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Big Data Mining in the Analysis of Factors Affecting the Occurrence of Natural Gas Incidents in East Azerbaijan Province (Iran)

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Abstract

In the past years, East Azerbaijan province in Iran has always been at the top of the number of incidents in the country in the reports related to the annual analysis of incidents of domestic natural gas subscribers. Despite planning and spending at the expense of previous years, there has been no significant reduction in incident statistics. The purpose of this article is to investigate the root factors affecting the occurrence of incidents in domestic consumers of natural gas in East Azerbaijan province and to provide control and reduction strategies for incidents. To study the statistical analysis of natural gas-related incidents, the big data mining data approach of natural gas incidents in East Azerbaijan province during the years 2014 to 2020 besides Pareto analysis, root analysis, and Delphi have been used. The results of data and information analysis indicate that the most important technical factors affecting the bite are: lack of proper installation of the chimney, use of non-standard chimneys, leakage due to seams between the chimney parts, the presence of cracks, and virtual blockage of the chimney.

Keywords: Natural gas incidents, Explosions and fires, Big data, Data mining.

1 | Introduction

The development and expansion of very complex and essential technologies in various industries, especially the chemical industry, has caused the philosophy of safety to change from the post-occurrence approach to the pre-occurrence process. Natural gas is one of the most widely used energy sources, and its use is overgrowing [1]. Natural gas is a colorless and odorless gas that consists mainly of methane gas, and its specific density is about 65%. Due to its lighter air, in case of leakage from pipes and piping connections, a large part of it has moved upwards. It collects under the roof, and the other piece mixes with the constituent elements of the air and, due to the slightest spark, causes fire or explosion in the building. But in the meantime, it is noteworthy that according to the available statistics, what threatens the consumers of natural gas the most is not gas leakage and the production of explosions and fires.

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Still, the incomplete combustion of gas and carbon monoxide production, which annually kills more it takes from a thousand people in the country. Research has shown that carbon monoxide poisoning is the most common cause of death from fuel-induced inhalation injuries [2]. In Iran, due to the increasing population and widespread use of vehicles and other sources of fossil fuels, there are significant deaths due to carbon monoxide poisoning, and gas poisoning is one of the most common causes of death [3]. Therefore, the study of the causes of carbon monoxide poisoning caused by gas appliances, which are currently the central part of heating equipment used by people, is more felt. Due to the anticipated safety measures, the risks of gas leaks and the production of explosions and fires are minimal, and negligence, carelessness, or little consumers' information cause incidents every year [4]. Investigating the factors affecting the occurrence of incidents in domestic consumers of natural gas has increased people's awareness of the factors affecting the event. As a result, the consequences of the risks of incidents will be reduced. It will also try to improve the existing standards by upgrading them. With proper planning for the project results, natural gas incidents such as poisoning, suffocation, death, explosion, and fire in residential areas and subscribers are expected to be reduced. Mousavi Rizi et al. [5] identified effective risks using the ET & BA method which is a suitable tool for identifying errors by tracking the energies in it. Experts' verbal variables in the fuzzy environment were used to allocate the risks. The results showed that kinetic energy is one of the most important energies of the system and human errors during operation are the most risk factors.

The inability of human senses to detect carbon monoxid emissions, is the most important stakes, the use of carbon monoxide detectors and alarms, extensive training for users through medias and implementation of 22 national building regulations were recommended as safeguards [6]. East Azarbaijan province in Iran has always been at the top of the number of incidents in the country in recent years in the reports related to the annual analysis of household natural gas subscribers' incidents. A study of carbon monoxide production and emission factors in 2020 shows that the most crucial element in the production and emission of this toxic gas in residential environments is the chimney and its related causes. The use of non-standard ducts, defects related to gas appliances, etc., pointed out. Also, among the fundamental reasons for fire and explosion incidents in the household sector of the whole country, with priority, we can mention the defects related to gas appliances, leakage from gas hose due to wear/decay, and leakage from hose due to defect or lack clamp [7]. According to the cases related to natural gas incidents in East Azerbaijan province in 2020, 219 were caused by explosion and fire, and 31 were caused by carbon monoxide (CO). The number of deaths due to explosions and fire incidents is nine, and the number of deaths due to carbon monoxide incidents is 43 people. In 2020, the number of injured due to explosions and fires was 63, and the number of poisoned due to gassing was 6; however, despite planning and spending considerable costs to implement various information programs during the previous years, unfortunately, there has been no significant reduction in the number of incidents. The present article has been compiled to present the factors affecting the occurrence of incidents caused by natural gas consumers (poisoning/injury, explosion, and fire) to prevent incidents caused by natural gas consumption as much as possible by implementing various information programs.

2 | Theoretical Foundations and Literature Review

Having rich resources from a factor of production can be considered a great opportunity and advantage for the host country if purposefully and adequately planned. Despite the large reserves in the country, it is observed that from time to time, especially in the cold seasons of the year, gas is cut off from factories and domestic companies and imported to meet the needs of the domestic sector, which is due to high consumption and growing gas and in general, energy in the country, especially in the household sector. Examining the trend of energy consumption in the world, it appears that in developing countries, the level of access to energy in the domestic and productive sectors will increase, which will improve the employment situation and create new job opportunities in these countries, as well as improve living conditions. And the welfare of the low-income strata of society will be. On the other hand, this trend is a warning for the worsening of pollution problems and the excessive increase of pollutants such as carbon dioxide in the air. Natural gas, as one of the valuable sources of energy in our country, is obtained from underground in the seas and on land, and by traveling thousands of kilometers and passing through various refinery facilities, and strengthening the pressure in the pipes, it is sent to the city and houses to a clean fuel in industry, supply and development of production and employment and provide welfare and heating needs in homes. Although this divine blessing is abundant in the underground resources in the geography of Iran and in the second rank in the world, in the operations of exploration, extraction, refining, and transfer to consumption, it has high costs that in the current situation with considering the law of targeted computers, how to use it should be managed and consumed in a way that does not burden the family economy. Optimal and rational consumption of natural gas requires two primary measures: 1) to improve the culture and behavior in consumption, and 2) to use appropriate equipment in the building and provide conditions that convert gas into energy in the fuel cycle and finally to fill space and other needs, but in any case, safety issues and tips that are recommended in this regard should be carefully considered so that the expected well-being of this energy does not cause loss of life and property [8]. Increased gas consumption is a matter of concern and requires planning and control, both due to environmental pollution and incidents. In order to plan and prevent natural gas incidents, it is necessary to know the root causes of incidents and how different factors affect their occurrence. Gas incidents often occur as a result of negligence, carelessness, or lack of knowledge of consumers. These incidents are divided into several categories in terms of technical reasons, the most important of which are: fire, explosion, and gassing [9].

2.1 | Fire

It is created by the proximity of flammable objects and objects to gas-burning devices, and then the fire spreads. Also, due to the use of non-standard rubber hoses near the connection to the heater or water heater, the hose gradually wears out and leaks, which ignites due to its proximity to the heat source, and if this happens, during sleep or in the absence of residents. The flame spreads and causes a fire in the house [9]. Fires are divided into the following four types:

- *Type: A burning of dry materials such as wood, fabric, cardboard, paper, etc., which leave ashes after burning. This type of fire is also called ashes.*
- *Type: B fire of flammable liquids such as gasoline, kerosene, alcohol, etc.*
- *Type: C combustible flammable gases such as liquefied gas vapors, natural gas, etc.*
- *Type: D fires that are caused by electricity, such as fires in electrical panels, transformers, wiring, etc.*

2.2 | Explosion

Due to the gradual leakage of gas and its accumulation in kitchens, bedrooms, living rooms, and receptions, conditions are created for the explosion. The spark from the on-off refrigerator of a house was the cause of the explosion leading to fire in many homes. In many cases, an explosion can occur when people enter these places and hit the power switch, as well as the diffused gas reaching the heater or water heater can be the cause of the explosion. The existence of an explosive concentration of gas in the air, if gas leakage continues, is a good condition for a blast. This concentration occurs mainly at low altitudes; a lot of gas accumulates in the upper parts of the room or kitchen but is not flammable [9].

2.3 | Choking with Gas

The most crucial cause of incidents for domestic and commercial consumers is gassing. As a result of insufficient oxygen supply or clogging of the combustion products, the gas burner is incompletely burned, and carbon monoxide gas is dispersed in space. Breathing this gas, which has a strong affinity for red blood cells, causes the formation of carboxyhemoglobin in the blood and deprives red blood cells of the ability to exchange oxygen and carbon dioxide. As a result, the person suffers from poisoning. If carbon monoxide continues to be inhaled, it deprives the poisoned person of the ability to move and any reaction and may eventually continue until death [10]. Such incidents sometimes occur because some people think natural gas no longer needs a chimney due to good combustion or that no major problem will arise if the vent is clogged. Several incidents occur due to several gas-burning appliances, especially wall-mounted water heaters, which are high-consumption appliances, in a small space with an area of 30 to 60 square meters. In some cases, insufficient oxygen supply by the gas burner due to blockage of doors and windows and even pores and joints that are effective in bringing air into the room has been the cause of many gas incidents.

2.4 | Literature Review

However, according to official annual statistics, some compatriots lost their lives due to carbon monoxide poisoning; for example, in 2006, about 973 people and 2007 about 1024 people (forensic medicine statistics). However, no study has been done to identify the causes and the necessary controls to reduce them. In European countries and the United States, the prevention of carbon monoxide poisoning in recent decades has been considered, and many measures have been taken to control injuries. The results of research in 17 European countries and the United States show that as a result of measures taken, the rate of carbon monoxide mortality has decreased in the last two decades, and most of the reported deaths were related to the use of carbon monoxide gas for suicide [11]. In order to investigate the incidents of natural gas household subscribers, after reviewing all incident reporting forms (494 incidents), they sorted the data in an excel file. The findings were then classified into two descriptive sections, including the season of the incident, the type of incident (bite/explosion and fire), the location of the incident, the type of incident damage (death/death/financial) and the gas burner and analytical findings including the root causes of the incident. Khosravirad et al. [12] investigated the root causes of process incidents at urban gas pressure reducing stations using functional hazard analysis and bow tie analysis techniques. First, by using two methods of analyzing functional hazards and failure situations and analyzing its effects, the locations of failures were identified along with their qualitative risk analysis. Then, to identify and analyze the causes of the incident, the bow tie analysis method was used. Yari et al. [13] conducted their studies using information recorded at Imam Khomeini hospital in Kermanshah, the main poisoning center in Kermanshah province, and the Forensic Medicine Organization during the years 85-87. In this study, in addition to describing the cases, the factors related to death in these patients have also been investigated. A total of 143 cases of CO poisoning occurred during the study period, of which 31 (21.7%) resulted in death. The mean age was 29.7 (standard deviation = 15.4). 52 people were men. Out of 84 cases of poisoning that occurred in 2007, 19 and 47 cases occurred in autumn and winter, respectively, which in total caused 11 deaths out of a total of 12 deaths this year. In the risk assessment process performed in this study, due to the lack of complete access to information and their weighting criteria, a hierarchical analysis technique was used to manage the risk of the urban gas distribution network. By examining the statistics of leakage events in the gas distribution network, effective factors were identified and the weight of each was determined by a hierarchical analysis process [14]. Lam and Cruz [15] analyzed the risk analysis for gas consumers' incidents using network modeling for Japan. In this paper, they propose a probabilistic network modeling method in which the intrinsic properties of risk factors for gas incidents at the consumer level are considered. In this approach, cause chains for gas incidents are formulated and network diagrams are made with probabilistic estimates. The results of their research showed that most gas incidents are caused by more than one risk factor. Fan et al. [16] examined the factors influencing carbon monoxide poisoning in western China's Sichuan province between 2008 and 2016. They obtained data on carbon monoxide poisoning statistics in Sichuan from the toxicology group, which included the month and year of the death, sex, age group, and manner of death. A total of 165 cases of carbon monoxide poisoning have been reported, of which more than 90% are fatal. Most poisoning occurs in the colder months of the year and among people aged 18 to 60. Hosseininejad et al. [17] examined carbon monoxide poisoning as a common cause in the world. Their study was conducted to describe and investigate the pattern of carbon monoxide poisoning in Iran. The results of their study were based on library records from 1999 to 2016, showing that there were a total of 6,372 victims of carbon monoxide poisoning. The estimated rate of carbon monoxide poisoning is 38.91 per 100,000. Mirahmadizadeh et al. [18] to identify the pattern of carbon monoxide poisoning in large cities of Fars province in southwestern Iran. This cross-sectional study was performed in 2011 on cases of abnormal carbon monoxide poisoning in Fars province. The target population was people who lived in 7 big cities under the supervision of Shiraz

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university of Medical Sciences, including Shiraz. The results showed that most incidents occurred in the cold months of the year and when they were asleep. Khadem-Rezaiyan and Afshari [19] examined the incidence of gas poisoning in northeastern Iran. They collected relevant information from files available at Imam Reza hospital in Mashhad between 2004 and 2011. In this statistic, 443 admissions related to carbon monoxide have been made, the age range of which was between 18.2-32.3 years and more than 60% of men. Accordingly, the mortality rate of the disease was higher in men than women. Ghosh et al. [20] reviewed and analyzed the causes of carbon monoxide poisoning in the UK between 2001 and 2010. The data of this analysis were collected from the statistical hospitalization data of UK hospitals. During the 10 years under review, 2463 admissions were made in UK hospitals, which is 48.7% of the total cases. Most factors occur in the colder months of the year (winter), which is 53% of admissions for people over 80. Sircar et al. [21] examined the factors affecting deaths due to carbon monoxide poisoning in the United States from 1999 to 2012. By studying the number of deaths available during the years under review, they identified 6,136 cases of monoxide poisoning, resulting in 438 deaths annually. They stated that the incidence rate of incidents in domestic natural gas was 54% and the highest mortality rate occurred in people over 85 years of age. Hamta et al. [22] developed a new Failure Mode and Effect Analysis (FMEA) framework for identification, prioritization and improvement of failure modes. A hybrid Multiple Criteria Decision-Making (MCDM) method combining Stepwise Weight Assessment Ratio Analysis (SWARA) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) was used to rank the risk of failure modes identified in FMEA. Lazar Farokhi [23] studied the assessment of the risks of gas transmission facilities in the 9 regions. After identifying the various activities of the facility, which included three safety measures for equipment, personal and environmental health, and 28 sub-criteria, from previous studies and surveys, and staff comments.

Studies of the above literature show that poisoning caused by natural gas incidents, as well as incidents caused by explosions and fires, has caused a lot of human and financial losses, and despite the offer of various solutions, the death rate is increasing. The importance of this issue has led to the study of technical and non-technical factors affecting the occurrence of natural gas incidents in East Azerbaijan province based on different methodologies and effective solutions to prevent natural gas incidents.

3 | Research Method

In this article, the factors affecting natural gas incidents in East Azerbaijan province during the years 2014 to 2020 have been studied. This research is of applied type. The collection method includes studies of the subject literature, files, and documents related to natural gas incidents occurring in East Azerbaijan province, Delphi technique, root analysis, and data mining. The data collection area of East Azarbaijan province includes five regions in Tabriz metropolis and 20 cities. The statistical population in this plan is the total incidents of natural gas household subscribers related to the years 2014 to 2020 in all areas of the province, including 20 regions of the city center with their sub-areas and five areas of Tabriz. The number of statistical samples is equal to the statistical population. The number of files reviewed in the spatial and temporal range of the project was 1604, which was fully observed, and its information and data were collected. In the data analysis section, all-natural gas incidents in 1604 cases have been investigated, and all the required information, including the causes of incidents, the conditions of incidents, the severity of incidents, etc., have been collected. Then, based on the analysis of the Pareto technique, the most critical factors related to biting and fire-related to natural gas incidents in East Azerbaijan province were determined and then using Delphi technique and during different meetings to investigate the root causes of each of the influential factors and also non-technical causes affecting the occurrence of incidents are known. Finally, a questionnaire was distributed to collect the opinions of the experts of the East Azarbaijan province gas company, and based on the consolidated statements, solutions to reduce and deal with the occurrence of natural gas incidents in East Azarbaijan province were presented.

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4 | Research Findings

In this section, the study results of 1601 cases related to natural gas incidents in East Azerbaijan province during the years 2014 to 2020 are presented.

4.1 | Spatial Distribution Analysis of Natural Gas Incidents in Tabriz Metropolis

Fig. 1 shows the spatial distribution analysis of natural gas incidents (fire/explosion and gassing) in the municipality of Tabriz during the years 2014 to 2020 and based on information 1601 files studied from the documents of the national gas company of East Azerbaijan province.

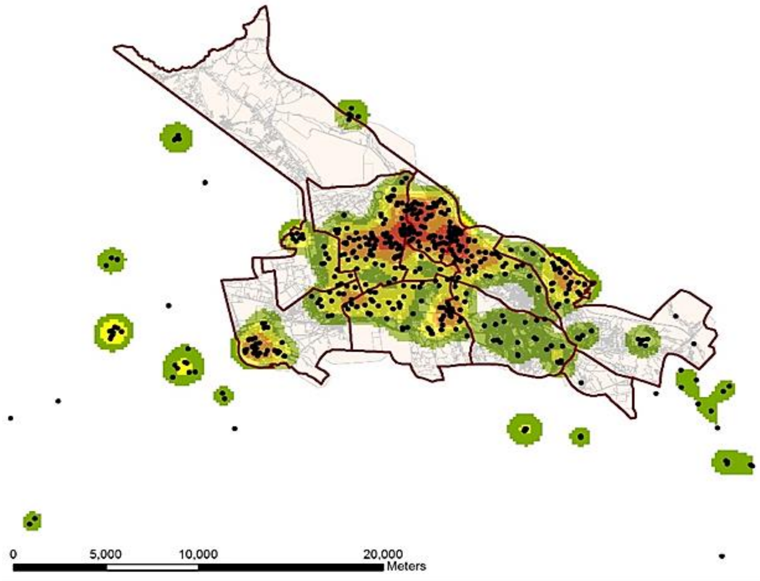

Fig. 1. Analysis of spatial distribution for the causes of all natural gas incidents in the metropolis of Tabriz.

According to the analysis, the most incident-prone areas in terms of total fire and gas incidents between 2014 and 2020 were the 10th district of Tabriz Municipality and the suburbs of Tabriz metropolis. *Table 1* shows the total number of natural gas incidents in East Azerbaijan province.

Table 1. Total number of natural gas incidents in East Azerbaijan province.

Province	Total Number of Incident	Number of Incident Per 100,000	Province	Total Number of Incident	Number of Incident Per 100,000
Tabriz	633	101	Mianeh	69	97
Azarshahr	49	104	Heris	34	240
Oskou	38	42	Malekan	55	150
Ahar	86	181	Hashtroud	30	163
Bostan abad	36	111	Jolfa	21	77
Bonab	60	115	Charoimagh	16	223
Shabestar	57	99	Khodaafarin	6	59
Sarab	109	224	Varzaghan	5	30
Ajabshir	27	117	Kaleybar	19	129
Maraghe	116	127	Hourand	3	52
Marand	128	142			

On the other hand, by examining the number of incidents related to natural gas per 100,000 subscribers, *Table 2* compares the highest number of incidents that occur each year.

Table 2. The maximum number of total natural gas incidents per 100,000 subscribers.

Year	Total Number of Gas Incidents in Tabriz Metropolis	Total Number of Fire/Explosion Incidents in Tabriz Metropolis	Number of Incidents Per 100,000 Subscribers in Tabriz Metropolis	Maximum Number of Incidents Per 100,000 Subscribers
2014	13	72	16 incidents	Kaleybar – 42 incidents
2015	15	63	14 incidents	Maraghe – 51 incidents
2016	21	96	20 incidents	Herris – 68 incidents
2017	9	69	13 incidents	Hashtrood – 42 incidents
2018	6	79	14 incidents	Charoimagh – 79 incidents
2019	13	76	14 incidents	Charoimagh – 76 incidents
2020	15	86	16 incidents	Malekan – 44 incidents

Statistics related to fire and gas incidents in East Azerbaijan province during the last seven years and 2020 are presented in *Table 3*.

Table 3. Details of natural gas incident statistics of East Azerbaijan province.

Incident	Description	Between 2014 and 2020	The Year 2020
Fire/explosion	Number of injured	497 people	63 people
	Number of deaths	71 people	Nine people
	Total number of rural incidents	407 incidents	62 incidents
	Total number of urban incidents	999 incidents	157 incidents
	Total number of incidents	1406 incident	219 incidents
Choking with gas	Number of injured	103 people	Six people
	Number of deaths	224 people	43 people
	Total number of rural incidents	47 incidents	Nine incidents
	Total number of urban incidents	148 incidents	22 incidents
	Total number of incidents	195 incidents	31 incidents

To summarize the statistics of natural gas incidents in East Azerbaijan province, the following items are presented. *Table 4* shows the most important factors related to natural gas incidents.

Table 4. The most important factors related to natural gas incidents.

Incident	The Most Important Technical Factor Affecting the Incident	Percentage of Occurrences
Fire/explosion	Leakage from gas hose due to lack or defect of hose clamp	38%
	Gas leakage due to wear / tear / decay	22%
	Exposure of flammable material in the vicinity of flames of gas appliances	8%
Choking with gas	Lack of proper installation of the chimney	21%
	Use of non-standard chimneys	12%
	Leakage due to joints between chimney parts/cracks	11%
	Lack of H-cap on chimney outlet	6 %

4.2 | Statistics Obtained from Clustering Natural Gas-Related Incidents

For more in-depth analysis and data mining of the causes of natural gas incidents in East Azerbaijan Province, in this section, the data mining of collected gas and fire data for the entire East Azerbaijan Province is discussed. Silhouette coefficient was used to determine the optimal number of clusters in the K-means method. According to the concepts of this coefficient, at the point where this coefficient has the highest digit, it indicates that the number is selected as the optimal number of clusters. Therefore, the following summarizes the clustering results related to total natural gas incidents, fires/explosions, and gas for the entire East Azerbaijan province. *Figs. 2 to 4* show the characteristics of each cluster in fire and bite incidents in East Azerbaijan province.

- 454 incidents, equivalent to 4.28% of the total incidents.
- The highest number of incidents in Sarab and Marand (56 incidents).
- The highest incidence of incidents in February (52 incidents).
- The highest incidence of incidents in 2015 (72 incidents).
- The highest number of incidents between 18-12 (161 incidents).
- The highest incidence of incidents in home subscriptions (440 incidents).
- The highest number of incidents in rural areas (454 incidents).
- The highest number of incidents in the owner's subscription (418 incidents).
- The highest incidence of incidents for buildings with an average age of 32.12 years.
- The highest incidence of incidents with an average temperature of 37.14 ° C.
- The highest incidence of incidents with an average wind speed of 23.13 km per hour.
- The highest incidence of incidents with an average humidity of 78.56%.

Fig. 2. Characteristics of the first cluster in fire and gas incidents in East Azerbaijan province.

- 525 incidents, equivalent to 32.8% of the total incidents.
- The highest number of incidents in Tabriz city, region 2 (70 incidents).
- Most incidents in December (76 incidents).
- Most incidents in 2020 (172 incidents).
- The highest incidence of incidents between 18-12 (192 incidents).
- The highest incidence of incidents in home subscriptions (463 incidents).
- The highest incidence of incidents in urban subscription (525 incidents).
- The highest number of incidents in the owner's subscription (371 incidents).
- The highest incidence of incidents for buildings with an average age of 15.70 years.
- The highest incidence of incidents with an average temperature of 13.98 ° C.
- The highest incidence of incidents with an average wind speed of 11.98 km per hour.
- The highest incidence of incidents with an average humidity of 58.99%.

Fig. 3. Characteristics of the second cluster in fire and gas incidents in East Azerbaijan province.

- 622 incidents, equivalent to 38.9% of the total incidents.
- The highest number of incidents in Tabriz city, region 4 (86 incidents).
- The highest incidence of incidents in April (88 incidents).
- The highest incidence of incidents in 2016 (142 incidents).
- The highest incidence of incidents between 18-12 (284 incidents).
- The highest incidence of incidents in home subscriptions (579 incidents).
- Most incidents in urban subscription (622 incidents).
- The highest number of incidents in the owner's subscription (449 incidents).
- The highest incidence of incidents for buildings with an average age of 16.49 years.
- The highest incidence of incidents with an average air temperature of 12.80 ° C.
- The highest incidence of incidents with an average wind speed of 15.23 km per hour.
- The highest incidence of incidents with an average humidity of 53.91%.

Fig. 4. Characteristics of the third cluster in fire and gas incidents in East Azerbaijan province.

4.3 | Pareto Analysis of Natural Gas Incidents in East Azerbaijan Province

In order to investigate the most critical factors related to fire/explosion and gassing in East Azerbaijan province, 1601 cases during the years 2014 to 2020 have been reviewed, and the number of causes of each incident is shown in *Tables 5* to *7*. Based on this issue, the most influential factors on the occurrence of natural gas incidents can be determined, and the root causes of each aspect can be identified. *Table 5* shows the total number of fire and gas incidents and their cumulative percentage from 2014 to 2020. *Fig. 5* shows the Pareto chart of fire and gas incidents and their cumulative percentage from 2014 to 2020.

Table 5. Total fire and gas incidents between 2014 and 2020.

Causes of the Incidents	Number of Incidents	Cumulative
Leakage from gas hose due to lack of or closed seal	527	0.329
Leakage from gas hose due to wear / tear / decay	305	0.520
Exposure of flammable material (such as curtains, etc.) in the vicinity of the flame of gas appliances	118	0.593
Other cases related to gas leakage (use of non-standard connections, etc.)	94	0.652
Leaving the gas valve	75	0.699
Defective parts in gas appliances	58	0.735
Use of non-standard equipment	57	0.771
Gas leakage from the internal piping system	57	0.806
Gas leakage from the consumption valve due to not installing the cap	50	0.838
Failure to install the gas burner in principle	44	0.865
Lack of proper installation of the chimney (high number of elbows, downward path, etc.)	42	0.891
Use of non-standard chimneys (accordion, non-compliance with proper diameter, etc.)	23	0.906
Leakage due to seams between chimney parts/presence of cracks and holes in the chimney	21	0.919
Gas leakage due to lack of thermocouple in gas appliances	20	0.931
Lack of H-cap on chimney outlet	20	0.944
Chimney ducts are blocked	19	0.956
Lack of chimney in gas appliances	14	0.964
Use of non-standard gas appliances	11	0.971
Use of high-consumption gas appliances in spaces less than 60 square meters without ventilation	10	0.978
Failure to install the gas burner in principle	8	0.983
Using inappropriate material and not observing the appropriate diameter of the chimney pipes	7	0.987
Other factors related to the chimney (inserting the vent in the water bucket)	7	0.991
Using cooking utensils (mobile rice cooker, etc.) as a heating device	5	0.994
Use of a typical chimney for several gas appliances	4	0.997
Use a flueless heater in confined spaces	2	0.998
Chimney crossing through unauthorized routes (false bathroom ceiling, closed ducts, etc.)	1	0.999
Defective parts in gas appliances	1	0.999
Use of high-consumption gas appliances in spaces more than 60 square meters without ventilation	1	1.000

According to *Table 5*, 527 incidents related to the cause of leakage from the gas hose are due to lack or defect of the hose clamp, the cumulative percentage of which is 32.9%. Additionally, 305 incidents are related to the cause of leakage from the gas hose due to wear, tear, or cavity, with a cumulative percentage of 52.0%. It is also known that 59.3% of all causes of fire and gassing incidents are related to gas hose leakage due to lack of or closed seal, gas hose leakage due to wear/tear/decay, and flammable material (such as curtains, etc.), in the vicinity of the flame of gas appliances. Therefore, 59.3% of the causes of fires and gassing can be solved by eliminating the above factors. *Table 6* shows the total number of gas incidents and their cumulative percentage from 2014 to 2020. *Fig. 6* shows the Pareto chart of gas incidents and their cumulative percentage from 2014 to 2020.

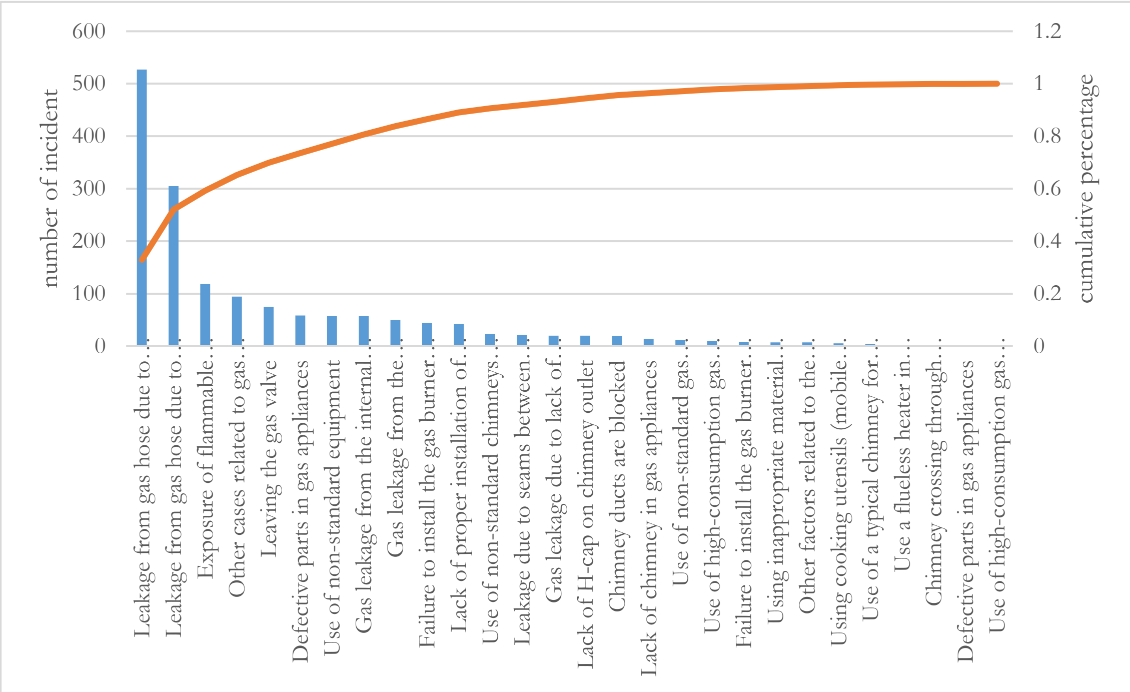

Fig. 5. Pareto chart of fire and gas incidents from 2014 to 2020.

Table 6. Total gas incidents between 2014 and 2020.

Causes of the Incidents	Number of Incidents	Cumulative
Lack of proper installation of the chimney (high number of elbows, downward path, etc.)	42	0.214
Use of non-standard chimneys (accordion, non-compliance with proper diameter, etc.)	23	0.332
Leakage due to seams between chimney parts/presence of cracks and holes in the chimney	21	0.439
Lack of H-cap on chimney outlet	20	0.541
Chimney ducts are blocked	19	0.638
Lack of chimney in gas appliances	14	0.709
Use of non-standard gas appliances	11	0.765
Use of high-consumption gas appliances in spaces less than 60 square meters without proper ventilation	10	0.816
Failure to install the gas burner in principle	8	0.857
Using inappropriate material and not observing the appropriate diameter of the chimney pipes	7	0.893
Other factors related to the chimney (inserting the vent in the water bucket)	7	0.929
Using cooking utensils (mobile rice cooker, etc.) as a heating device	5	0.954
Use of a common chimney for several gas appliances	4	0.974
Use a flueless heater in confined spaces	2	0.985
Chimney crossing through unauthorized routes (false bathroom ceiling, closed ducts, etc.)	1	0.990
Defective parts in gas appliances	1	0.995
Use of high-consumption gas appliances in spaces of more than 60 square meters without proper ventilation	1	1.000

According to *Table 6*, 42 incidents are related to the non-installation of chimneys with a cumulative percentage of 21.4%, 23 incidents are associated with the use of non-standard vents with a cumulative rate of 32.2%, and 21 incidents. The leakage factor is due to the joints between the chimney parts or the presence of cracks and pores, the cumulative percentage of which is 43.9%. Also, 20 incidents are related to the lack of H-cap factor on the chimney outlet, the cumulative rate of which is 54.1. As can be seen, 54.1% of the causes of gassing incidents are due to four cases. So by solving the four reasons, "no proper installation of the chimney", "use of non-standard chimneys", "leakage due to seams between the chimney parts or the presence of cracks and holes," and "lack of H-cap on the chimney outlet," 54.1% can be Solved the causes of gas incidents.

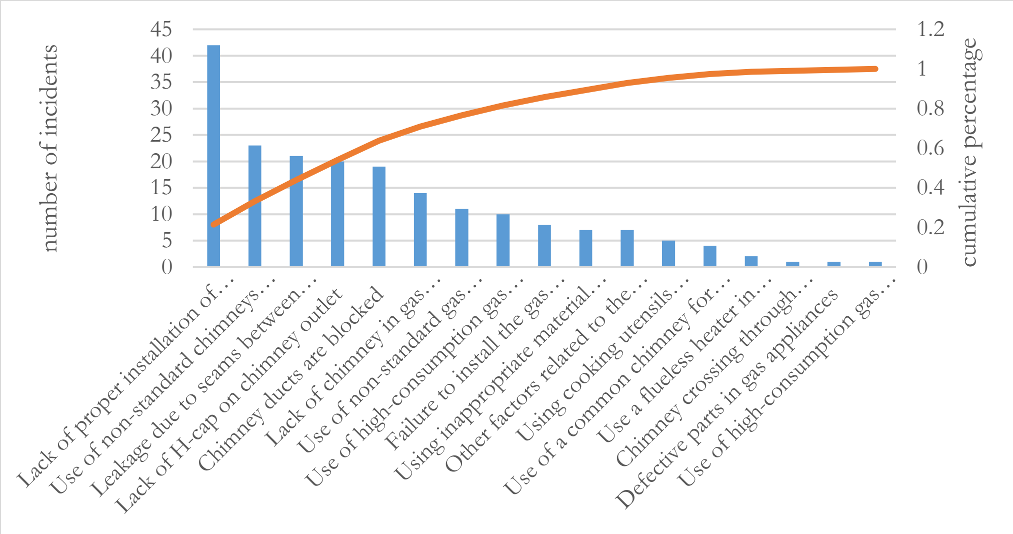

Fig. 6. Pareto chart of gas incidents from 2014 to 2020.

Table 7 shows the total number of fire incidents and their cumulative percentage from 2014 to 2020. *Fig. 7* shows the Pareto chart of fire incidents and their cumulative percentage from 2014 to 2020.

Table 7. Total fire incidents between 2014 and 2020.

Causes of the Incidents	Number of Incidents	Cumulative
Leakage from gas hose due to lack of or closed seal	527	0.375
Leakage from gas hose due to wear / tear / decay	305	0.592
Exposure of flammable material (such as curtains, etc.) in the vicinity of flames of gas appliances	118	0.676
Other cases related to gas leakage (use of non-standard connections, etc.	94	0.743
Leaving the gas valve	75	0.796
Defective parts in gas appliances	58	0.838
Use of non-standard equipment	57	0.878
Gas leakage from the internal piping system	57	0.919
Gas leakage from the consumption valve due to not installing the cap	50	0.954
Failure to install the gas burner in principle	44	0.986
Gas leakage due to lack of thermocouple in gas appliances	20	1.000

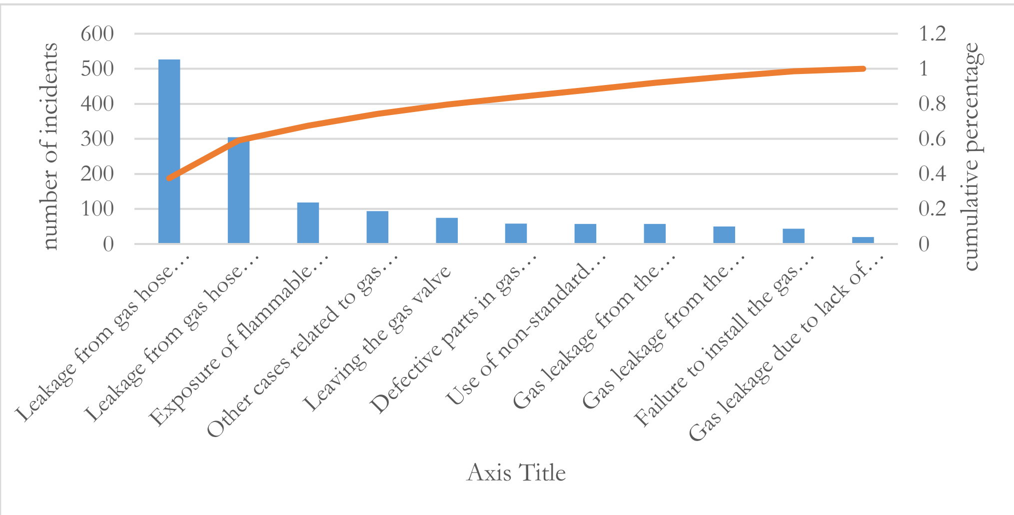

Fig. 7. Pareto chart of fire incidents from 2014 to 2020.

According to *Table 7*, 527 incidents related to the cause of leakage from the gas hose are due to lack or defect of the hose clamp, the cumulative percentage of which is 37.5%, 305 incidents related to the cause of leakage from the gas hose due to wear, tear or decay. The cumulative rate is 59.2%. As shown in *Table 7*, 59.2% of the causes of gas incidents are due to two cases. Therefore, by solving the two causes of gas hose leakage due to lack or defect of hose closure and gas hose leakage due to wear, tear or decay, 59.2% of the causes of fire incidents can be solved. After prioritizing the technical factors affecting fire and gas incidents, the most critical technical and non-technical factors affecting the event of natural gas subscribers' incidents for gas and fire incidents are described in *Table 8*.

Table 8. Factors affecting the occurrence of natural gas subscriber incidents.

Technical Factors Affecting the Occurrence of Incidents	The Factors
Explosion/fire	Leakage from gas hose due to lack or defect of hose clamp Leakage from gas hose due to wear / tear / decay Other cases related to gas leakage (use of non-standard connections, etc.) Leaving the gas valve Gas leakage from the consumption valve due to not installing the cap Exposure of flammable material in the vicinity of flames of gas appliances
Choking with gas	No proper installation of the chimney Use of non-standard chimneys Leakage due to seams between chimney parts/presence of cracks Chimney ducts are blocked Use of high-consumption gas appliances in spaces less than 60 square meters Using cooking utensils (mobile rice cooker, etc.) as a heating device Lack of H-cap on chimney outlet Use of a typical chimney for several gas appliances
Effective non-technical factors	Poor customer response to gas hazards Low level of safety of gas appliances equipment Heterogeneity in urban planning (existence of multi-story buildings next to one-story buildings) Unfavorable and stormy weather Do not visit the chimney path Failure to re-inspect building transfers and transactions Lack of subscriber awareness Ineffective notifications Insufficient and adequate supervision by the inspectors of the Engineering System Organization The low effectiveness of advertising and information is vital and incident-prone The low purchasing power of the people

After analyzing the data, the root causes of natural gas incidents in the province related to consumers, safety culture, and technical problems, quality of equipment and supplies, and improper design have been classified and identified as described in *Table 9*.

Table 9. Root factors affecting the occurrence of fire and gas incidents.

	Root Factors	
Consumers	- Power purchasing people - Hanging heavy and unauthorized items - Frequent movement of gas appliances - Inattention of subscribers	- Lack of awareness of subscribers - Lack of warning system - Rental accommodation - Temporary use for unbuilt building
Safety Culture	- Inadequate training and supervision - Lack of belief in safety - Ineffective training and information	- No custodian of education - Customer lawlessness
Technical Problem	- Lack of cap - Inadequate urban planning regulations - Do not use Teflon tape - Technical incompetence of the presenters - Lack of optimal size of chimneys - Lack of up-to-date regulations - Reduce chimney size by joint - Multiple knees - Long hose length - There was no well - Proximity to heat and closure - Unauthorized use of gas appliances - Hose and gas are not adjacent - No cups fittings - Do not move the chimney to the roof - Chimney not insulated - Improper hose and gas structure (coupling connections) - Lack of monitoring of gas hose distribution system - Decoration of metal chimney with aluminum foil - Run the chimney through the window glass/under the balcony - Do not close the lid when collecting heaters during the seasons - Inadequate execution of chimney installation	- Short chimney height - Homogeneity of caps and tubes - Lack of qualified service companies - Non-standard warhead - Common chimney - Improper installation - Chimney fabric transfer - Use a plastic cap instead of a metal one - Accordion (spring) chimneys - Non-standard warhead H - Accordion chimneys - Hose quality - Horizontal chimney/negative slope - Asynchronous threads - Lack of up-to-date regulations - Lack of supervision of gas hose production - Ineffective monitoring (incomplete checklist) - Improper connection of the clamp to the gas hose - Lack of continuous supervision of inspectors - Failure to observe the distance from an adjacent wall - Lack of proper connection of chimneys inside the wall
Quality	- Absence/non-standard closure - Inadequate quality/low cap material - Low-quality chimney parts - It was broken - Lack of optimal chimney standard	- Crisp hose - Lack of supervision over production - Occurrence of earthquake - Inadequate gas hose route
Improper Design	- Gas valve availability - Improper design of the piping system	- Improper handle design

5 | Proposed Solutions to Reduce or Control Incidents

This paper investigates the root causes of natural gas incidents in East Azerbaijan province through big data mining. Accordingly, by studying 1604 cases of accidents that occurred during the years 2014 to 2020, 28 factors were identified and analyzed. By conducting data mining and Pareto analysis, etc., it was determined that the most important technical factors affecting the bite are: lack of proper installation of the chimney, use of non-standard chimneys, leakage due to seams between the chimney parts,/the presence of cracks, and virtual blockage of the chimney. After analyzing the root causes of fires and gassing, the following solutions have been proposed to eliminate, change or control the root causes of the incident to prevent the recurrence of the incident:

- *Reviewing and improving the relevant method in the engineering system for the safety of the internal piping system of the building.*
- *Review of article 17 of the national building regulations (section related to chimneys, supervision, installation and implementation).*

- *Adding the title "safety regulations and safety requirements of building plumbing," including the installation of carbon monoxide and methane alarms, etc., to the topic of 17 national building regulations.*
- *Reviewing article 22 of the national building regulations related to the maintenance and upkeep of buildings concerning inspection and inspection.*
- *Obligation regarding the implementation of (22-8-4) "annual inspection of buildings by inspectors of the engineering system in terms of plumbing, chimney and ....*
- *Requirement of installing safety warning equipment in the building.*
- *Continuous monitoring of the organization's representatives, especially in installation, control of chimney, air valve.*
- *Obtaining safety certification from the fire department or ... regarding buildings.*
- *Effective and continuous information about the dangers of gas and carbon monoxide leaks through radio, education, and a part of it in textbooks.*
- *Replacing the package with a heater and water heater.*
- *Using gas stoves with thermocouples.*
- *Strict supervision over the design and construction of housing based on safety principles.*
- *Intensifying the management of the engineering system in the design and implementation of gas piping within the units.*
- *Supervising the design and construction of safe gas appliances according to standard rules.*
- *Mandatory installation of ventilators next to gas appliances.*
- *Do not install gas appliances in closed environments (bathroom locker room).*
- *Develop laws to oblige landlords to ensure the complete safety of rental homes.*
- *Providing a bed and culture of correct gas consumption.*
- *Informing safety issues by relevant experts.*
- *Amending the laws related to the issuance of finishing works for the construction of houses by including the observance of safety principles.*
- *Issuance of a safety certificate for long-term (rental) houses and provision of municipal services subject to obtaining the minimum safety conditions in each extension period.*
- *Develop laws to protect the rights of tenants and owners about home safety.*
- *Codification of regulations related to the pursuit and punishment of violators in the construction of places.*
- *Developing the necessary laws concerning the issuance of safety certificates for gas appliances and regular and regular maintenance of gas appliances.*
- *Establishing a permanent secretariat for home safety monitoring in the provincial health council.*
- *Fighting against providing gas-burning instruments and non-standard accessories.*
- *Support for the production of carbon monoxide gas detectors.*
- *Issuing licenses and supervising companies for repair and maintenance of gas appliances.*
- *Establish competent companies for the production, installation, and maintenance of carbon monoxide detectors and alarms.*
- *Raising the awareness of gas equipment manufacturers.*
- *Compilation of brochures related to proper installation, service, and maintenance.*
- *Practical training for the accurate and safe installation of gas appliances.*
- *Training on how to maintain and use gas appliances.*
- *Training on how to inspect and inspect gas appliances in terms of safety.*
- *Public education for inspection of ducts and chimneys of gas appliances after natural disasters such as earthquakes.*
- *Teaching the culture of inspecting houses and dangerous places at different times of the year, especially when moving to new homes.*
- *Promoting the culture of accuracy and lack of negligence.*
- *Educating and institutionalizing the culture of apartment living.*
- *Adjusting the checklist of observers during the visit to increase the effectiveness.*
- *Teaching the basic installation of chimneys for consumers through TV programs and etc.*
- *Law requirement to remove accordion (spring) chimneys.*

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- *Insulation of metal chimneys through fiberglass.*
- *Effective information in bad and stormy situations through social networks and television.*
- *Increasing the safety culture of consumers towards the consumption of natural gas.*
- *Installing signs, labels, and safety instructions for maintaining the natural gas system in the lobby, parking lot, and entrance of residential, commercial places.*

Conflicts of Interest

No potential conflict of interest was reported by the authors.

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