions e-mail and standard telephone have proved to be not as effective as face-to-face meetings, as both solutions provide no interactivity and real document collaboration at the same time, which is crucial to achieve effectiveness. In a multiple location environment document distribution becomes a challenge itself, provided we want the information to be traceable, accessible, secure and, most of all, up to date.

To solve this dilemma a group-work environment, including document repository as well as voice and video conferencing (if and where possible), will be used. As work on a nation-wide groupware system is not finished yet, commercially available tools will be used throughout the first phase of the project.

Finally, the central part of the system is a database of collected data and maps after processing. The system has to be hosted in a reliable environment (power, connectivity, storage) and maintained properly. To fulfil this requirement the central part of the database will be hosted in HPC centres where both the necessary infrastructure and trained people are available at the moment.

5. DESCRIPTION OF INVESTIGATIVE AND DEVELOPMENT TASKS IN THE “A-MAP” PROJECT

The schedule of the above-mentioned “Pionier-A-Map” project is planned to contain the following main tasks:

1. Elaboration of a questionnaire for identification of the implementation level of GIS technology in cities with more than 100 000 inhabitants

One of the superior aims of the presented project is to elaborate suitable computer tools, permitting the creation of digital acoustic maps. The accepted basic assumption – to use for this purpose the GIS technology - is to take into consideration a wide range of possibilities to disseminate GIS, especially in local government units. For this reason the necessity as well as possibility is therefore assumed to carry on questionnaire investigations concerning already existing applications of GIS in selected cities. The recognition obtained in this way will be the base for a rational choice of the particular GIS software, which will be used in this project. Concerning this choice both the level of dissemination of GIS software and possibility of automatic reading with acoustic map files will be deciding. As stated above, acoustic maps will be considered as one of layers for environmental managements in GIS system.

2. The choice and implementing of GIS software by consortium participants

On this stage an individual implementation of selected software packages is foreseen at the seats of consortium members. It is assumed that, at first, existing and obtainable digital maps of selected town will be utilized. Efforts will be undertaken to safeguard the assurance of convertibility and communication with the most frequent practical GIS software in this country. It is advisable to take into consideration the possibility of adapting the presently applied software in suitable institutions as well as the susceptibility of the transfer of data among GIS systems. At this stage of the project, as well as at the previous one, a large-scale co-operation with the local and regional administration is of great importance.

3. Elaboration of the methodology of gathering and processing data needed for the creating of noise maps

In accordance with Polish laws and suitable to EU regulations the indicators for noise assessment will be fixed, whose distribution in city's area will be the content of noise maps. It has been assumed that for this purpose the data of both simulating calculations and measurements can be obtained. The calculation and measurement procedures will be defined for the basic sources of environmental noise, i.e. road traffic, railways, air transport, industry.

The resolution of noise maps will differ both in their precision level and kind of source data needed for their preparation. These factors will be defined individually for every considered case. The resolution of maps ought to be adapted to basic map applications: spatial planning, local activity planning and for spreading and accessing information about the quality or condition of the environment.

The GIS database, supporting the setting up of noise maps, should make it possible to collect and store information, particularly measurements from environmental monitoring. For the realisation of calculation procedures, the professional software for noise simulations will be used with regard to input and output data. For this purpose it is considered to apply packages such as: MITHRA, IMMI, CADNA, SoundPlan.

4. Planning and programming

First of all, the types and sizes of datasets, processed within the project, have to be fixed. Two systems data of processing are foreseen:

- **inside the GIS** – source data, which are included in GIS (digital maps, geocoding and mapping data),
- **outside the GIS** – data transferred to GIS (measurement and calculated data)

A hybrid system ought to be developed as a connection between GIS and outside software, with these two ways of data transfer.

5. Application of a global satellite positioning system (GPS)

The large number of measuring points indispensable for the preparation of acoustic maps requires a powerful tool for the needs of positioning these points as well as characteristics for acoustic climate objects. Global positioning systems (GPS) seem to be a proper solution for this purpose. For the realisation of this aim it is foreseen to

apply a method of high precision positioning by means of two GPS's (Differential GPS) as a particular solution.

6. Development of Noise Monitoring Stations

For the needs of a flexible acquisition and effective transmission of noise data at least 10 sets of noise monitoring stations should be set up. The stations ought to be prepared according to the results of the recently carried out research project (KBN 7 TO7B03419), in which the construction of local noise traffic stations was worked out. The stations used in those projects will be manufactured according to this construction and passed on to the groups verifying the measure methods in selected cities.

7. Practical verification and corrective investigations of the GIS software

The task embraces the realisation of exemplary acoustic maps in selected and representative districts of cities. Both calculation procedures and physical models in the software for noise simulation mentioned above and also the system of data transfer to GIS software will be verified.

8. Elaboration of procedures for the implementation of the technology of acoustic mapping

The task embraces the preparation of essential elements for the implementation of project results in local government units. A didactic program of instruction courses concerning passive and active methods of passing over the knowledge will be provided.

With regard to the recognition and analysis of instruction programs relating to a higher education system, a standard didactic methodology of preparing acoustic maps will be prepared. Special attention will be paid to the preparation of programs for postgraduate studies in the field of environmental noise management.

9. Short-term training program for operators of local systems

The course programs, developed as shown in the previous task, will be applied for courses to be carried on in selected cities. Two kinds of courses are planned to be organised:

- for the personnel of local administration
- for the GIS operator management

The program of the first course should cover the area of spreading knowledge about the possibilities of using an elaborated noise mapping system in the process of spatial planning and environmental management.

Special attention will be paid to the training of operators and supervisors of the GIS system and to procedures of collecting and preparing information about the city in the second course. Requirements for operators in creating and utilizing noise mapping will be defined.

10. Placing of informatic results of the project in computing centres of a high calculation power

General results of researches will create the database system, containing an enormous amount of information. Thus it becomes inevitable to warrant a high calculation power and an efficient system of data storage.

Both these requirements lead us to the need of using an Advanced Computational Infrastructure that provides also security and authorization of access. The access to the database will be possible within a wideband network, which comes into being thanks to the program PIONIER. Putting into practice such a network, a suitable quality for all users, including local, regional and central government administration, will be guaranteed.

11. Elaboration of instruction for the creation and exploitation of the acoustic mapping of urban areas as an element of the general system of environmental management

The instructions will contain a compendium of knowledge about the preparation and utilisation of acoustic maps. In particular the instruction will provide information about:

- Legal bases and regulations connected with environmental noise management;
- Requirements and methodology for preparing acoustic maps of different classes of resolution
- Requirements and standards for preparing the input data and visualization of results
- Rules for accumulating and processing data in the GIS system

Instruction must be adjusted to procedures applied in local government units (communal and district authorities) regarding ISO 9000 and ISO 14000 standards.

The performance of the tasks listed above will be managed by means of the “milestone” methodology. Some of them are performed or currently realised.

6. CURRENT PERFORMANCE AND FIRST RESULTS

The first stage of realization of the project consisted in the recognition of applying the level of GIS software in selected local government units as a basic component of the noise mapping system in the processes of spatial planning and environmental management.

For the realisation of this task a unified questionnaire had been prepared, which was delivered to the city offices in the 40 largest cities in Poland (Report of the own research: *Comparative analysis of GIS software in range of identification of interaction of environment*. BW 502/ROZ5/2001. Zabrze 2001).

The questionnaire contained the major issues about:

- The kind of GIS systems used by local government units
- aims and range of implementation of GIS
- ways of collecting information used to create and develop the databases
- degree of utilization of GIS software in communication with the society
- basic limitation factors for applying or enlarging the GIS software,

The response rate in the reported questionnaire investigation was very satisfying. The obtained results of such a questionnaire investigation are the starting point for the comparative analysis in the range of utilising the GIS systems to solve tasks from the area of informatic supporting of environmental management.

The main areas of implementation of GIS software in the investigated cities are shown in the diagram below (**Fig.4**):

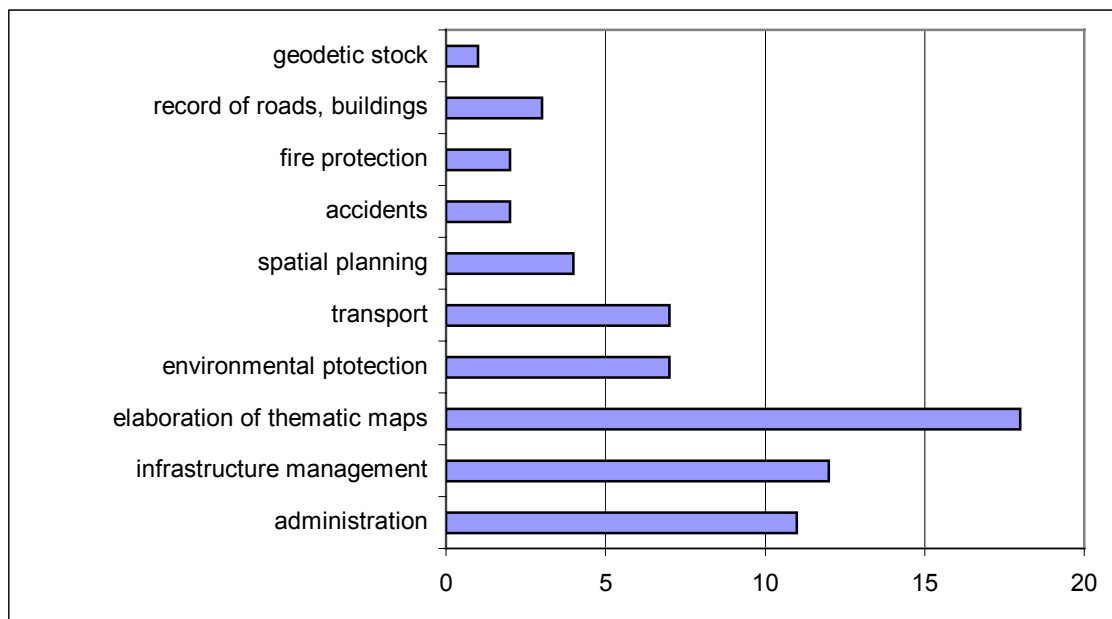


Fig.4. Identification of implementation areas of GIS software in the local administration in Poland

The questionnaire research has shown that the level of implementation of the GIS system in local units is high (in enquired city offices - 91%), but its possibilities are not fully utilised. The reasons of such a small utilisation are:

- the lack of a properly educated staff and specialised computer units to work with GIS software,
- the high costs of software and time-consuming procedures of developing of database and thematic maps.

Recapitulating, the results of preliminary researches let us to notice that the state of utilising the GIS technique in supporting the environmental management in Poland is still poor. First of all, it lacks good skilled staff as well as specialised departments dealing with the instruction of employee. The application of the GIS technology in various domains of the activities of enquired offices is still in the sphere of planning. In particular it is clearly visible in the task relating to current analysis of the state of the environment, environmental protection and management and the identification and localisation of environmental hazards.

7. CONCLUSIONS

In the opinion of the authors, the introduced project ought to result in an efficient and effective system of developing and utilizing acoustic maps. This should be obtained thanks to combining reasonably very advanced and highly specialized informatic technologies (acoustic modelling and simulations, GIS) with suitable measurement tools and the network approach. Just the application of this approach offers effective methods of preparing as well as implementing the system, processing large sets of data, educating personnel and monitoring the system functions. In particular, such a network solution makes it possible to use the knowledge concentrated in few specialised scientific institutions and the informatic potential of few computer centres in many local and regional institutions. Special attention deserves the fact that the worked out system is assumed to be an integral part of a superior system of environmental management and will be a base for decisions made by local authorities, not necessarily specialists in the acoustics domain.

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