Available online at http://www.iorajournal.org/index.php/ijgor/index

International Journal of Global Operations Research

e-ISSN: 2722-1016
p-ISSN: 2723-1739

Vol. 2, No. 1, pp. 7-16, 2021

An Empirical Research of Critical Incident of Earthquake Disaster Based on Credible Association Data Mining

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Abstract

Earthquake disasters usually cause panic in the community affected areas, so it is necessary to be analyzed to deal with earthquake events in the future. This paper analyzes data from 9 major earthquakes in Indonesia over the past 4 years and determines 14 critical events. The analysis is based on credible association rules (CAR), data mining, and the maximum clique algorithm. To verify the accuracy of the association relationship and CAR effectiveness, it is performed using a maximum clique algorithm. Based on the results of data mining, that earthquakes have a credible association relationship and have a probability of critical events in various regions in Indonesia. Thus, these results can be used for prediction, early warning, and logistic distribution planning.

Keywords: Maximum clique, probability, prediction, early warning, logistic distribution.

1. Introduction

Critical incidents of earthquake disaster are series of problems about the society and economy in the secondary disasters which are caused by the earthquake disasters, such as people's lives being threatened, a huge loss of the economy, the destruction of regular production and living order, the turbulence and confusion of some part of society. At present, the work against natural calamities is gradually changing from passive rescue to initiative precaution. Early warning of a critical incident of earthquake disaster is on the basis of analysis of the historical data, using data mining algorithm, to find useful information from huge data, and finally in order to provide scientific proofs and effective solutions to promptly handle coordinate critical incidents in the future. Now, early warning of a critical incident of earthquake disaster is still in the first stage. The frame of public crisis management theory is lack of research achievements of maneuverability (Ding, 2009). This paper is based on credible association rules and its mining algorithm based on maximum clique (Xiao et al., 2008) to analyze 9 influential crises of earthquake disasters in recent 4 years in the world, according to mine the credible association

relationships and probabilities of these crises to forecast the occurring probability of related critical incidents and then to achieve the purpose of forecasting and early warning.

2. CAR and its mining algorithm based on maximum clique

2.1. Synopsis of CAR

In the area of data mining, association rule is a hot research direction, which is used to extract unknown yet potentially useful rules from a large number of data. Agrawal first suggested to find the association relationships of projects from transaction database, and gave the Apriori (Agrawal et al., 1993; Agrawal et al., 1994) algorithm based on frequent item set in 1993. This algorithm attributes to using minimum support pruning to create frequent item set. Various mining methods appeared then mostly rely on this strategy to reduce the space of combinatorial search in order to produce frequent sets more quickly and people can use the minimum confidence parameters on every set to evaluate the effectiveness of the rule (Han et al., 2000; Hipp et al., 2000). Association rule mining is also applied to discover the frequent pattern of orderly events, such as alarm correlation analysis. The method is still based on supportive confidence framework (Mannila et al., 1997; Xu et al., 2007).

Credible association rule (CAR), which its definition is differ from the traditional association rule, CAR requires each item to have same support level, while does not care about the size of the whole support degree, which uses the redefined confidence to reflect the rule's credibility, noted as credibility of CAR. This paper adopt Max Clique Mining algorithm, which uses the adjacency matrix to create two credible sets, and then using the thought of maximum clique (Chen et al., 2004) to create all the credible association relationships. According to the related content, this paper gives the following definition:

Definition 1. (CAR) To suppose that$I = \{i_1,\ i_2, \cdots, i_m\}$ is a set with m different items, given a work database $D = \{T_1,\ T_2, \cdots, T_n\}$, each transaction $T_i$among the database is one set of itemsin I , that is $T_i \subset I$. If there are k items which represent as $x_1,\ x_2, \cdots, x_{k,} \forall i, j \in \{1, \cdots, k\}(i \neq j)$, having the result of$\left(x_i \rightarrow x_j\right) \wedge \left(x_j \rightarrow x_i\right)$, it says these k items constitute a k-item credible association rule, which is noted as $R(x_1,\ x_2, \cdots, x_k\ )$. Its essence is that any 2 items of the rule are meeting as co-occurrence, therefore, itexpresses a stronger association degree than any others. Especially, 2-item CAR can be directly represented as $x_1 \leftrightarrow x_2$.

Definition 2. (support of CAR) As the definition of the support of the traditional association rule, if s % records in the work database D contain $x_1,\ x_2, \cdots, x_k$, the support of CAR$R(x_1,\ x_2, \cdots, x_k\ )$ is s %, noted as $\sup(x_1,\ x_2, \cdots, x_k\ ) = s$ %.

Definition 3 (credibility of CAR) To suppose that$a$ % records in the work database D containx_1, b %records contain $x_2$and s % records containboth x_1 and x_2, as a result, the credibility of 2-item CAR$x_1 \leftrightarrow x_2$ is$\frac{s}{a+b-s}$, noted as $C_{x_1 x_2}$.

Definition 4. (maximum clique) For graph G = (V, E), $\exists V' \subseteq V$, if the subgraph $G' = (V', E')$which derived from the given point set V' is a completegraph, defining G' as the clique in the graph G . If$\neg \exists v \in V$ and $v \notin V'$making the subgraph which derived from the point set $V' \cup \{v\}$ is a completegraph, defining G' as the maximum clique of thegraph.

2.2. Implementation process of max clique mining algorithm

1) Scanning the work database *D* to calculate the support of all 1-item sets and setting minimum credibility for all 2-item sets in the program to obtain setL_2which constitutes from all frequent 2-item sets that meet conditions.
2) Combined different items in the item set L_{k-1}consisted of known frequent *k*-1with each other to expand to candidate k-item sets C_k . If $P, Q \in L_{k-1}$, $P = \{p_1, p_2, \cdots, p_{k-2}, p_{k-1}\}, Q = \{q_1, q_2, \cdots, q_{k-2}, q_{k-1}\}$and when$1 \le i \le k-2$, $p_i = q_i$, while$i = k-1$, $p_{k-1} \ne q_{k-1}$, then $P \cup Q = \{p_1, p_2, \cdots, p_{k-2}, p_{k-1}, q_{k-1}\}$ are the elements of candidate k-item sets C_k .
3) When a $k-1$ subset in the candidate k-item sets C_k is not the member of L_{k-1}, namely this subset is not credible, this candidate item set is impossible frequent, deleting it from C_k .
4) Scanning work database *D*, calculating the support degree of each item set in C_k, eliminating items which are not meet the minimum support of s % , forming set L_k that constitute from frequent k-item sets collection.
5) Iterating and repeating the steps (2) ~ (4), until it cannot produce new collection of frequent item sets. The final result of such frequent item sets collection, namely the maximum clique arising from data mining.

3. Empirical Research

The data collection of this empirical research is collected from several large Indonesia websites (including https://id.wikipedia.org/wiki/Daftar_gempa_bumi_di_Indonesia), which is related records (47,492 records) about 9 earthquake disaster (Table 1) which have great impact all over the world in the past 4years. Combined with characteristic analysis of evolution and derivation chain of critical incidents (Chen et al., 2009), considering various unexpected risk events such as life line engineering accident, group incidents, political events in database, this paper ultimately determines 14 representative earthquake disaster critical incidents, shown as Table 2. According to relevant principles of Bayes classifier, this paper classifies the records to obtain the support degree of different critical incidents of the earthquake disasters in different countries or regions, shown as Table 3.

Table 1. Earthquakes

Time	Location	Magnitude	**Number of records**
2009-09-02	Tasikmalaya and Cianjur (West Java)	7.30	1694
2009-09-30	**Padang Pariaman, Kota Pariaman, Kota Padang, and Agam(West Sumatra)**	7.60	1694
2009-10-01	Kerinci	6.60	1694
2009-11-09	Pulau Sumbawa	6.70	1555
2010-10-25	Kepulauan Mentawai (West Sumatra)	7.7	41056
2012-04-11	**Banda Aceh**	8.50	1251
2013-07-02	Aceh	6.20	750
2016-03-02	Kepulauan Mentawai	8.30	6236
2016-12-07	**Kabupaten Pide Jaya**	6.50	2050

Table 2. Critical incidents of earthquake disaster

No.	**Critical incidents**	**Specific information**
1	Land traffic jams	The cracking of roads and bridges, tram damage and the collapsing of the tunnels in the cities or suburbs, hindering the supplies transportation and rescue after the earthquake
2	Waterway congestion	Port damage caused by the earthquake, leading to the closing of the port after the disaster
3	Aviation congestion	Airport or related facilities damage caused by the earthquake, leading to the stagnation of air traffic after the disaster
4	Shutdown of enterprises	Shutdown of the factories or enterprises
5	Shutdown of school	Shutdown of the schools or related education departments
6	Social chaos	Small range of social chaos such as theft, steal and loot, leading to the rising rate of crime
7	Political chaos	A wider range influence on social security, such as terrorist attacks, regime change and social riots
8	Price inflation Price inflation	The rapidly rising of the price of the necessities for life during a short time after earthquake
9	Supplies scarcity	The scarcity of the supplies including professional materials for the earthquake, necessities for life and producer goods
10	Shortage of water and power supply	Water or power supply system damage caused by earthquake, leading to the shortage of water and power for victims
11	Radioactive pollution	The radioactive toxic substances massive leak caused by the nuclear power station or chemical plant damage
12	Environment pollution	The non-radioactive pollution such as water pollution, air pollution, etc
13	Plague epidemic	The group epidemic disease or animal epidemic plague after the disaster
14	Communications blackout	The interruptions of Internet, phone or other basic communication facilities transmission caused by the earthquake

Table 3. The support of different critical incidents of the earthquake disasters (%)

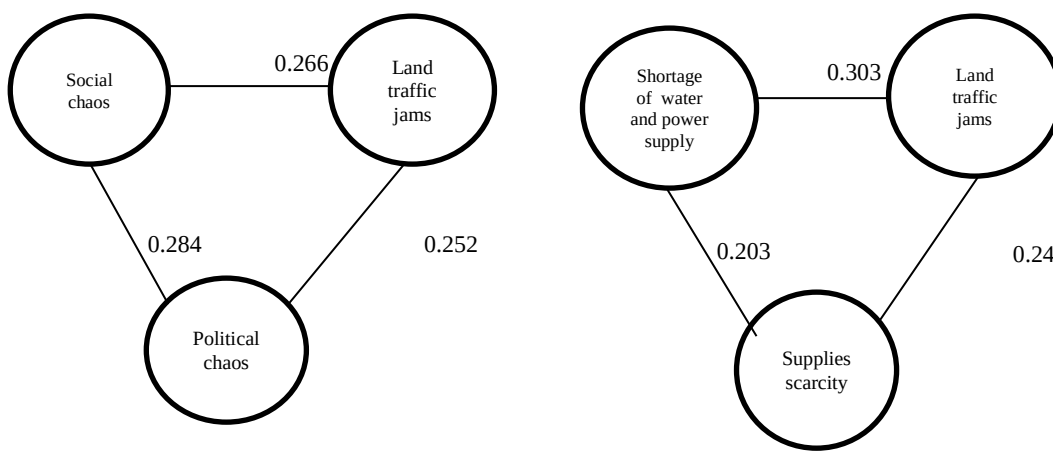
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tasikmalaya and Cianjur (West Java)	13	0	2	1	15	1	4	14	15	4	0	1	5	7
Padang Pariaman, Kota Pariaman, Kota Padang, and Agam (West Sumatra)	10	4	4	0	6	14	39	29	21	5	0	2	9	16
Kerinci	13	2	3	0	3	0	12	15	12	3	0	1	0	8
Pulau Sumbawa	10	4	4	0	6	14	39	29	21	5	0	2	9	16
Kepulauan Mentawai (West Sumatra)	8	0	0	0	17	0	4	2	0	17	0	1	10	14
Banda Aceh	15	6	6	2	5	13	20	16	13	14	0	0	1	8
Aceh	11	0	3	0	15	1	5	24	12	6	0	2	8	8
Kepulauan Mentawai	6	3	4	2	4	0	7	14	13	12	28	0	3	16
Kabupaten Pide Jaya	8	0	2	0	4	16	14	18	10	16	0	0	8	4

Using CAR algorithm in the database of the critical incidents of the earthquake disasters, the initial condition should be set at first, including the minimum support and the minimum credibility (Tian, 2009; Cheng et al., 2009) of CAR. In this research, setting the minimum support as 10%, the minimum

credibility as 20%, according to the fact that the data set of earthquakes is an extremely discrete one, if the minimum support and the minimum credibility are set to a high value, it is entirely possible that no credible association relationships could be found or the result of mining is useless. In addition, the value of minimum support in this research is enough to assure that support of all critical incidents are at the same order of magnitude, which represent within the range of 10% to 50%. At the same time, due to that the digging result of 2-item credible association represents the necessary and sufficient relationship between two objects, the lower credibility level does not affect the research ability of the results, therefore, the minimum support and the minimum credibility are both set to a low value. After mining earthquakes data in different areas, the results of maximum clique are shown in Table 4 and Figure 1 and Figure 2.

Table 4. Maximum cliques of 2-item credible set

	Maximum clique	Credibility
Tasikmalaya and Cianjur (West Java)	Price inflation ↔ Supplies scarcity	0.20
Kerinci	Land traffic jams ↔ Communications blackout Price inflation ↔ Supplies scarcity	0.33 0.25
Pulau Sumbawa	Land traffic jams ↔ Supplies scarcity Price inflation ↔ Supplies scarcity	0.35 0.29
Aceh	Shortage of water and power supply ↔Communications blackout Shortage of water and power supply ↔ Plague epidemic Shutdown of school ↔ Shortage of water and power supply	0.50 0.28 0.24
Kepulauan Mentawai	Price inflation ↔ Supplies scarcity	0.23
Kabupaten Pide Jaya	Land traffic jams ↔Shortage of water and powersupply Shortage of water and power supply _ Plague epidemic	0.20 0.20
Kepulauan Mentawai	Supplies scarcity ↔Communications blackout	0.23



(Banda Aceh)

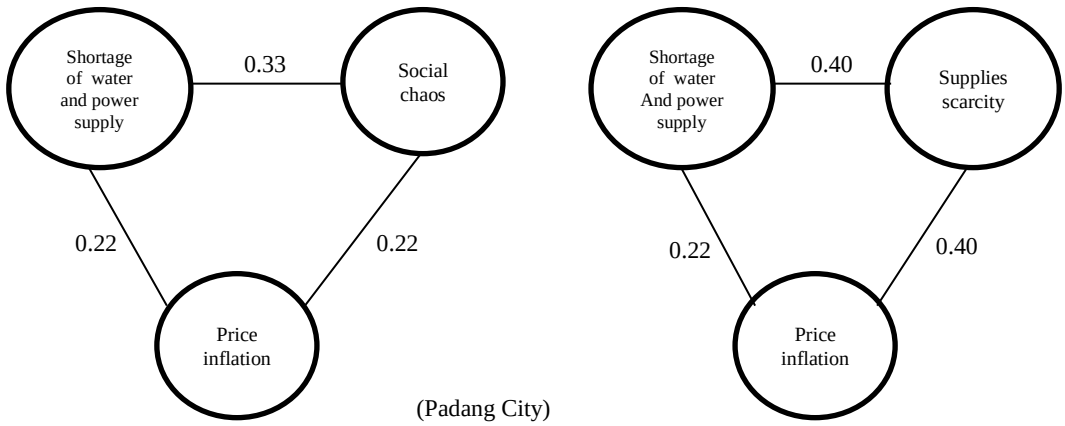


Figure 1. The graph of maximum cliques of 3-item credible set

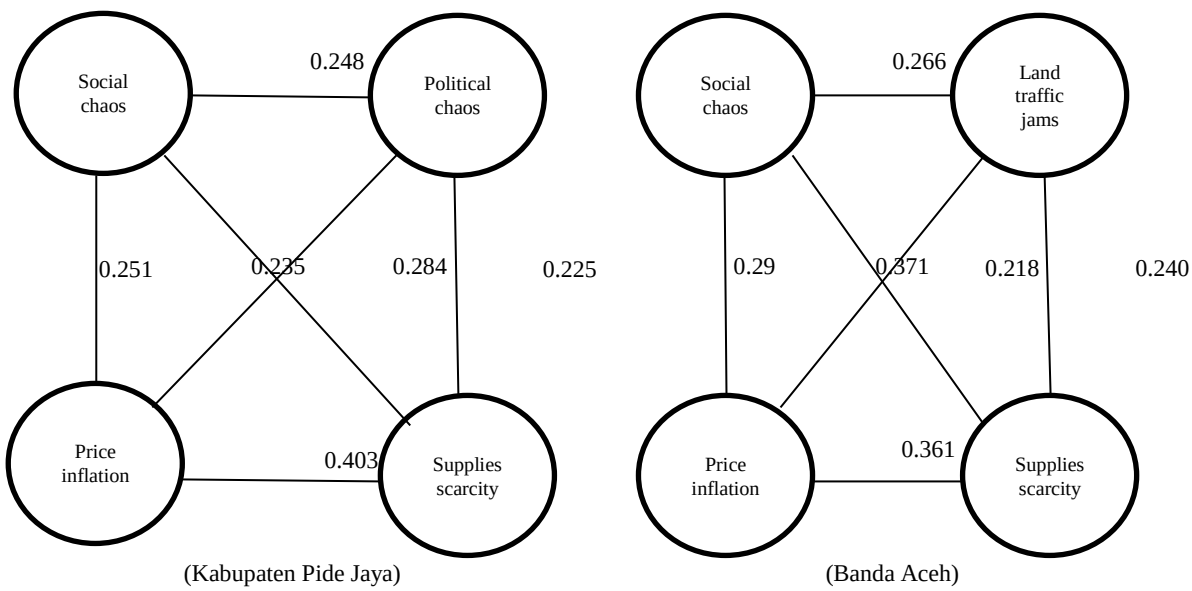


Figure 2. The graph of maximum cliques of 4-item credible set

4. Data Analysis

4.1. Analysis of 2-item credible set

Based on the order of credibility, we can find from the statistics of the research, all the obtained results of 2-item credible set are different in the critical incidents of earthquake disasters in different areas, however, they have some kind of tendency, some critical incidents with high credibility in

common, such as price inflation, supplies scarcity, land traffic jams, shortage of water and power supply and plague epidemic etc. In some special areas there are other incidents that need to be carefully paying attention to such as radioactive pollution. This paper will use the2-item credible set which are high ranking in the order of the credibility and happen in different areas but still have the universality to analysis, and will illustrate in detail of special cases in special places.

1) Price Inflation ↔ Supplies Scarcity

It is suggested that demand is a decreasing function of price by general microeconomic theory, however, demand may become an increasing function of price, due to the prospects of imbalance between supply and demand, and panic of victims after disasters (Wang et al., 2010). This theory fully explains the credible association relationship between the two critical incidents, which are price inflation and supplies scarcity respectively. After the unexpected earthquake, it may stimulate the public's demand of basic living materials, which grows rapidly in a very short time, for people tend to exaggerate the consequences of the disaster psychologically. Meanwhile, the earthquake may affect the production capacity of the relevant materials in disaster-affected regions, which could lead to strategic behavior, such as hoarding, by material supply enterprises and logistics service enterprises. What is more, it will also affect the serviceability and costs of transport and logistics network dynamically and uncertainly (Ji et al., 2006), which was listed in Table 2, including land traffic jams, waterway congestion and aviation congestion. These effects will lead to an imbalance of supply and demand of living materials. Simultaneously, the price formation mechanism after the earthquake, should consider the process of interaction behavior among consumers, businesses and government in the seismic environment. To some extent, the price formation process after disaster is decided mainly by the game between the stakeholders, but not by the balance of supply and demand. The influencing factors include not only consumer's demand for goods, from basic needs to disaster requirements, even to panic demand, but also factors in the enterprise level, like horizontal competition mechanism and supply chain transmission factors. In addition, government plays a decisive role in price formation process, with price intervention policies, the degree of commodity reservation and the suitable guide.

2) Shortage of water and power supply ↔ Plagueepidemic

Earthquakes will always cause ground cracking, which is likely to cause body or tube joint damage of water pipes, and result in lacking of water pressure or losing water supply capacity. Meanwhile, it might also cause power plants, substations or transmission lines do not work in particular regions. Power systems as well as water supply systems are important components of the lifeline systems, which are directly related to the normal operation of social production and all aspects of life. Moreover, in emergency rescue after earthquake, as an important energy supply, power system is not only the source of motive power for lifeline project like communication, but also the main guarantee to transport materials and rescue the wounded. Meanwhile, the normal running of water supply system determines the condition of victims' living water and public health situation directly. During 48 hours after the disaster, the meaning of pure water for the survivors is more important than food, unless enough clean water is supplied by the rescuers quickly, otherwise, survivors may be infected with any diseases one can imagine. In Aceh, the most common diseases of the victims are respiratory disorders caused by heavy smoke and dust inhalation and diarrhea caused by drinking polluted water, which lead to increasing risk of suffering from dengue fever, malaria and urticaria. Once the earthquake or epidemic plague occurs, it might not be limited to a certain part, but spread rapidly affecting the entire region, threatening the entire country and even other countries. Large - scale public health epidemic that has the characters of

spreading rapidly, continuity and chain properties, which often make a regional disaster, quickly escalated into a national or even global crisis. And with the development of information age, the link between things become diversification and synchronic, and limited resources can also lead to attend one thing and lose another, forming a "cascade effect", which will increase the impact of the crisis (Xue et al., 2003). Therefore, the spread of crisis will be more visible and prominent in globalization and information age. Thus, the stagnation of water and power supply systems, is likely to cause infectious disease outbreaks in a very short time after natural disasters (He, 2009). Therefore, it is impossible to ignore the credible association relationship between shortage of water and power supply and plague epidemic, and the mining results of this study indeed confirm the relationship between the two critical incidents.

3) Shortage of water and power supply ↔ Communications blackout

The anti-earthquake ability of a communication system will affect the rescue after the disaster directly, without considering the breakdown of the signal propagation which attributes to the power supply which was destroyed in the earthquake, when the communication equipment such as the signal tower is destroyed, the whole system will crash as well. It probably leads to the situation that the information of disaster rescue operation cannot reported to the headquarter in time, the rescue command cannot arrive and the effective rescue cannot be taken place within a short time after the earthquake, these will result in the situation expanding to an uncontrollable state (Shen, 2010). For example, after the earthquake in Kota Padang, Sumatra Barat, the communication between the distress area and the outside was cut off as long as 20 hours, it highly increased the difficulty of rescuing. The blackout of communication can be mainly represented as telephone line cutoff or internet cutoff. Based on the mining results, the situation happened more obviously in the Aceh and Kota Padang earthquakes than any others, for most of the voice and internet data are transmitted through the fiber-optic cable in the ocean, which would be easily destroyed in the earthquakes in the islands areas such as Aceh and Kota Padang. According to this point, a higher credibility of the relationship between communication blackout and shortage of water and power supply was concluded. Thus, this result indicates the effectiveness of CAR and its maximum clique mining algorithm again to a certain degree.

4) Supplies scarcity ↔ Radioactive pollution

In the mining result of 2-item credible set of this empirical research, there is a couple of incidents need to be paid high attention, which is the relationship between radioactive pollution and supplies scarcity, the two critical incidents of the earthquake in March 2011,Japan. Due to the earthquake, Fukusgima nuclear power plant got a large-scale nuclear leakage accident, which led to a huge damage to the environment, not only polluting the air with radioactive substances and atomic dusts, but also it caused secondary pollution for the residents in Japan. The accident intensified the worry from all the parties about the Japanese food, which is influenced by the nuclear pollution seriously, and unfortunately, it tended to be diffusion. By March 26th 2011, it had already been 99 kinds of products suffered from nuclear contamination in Tokyo and five other areas (Mo, 2011). In Japan, lots of individuals panic bought agricultural products and necessaries for living, as a result, the phenomenon of supplies scarcity appeared gradually. Meanwhile, Japan is one of the world's biggest food import state, its domestic resources are limited, what was worse, these limited products would decrease rapidly attributing to the nuclear pollution. Therefore, the import demand of agricultural products would expand to a higher level, it is likely to stimulate the increasing of agricultural products imports in some Asian economies, and then it is entirely possible to push some worldwide food prices to a higher level. Although the effect may be not appear very soon, it indeed confirm the credible association relationship

between radioactive pollution and supplies scarcity. However, in the territory of Indonesia did not happen so.

4.2. Analysis of 3-item credible set and 4-item credibleset

To observe the results of the maximum cliques shown in Figure 1 and 2, any two vertices, namely any credible association credibility between two critical incidents is greater than 0.2, which means that in many critical incidents of earthquake disasters of the special areas, several events shown in the figure are most likely to occur simultaneously. In the analysis of the 2-item credible set, it has been illustrated the relationships between the incidents and the reasons for them such as supplies scarcity. Therefore, this paragraph would pay more attention to explain the credible association relationships between the political chaos, social chaos and other critical incidents in special areas.

Due to the earthquake, lacking of supplies, the rising prices and other series of crises become inevitable incidents to victims, and it indirectly lead to social disorder and unrest. After the earthquake, not only the victims were difficult to obtain drinking water, food, basic shelter and social security, but also the social contempt for the dead demonstrated a kind of disrespect for life, which caused large-scale post-earthquake humanitarian crisis, and violence events occurred frequently. Thus, as the results shows above, there are strong credible association among the critical incidents, supplies scarcity, price inflation, land traffic jams, social chaos and political chaos.

5. Enlightenment of the Paper

In recent decades, due to the frequent occurring of the earthquake, different governments all over the world positively formulated diverse emergency response plans for destructive earthquake according to their national conditions. They published relevant policies and took measures to try to decrease the damage of the earthquake into a small range. Considering the analysis above, results of data mining based on CAR and its maximum clique mining algorithm indeed reflect the relationships between different critical incidents of earthquake disaster, so it is entirely possible to propose more effective emergency response plans based on this research, that means to observe these relationships of the incidents systematically. The government should fully consider the cascade effect of the critical incidents of earthquake disasters, through the occurring of one incident, they could forecast which one is the most likely to happen next. It would help to avoid suggesting single solution to only one critical incident and overmuch paying attention on lower possible ones, in other words, it is entirely possible to try to suggest more effective and comprehensive emergency response plans. As a result, not only can it help to rescue smoothly, but also it is significant to stabilize the society and decrease the negative impacts.

6. Conclusion

This paper introduces credible association rule and its maximum clique mining algorithm, combined with the composition of the evolution of risk events, this paper analyzes the data of 9 earthquakes which bring greater impact to the world than any others in recent 4years as an empirical research. According to related theories and discussions, this paper verifies the exactness of the mining results and the effectiveness of the CAR and its maximum clique mining algorithm under the situation of earthquake. The results of data mining represent the credible association relationships of the critical incidents of the

earthquake disasters, after the global observation, the paper analyzes couples of critical incidents which have the universal properties and higher potential occurring probabilities, and it is significant to conduct the governments in different areas for proposing the emergency response plan scenario for destructive earthquake. However, there is a defect in this paper as well, namely lacking of the research on the incidents which credibility is lower than the threshold, while, they would be analyzed in the future study to avoid omitting other constructive significant information.

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