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ELECTRONIC SCIENCE: CURRENT STATUS, PROBLEMS AND PERSPECTIVES

The article analyses topical problems of an e-science project carried out in the Republic of Azerbaijan. In the context of the information society, the essence of e-science, its goals and objectives are clarified. In addition, the international experience of e-science and the accompanying scientific-theoretical and practical problems are analysed. The conceptual problems of e-science are considered and trends for Azerbaijan are presented.

Keywords: *information society, e-science, AzScienceNet, Internet services, cloud technologies.*

1. Introduction

The development of an information society in the Republic of Azerbaijan is considered as a priority, and its legal-normative basis, coverage and the problems it solves are expanding and developing. The general concept of the information society was adopted at the World Summit on Information Society (WSIS) held in 2003 (Geneva) and 2005 (Tunisia), where its main principles and goals were specified. The use of information-communication technologies (ICT) for improvement of people's living standards and reduction of digital divide was adopted as the main target of development. The application and development of ICT in different fields of activity in the country during the past decade have become an integral part of socioeconomic growth and sustainable development, and a means of increasing transparency and accountability.

The C7 activity of the WSIS Action Plan applies ICT in all spheres of life, covering the seven fields of e-government, e-business, e-education, e-health, e-environment, e-agriculture and e-science. The principles proposed in C7 and the state programs implemented in the formation of an information society in the Republic of Azerbaijan include specific duties assigned to the appropriate entities of the Azerbaijan National Academy of Science (ANAS). Information society ideas are being successfully implemented in science, education, healthcare and other fields. The application of information technologies in scientific activity and scientific governance has been executed within the framework of the e-science project as one of the prioritised reforms of ANAS [1]. The aim of the project is to support the joint activity of scientific enterprises, organisations, staff and individuals active in research that have information-communication infrastructure and access to information and computing resources via a high-speed Internet network in virtual space. The aim of this article is to investigate the problems related to an e-science project implemented in the Republic of Azerbaijan.

2. Emergence and development stages of e-science

There are different international approaches, standards and state programs regarding e-science. Multiple projects are called e-science in the US, the UK, Germany, Japan, India, Australia, the CIS region, and other countries, and the research continues intensively. The projects that implement ICT in different fields of scientific research can be divided into three groups:

- Complex automation of scientific research activities based on modern ICT (management systems of projects, grant, publications, etc.), which is called Current Research Information Systems (CRIS)in an international scientific environment;
- Establishment of a solid online scientific infrastructure for research that is achieved through the formation of an online research environment integrating CRIS with different scientific enterprises;

The socioeconomic benefits from technical innovation data for scientists and scientific organisations (this is interpreted as a social development of e-science).

The term e-science was first introduced by John Taylor, the general director of academic boards of the United Kingdom in 1999, and includes new methods for conducting collective experimental research including computer modelling and the organisation of virtual experimental environments [2]. According to Malcolm Atkinson, the goal of e-science is to create better research opportunities on all subjects by supporting the development of scientific collaboration with rich information resources obtained and analysed as a result of leading-edge distributed computations [3].

The research indicates that the history of e-science development is closely related to the emergence of network technologies. As an example, the ARPANET project of the Perspective Research Projects Agency in the United States in the middle of the twentieth century had the goal of interconnecting the research enterprises [4]. ARPANET is the prototype of the Internet and TCP/IP, which is the current main protocol of data transmission in Internet The Joint Academic Network (JANET), the Council for European Nuclear Research (CERN), the Gigabit European Advanced Network Technology Association (GEANT) and the Central and Eastern European Networking Association (CEENet) have greatly contributed to the development of e-science.

The United Nations Educational, Scientific and Cultural Organisation (UNESCO),UNDP (United Nations Development Program), World Intellectual Property Organisation (WIPO), the International Council of Scientific Unions (ICSU), International Scientific Technical Centre (ISTC), International Centre for Scientific and Technical Information (ICSTI), the Committee on Data for Science and Technology (CODATA) and other international organisations have played a significant role in the development of e-science and constantly deal with solving problems in this field [5]. Those organisations implement relevant projects and programs, and organise international conferences, forums and symposiums. UNESCO monitors the solution of problems considered in WSIS Action Plan with the parties of interest and handles forums and tenders. Since 2006, nine high-level meetings supporting e-science for the WSIS Action Plan C7 have been organised [6]. Current projects are discussed and emerging problems are scheduled for the next year within the framework of those meetings. At the ninth WSIS+10 Top-level Event held on June 10-13, 2014, at the Geneva headquarters of the International Telecommunication Union (ITU),the achievements during the past 10 years were summarised and suggestions were made for determining goals for the period after 2015.

The establishment of e-science implies the formation of an online research e-infrastructure at the national level. This, in turn, forms the global information space of information systems of separate scientific organisations. The idea of establishing a national e-infrastructure is executed within the framework of state programs in several countries. Cyber-infrastructure in the US, European research infrastructure, Japan's scientific grid, and the national e-infrastructure projects of the UK, Australia, Canada, Russia and Moldova are examples.

E-science was established in the 1980s in Azerbaijan and some projects are listed chronologically as follows:

- In the 1980's the network of Computing Centre of Scientific Organisations of Academy of Sciences of USSR (ACADEMSET), the Republic Automatised Control System of Management for Science and Technology (RASUNT) and the Automatised System for Information Processing of Academy of Sciences of Azerbaijan (ASOIAN) projects were implemented;
- In 1991 the first access to Internet was obtained in Azerbaijan;
- In 1995 www.ab.az (www.science.az) was the first website to be put into operation in Azerbaijan;
- In the middle of the 1990s, with the support of the Turkish Republic, a network infrastructure covering scientific enterprises located in the ANAS campus was established and access to the TURKSAT satellite was provided;
- The network of the Academy of Sciences was provided with several work stations and equipment offered by British Petroleum;

- The network was connected to the telecommunication satellite within the framework of the "Virtual Silk Way" project of NATO in 2003.

The concept of national e-science is based on the solution of two fundamental problems including re-establishment of the existing scientific environment in accordance with information society requirements and the application of ICT in that environment [7]. For this purpose, the solution of complex problems such as studying other countries' experience, monitoring ICT application status in scientific activity, e-science management and the investigation of problems of information security provision, development and the actualisation of scientific-theoretical principles are considered. Results will be achieved when those problems are solved.

First, a national e-science program will be implemented according to global standards after studying other countries' experience; the regulation of informatisation of science based on monitoring results and improvement of the legal-normative base are part of this effort. Second, the communication-network infrastructure of e-science will be formed based on the maintenance of a material and technical base, establishment of local networks of scientific organisations, the provision of high-speed Internet access, establishment of a solid network linking the scientific enterprises of Azerbaijan, development of a security strategy and integration with international scientific networks. Third, information resources with different applications will be created. Fourth, the application of ICT in scientific activity will solve the problems of organising the workplaces of researchers, problems involving the activities of scientific collectives, and ICT will aid in the establishment of new research relations based on different fields of science, the organisation of mutual relations with international scientific organisations, the formation of scientific information spaces, establishment of computing environments based on supercomputer and grid technologies for solving problems requiring major computing and information resources, and the commercialisation of science. Fifth, the education of scientific personnel in ICT and staff training to maintain technical-program tools will be implemented.

3. E-science and state policy

The successful reforms carried out in e-government building under the leadership of the President of the country were part of the National Strategy on ICT for the development of Republic of Azerbaijan (2003–2012), the "Electron Azerbaijan" State Program, the Action Plan on "Electronic Government" formation, the National Strategy on scientific development in 2009–2015, the "Azerbaijan 2020: Outlook for the future" development strategy and the National Strategy for 2014–2020 on the development of the information society.

The National Strategy on science development in 2009–2015 in the Republic of Azerbaijan consists of 20 clauses covering the main objectives for science in Azerbaijan, trends in innovation, modernisation of scientific infrastructure, international scientific collaboration, highly qualified staff training and the integration of science and education. The 19th clause of the Strategy and one sub-clause are devoted to information provision problems and the science and development of the e-science model, respectively. The strategy identifies the problems of forming a new type of economy based on knowledge, modernisation of the management system in science and the training of highly qualified staff. One of the goals considered in the Strategy is reforms in scientific activity, wide application of ICT, and the development of an e-science formation process. In the strategy reflecting the expansion of research in the sciences, important problems such as the improvement of the management system in science and technology, establishment of a normative legal framework, provision of scientific information, strengthening of integration to international scientific space, the increase of efficiency of research and innovation policy and technological modernisation are considered, which are the problems directly related to the formation of e-science.

The development of information technology infrastructure, emergence of e-science and the knowledge economy are among the main requirements of an information society in Azerbaijan,

and they have been on the agenda of ANAS and other relevant institutions. The provision of the active participation of science in the development of the society necessitates establishment of an improved organisational structure for science itself and the transformation of traditional models in science and education. Establishment of an information society, efficient use of opportunities enabled by the information society for the development of citizens, society and the state, comprehensive application of ICT in state governance, and development of an information society as an economic sector stimulating socioeconomic and cultural fields are considered in "Azerbaijan 2020: Outlook for the Future" Development Concept and the National Strategy on information society development in the Republic of Azerbaijan for 2014-2020. E-science is prioritised in the Strategy through the development of e-government. This includes increasing the efficiency of research and expanding ICT in infrastructure development; the application of e-document circulation and the provision of necessary systems (archiving, analyses, reports, etc.); electronic management of documents, and the creation and development of internet resources (digital archives) on Azerbaijan's history, patriotism topics, literature and cultural heritage; application of ICT in libraries, archives and museums and expansion of the e-library network.

Due to the lack of a solid concept on the formation of e-science, the organisations located in different areas of Azerbaijan that are engaged in scientific activities encounter several technical, economic and other problems while conducting e-science-related work. However, these problems can easily be solved through e-science becoming part of the creation of e-government within the "Electronic Azerbaijan" State Program (Figure 1).

4. Scientific-theoretical and practical problems of e-science formation

The research indicates that e-science is being continuously developed globally and the number of institutions and organisations and scientists and specialists engaged in this field is rapidly increasing [8-13]. The international conferences conducted by the Institute of Electrical and Electronics Engineers (IEEE) on e-science solely are evidence of this interest. Since 2005the Technical Committee of the IEEE Society on Large-Scale Computations has hosted international conferences devoted to e-science jointly with prestigious organisations in ICT field [14].

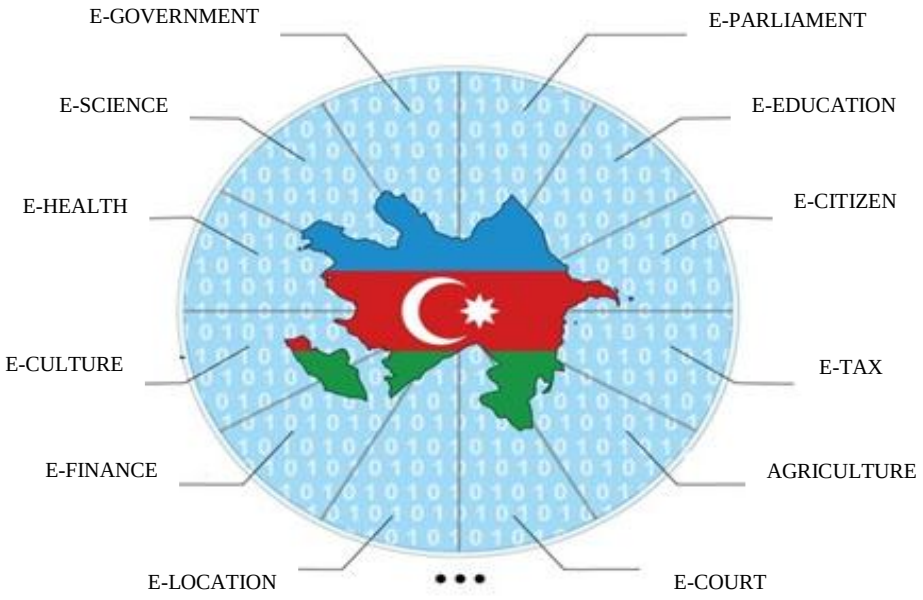

Figure 1. Integral parts of E-Azerbaijan

The aim of the conferences is to introduce the latest scientific achievements of e-science and to discuss the problems to be investigated in future research. The First IEEE International

Conference on E-Science and Grid Computing (December 5–8, 2005, Melbourne, Australia) discussed the following problems related to e-science and grid computing:

- Internet and web services;
- Scientific collaboration models and tools;
- Service-oriented grid architecture;
- Programming paradigms and models;
- Resource management and planning;
- Grid economy and business models;
- Grid networks;
- Sensor networks and e-science;
- Software and social engineering;
- E-science and grid applications in physics, biology, astronomy, chemistry, finance and engineering.

At later conferences, new problems such as virtual e-science organisations, metric indicators and measures, grid computing, grid tools and applications and e-science experience and education were discussed. At "The 10th IEEE International Conference on e-Science" [15] held in Brazil on October 20–24, 2014, emerging problems such as new equipment supporting e-science, cyber-infrastructures reflecting software and services and e-science in cloud technology were discussed. The traditions of previous conferences were continued and the conference acted as a forum to describe recent achievements in e-science, manufactured ICT products and tools. These conferences on e-science confirm that e-science as an important field of research including investigation of its scientific-theoretical and practical problems, similar to other science fields that share their results.

If we review the integral parts of e-science (Figure 2) the scientific-theoretical and practical problems in its development can be seen. The scientific-theoretical and practical problems of e-science include the infrastructure development, data collection, storage, processing, search, analysis and transmission determine.

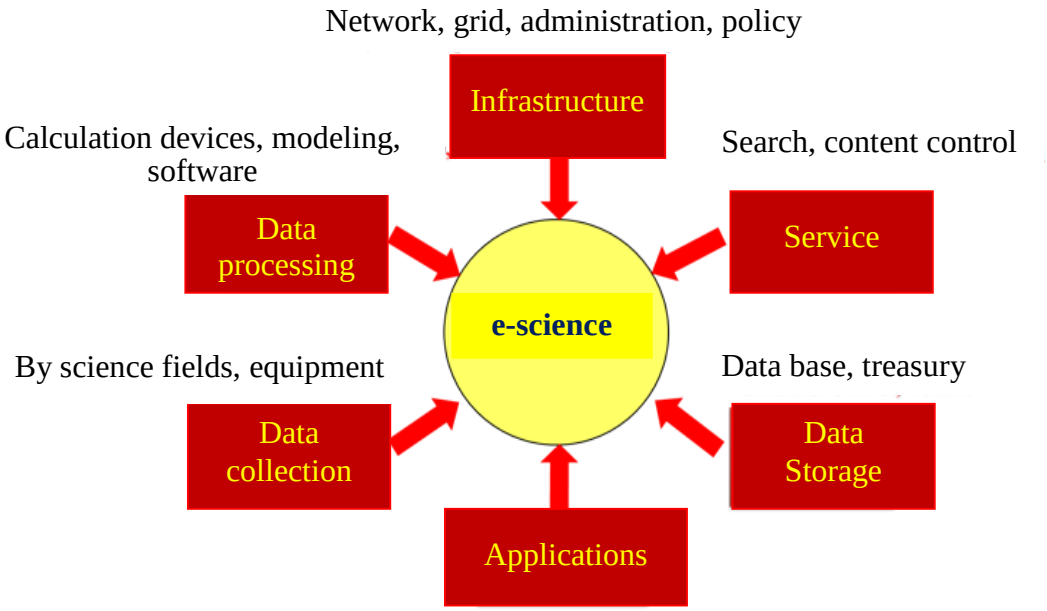

Figure 2. Integral parts of e-science

In terms of the infrastructure itself, several components are necessary: Designing and creating the computer network, developing and implementing management policies,

commissioning the required computing and memory resources, and the organisation and optimal management of solutions to complex scientific problems requiring massive resources in a distributed environment based on the application of grid and computing cloud technologies. In addition, the research and application of the grid, cloud computing and social networks, big data, OLAP, data mining and information security problems in e-science are of major significance.

5. Status of national e-science concept formation

Research and practical results are very important in the e-science field in the Republic of Azerbaijan. E-science has a territorially distributed infrastructure and covers the scientific institutions across the Republic. The institutes and organisations of ANAS, higher education institutions and other academic institutions constituting the majority of scientific institutions are located in Baku city, Nakhchivan and Ganja Branches and Sheki, and the Lankaran Regional Scientific Centres of ANAS are located throughout the Republic. Any e-science project in the Republic has a complex infrastructure based on the AzScienceNet network infrastructure. The following section is an analysis of the current status of implemented projects within the framework of e-science.

5.1. The current status of the e-science network infrastructure

- The monitoring of the application status of ICT in scientific activity must be primarily conducted for the development of a national e-science concept; priorities and trends of science informatisation must be specified based on obtained results. For this purpose, the ANAS Institute of Information Technology (IIT) has conducted a monitoring project to investigate the application status of ICT in approximately 150 scientific organisations active in the Republic of Azerbaijan including ANAS institutions in 2009 [16,17]. Another monitoring project was conducted exclusively for ANAS organisations in 2013.
- AzScienceNet, which is a network platform of e-science, covers all scientific enterprises of ANAS, and scientists experience no problems while using the Internet services.

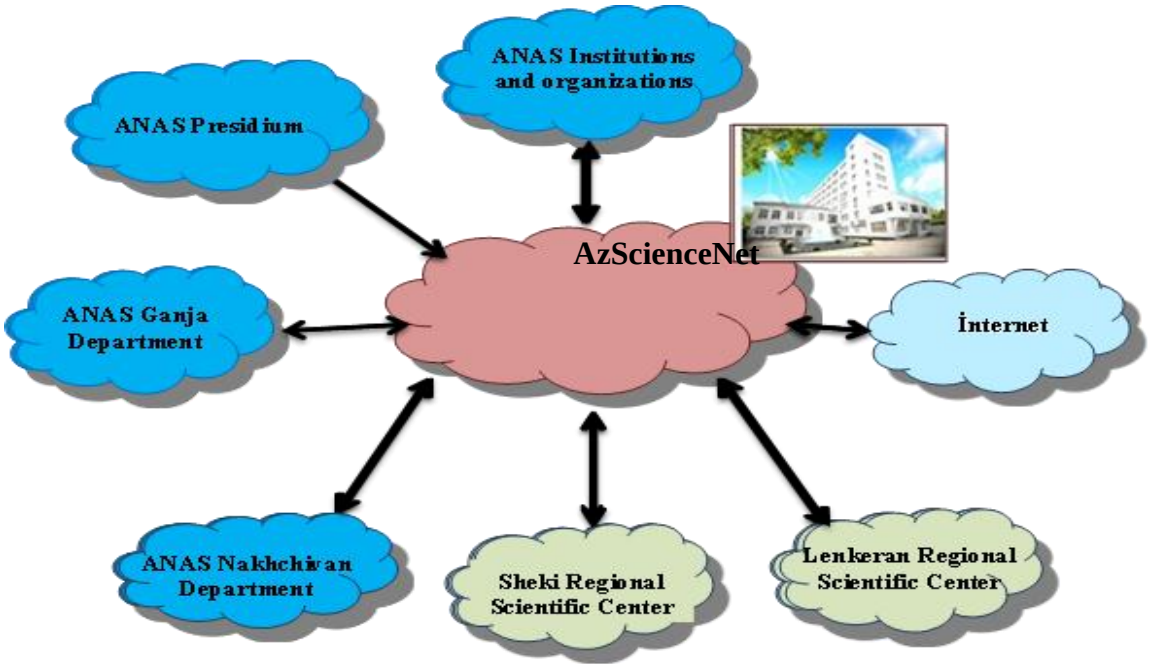

Figure 3. AzScienceNet infrastructure

- Around 4,000 computers are connected to AzScienceNet.
- The Internet access speed of AzScienceNet is 270 Mbit/sec.

- The Data Centre of AzScienceNet, with its large memory and computing resources (200 terabyte, 14 Tflops), was created and its technical characteristics are continuously improving.
- This active network and computing e-infrastructure creates a high-speed connection among scientific institutions, provides multiple services to users and enables integration with international systems (Figure 4).
- Within the framework of the AzCloud service, virtual computing machines are provided for the solution of complex scientific problems requiring major computing resources in a user-distributed environment.
- The AzScienceStorage service provides memory resources for storage of information, theprovision of which is considered important for ANAS institutions and organisations.
- The Monitoring and Security Centre of AzScienceNet is operating.
- The AzScienceCERT service was launched for providing operative responses to information security incidents in AzScienceNet, data collection, scientific-analytic research and the development of relations with international institutions. This service has been registered in the Trusted Introducer system operating within the framework of TERENA since May 31, 2011.

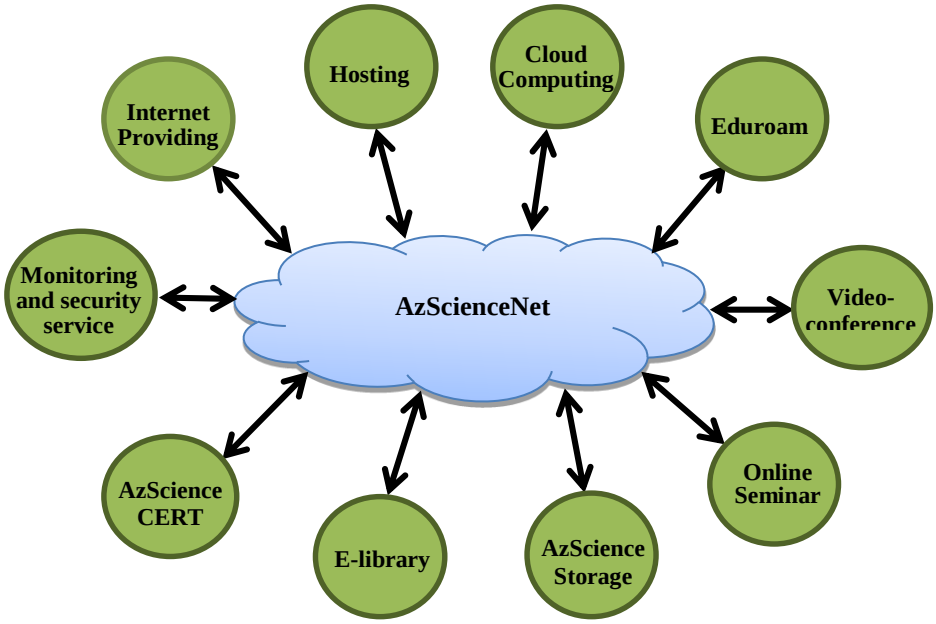

Figure 4. AzScienceNet services

- A user and security policy of AzScienceNet has been developed; the network monitoring and information security service was launched for performance of its efficient management and operative control of information security and centralised antispam and antivirus services.

5.2. The status of e-science informatisation

One of the main priorities of e-science is the informatisation of science. Multipurpose projects have been conducted accordingly:

- The Information Resources Centre of ANAS Central Library has been established based on the order of the President of the Republic of Azerbaijan, Mr. Ilham Aliyev.
- The operation of the ANAS Presidium is rapidly informatising.
- The rating of the www.science.az website of ANAS, created as the first website of the country in 1995, has become more popular among the public recently, which is a webometric indicator of ANAS's prestige (Figure 5).

- Multipurpose information resources have been created at the scientific enterprises of ANAS, and each of them has an active website.
- Relevant projects are being conducted for the establishment of electronic document circulation for ANAS.
- Monitoring is conducted for adapting countrywide scientific journals to international requirements, and their electronic versions are located at the DATA Centre of the AzScienceNet network.

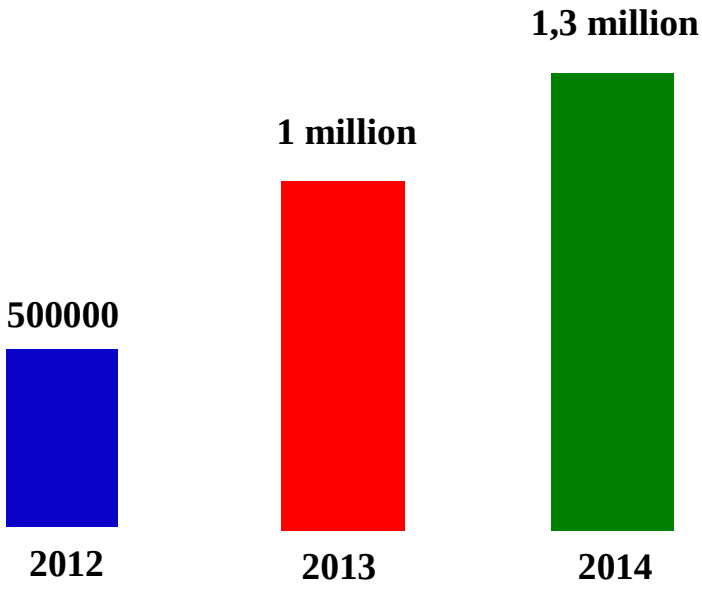

Figure 5.Calls to www.science.az portal of ANAS

5.3. Scientific problems and the research status of e-science

- The scientific-theoretical foundations of e-science have been researched and suggestions have been developed. An investigation of the creation of a national scientific reference index [18, 19], scientometrics [20], the assessment of scientific activities, the application of the grid and cloud computing [21, 22 and the organisation and management of scientific activity with the application of ICT can be listed as examples.
- Methods have been developed for the assessment of activities of scientific enterprises and scientists and their information culture, using web-analytic technologies.
- Different problems of scientometrics and bibliometrics have been researched; several important models were suggested.
- Conceptual approaches have been proposed for the coordination and management of science and the support of scientific information provision in the online environment.
- The models of obtaining knowledge from scientific information resources have been developed.
- The protection of copyrights, intellectual property and technologies against plagiarism are being developed in the online environment.
- As a trend in e-science, citizen science formation problems are investigated.
- The solution of problems in applying big data technologies, data storage and processing problems that have rapidly increased due to scientific activities has been investigated.
- The first Republic-wide scientific-practical conference on electronic science problems organised by the Ministry of Communications and High Technologies (MCHT), ANAS and ITI was held; the results of the conference were very significant and contributed to the development of e-government building [23].

- The collaborative relations with organisations such as Springer, Elsevier, IEEE, and Thomson Reuters have been strengthened to organise joint projects; trainings and seminars have been conducted. To ensure the adaptation of scientific journals published in the Republic to international requirements, monitoring of their compliance status with international requirements is being conducted. [24].

5.4. State of the art of e-science integration to international institutions and science markets

- Since mid-1994, ANAS has been a member of the TERENA international institution, which carries out the mission of developing the computer networks of scientific and higher education institutions of Europe.
- The science and education societies of Azerbaijan are represented in the GEANT Association, which was founded from the merging of TERENA and the Delivery of Advanced Network Technology to Europe (DANTE) in October 2014.
- Relations with UNESCO, CODATA and other international institutions have also been established within the e-science project.

5.5. The status of e-science staff training

- Staff training is one of the important aspects of e-science, and is conducted at the Training-Innovation Centre of ANAS IIT.
- In 2003-2013 at the Training-Innovation Centre of IIT "The Principles of Science Informatics" (covering basic informatics, scientometrics, plagiarism and antiplagiarism, supercomputers, Wikipedia, the Information Society, e-healthcare, knowledge economy, GIS technologies, information security, modelling, e-libraries and online academic journals) has been taught to more than 13,000 PhD students from scientific and academic institutions of the country.
- With the order of the ANAS Presidium (January, 2014), a training centre on Wikipedia in IIT and Wiki groups in other scientific institutions was founded.
- Distant Training Centres were founded at Nakhchivan State University and the Ganja Department of ANAS. "Scientific Informatics" is being taught to doctoral students at scientific and higher education institutions located in those regions by the employees of ANAS ITI.
- The Republic-wide annual Academic Olympics on "Informatics" organised by the H.Aliyev Foundation, ANAS, MCHT and ME are held among university students.
- Different books, textbooks and other materials for ICT education have been prepared by ANAS IIT specialists.

5.6. Scientific problems of e-education

- Scientific-theoretical principles of e-education formation are being investigated.
- Formation and assessment methods of the information culture of school students have been recommended.
- The preparation technologies of intelligent e-textbooks have been developed.
- The models of formation and intellectualisation of e-universities are being developed.
- The investigation of citizen education formation problems has commenced.
- The problems of children safely using the Internet are being analysed and suggestions are being developed.

6. Development perspectives of e-science

- The networks of AzScienceNet, AzEduNet and other scientific institutions must be integrated in strong cooperation;
- The integration process of AzScienceNet with international scientific and academic networks must be carried out;

- Scientific-organisational and management activities of scientific institutions of the Republic must be completely informatised;
- Electronic document circulation among scientific organisations must be organised;
- Research on scientific-theoretical principles of e-science and their practical realisation must be conducted;
- The projects on information provision in science must be continued. Several books, museum pieces, fauna and flora, encyclopaedias, manuscripts, atlases and scientific works must be digitalised;
- The capabilities of e-science for the formation of the knowledge economy in the country must be implemented;
- Projects to develop all science fields in accordance with modern world standards and their rapid integration with the global application of e-science must be carried out.
- The storage and processing problems of scientific data must be continued with the application of big data technologies.
- Academic personnel training must be continued;
- Citizen science as one of the new trends of e-science development in the country must be improved.

7. Conclusion

The rapid development of modern ICT and its broad capabilities affect scientific activity. For the scientific institutions in Azerbaijan, it is necessary to conduct investigations according to global standards, increase the scientific potential in the country and execute a national strategy on the development of science and the integration of Azerbaijani science with the international scientific environment. Research, global experience and analysis of the current state of e-science have confirmed this. Thus, projects must be conducted at each institution engaged in scientific activity in the Republic in light of the realities and requirements of the 21st century and international experience. Primarily, their scientific, organisational and management activities must be brought into the online environment and national e-infrastructure providing their mutual integration must be established.

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