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THE ROLE OF GRAPHICAL MODELLING OF AN EMERGENCY SITUATION IN ENSURING RATIONAL DECISION-MAKING AT THE OPERATIONAL LEVEL

Abstract. The article examines the role and significance of graphic modeling of emergency situations in ensuring rational and prompt management decision-making at the operational level. The relevance of using geoinformation systems in conditions of high dynamics of the situation, time deficit and incomplete source data, typical for emergency situations, is substantiated. The essence of graphic modeling as a tool for spatiotemporal analysis is revealed, allowing to integrate heterogeneous data on the parameters of the source of danger, geographical conditions, vulnerability of the population and infrastructure facilities, as well as the capabilities of forces and means of response. The article analyzes the foreign and domestic experience of using GIS in the activities of civil protection bodies, including the practice of the Ministry of Emergency Situations of the Republic of Kazakhstan in recent years. It is shown that the visualization of emergency scenarios and predicted consequences reduces the subjectivity of management decisions.

Keywords: modeling, layers, efficiency, geoinformation systems.

The operational level of emergency management is characterized by a highly dynamic situation, time constraints, incomplete and heterogeneous initial data, and the need for coordinated and prompt actions by civil protection services. Under these conditions, the key problem is not so much the availability of information, but its rapid processing and transformation into a management decision. Therefore, graphical modeling of emergencies using geographic information systems (hereinafter referred to as GIS) in the activities of the Ministry of Emergency Situations of the Republic of Kazakhstan (hereinafter referred to as the MES RK) is considered to be one of the most effective tools for rationalizing management decisions at the operational level.

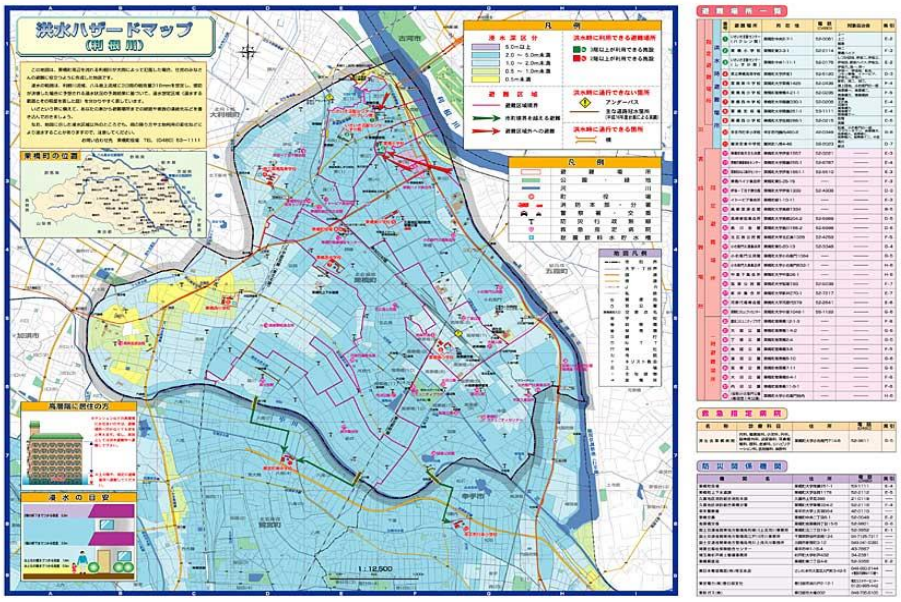
International practice shows that the geoinformation and visual-analytical approach is becoming the most rational method in interagency cooperation and crisis management.

In the Ministry of Emergency Situations of the Republic of Belarus, the use of GIS in information and analytical activities ensures the integration of spatial data, supports emergency monitoring and forecasting, and increases the effectiveness of decision-making through the processing and visualization of large volumes of spatially referenced data. A unified platform has been created on the basis of the Republican Data Processing Center of the unified Republican Data Transmission Network. It is a hardware and software complex designed to host software and technical tools, information resources, and information systems of state bodies and other state organizations [1].

In the Russian Federation, an automated information management system (hereinafter referred to as AIMS) is used. It is focused on the collection, storage, processing, and provision of data required by management bodies, as well as on the automation of processes supporting management decision-making and the communication of decisions to subordinate structures with subsequent monitoring of implementation. Data consolidation in a spatial context makes it possible to coordinate actions more effectively, assess risks, and make decisions based on up-to-date information [2].

In the United Kingdom, emergency response services use Resilience Direct, a secure environment for exchanging information and cartographic materials. It is used for planning, timely response, recovery operations, and the integration of necessary information into a unified operational data field for the population and participants in rescue operations [3].

Japanese practice, using the example of flood hazard mapping guidelines, demonstrates the use of risk maps as a tool that provides a clear representation of flood zones, procedures for evacuating the population, and the actions of municipal services. In other words, it directly links cartographic modeling with management decisions at the local level. Such maps help residents understand risks, accelerate evacuation decision-making, increase awareness of the need for preventive measures, and serve as a basis for developing municipal response plans, facilitating timely evacuation as the main form of protection [4].



Picture 1 – Example of a flood risk map in Kurihashi, Saitama Prefecture [4]

Graphical modeling of an emergency using geographic information systems is a method of spatio-temporal analysis and visualization of emergency development through GIS. It enables well-grounded support for management decisions at the operational level, taking into account [5]:

– geographical conditions;
– parameters of the hazard source;
– vulnerability of the population and facilities;
– scenarios of situation development over time.

The key objective is to forecast the consequences of emergencies and visually represent risk zones in order to improve the speed and validity of decision-making.

The main elements of graphical modeling include:

– spatial basis: digital terrain maps, safety passports, cadastral and topographic layers;

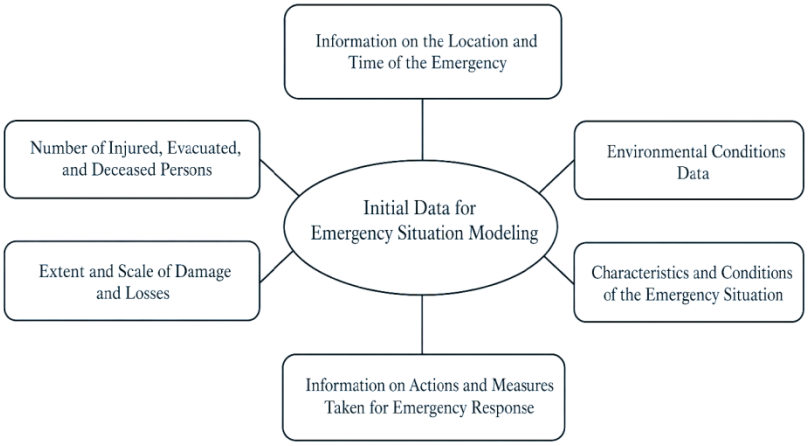
– initial emergency data: intensity, rate of spread, direction of impact, time parameters;

– modeled layers: affected zones, evacuation routes, command posts and response forces, critical infrastructure facilities;

– temporal modeling of emergency dynamics: displaying the development of an emergency by stages, for example H, H+1, H+6, H+24, and so on.

The use of geoinformation technologies for visualizing and analyzing emergency data is an appropriate and effective approach. GIS makes it possible to present information on a map and analyze spatial relationships and interactions between various parameters in real time. With the help of GIS, it is possible to display the location of an emergency, the distribution of affected and evacuated persons, the extent of damage, and many other indicators on a map. This allows operational decisions to be made regarding the deployment of forces and resources for eliminating the consequences of emergencies.

The analysis of geospatial data using GIS can also assist in forecasting possible developments, determining optimal routes for delivering assistance, and managing resources in a crisis situation. Effective modeling of emergency consequences requires access to various types of data, as shown in Picture 2.



Picture 2 – Initial data for emergency modeling [5]

It is particularly important to note the significance of graphical emergency modeling for management bodies, where visual information is especially necessary for making well-grounded decisions, taking into account the rapid development of events and the shortage of time.

The development of graphical modeling at the operational level is directly linked to the digital modernization of the Command Center for Strategic Planning and Operational Management of the central office and the regional planning and operational management centers of territorial subdivisions.

At present, a modernized situation room of the Command Center for Strategic Planning and Operational Management has been put into operation in the central office of the MES RK. The digital service "GIS Emergencies" is functioning and, together with the geoportal of JSC "NC Kazakhstan Gharysh Sapary," is used as the main tool for monitoring, analyzing, forecasting, and visualizing natural, technogenic, and social emergencies throughout the country. In addition, this system includes fire monitoring and forecasting subsystems, including "Pyrology," which is used to calculate fire spread zones and select calculations according to crown, surface, peat, coniferous, and deciduous fire parameters [6].

The digital services of the MES are based on a GIS core that includes monitoring subsystems, forecasting subsystems for various emergencies, digital safety passports, interactive maps, and an atlas of natural and technogenic emergencies with historical data. The system integrates video surveillance cameras and unmanned aerial vehicles, which make it possible to monitor the development of hazardous hydrological situations at the Turgen Lakes and the Talgar River dam in real time. For early fire detection during the fire-hazardous period, "Sergek" cameras have been installed in the forest enterprises "Ertis Ormany," "Burabay," "Semey Ormany," and the Republican State Enterprise "Medeu". The system is also integrated with GeoRAPTOR and sensors installed in Almaty and adjacent regions, which makes it possible to monitor earthquakes in real time [6].

Within the framework of cooperation with the international organizations MapAction and the Center for Emergency Situations and Disaster Risk Reduction in Central Asia, training sessions are conducted for rescuers. During these sessions, GIS tools are applied on the basis of the Quantum GIS 16X geoinformation software of OSGeo. Maps prepared in QGIS can be used for modeling and forecasting emergencies and their consequences, developing response scenarios for earthquakes, natural fires, floods, and technogenic emergencies, and preparing reporting documents that are maintained and supplemented with information during the operation of the hardware and software complex [7].

The use of GIS in the MES RK and its territorial subdivisions has not yet been fully implemented; however, there are already positive examples of the practical application of QGIS geoinformation software. For instance, the Department of Emergency Situations of Almaty used QGIS tools to build a map of the site of a major warehouse fire, indicating the distances to the nearest fire stations. This made it possible to plan the deployment of forces and resources more effectively. The acquired skill was used during a real fire.

Graphical modeling is developing not only at the level of the Command Center for Strategic Planning and Operational Management, but also at the regional level. Thus, centers for strategic planning and operational management have been established in the territorial subdivisions of the MES RK according to a unified concept. These centers ensure operational management of forces and resources, organize cooperation between civil protection services, and coordinate subordinate organizations at the regional level.

Conclusion

The conducted study confirms that graphical modeling of emergencies is an important tool for ensuring rational, well-grounded, and prompt decision-making at the operational level of management. Under conditions of time shortage, highly dynamic situations, and incomplete initial data, it is precisely the visual-spatial representation of

information that makes it possible to transform fragmented information into an integrated and manageable model of the current and forecasted situation.

Graphical modeling based on the use of geographic information systems ensures the integration of data on the parameters of the hazard source, geographical conditions, vulnerability of the population and infrastructure, as well as the possibilities for the effective use of the required grouping of forces and resources.

The GIS practices presented in the article show that graphical modeling of emergency development scenarios and their consequences significantly reduces the subjectivity of management decisions, increases their scientific validity, and allows alternative courses of action to be compared quickly. It is especially important that graphical modeling acts as a tool for interagency cooperation, ensuring a common understanding of the situation by all participants involved in emergency response, thereby reducing time losses in the coordination of decisions.

The experience of the MES of the Republic of Kazakhstan and foreign countries demonstrates that the effectiveness of graphical modeling is achieved only when it is integrated directly into the decision-making process, rather than functioning as an isolated analytical product. In this case, it becomes a system-forming element of modern operational management, directly influencing the timeliness of response, risk reduction, and minimization of emergency consequences.

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ЖЕДЕЛ ДЕҢГЕЙДЕ ҰТЫМДЫ ШЕШІМ ҚАБЫЛДАУДЫ ҚАМТАМАСЫЗ ЕТУДЕГІ ТӨТЕНШЕ ЖАҒДАЙДЫ ГРАФИКАЛЫҚ МОДЕЛЬДЕУДІҢ РӨЛІ

Аңдатпа. Мақалада жедел деңгейде басқарушылық шешімдерді ұтымды және жедел қабылдауды қамтамасыз етудегі төтенше жағдайларды графикалық модельдеудің рөлі мен маңызы қарастырылады. Жағдайдың жоғары динамикасы, уақыт тапшылығы және төтенше жағдайларды жоюға тән бастапқы деректердің толық болмауы жағдайында геоақпараттық жүйелерді қолданудың өзектілігі негізделген. Графикалық модельдеудің мәні қауіп көзінің параметрлері, географиялық жағдайлар, халықтың және инфрақұрылым объектілерінің осалдығы, сондай-ақ әрекет ету күштері мен құралдарының мүмкіндіктері туралы гетерогенді деректерді біріктіруге мүмкіндік беретін кеңістіктік-уақыттық талдау құралы ретінде ашылады. Мақалада соңғы жылдардағы Қазақстан Республикасы ТЖМ тәжірибесін қоса алғанда, азаматтық қорғау органдарының қызметінде ГАЖ пайдаланудың шетелдік және отандық тәжірибесі талданған. Төтенше жағдайлар сценарийлері мен болжамды салдарларды визуализациялау басқарушылық шешімдердің субъективтілігін төмендететіні көрсетілген.

Түйінді сөздер: модельдеу, қабаттар, жеделдік, геоақпараттық жүйелер.

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РОЛЬ ГРАФИЧЕСКОГО МОДЕЛИРОВАНИЯ ЧРЕЗВЫЧАЙНОЙ СИТУАЦИИ В ОБЕСПЕЧЕНИИ РАЦИОНАЛЬНОГО ПРИНЯТИЯ РЕШЕНИЯ НА ОПЕРАТИВНОМ УРОВНЕ

Аннотация. В статье рассматривается роль и значение графического моделирования чрезвычайных ситуаций в обеспечении рационального и оперативного принятия управленческих решений на оперативном уровне. Обоснована актуальность применения геоинформационных систем в условиях высокой динамики обстановки, дефицита времени и неполноты исходных данных, характерных для ликвидации чрезвычайных ситуаций. Раскрывается сущность графического моделирования как инструмента пространственно-временного анализа, позволяющего интегрировать разнородные данные о параметрах источника опасности, географических условиях, уязвимости населения и объектов инфраструктуры, а также возможностях сил и средств реагирования. В статье проанализирован зарубежный и отечественный опыт использования геоинформационной системы в деятельности органов гражданской защиты, включая практику Министерства по чрезвычайным ситуациям Республики Казахстан за последние годы. Показано, что визуализация сценариев развития чрезвычайной ситуации и прогнозируемых последствий снижает субъективность управленческих решений, повышает их научную обоснованность и

эффективность межведомственного взаимодействия. Сделан вывод о том, что графическое моделирование является системообразующим элементом современного оперативного управления при условии его непосредственной интеграции в контур принятия решений.

Ключевые слова: моделирование, слои, оперативность, геоинформационные системы.

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