Spatial Location of Urban Water and Wastewater installations, with the aim of increasing the resilience of crises

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Abstract:

Crises have always caused many, and sometimes irreparable, damages and injuries to human nations having had adverse impacts on indices of society, economy and environment. Therefore analysis and optimum management of these crises are the priorities in the states around the world.Access to valid and up-to-date information plays the pivotal role in proper and timely programming and performance on managers' and responsible organizations' side in various phases of the crisis management cycle. While more than 80% of the required information in crises actually have a local and geographical nature, utilizing the modern technology of GIS with special capabilities in modeling, combining and analyzing the data can be effective and impasse-breaking while analyzing vast layers of information in both phases of prediction and strike of crises.A good knowledge of the crisis-causing factors before their strike or prediction of the essential arrangements to prevent or reduce their affects or aftermaths to the least is one of the base procedures in the management of unexpected events. In this direction, precision in properly locating the installations and passages of the pipes and canals would be immensely important; bearing in mind the key role of continuation of serving essential arteries; particularly water and sewage installations, in controlling and preventing the expansion of crises, and preserving public health and hygiene on the one hand, and the significant expenses of construction or reconstruction of these systems on the other. Thus, through this study, we have discussed how to exploit the creation and production procedures in purposefully locating water and sewage installations and also their other usages in designing, management, programming and development of these installations, in addition to introducing the geographical information systems and clarifications of the creation and production procedures. The location of urban water and sewage facilities is very effective in increasing the resilience of natural disasters through the use of the geographical information system.

Key words: water and sewage installations, crisis, crisis management, geographic information system, GIS

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1_Introduction:

Iran is one of the 10 most vulnerable countries around the world and according to the registered statistics on 40 natural disasters in the world; so far 31 of them have taken place in Iran. On the other hand, Iran has always been exposed to foreign encroachments due to the special political, social, geopolitical conditions, natural supplies and resources (such as oil), and the strategic location (such as being in close proximity to Hormoz strait).

Therefore in such a situation a decent programming in systematic and appropriate encounters with crises by governments is inevitable and of major priority in our country. In this direction profiting from modern technologies of communication and information, and particularly GIS would be absolutely fundamental and inevitable due to the data volume, various imaginable crises and events and the numerous things that have a hand in their occurrence and prevention, and the necessity of modeling and complex analysis and digestions.

Although in Iran, the major attention is devoted to the weak structures in many regions and reducing the number of human casualties, when a natural disaster or unexpected event, specially an earthquake strikes; discussing the subject of retrofitting and improving essential arteries (water, sewage and gas systems, national grid, telephone company and main paths and bridges) against various incidents is inevitable and essential; having in mind the crisis management cycle and high expenses of constructing, repairing, and conserving them and the necessity of providing services for the casualties in order to decrease sufferings and prevent expansion of the crisis or aggravation of the aftermaths and also the possibility of service for the rescue squad centers.

Thus meanwhile, bearing in mind the vastness of discussions and number of priorities, while having a brief look at the definitions and concepts of the most important crises and their management and the effective role of GIS in this field, we will embark on the specialty of GIS in locating, designing, performing and exploiting the water and sewage installations using crisis management approach.

2_The definition of crisis:

Crises are the events which are led to, or intensified by natural factors or human activities and result in significant casualties and damages. To deal with them, specific fundamental and urgent actions are required.

3_Crisis management:

Crisis management is a practical science that is achieved through observation, examination and systematic analysis of crises. A nd is on the lookout for the proper methods and tools in order to prevent the crises or reducing their impacts and unfavorable results to a minimum, and providing a fast recovery of the condition.

The aim in fact is to prepare and face the crisis properly and minimize the chances of occurrence or reduce destructive effects and the prices of its occurrence in all aspects: humane, economical, security-wise, cultural and social.

Number	Crisis	Definition
1	Earthquake	The act of releasing the vibrating energy which is transferred to the surface of the earth from the depth of it and results in destruction of structures and installations and casualties and economical damages which vary depending on the magnitude.
2	Flood	Mechanical pressure and rapid and intense flow of water along with turbulent flows on the surface of earth which results in massive destruction of the environment and carries people, animals, vehicles,… away in shallow depth.

3	Sliding And buoyancy	Movement and replacement of parts of the earth due to various factors (such as flood and earthquake) which results in severe casualties and causes buildings, roads, installations and… to be buried away.
4	The blowing of severe winds	Rapid replacement of the air such as pressure and suck of wind which affects numerous things in a short time and at times results in large-scale damages and destruction, Tsunami in eastern Asia, Hurricane Rita and Hurricane Catherine in America are among the examples.
5	Fire	This crisis can have either a human or natural origin, which will destruct and turn everything into ashes, such as huge fires in forests and pastures or industrial or residential regions.
6	Volcano	One of the natural crises including ejection of lava from the crater of volcanoes and explosion and eruption of hot and poisonous gases, volcanic material like dust and ash which result in annihilation of the environment, forests, structures and living creatures.
7	Wars and terrorist actions	One of the incidents with humans being the factors and normally results in human and economical casualties and destruction.
8	Crises, disputes, and terrorist acts	This kind of crises are also originated by humans and they are most effective in economical, communicative, and cultural fields (such as computer crisis in the early 2000, electronic war (such as the 10th election), cultural invasion, economical sanctions and…)
9	Drought	Severe shortage in providing the drinking water; hygienic, industrial, agricultural use and Greenfield sites, which will have many more economical aftermaths and human casualties.
10	Epidemic diseases	Instances and serious casualties due to epidemic diseases can be seen in the past and even in the new era.

Table 1 – a selection of crises and their definition

Meanwhile events such as earthquake, flood, sliding and buoyancy amongst the natural disasters and distinctive destructions and annihilations of systems and installations, or chemical and microbe contaminations in water supplies are the main sources of effective crises in the field of water and sewage installations.

4_Crisis management cycle:

Cycle of performances and confronting actions and crisis controlling consists of the following partitions:

1_prevention
2_Decreasing the destructive effects
3_Preparation
4_Improving and rebuilding
5_Development

Number	Activity Title	Description	Time of action	
			Before the strike of crisis	After the strike of crisis
1	Prevention	A series of actions which prevent the unfavorable effects of the crisis on the society in addition to preventing the crisis from taking place.	√	
2	Decreasing the destructive effects	A series of actions that are performed in form of a comprehensive plan in order to reduce the negative impacts in the country or region.	√	

3	Preparation	Creation of the ability in governments, societies and each single person to confront events; which consists of preparation of an anti-crisis plan, an exact prediction of resources and educating.	√	
4	Aid, improving the conditions and rebuilding	A series of actions which start by the strike of crisis and in order to improve the conditions and normalizing the situation; and can sometimes last years in order to achieve the ultimate goal (return to the condition before the strike of crisis)		√
5	Development	Crises and unexpected events have always been one of the major factors threatening a stable development in societies and states. Thus, engaging in reaching this goal in the development plan is one of the policymaking and ground plans' priorities in crisis management.	√	

Table 2 – Crisis management cycle

5_the role of information in crisis management:

Today access to well-timed data and drawing the needed information out this data is of high importance. Geographical information systems are considered as crucial tools in managing the earth data which enable the capability of drawing out the needed information and discovering the complicated and hidden connections among different phenomena by bringing about the possibility of the integration of the data achieved from various resources.

Access to information and valid and up-to-date local data in particular plays a decisive role in different procedures of crisis management. Bearing in mind that more than 80% of the required information in crises have a local nature, Using modern technologies of GIS is crucial to the process of data management of crisis managements. while keeping in mind the numerous effective factors and provocation in strike of a crisis and its impacts and results, it can also be stated that by analyzing the layers of data throughout both procedures, before and after the crisis; geographical information system with special capabilities in modeling and data analysis can help the authorities and managers toward the proper deci-

Number	Informational Layer	Usage in crisis management
1	Concentration and division of the population	Detecting the dangerous spots that inflict heavy casualties
2	The rescue squad centers	A sought-after plan for development and distribution of centers before striking of disasters and optimum management and proper guidance of performing teams.
3	Medical centers	A proper plan for facilitating and developing before striking of a crisis and optimum management of transferring the injured and providing medical service during a crisis.
4	Routes and passages	Professional guidance of performing teams through a crisis, bearing in mind cases such as the width of the passages, access, and… also predictions and modifications of routes in hazardous regions.
5	Mosques and governmental departments	As backup and service centers, providing the volunteers.
6	Greenfield sites	For temporary camps or rescue squads' serving spots

7	Geological zone scheming (such as geological information, pedology, and underground waters and…)	Modeling and analyzing the natural conditions of the earth in order to help the programming and proper crisis management to reduce its unfavorable impacts.
8	Seismic zone scheme	Verifying the perilous locations and avoiding constructions of dangerous industrial centers (such as chemical material factories) in these regions by remaining in the appropriate distance for residential centers or crowded structures and also programming the proper retrofitting of the structures
9	Determining the limits and categorizing different structures such as historical constructions,…	Programming a plan to modify the texture, access, retrofitting
10	Main arteries data (Water and sewage system, electricity grid,…)	Predicting the incidents and accident-prone spots, performing preventive actions in order to have the minimal damage and maximal service at the strike of a crisis.
11	Health GIS	In order to predict and model the crises of hygiene and health and epidemic diseases, and have a plan to prevent and properly confront the situation, proper distribution of services in keeping with the aforementioned cases.

Table 3 – a selection of the origin locations and their role in optimum crisis management

sions and actions.

6_History and concept of GIS:

Technology of GIS originated more than 30 years ago in the business world, but its widespread use goes back to the recent few years only.

Geographic information system is in fact a system which has been created to receive, store, combine, process, analyze and exhibit the data that locally have been referenced to earth. This system normally consists of a reference computer base and a software

in keeping with its practice.

7_GIS usages:

- Preparing plans of natural calamities

- Site selection plans: this means to select the most appropriate locations for engineering projects such as burying the waste material, pipeline, railroads, dams, and building development.

- Various geological processes:

This is in order to navigate resources such as water, sand and gravel, stone, crude oil, natural gas, coal,

geothermal energy in the metallic minerals.

• Exploration researches:

This is in the field of mutual connections between series of data during the period of geological researches, such as comprehending the regional geochemical and geophysical granites of types S or I and sign assessment from satellite images in connection with litho logy and vegetation.

• Water resources and watershed management:

To discover underground water sources and examine surface water.

• Agriculture and planning for land utilization:

Many of the agricultural organizations and land utilization are now using GIS. For instance, data from land and weather satellites, ground measurements and product information of years ago can all be analyzed together to predict the amount of one or more crops in a region.

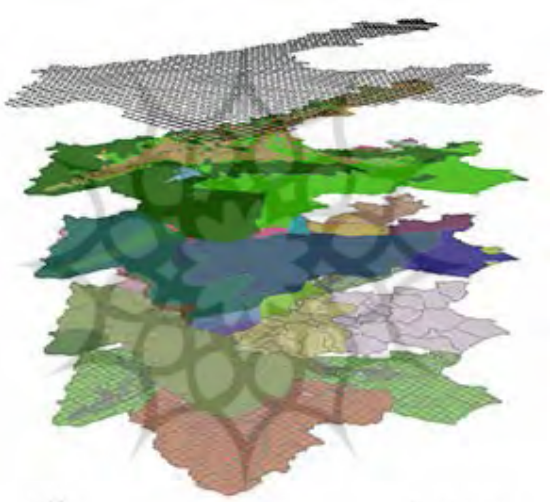


Figure 2: Layers of GIS information

• Forest protection and management of the wild:

Forests can get up-to-date constantly using GIS. GIS can also be used for storage and analysis of the forest information such as the possible amount of wood to harvest in a region, examining the division of fire in the forest or evaluating different plans of wood harvesting; while many of these analyses will not be possible without GIS.

• Business:

Appropriate locations and delivery systems in business affairs.

• Transport and communication industry:

Usage of GIS in industry can be one of the following: determining the course of transmitting goods, determining the proper location to build roads, power lines, telephone systems and…

• Organization: Used in all local and provincial matters

• Emergency services: such as fire stations

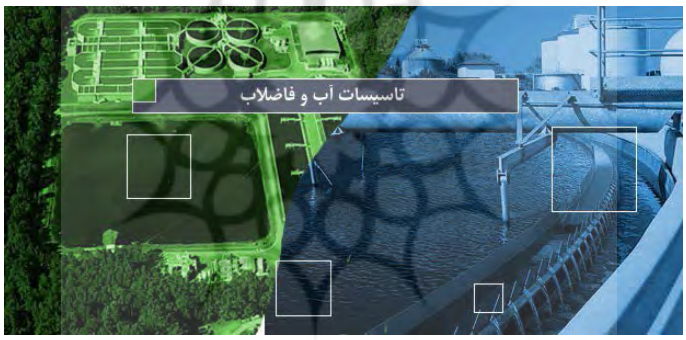
and police

- Military: Used in military planning
- Education: research training of tools and monitoring

8_GIS in Water and Sewage industry:

Due to its diverse capabilities GIS can be effective in various aspects of water and sewage industry, including areas to locate and design, implement and operate, and supervision of installation and network management.

9_ Application of GIS in designing and locating facilities and network:



of factors of their creation or their numerous effects, collection, storage, processing and upgrading this information without using advanced technologies of information and communications technology would be difficult and impossible. The application of geographic information systems for the type and extent of this information can be very useful and decoder.

As described in the cycle of crisis management major activities and actions are related to the crisis before the time of occurrence. So, understanding types and causes of crises with their incidence and identifying prone areas and locations are of much importance; because on the one hand, access to such information with appropriate supplied measures enables us to minimize the possibility of a crisis occurrence or its undesirable effects; and on the other hand knowledge of hazardous areas according to the bases of sustainable development will prevent us from building significant installations and structures in those locations. Also if necessary, the essential things and needed predictions will be done and made in order to deal with crises and keep the stability of service giving after the crisis occurrence.

Due to the diversity between the crises and the variety

Preparing various the layers of information such as geological maps, vulnerability and… are amongst the applications.

Meanwhile, GIS will be highly appropriate and effective in locating and designing water and sewage installations:

Number	Description
1	Enormous expenses of designing and running water and sewage projects and the need to reduce running and maintenance costs while maintaining the quality.
2	Area network expansion and crossing the different areas and the need to identify the most suitable, low risk and most shortest path

3	The need to select the most secure areas necessary for installations and implementation and restoring the system facilities in a short time, and network services to more citizens after the occurrence of crises considering its key role in preventing the expansion of the crisis (for instance, the provision of health and fire control)
4	Selecting the proper location for installations in order to prevent the occurrence or intensification of the crises (such as the suitable location for dams or networks for collecting and excretion of surface water to prevent flood)
5	Number of reference location parameters which is effective in designing optimum water and sewage networks
6	Possibility of using the compliance capability of different layers of information and data analysis by GIS system to access the above objectives

Table 4 – Reasons of the high effectivity of the use of GIS in locating and designing water and sewage installations

In designing water and sewage networks manual methods can be used only to calculate and use the general and limited parameters such as slope, courses of paths and density, which will not allow an optimum and multilateral plan considering the vastness of effective information and the aforementioned descriptions. Including information and analysis of the optimal network design using GIS operation, the fol-

Number	Data type	Number	Data type
1	slope of ground	14	Providing the shortest remaining time of sewage in the network
2	Type of soil	15	Groundwater level
3	Main thoroughfares and secondary access routes	16	Identifying high-risk fire areas to predict offering services during a crisis
4	Specifications of passages	17	Identifying the areas with liquefaction and displacement or land failure and avoiding these areas or doing the necessary retrofitting
5	Various canals and installation networks and lifeline routes	18	Predicting and providing the non-operating defense rules in locating and designing the facilities
6	land-use	19	determining the main and sub-lines in the network
7	Price of land and property	20	The possibility of assessing the whole network in different modes in the stage of designing by exerting any little change and choosing the optimal conditions
8	Distribution of faults in the region and avoiding cutting them	21	Estimating costs of the projects related to road rules and Cost Estimation in GIS database
9	Neighborhoods	22	Determining the exact locations of diameter change in network lines based on correct classifications
10	Determining the shortest paths for providing services	23	Area classification of designed network in development, based on information about density in different areas, number of incidents recorded in different parts of the network and the oldness of network for better exploitation of the existing facility centers
11	Determining the depth of pipes	24	Distance from each other and installations of various centers
12	Delay in increasing the network diameter	25	Determining the area covered by the sewage pipe based on three parameters of the nearest distance, topography and the kind of connection to regional network
13	Providing the speed of self-cleaning in sewage systems	26	And…

Table 5 – information and analyses that can be used in optimal network designs using GIS

lowing can be cited: Amongst the discussions mentioned in this section, it can be said that using a powerful system of spatial information specialized for use in water and sewage category can have a crucial role in compatibility and analysis of data which are effective in locating and design of water and sewage installations. These for sure, provide firstly the optimum, cost-effecting, resistant and flexible designs in crises and secondly, the opportunity to monitor and manage the network properly, particularly during an event or a problem.

10_ Best time of production and utilization of GIS in water and wastewater industry:

Obviously, GIS, like any other software will need the required data in the proper form (GIS ready) in order to get activated and work. Considering the necessary arrangements are for easy and fast upgrading of this data. To do this, the system must be produced before designing and running of the lifelines, so the data on it can also be downloaded while it is being used in designing and locating stage. due to the major part of the network being buried, over time and with no recorded incidence of changes in the manual plans; or due to the scattered plans getting damaged or lost at times, the decent data transfer of GIS is practically only possible through time-consuming actions and considerable costs. This matter is now one if the major challenges in producing and operating GIS in water and wastewater industry in our country. Building and developing urban GIS is one of the best ways to reduce these problems and costs which has been postponed so far due to a lack of an urban management unit in our country. Regional appropriate interaction between urban service organizations and city ***** can be highly effective and more dynamic of the process to prevent formation of island systems and the heavy and recurrent costs.

11_ GIS application in water and wastewater projects:

Besides other benefits of applying this system in the project implementation stage, it can also be used to rapidly and correctly calculate and estimate the operations and developments, such as excavation volume, the distance of soil and construction materials transportation, asphalt level planning and ... Or even to determine the nearest locations to receive services.

In addition, considering the possibility of applying corrections and changes in operational plans in the construction phase, this system will provide the platform needed to enter and apply changes in the system in order to upgrade the data with the minimal cost while enabling the analysis of these changes before any actions.

12_ GIS role in the exploitation of water and sewage systems:

Considering their variety and extent, in traditional methods of utilizing and managing office facilities and water and sewage networks some problems and challenges can be cited, that are briefly mentioned in the following:

Number	Challenge
1	Interaction with loads of data and paper plans, worn and decentralized at times, which are impossible to implement.
2	Dependence on employees' information and mental data which contradicts the concept of the 44th rule of privatization, and transferring the executive matters to the operational companies. This is considered a serious blockage.
3	The impossibility of recyclable focused registering which suitable for incidents, maintenance activities and… for fast access in different parts of the network
4	The impossibility of management and monitoring of installations and network based on human resources
5	The high cost of operations and maintenance and increase in practical errors considering the network is buried, and also the necessity to direct visits and revisits

6	Limitations in a coherent programming of maintenance
7	Impossibility of valid predictions of incidents and damages, and consequently absence of operation speed and preparation in preventing or confronting the events
8	Serious problems in managing the crises throughout the whole cycle of crisis, specially the recovery stage.
9	And…

Table 6 – The problems of the traditional methods of utilizing water and sewage networks

Figure 4: Sewage Treatment System

13_Benefits of using GIS-based management systems:

Applying GIS and proper databases, provides the beneficiary companies and network and installations managers with the appropriate tools for a quick access to information and required analysis and modeling, and in a nutshell an optimum implementation management particularly in occurrence of incidents and crises. Amongst the effective and significant capabilities of these types of systems, the following can

Number	Advantages
1	Appropriate database connection to networks and pipelines and registration and call of the required information in the minimum time possible
2	Mental independence of personnel's information in network management and leadership
3	Familiarity of the beneficiary companies with the generalities and details of network information and changes
4	The possibility to register all incidents, actions, and… by the beneficiary companies in different periods of time which will result in a valuable source of statistics and experiences in order for the network and future designs and confrontations to be repaired and developed
5	The possibility of modeling and monitoring the water and sewage networks by the help of proper sensors and auto-registering of the information; and the chance of creating the suitable conditions of predicting, programming and dealing with the incidents, such as the coherent opening and closing of the valves in order to deliver water to citizens in shortage of water and controlling the fluctuations of sewage level
6	The possibility of various analyses of information in the network and operation speed in statistics, and providing various reports throughout the different layers of present information such as old pipes, their specifications (thickness,…), abundance of damages,…
7	Optimum crisis management and unexpected events in the preparation, recovery, and restating stage of the network

8	The possibility to guide the operating teams towards the best and nearest paths using GIS-based navigation systems (AVL and…)
9	The possibility to model various critical conditions in a virtual environment, provide proper preparations and increase the level of strength in personnel of the events and crises by doing drills and maneuvers.
10	And…

Table 7- Capabilities of GIS-based management systems

be cited:

14_Conclusion:

Crises, with adverse effects on social, economic and environment indicators have always caused great and sometimes irreparable damages to human communities; so identification and optimal management of them are among the priorities of countries.

In different stages of crisis management cycle, access to accurate and up to date information has a central role in planning, and Accurate and timely performance of responsible managers and organizations. Considering the fact that more than 80 percent of the required information in crises have spatial and geographical natures, using the GIS technology with special abilities in modeling, combination and data analysis can be very effective by analyzing extensive layers of information in both prediction and occurrence stages. One of the basic stages of the management of unexpected events is appropriate recognition of the factors involved in crises, before the occurrence, and predicting the provisions necessary to prevent or reduce the possible consequences. Considering the key role of continuing the serving of lifelines and specially networks and installations of water and sewage in controlling and prevention of crisis expansion and keeping the public health on one hand, and the high cost of construction or reconstruction of these systems on the other, careful location selection for installations and passage routes of pipes and canals will be very important. Here, in addition to the introduction of geographical data systems and representing the stages of production, exploiting them for locating the water and sewage installations and also other uses in design, management, planning, and network development have been explained. This will have an important role in increasing the resilience of urban water and wastewater systems in the face of crises.

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