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QRA-Grid: Quantitative Risk Analysis and Grid-based Pre-warning Model for Urban Natural Gas Pipeline

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Abstract: With the increasing use and complexity of urban natural gas pipelines, the occurrence of accidents owing to leakage, fire, explosion, etc., has increased. Based on Quantitative Risk Analysis (QRA) models and Geographic Information System (GIS) technology, we put forward a quantitative risk simulation model for urban natural gas pipeline, combining with a multi-level grid-based pre-warning model. We develop a simulation and pre-warning model named QRA-Grid, conducting fire and explosion risk assessment, presenting the risk by using a grid map. Experiments show that by using the proposed method, we can develop a fire and explosion accident pre-warning model for gas pipelines, and effectively predict areas in which accidents will happen. As a result, we can make a focused and forceful policy in areas which have some potential defects in advance, and even carry out urban planning once more, rebuilding it to prevent the risk.

Keywords: natural gas pipeline; quantitative risk analysis (QRA); pre-warning; multi-level grid; geographic information system (GIS)

1. Introduction

With the long-term use of urban natural gas pipelines, large-scale laying and increasingly complex, related accidents such as leaks, fires and explosions have occurred frequently [1]. According to statistics, there have been many serious natural gas accidents at home and abroad in recent years [2]. For example, on 9 May 2009, the Russian natural gas pipeline in Moscow leaked and exploded, causing the largest urban fire in Moscow since the end of World War II; and on 22 November 2013, the oil pipeline in the Hangdog District of Qingdao City, China, exploded, causing 62 deaths, 136 injuries and a direct economic loss of 750 million RMB. It can be seen that natural gas accidents with great destructive power should not be ignored, and it is necessary to establish a natural gas pipeline accident early warning model.

In the area of natural gas pipeline accident risk assessment and accident warning, researchers have done a lot of long-term research, and achieved certain results. In the early 1970s, the United States began to evaluate the risk of oil and gas pipelines, then summarized 22 basic factors that caused pipeline failure [3]. Since then, qualitative research methods such as Analytic Hierarchy Process (AHP), Fuzzy Mathematics (FM), Fault Tree Analysis (FTA), and Data Envelopment Analysis (DEA) have been used by scholars and research institutions for natural gas accident risk analysis [4–7]. In 1992, W. Kent Muhlbauer summarized the existing research results in the Pipeline Risk Management Manual, this being for the first time a quantitative risk assessment of oil and gas pipelines [8].

It is universally accepted as a standard for the development of risk assessment software in countries around the world, and has been successfully used for the development of multiple systems, and has been used continuously for more than 10 years. In the early 1990s, Canada established a special pipeline risk assessment committee, which is responsible for the implementation of the pipeline risk assessment management technology development program in the country [9]. The UK Health and Safety Executive Committee developed the MISHAP software package in the pipeline risk management project study to calculate the risk of pipeline failure [10]. The International Gas Union (IGU) conducted a risk assessment study from 1997 to 2000 [11]. In 2000, it issued a concluding report, and proposed methods for risk assessment, environmental risk assessment, and risk control. Several researchers used quantitative risk assessment methods to establish GIS-based natural gas pipeline warning systems [8,12]. Through this research and analysis, quantitative risk assessment has become one of the important ways to improve the performance of urban gas pipelines while avoiding risks. However, most of the analysis models in the current research are not completely considered in the accident types. They are mostly directed to the consequences of an accident or a certain part of the analysis process. They lack an early warning grading standard, and urgently require an integrated quantitative risk analysis method.

Through analysis of the above research and application, we could see that the key to effectively resisting disasters is to accurately predict and evaluate the occurrence, development, and destruction of disasters, and then use Quantitative Risk Analysis methods to analyze the impact of accidents. This method provides an effective solution to the above problems, but lacks grading for different levels of warning. In addition, GIS is currently the most widely used spatial data processing technology, and the simulation system is constructed on the GIS platform to more vividly simulate the entire disaster process [13,14]. However, QRA modeling always involves the modeling of spatial elements when quantitatively assessing regional risks. The gas pipeline network discussed in this paper is the line element, the accident point, and the gas point is the point element. It is generally modeled as a vector element; the spatial grid model is a very intuitive way to quantify risk. It is very intuitive, vivid and easy to quantify based on the grid to model point features and line features. Through the above two technologies, this paper adds a graded pre-warning model, quantifies the risk into the spatial grid, proposes a QRA-Grid model, and develops a quantitative risk simulation and early warning system for urban natural gas pipelines.

2. Methods

This section describes in detail the QRA-Grid model and the general method of establishing a natural gas pipeline warning system. This is to be based on the quantitative risk assessment model, combined with pipeline parameters, environmental parameters, leakage parameters, etc., to calculate the pipeline failure rate, leakage, and analyze the physical effects of fire and explosion. Then a single point of fire and explosion accident simulation was performed to analyze the accidents affecting people and buildings and to realize risk assessment. According to the results of risk assessment, a warning and graded model was proposed for the first time to provide different degrees of pre-warning for disasters. Then the risk can be quantified and visualized into an urban grid model. The research process is shown in Figure 1.

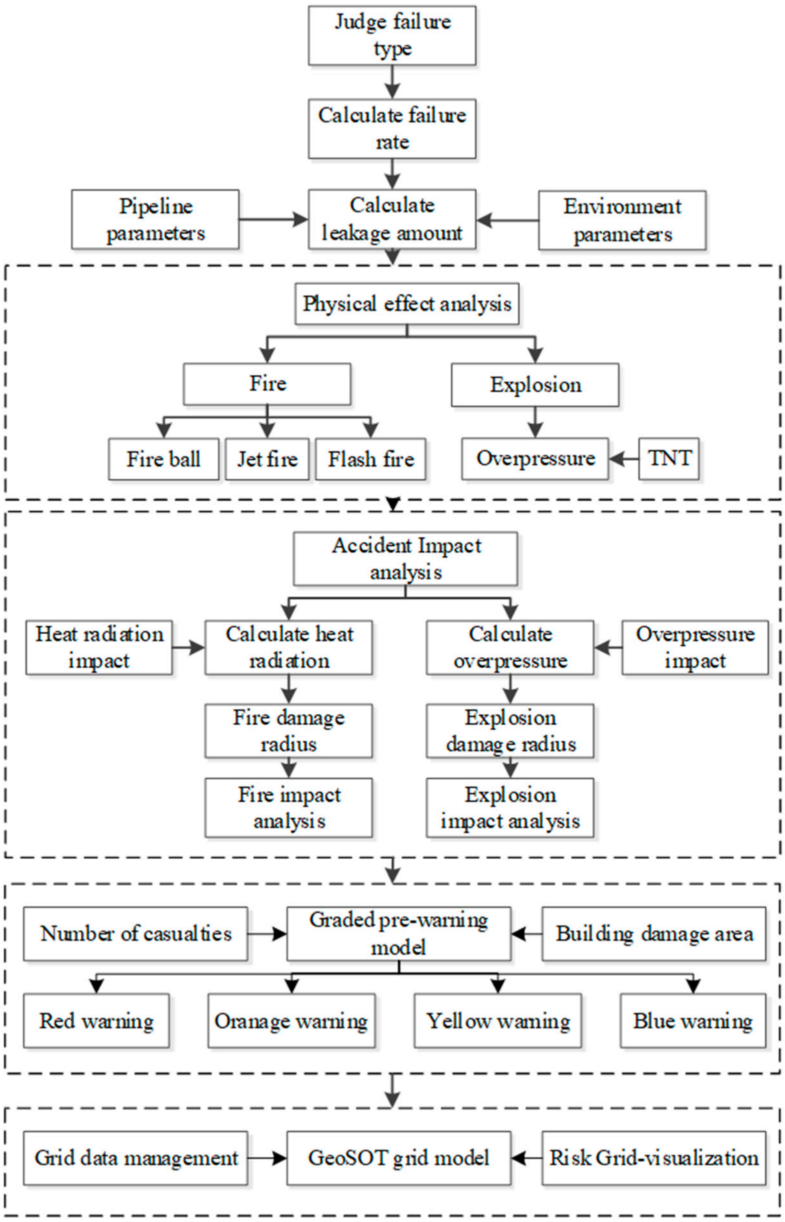


Figure 1. Research process.

2.1. Quantitive Risk Analysis

2.1.1. Calculation of Failure Rate

The failure mode of the natural gas pipeline is usually caused by the external network or the inherent risks of the pipeline. Pipeline failure rate is usually defined as the number of failures per year per unit length of pipeline [1,15]. Thus,

$$\varphi_i = \sum_j \varphi_{i,j,0} K_j(a_1, a_2, a_3, \ldots) \quad (1)$$

where φ_i is the failure times of type i accident, for per unit length per year (1/km·year); i is the assumed type of failure, generally including small holes (size less than 2cm), large holes (greater than 2cm, smaller than the pipeline diameter), fracture (complete rupture, size greater than the pipeline diameter); j is the cause of failure, including third-party damage, design defects, corrosion, ground activities, etc.; $\varphi_{i,j,0}$ is the probability of different failure types caused by a specific failure cause; K_j is the correction reason for the corresponding failure cause, which is a weighting factor, and can be obtained by expert scoring; A_k is the correction equation parameter, and for third party damage it includes depth of burial, wall thickness, ground population density, preventive measures, etc.

According to EGIG (European Gas Pipeline Incident Data Group) statistical data, third-party damage has the greatest impact on pipeline failure rate relative to other impact factors. When condition permits, it can directly take 5.75×10^{-4}/km·year [15].

2.1.2. Calculation of Leakage Amount

One of the most common failure modes in pipeline is leakage. The calculation method of leakage flow rate is different for different pipe diameters and sizes of pipe holes, including the calculation of the model corresponding to the small hole model, the pipe model and other pipe diameters. When the conditions permit, the low-pressure thermostat can be used to stabilize the pore model under one-dimensional adiabatic conditions [16,17]. The following mainly introduces the small hole model.

Assume that the gas which has leaked through the small holes conforms to the ideal gas state equation. The formula for calculating the gas leakage flow based on the Bernoulli equation is as follows:

$$q = pS\sqrt{\frac{2nM}{(n-1)GT}\left[\left(\frac{p_0}{p}\right)^{\frac{2}{n}} - \left(\frac{p_0}{p}\right)^{\frac{n+1}{n}}\right]} \tag{2}$$

where q is the gas leakage amount (kg/s); p, the internal pipeline pressure (Pa); S, the area of the pipeline crack (m^2); M, the molecular weight of the gas in the pipeline (kg/mol); G, the gas constant (8.314J/(mol·K)); T, the temperature of the gas in the pipeline (K); p_0, the ambient pressure (Pa); and n, the adiabatic exponent, i.e., the ratio of constant pressure specific heat capacity to constant volume specific heat capacity.

2.1.3. Physical Effect Analysis

When a dangerous substance leaks, a fire can be caused by the ignition source. If the leaking gas concentration is within the explosion limit, an explosion accident may occur. High-temperature radiation during combustion and shock waves at the time of explosion are the main causes of damage, including damage to the human body and buildings.

1. Fire physical effect analysis

According to previous academic studies, fires can be divided into three models according to the shape of the flame: Fire ball, jet fire, flash fire. The natural gas pipeline failure leakage is mostly small hole leakage, and the fire caused by the fire is mostly jet fire [18]. In the jet fire model, the heat radiant flux formula accepted at a specific location is as follows:

$$Q = \frac{\gamma\tau q H_c}{4\pi r^2} \tag{3}$$

where Q is the thermal radiation (W/m^2); γ, the radiance coefficient (0.2); τ, the atmospheric transmittance (1); q, the leakage flow (kg/s); H_c, the heat of combustion of the natural gas (5.56×10^4 KJ/kg); and r, the distance (m).

2. Explosions physical effect analysis

Considering that the main form of explosion caused by urban natural gas pipeline leakage accidents is overpressure, the shock wave overpressure model is selected as the analysis basis for the damage hazard scope of explosion accidents. The most widely used method for calculating the blast wave is the TNT equivalent method, which compares the flammable gas cloud explosion result with the explosive explosion result and is an empirical model [19]. The formula for calculating the overpressure explosion pressure accepted by a specific location target is as follows:

$$\Delta P = 0.71 \times 10^6 \left| \frac{R}{\sqrt[3]{m_{TNT}}} \right|^{-2.09} \tag{4}$$

where ΔP is shock wave pressure (Pa); R is distance (m); m_{TNT} is TNT equivalent (kg).

$$m_{TNT} = \frac{m_d \Delta H_d}{Q_{TNT}} \tag{5}$$

where ΔH_d is the explosion heat of natural gas, generally taking the heat of combustion 5.56×10^4 KJ/kg; Q_{TNT} is the explosion heat value of the standard TNT explosion heat, 4.2 MJ/kg; m_d is the mass of natural gas involved in explosion (kg) and can be calculated as follows:

$$m_d = 3\% m \tag{6}$$

where the efficiency factor of methane in natural gas is 3% generally, and the proportion of the total mass of leaked gas is 3%. m is the leakage quality (kg) and can be calculated as follows:

$$m = qt \tag{7}$$

where q is the gas leakage flow (kg/s); t is the duration of leakage (s).

2.1.4. Accident Impact Analysis

When determining the high-risk areas of fire and explosion accidents, it is necessary to select the corresponding heat radiation and shock wave destruction criteria based on the calculation formula of heat radiation and shock waves in the physical effect model. Then different damage radii can be obtained, which can simulate the impact of accidents at specific locations on the human body and buildings. In addition, it can also be extended to the entire city pipeline, through the analysis of dangerous distance buffers, to determine the city's accident risk area. The damages of heat radiation and shock waves to the human body and buildings/equipment are shown in Table 1, Table 2, and Table 3, respectively [20–22].

Table 1. Impact of heat radiation from fires on people and buildings/equipment.

Radiation Intensity (kw/m^2)	Impact on People	Impact on Buildings/Equipment	Influence Division
37.5	1 min, 100% people die; 10 s, 1% people die;	All operating equipment are damaged	A
25	10 s, serious injury	Minimum energy for wood burning with no fire and long radiation	B
12.5	1 min, 1% people suffer serious injury; 10 s, first-degree burn	Minimum energy for plastic melting with flame	C
4	Feel pain, even burns, above 20 s	30 min, glass broken	D

Table 2. Impact of overpressure explosion pressure from explosions on people.

The Threshold ΔP that the Human Body can withstand (0.1 MPa)	Impact on People	Influence Division
1.0	Most people die 70%~100%	A
0.75	Severe internal organs or death (10%)	B
0.40	Auditory organ hurt or fracture	C
0.25	Slight hurt	D

Table 3. Impact of overpressure explosion pressure from explosions on buildings/equipment.

The Threshold ΔP that Buildings/Equipment can withstand (0.1 MPa)	Impact on Buildings/Equipment	Influence Division
2.5	Destruction of steel structure	A
1.5	Earthquake-resistant reinforced concrete damage, small houses collapse	B
0.25	Minimum energy for plastic melting with Wall crack	C
0.06	Door and window glass broken	D

Different standards correspond to different injuries. The model can be used to simulate the damage situation of the site where the accident has occurred according to the actual situation, and can also analyze the targets to be protected in advance to obtain the damage that the human body and buildings may suffer. Besides, the model can also analyze the dangerous distance buffer of the natural gas pipeline network of the whole city, and select the buildings that are more dangerous due to pipeline accidents in the city. Among them, for the impact analysis of the entire pipeline network, the model selected the C-level damage standard for thermal radiation damage to buildings and the B-level damage standard for explosions on building damage, as well as identifying the buildings that were potentially more harmful, most of which were wooden buildings.

2.2. Pre-Warning Model

2.2.1. Graded Pre-Warning Model

For the fire and explosion accidents that may be caused by the leakage and diffusion of the gas pipeline, this paper proposes to predict and early-warn about the accident consequences with the two indicators of the number of casualties and building damage area, and establish a forecast and early warning model:

$$\begin{aligned} S &= \pi R^2 \\ Num &= S \times D \end{aligned} \tag{8}$$

where R is the injury radius, and D is the population density (person/square kilometer).

Based on the early warning and forecasting model, the population density factor is added, and the warning level is judged by calculating the number of casualties within the scope of the accident injury. The warning levels of the warning are red, orange, yellow and blue. The corresponding warning limits are as follows: In order to effectively link the early warning prediction model with the initiation of the emergency plan, the function of early warning-emergency linkage is realized.

Hereby, the number of casualties in the four levels of early warning has been unified with the grading standards in the emergency plan for public emergency prepared by the State, and the division of the level of early warning emergency response has also been unified [23]. In particular, the number of casualties estimated by the warning prediction model includes both deaths and serious injuries.

The four levels of warnings are shown as follows:

- Red Warning—Corresponds to "Special Major Gas Incident (Level I)"

Fires, explosions or gas leak occurring in long-distance gas pipeline in a city, city gate station and high pressure B (2.5 MPa $\geq$ P $\geq$ 1.6 MPa) grade gas supply system, transmission and distribution station, liquefied natural gas reserve base and liquefied petroleum gas reserve base. The accident has led to more than 30 deaths, or more than 100 serious injuries, or direct economic losses of more than RMB 100 million, which seriously affected gas supply and endangered public safety.

- Orange Warning—Corresponds to "Significant Gas Incident (Level II)"

Fires, explosions or gas leak has occurred in special vehicles for gas transportation or gas supply systems such as sub-high pressure natural gas supply systems, compressed natural gas supply stations, liquefied natural gas supply stations, liquefied petroleum gas storage tank stations, liquefied petroleum gas pipeline networks (including gasification or gas mixture gas supply systems) and or bottled liquefied gas supply stations. The accident caused deaths of more than 10, but less than 30 people, or serious injuries of 50 to 100 people, or direct economic losses of more than RMB 50 million to less than RMB 100 million, which seriously affected gas supply in local areas and endangered public safety.

- Yellow Warning—Corresponds to "Larger Gas Incident (Level III)"

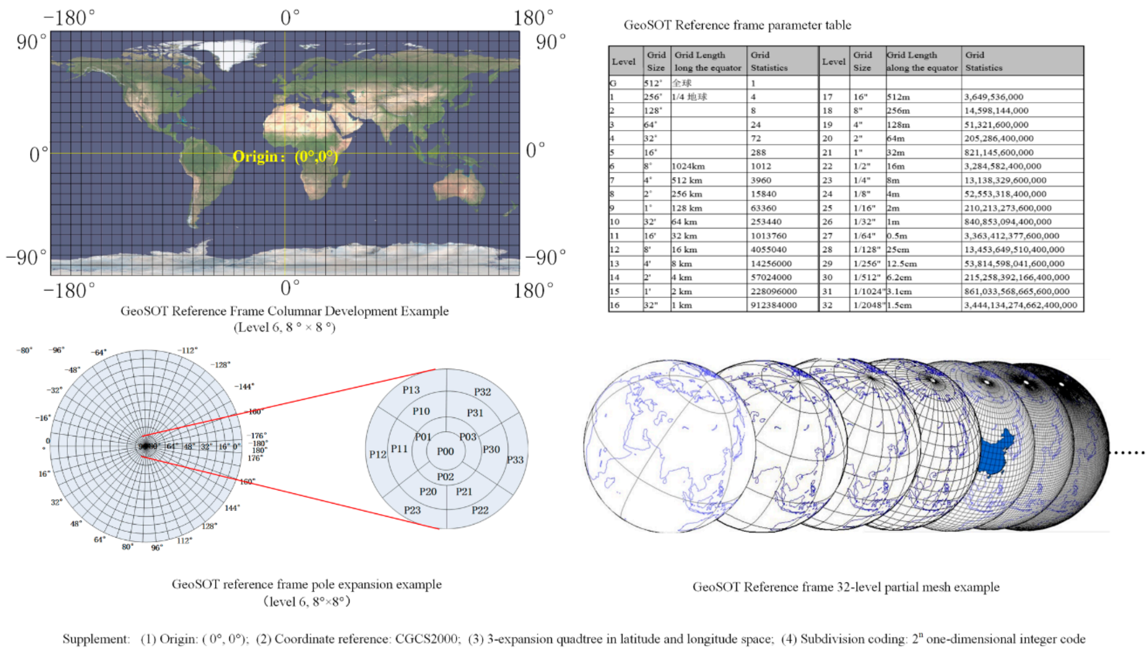
Fires and explosions in the gas supply system resulted in deaths of more than 3 persons and less than 10 persons, or severe injuries of 10 to 50 persons, or direct economic losses of 10 million to 50 million yuan, which affected gas supply in local areas and endangered public safety.

- Blue Warning—Corresponds to "General Gas Incident (Level IV)"

Gas leaks from gas supply systems at all levels resulted in deaths of less than 3 persons, or serious injury to 10 or less, or direct economic losses of less than RMB 10 million, which affected regional gas supply and endangered public safety.

2.2.2. Grid-Based Warning Map

Grid-based fine management is an important direction of urban research. More and more people, economics, environment and other data are selected in the form of grid for data organization and expression. The form of the grid is convenient for dynamic management and real-time update. Urban grid management is based on the city's digital spatial data. According to the administrative division, the internal area is divided into several grid units according to a certain division scale, forming different levels of a multi-level grid. The global GeoSOT grid proposed by Cheng et al. is very suitable for urban grid management because of its hierarchical nesting, high computational efficiency, and easy conversion of latitude and longitude [24]. We also introduce GeoSOT grid in this model. The GeoSOT gird model is shown in Figure 2 as follows:



Level	Grid Size	Grid Length long the equator	Grid Statistics	Level	Grid Size	Grid Length along the equator	Grid Statistics
G	512°	全球	1				
1	256°	1/4 地球	4	17	16"	512m	3,649,536,000
2	128°		8	18	8"	256m	14,598,144,000
3	64°		24	19	4"	128m	51,321,600,000
4	32°		72	20	2"	64m	205,286,400,000
5	16°		288	21	1"	32m	821,145,600,000
6	8°	1024km	1012	22	1/2"	16m	3,284,582,400,000
7	4°	512 km	3960	23	1/4"	8m	13,138,329,600,000
8	2°	256 km	15840	24	1/8"	4m	52,553,318,400,000
9	1°	128 km	63360	25	1/16"	2m	210,213,273,600,000
10	32'	64 km	253440	26	1/32"	1m	840,853,094,400,000
11	16'	32 km	1013760	27	1/64"	0.5m	3,363,412,377,600,000
12	8'	16 km	4055040	28	1/128"	25cm	13,453,649,510,400,000
13	4'	8 km	14256000	29	1/256"	12.5cm	53,814,598,041,600,000
14	2'	4 km	57024000	30	1/512"	6.2cm	215,258,392,166,400,000
15	1'	2 km	228096000	31	1/1024"	3.1cm	861,033,568,665,600,000
16	32"	1 km	912384000	32	1/2048"	1.5cm	3,444,134,274,662,400,000

Figure 2. GeoSOT grid model [25].

The basic level we selected is the 16th level, and the spatial resolution is 1km, which is convenient for fusion and correlation analysis with other 1km city data. If we need to refine the scale, we can also choose the 19th level of 100 meters, the 22nd level of 10 meters, and the 26-level level of 1 meter. Different scale grids can be applied to different levels of accident warning, and also support grid accident probability quantification at different scales. According to the early warning model in Section 2.2.1, four levels correspond to four colors, and grid coloring is very suitable for expression. More importantly, there are accident alarms in the grid, which can quickly identify the safety leaders in the area and improve the early warning efficiency.

3. Experiments

3.1. Experiments Design

Using GIS technology to validate our QRA-Grid model, and establish a natural gas pipeline accident early warning system can achieve the analysis of the impact of fire and explosion accidents on human bodies and buildings, analysis of accident danger areas, and can also conform to the current general trend of smart city construction [26,27].

To verify the feasibility of the proposed method, we conducted an urban natural gas pipeline risk simulation and pre-warning system by using the ArcGIS Engine (of ESRI) secondary development module. The system has the following functions: (1) Calculate the failure rate; (2) calculate the leakage amount; (3) analyze physical effect; (4) analyze accident impact; (5) grade the impact and pre-warn the risk; and (6) quantify and visualize in grid format.

The system uses the complete natural gas pipeline network data and the basic geographical database of a city, provided by Gas Co., Ltd, Leshan, Sichuan. The specific spatial layer data mainly includes data such as pipelines, surge tanks, accident addresses, valves, residential areas, and streets.

Among them, the pipeline data and its attribute data table structure are shown in Table 4:

Table 4. Pipeline information table.

Name	ID	Data Type	Can be Null
Pipeline number	OBJECTID	int	N
Shape	Shape	geometry	N
Pipeline diameter	Diameter	double	N
Pipe length	Length	double	N
Nearby information description	Description	string	Y
Install date	Install_date	date	Y
Repair date	Repair_date	date	Y
Buried depth	Depth	double	Y

3.2. Experiments

With regard to a natural gas single-point leakage accident, the degree of harm suffered by people and buildings within a certain area around the accident point may be simulated based on the jet fire model and by inputting parameters such as leakage area, internal pipe pressure, gas temperature, leakage model, and leakage time. Table 1 lists the five and four levels of impacts of various durations of fire to people and buildings, respectively, and Table 2 lists the explosion levels. Different levels are labeled by different self-defined colors (levels of damage impact, in the legend of Figure 3). Under the condition that the leakage opening area is 300 mm^2, the internal pipe pressure is 0.1 Mpa (standard atmospheric pressure), gas temperature is 20 °C, leakage model is the small-hole model, and leakage time is 5 min; then, according to Tables 1–3, the harm radius of different levels can be calculated. The harm that a fire and an explosion do to people and buildings is shown below in Figure 3. According to regional statistics provided by the Statistics Bureau of Leshan, the population density of the study area is 38,507/km^2. Then the harm radius r can be calculated inversely according to formula 3, and the specific formula is as formula 9. So, when the A-level in the human injury standard is selected, that is, Q is 37.5 kw/m^2 (shown in Table 1), and the radius r is calculated to be 4.38 meters.

$$r = \sqrt{\frac{\gamma \tau q H_c}{4\pi Q}} \tag{9}$$

Based on the damage radius, the area of the injury area can be calculated. Combined with the population density, the final predicted death number is 2.33. According to the Graded pre-warning model, a blue alarm is determined. At the same time, according to the A-level injury standard for human death, the damage radius is 8.48 meters, and the final predicted death toll was 6.10, which is judged as a yellow alarm. We selected the 22nd level in the GeoSOT grid to visualize the local study area (Figure 4).

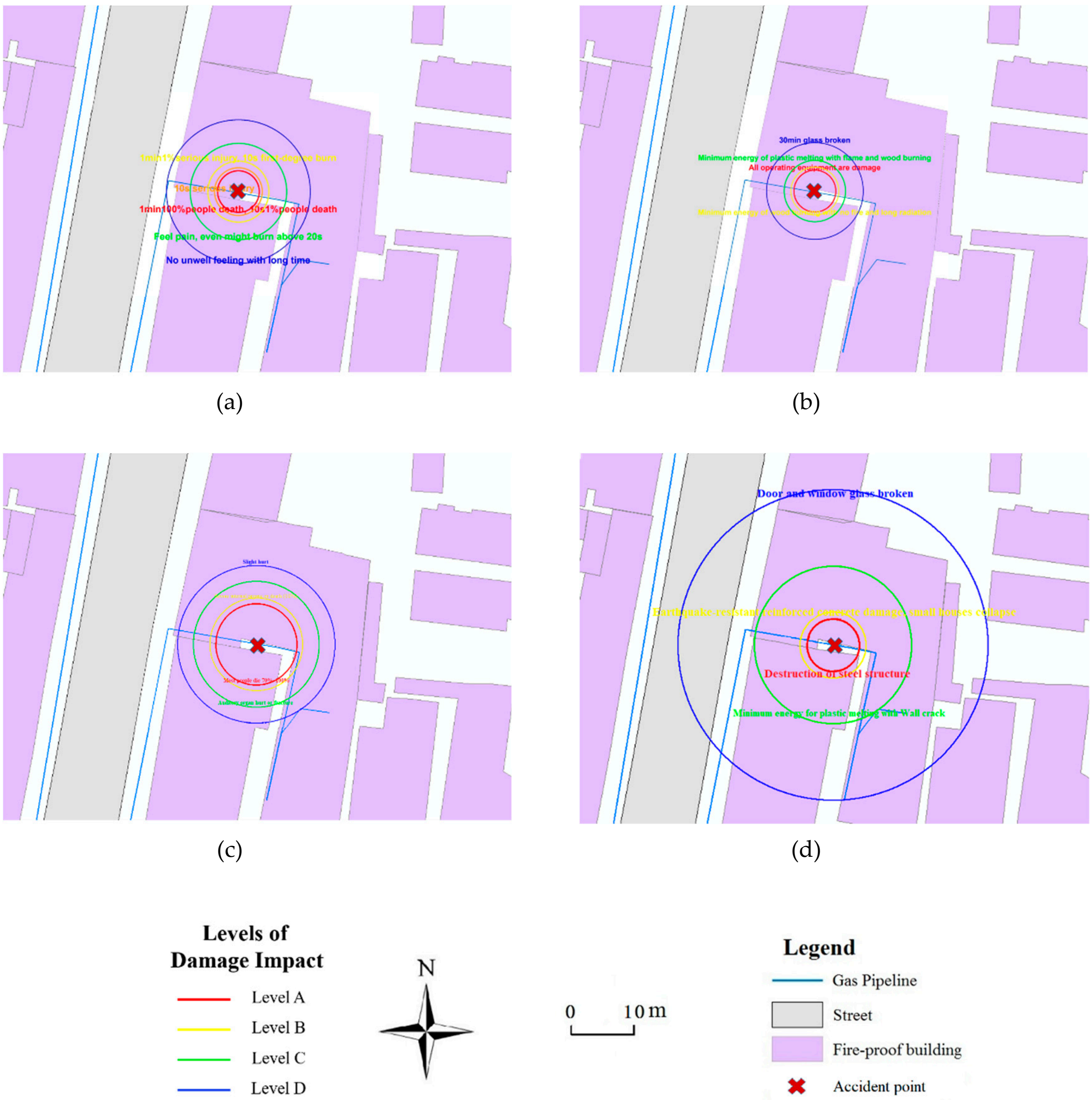


Figure 3. The harm to people and buildings/equipment: (**a**) Fire harm to people; (**b**) Fire harm to buildings/equipment; (**c**) Explosion harm to people; (**d**) Explosion harm to buildings/equipment.

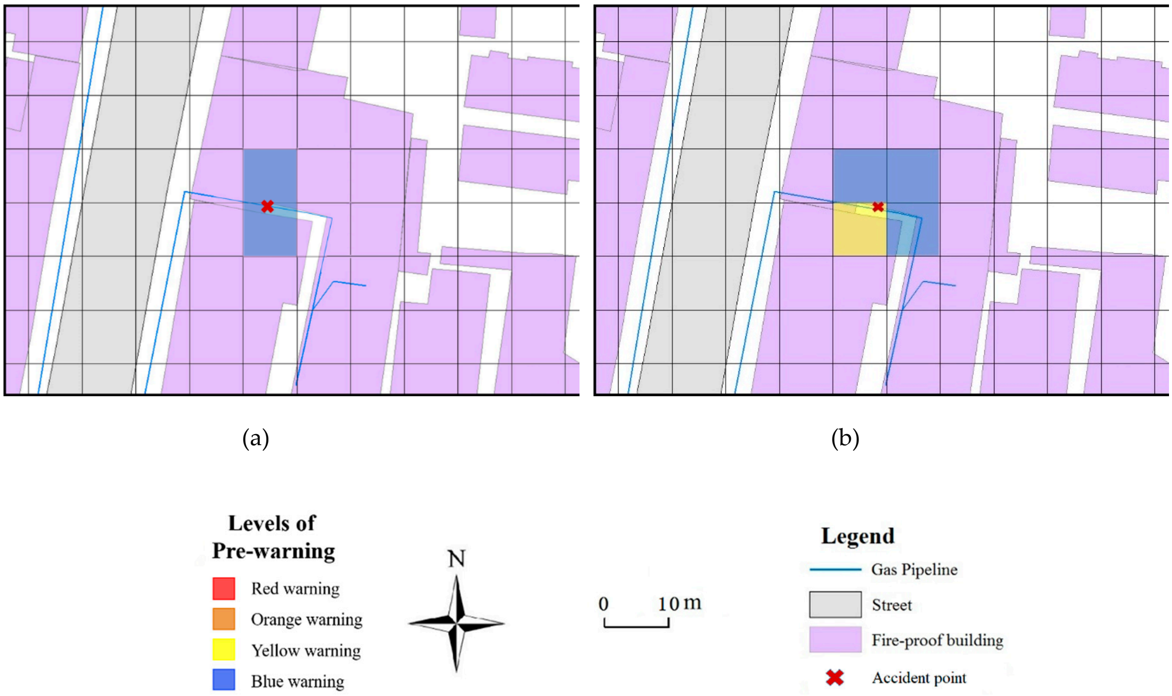
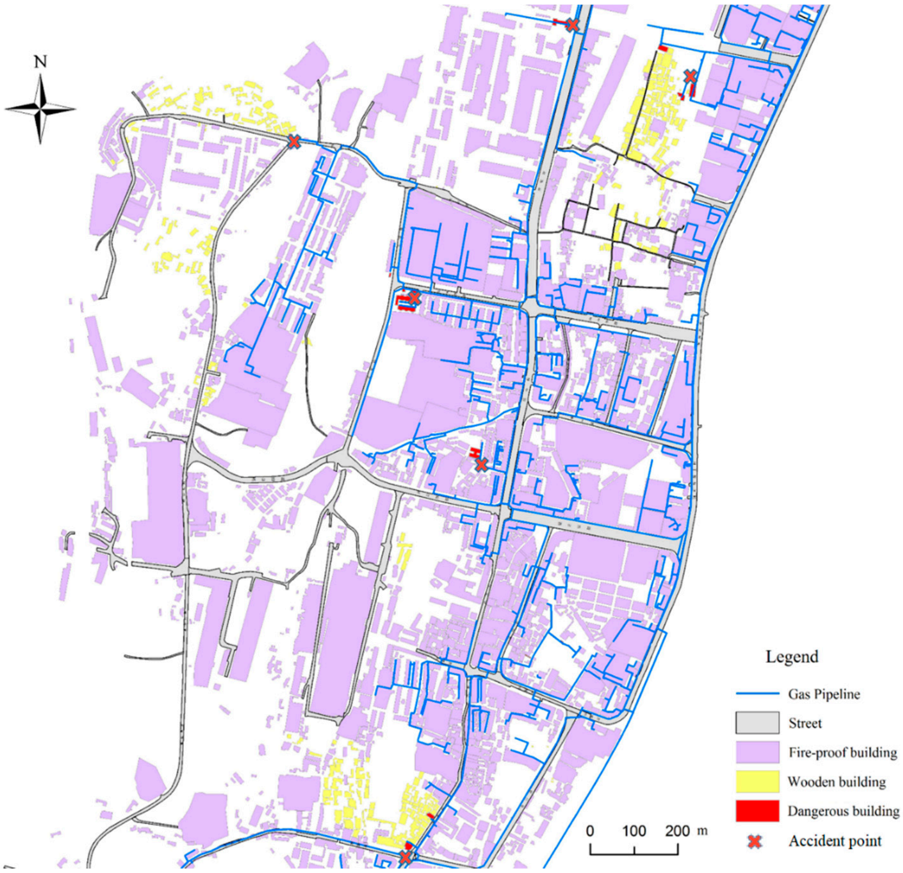
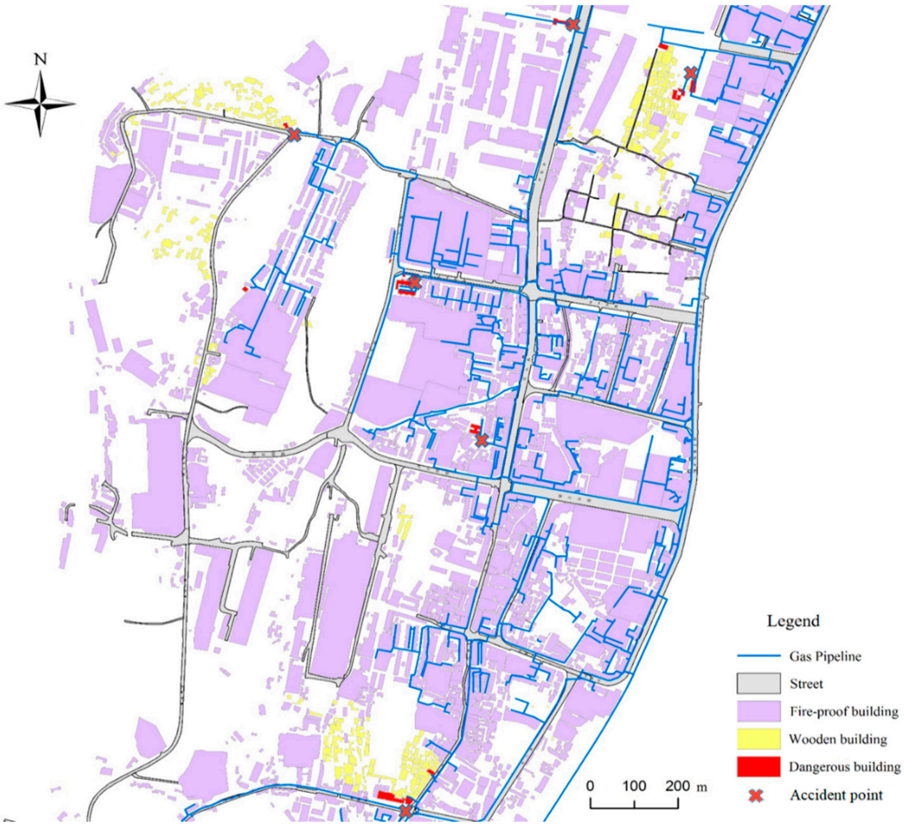


Figure 4. The grid-based pre-warning map: (**a**) Fire risk pre-warning; (**b**) Explosion risk pre-warning.

In order to conduct a risk analysis of the entire study area, we randomly selected six accident points in all areas. When a fire accident occurs at the selected point, according to the C-level damage standard of the building for the thermal radiation, the calculated damage radius is selected for buffer analysis to determine the dangerous building that is affected by the urban pipe network fire. The result is shown in Figure 5a. When an explosion accident occurs at a selected point, the dangerous building of the urban pipe network explosion accident is determined according to the B-level damage standard of the building according to the overpressure value, and the result is shown in Figure 5b. Based on the above damage radius, hazard house and damage classification, the grid-based risk visualization of the whole city was carried out (Figure 6). The 19th level grid is selected to visualize the risk.



(a)



(b)

Figure 5. Hazard Buildings: (**a**) Fire hazard buildings; (**b**) Explosion hazard buildings.

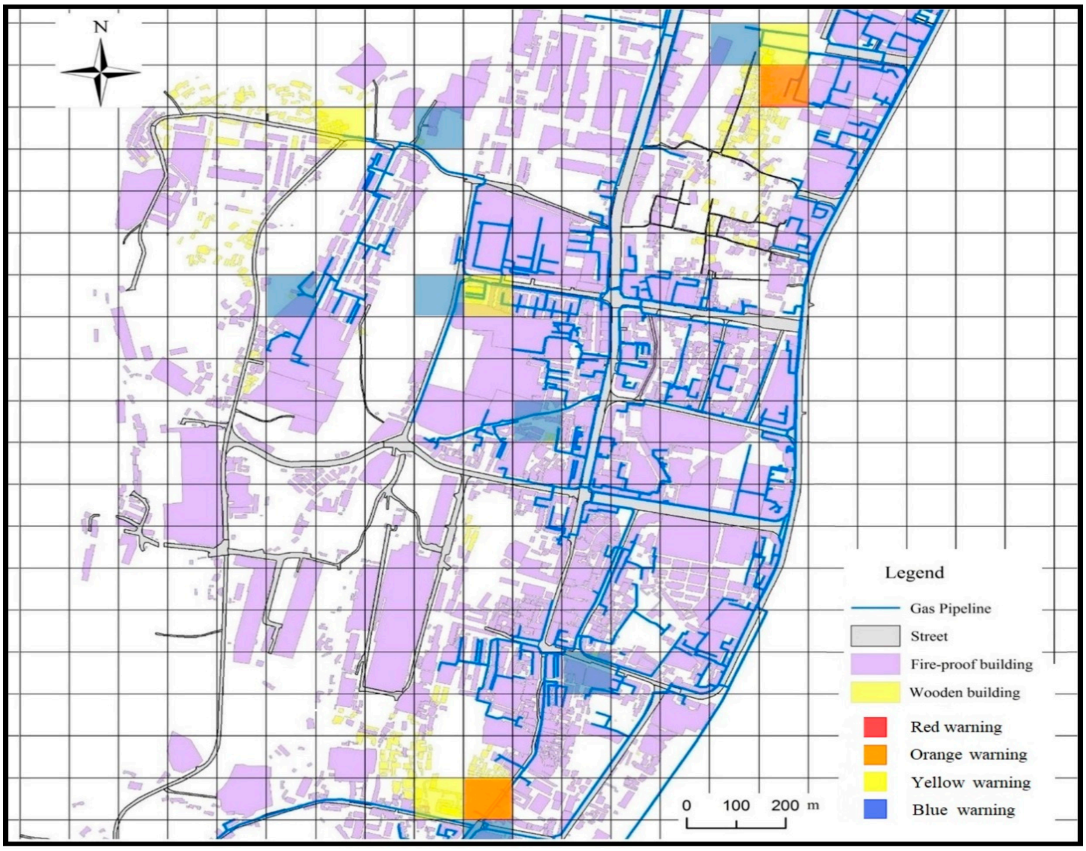


Figure 6. The grid-based risk simulation map.

3.3. Analysis of Experiment Results

Through the experiments above, we can analyze the following conclusions:

(1) It is feasible to use the QRA model to solve the accident damage radius of a single point in the reverse direction.

Combine the different levels of damage influences in Tables 1–3, calculate the damage radius r, and use different colors of circles to identify different levels of damage. This method is very intuitive and feasible, and it can directly see that different areas will be harmed to varying degrees. By calculating the damage area, combined with statistical data, such as population and economic data, it can also calculate the population and socio-economic damage.

(2) Using QRA model on several points, it is possible to predict the disaster situation throughout the city.

Several points are selected throughout the study area for QRA analysis and obtained a risk assessment for the study area. According to the method we proposed, it is easy to analyze the accidents to examine the areas in which disasters may occur. By analyzing the above results, it is found that the buildings with fire and explosion hazards are mainly distributed in the concentrated areas of wooden buildings in the city. The density of the road network is large but generally narrow, and it is prone to secondary disasters, resulting in greater damage.

(3) Grid quantification is more intuitive and easy for city management.

Grid management is an important direction of urban development. Quantifying risk based on grid can be used to determine the risk value of a grid. The city risk management department assigns personnel according to the grid, and each manager is responsible for one or more grids. When the risk of the grid reaches a warning value, the grid manager will be reminded to deal with the incident in time. In the normal disaster simulation, the simulation results can help employees to pre-determine the impact degree of the accident and effectively check the hidden danger points of the pipeline network. The government will publicize and educate the construction areas that may be affected, pay attention to prevention and control, and even carry out secondary planning for urban pipe networks and construction areas to fundamentally prevent and resist the occurrence of disasters.

4. Conclusions

The occurrence of natural gas pipeline accidents in cities is often accompanied by serious disasters such as fires and explosions, which have great potential for destructive power. This article proposes a QRA-Grid model to form a set of methods for determining the direct impact of natural gas accident fires and explosions, and then perform risk quantification and visualization. At present, the main functions have been realized through related software and hardware support. The research work of this paper is mainly reflected in the following:

(1) A systematic analysis and discussion on the impact analysis of urban natural gas pipeline accidents was carried out. The failure rate, leakage, fire and explosion models of the pipeline network were summarized and classified in detail, and the characteristics of different research methods were compared and analyzed.

(2) Using the GIS-based quantitative risk assessment method to analyze the impact of accidents: Calculate the damage radius according to the standards of human body and building subjected to thermal radiation and shock waves. Using GIS development tools, the impact range of single-point accidents is simulated in the form of contours, and the safety distance buffer analysis of the pipeline network is carried out to analyze the accident danger area of the whole city.

(3) Grid models are used to quantify and visualize risk. The grid is a very intuitive way to visualize, and is also tightly integrated with the grid management of city management. When the risk of the grid reaches a warning value, the grid manager will be reminded to deal with the incident in time. By predicting the occurrence of fires, explosions and accidents, the system pre-designs and reconstructs potentially dangerous areas. This article also applies to other cities because it provides a general approach to building systems.

At present, the model is in the initial stage of construction. Problems such as the spread of accident risk in the pipeline and the linkage between early warning and emergency response have not yet been resolved. The author believes that these issues should be further studied and a more scientific and effective comprehensive system of pipeline should be established to provide more effective and reliable information for the majority of disaster reduction workers to prevent and resist the tremendous damage that may be caused.

Author Contributions: Shuang Li conceived, designed and performed the experiments, and wrote the manuscript; Guoliang Pu and Chengqi Cheng supervised the study; and Bo Chen offered helpful suggestions and reviewed the manuscript. All authors have read and approved the submitted manuscript, have agreed to be listed, and have accepted this version for publication.

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