

THE EVOLUTION PATH OF ANIMAL EPIDEMIC PUBLIC CRISIS UNDER THE BACKGROUND OF NETWORK PUBLIC OPINION

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Abstract: Animal epidemic emergencies are prone to rapid fermentation and diffusion via network public opinion, escalating into public crises and increasing the pressure on government emergency management. The evolution of animal epidemic public crises is governed by four core elements: subject, object, carrier, and inducer, resulting from the interactive effects of multi-agent behaviors, emotions, and cognition. Selecting 30 typical African swine fever cases in China, this paper adopts the Qualitative Comparative Analysis (QCA) to identify the key conditional variables of crisis evolution, analyze multiple evolution paths under multi-factor configuration, and clarify the mechanism of factor combination on crisis diffusion and abatement. It provides theoretical and practical references for public opinion guidance and emergency governance of animal epidemics.

Keywords: Network public opinion; Public crisis; Evolution path

1 INTRODUCTION

Animal epidemic emergencies are characterized by suddenness, transmissibility, and wide coverage. With the help of internet communication platforms, network public opinion is easily fermented and amplified, pushing the situation to escalate into a public crisis [1]. The evolution of such crises involves multiple participating subjects that interact and intertwine with each other. Failure to accurately grasp the evolution laws and key time nodes of the crisis will miss the optimal window for public opinion guidance and crisis control. In the whole process of occurrence, development, transition, subsidence and extinction of public crises, the social impact of public crises presents wave-like changes or transitions. During the crisis evolution, the equilibrium state of each subject varies greatly with crisis types. The movement of various forces within emergencies, the movement of various forces in the external environment of crisis events, and the interaction between diverse forces all exert significant impacts on the causes of crisis evolution [2]. Livorati constructed a data model based on system dynamics theory and calculated the risk base value of crises, so as to divide the evolution stages of public crises and attempt to explain the evolution mechanism of each stage [3]. Peng et al. adopted the attention degree model to describe and analyze the relationship and evolution mechanism of phenomena in unconventional public emergencies [4]. Li et al. found in the research on emergencies that the basic evolution chain of crises would generate derivative chains causing harm to humans and the environment, as well as consequence chains outputting destructive energy; these complex factors exert practical influences on crisis evolution [5]. Pan et al. explored the causes of network mass incidents and their impacts on the evolution mechanism [6].

Studies have shown that the evolution path of sudden public crises is highly complex and runs through the entire crisis process. An important feature of crisis management is to take rapid measures to minimize losses [7]. Sudden public crises occur unexpectedly and carry potential huge risks. Grasping the time nodes of crisis evolution and striving to find the "golden time window" is the key to resolving crises quickly [8]. In the occurrence and development of public crises, media and network public opinion can affect crisis evolution to a certain extent. Some scholars propose that the media can carry out "simulated governance" in crisis management, conduct policy information transmission between the government and the public by guiding the content and value of crisis information, and further trigger public feedback to form network public opinion, which becomes an order parameter affecting the process of crisis evolution [9]. Bukar et al. took emergencies as examples, collected the number of media reports related to crises as data sources, and studied the crisis evolution process. They divided crisis evolution into five stages: latent, developing, eruptive, declining and recovering by sorting media reports chronologically, and analyzed the regional effect of emergency communication through statistical analysis of titles or keywords in media reports [10]. With the rapid development of the internet, it plays an increasingly important role and deeply participates in the development process of crises; effective crisis management can be achieved with the assistance of media. Emergencies often become hot topics on online media [11]. Yuan et al. analyzed the temporal and spatial evolution of events based on netizen comment data on internet media. The results show that regional differences have little impact on event public opinion, while public opinion orientation can affect event attention and communication speed. Therefore, effective public opinion supervision in crisis handling can curb the deterioration of the crisis situation [12]. Due to the timeliness of media reports, researching the evolution of emergencies from the media perspective is a feasible approach in the absence of other reliable data.

However, existing studies fail to accurately clarify the evolutionary paths of public crises caused by animal epidemics and conduct in-depth correlation inference. Public crises related to animal epidemics are complex phenomena involving multiple stakeholders, stages and influencing factors. Current academic research on the governance of such crises mainly focuses on single-factor analysis and static countermeasures, while few explore the complex causal mechanisms of crisis evolution from the perspective of multi-factor configurations. Previous research also neglects the evolutionary logic of animal epidemic public crises, making it difficult to dig out and identify the underlying logical relationships behind numerous explicit events. Against this background, this paper adopts the QCA method to explore the typical evolutionary paths and internal mechanisms of animal epidemic public crises in the context of online public opinion from the perspective of multi-stakeholder and multi-factor collaboration.

2 RESEARCH DESIGN AND VARIABLE SELECTION

2.1 Research Method

The Qualitative Comparative Analysis (QCA) was first proposed by American sociologist Charles C. Ragin in 1987 [13]. QCA focuses on the relationship between the combination of conditional variables and outcome variables, and adopts a small-sample case study method. With the expansion of case research content, this method has been widely applied in management and other fields [14]. In response to scientific problems, researchers identify conditional variables combined with practical scenarios, analyze necessary conditions and interdependent configurations, and finally determine the presence or absence of outcome variables. Starting from the overall structure, QCA conducts a holistic analysis of cases, regards cases as configurations of conditional variables, and identifies the configurational relationship between conditional variables and outcome variables through case comparison, so as to discover which configurations of conditional variables can produce expected outcomes-results that conventional regression analysis cannot obtain [15]. This study focuses on the research of "crisis evolution configuration paths" by adopting QCA. The animal epidemic public crisis under the background of network public opinion is formed by the interaction of multiple subjects and factors. Therefore, incorporating core elements including the government, online media, producers, consumers and the public as well as events into QCA is crucial for studying the crisis evolution mechanism.

2.2 Case Selection

In QCA research, selected cases greatly affect data quality and result accuracy. QCA emphasizes that researchers should continuously reflect on and analyze cases in the process of case selection, so as to identify main factors affecting cases and research problems and set corresponding outcome and conditional variables accordingly [16]. Case selection must follow the principles below: (1) Similarity: Selected cases share similarities in research issues and are comparable in certain dimensions of influencing factors [17]. (2) Heterogeneity: Cases are diversified with certain differences among them [18]. (3) Multiple Outcomes: Selected cases must include multiple results; for crisis evolution path analysis, results include crisis diffusion and non-diffusion [19]. Taking African swine fever as the research object, this study selects 30 cases in different regions to analyze the crisis evolution path. By summarizing African swine fever incidents released by the Press Office of the Ministry of Agriculture and Rural Affairs, typical prominent incidents under the background of network public opinion are selected into the case database, involving Jiamusi City of Heilongjiang Province (northernmost), Danzhou City and Wanning City of Hainan Province (southernmost), and Shenbei New District of Shenyang City, Liaoning Province (earliest discovered), etc. The basic information of selected cases is shown in Table 1. The selected cases conform to the above selection principles, rooted in the same scenario and highly comparable. Case supporting materials are comprehensive and abundant, including press conferences, media reports, academic papers, forum posts, Weibo blogs, open letters, symbolic slogans, pictures, videos and other forms of data. The triangulation method is adopted for cross-checking to ensure high reliability. Due to limited data availability, most cases are supported by more than 8 text documents, and influential cases have more than a dozen or even dozens of documents, with the total text volume of the case database reaching over 100,000 words.

Table 1 Case Database of African Swine Fever Incidents

No.	Incident Name	No.	Incident Name
1	Shenbei New District, Shenyang City, Liaoning Province	16	Zuoyun County, Datong City, Shanxi Province
2	Economic Development Zone, Zhengzhou City, Henan Province	17	Lianyuan City, Hunan Province
3	Haizhou District, Lianyungang City, Jiangsu Province	18	Longli County, Qiannan Prefecture, Guizhou Province
4	Yueqing City, Wenzhou City, Zhejiang Province	19	Bishan District, Chongqing City
5	Nanling County, Wuhu City, Anhui Province	20	Youxi County, Sanming City, Fujian Province
6	Jiamusi City, Heilongjiang Province	21	Taojiang County, Yiyang City & Taoyuan County, Changde City, Hunan Province
7	Zhenglan Banner, Xilingol League, Inner Mongolia Autonomous Region	22	Huangpu District, Guangzhou City, Guangdong Province
8	Tai'an County, Anshan City, Liaoning Province	23	Zezhou County, Jincheng City, Shanxi Province
9	Xiangxi Tujia and Miao Autonomous Prefecture, Hunan Province	24	Economic and Technological Development Zone, Yongzhou City, Hunan Province

No.	Incident Name	No.	Incident Name
10	Yuanling County, Hunan Province	25	Lushui City, Yunnan Province
11	Sanmen County, Taizhou City, Zhejiang Province	26	Jingbian County, Yulin City, Shaanxi Province
12	Hecheng District, Huaihua City, Hunan Province	27	Gangnan District, Guigang City, Guangxi Zhuang Autonomous Region
13	Hezhang County, Bijie City, Guizhou Province	28	Lichuan City, Hubei Province
14	Qixingguan District, Bijie City, Guizhou Province	29	Danzhou City & Wanning City, Hainan Province
15	Zhenxiong County, Zhaotong City, Yunnan Province	30	Yanshan County, Wenshan Prefecture, Yunnan Province

2.3 Variable Definition

The evolution of animal epidemic public crises under network public opinion involves four core constituent elements: (1) Evolution Object: Centered on animal epidemic emergencies; the outbreak scale and social influence of the epidemic are the initial inducement of public opinion generation. (2) Evolution Inducer: Led by the government; special rectification actions and positive network public opinion guidance are the key to controlling crisis trends and curbing crisis diffusion. (3) Evolution Carrier: Relying on online media; media report linkage amplifies public opinion momentum and easily induces public irrational emotions and behavioral choices. (4) Evolution Subject: Including producers, consumers, netizens and other social groups; their risk perception and behavioral attitudes directly affect the crisis evolution situation. QCA holds that an increase in conditional variables will raise the risk of "individualized" case interpretation. Therefore, the number of conditional variables should be controlled at a reasonable level to balance the number of cases and conditional variables. Following the QCA standard of selecting 4–8 conditional variables for small samples within 40 cases, this study refines 8 conditional variables from the four dimensions of crisis evolution, matching the 30 selected cases.

2.3.1 Outcome variable

The evolution of public crises caused by animal epidemics amid online public opinion is an extremely complex issue driven by the joint effects of multiple stakeholders and factors, and its development is influenced by elements from different participants. This chapter focuses on the evolution paths of such crises, aiming to identify the core influencing factors and driving paths. Therefore, this study takes whether the animal epidemic public crisis spreads under online public opinion as the outcome variable. This setting covers the entire process of crisis outbreak and abatement involving all relevant participants, reflects their impacts on crisis evolution, and enables the assessment of crisis driving paths based on collected cases.

2.3.2 Conditional variables

The theoretical framework for the evolution mechanism of animal epidemic public crises constructed in previous sections lays the foundation for selecting conditional variables in this chapter. Ultimately, eight factors across four dimensions — crisis subject, crisis object, crisis carrier and crisis inducer — are adopted as conditional variables. Factors of the crisis subject mainly include producers, operators, pork consumers and other members of the public. The crisis object refers to the original animal epidemic incident and online public opinion itself, measured by the scale of animal epidemic and the scale of online public opinion. As the major crisis carrier, online media is reflected through online media linkage and opinion leader involvement. As the crisis inducer, the government is evaluated by two indicators: special rectification targeting animal epidemics and effective guidance on online public opinion.

Consumer Risk Perception: Consumers' subjective cognition and prediction of epidemic risks; panic emotions easily trigger irrational consumption and social order fluctuations, serving as the first line of crisis prevention and control.

Producer Legitimacy: Producers and enterprises violate laws and regulations for self-interest in breeding, production, processing, transportation and sales links, such as circulating uninspected livestock, discarding sick and dead livestock at will, isolating diseased livestock without treatment, and processing diseased animals into the market, triggering public crises and food safety problems.

Animal Epidemic Scale: Reflecting the outbreak degree and influence scope of incidents, divided into national and local levels; national emergencies cover a larger audience and involve broader public interests.

Network Public Opinion Scale: A large-scale information flow formed in a short time, likely to become a crisis fuse, generalizing individual problems into group ones and simplifying simple problems into complex ones through aggregation and amplification in the public opinion triggering process.

Online Media Linkage: A product of the new media era; interactive and aggregated online media ease public negative emotions and act as an important channel resource for crisis evolution.

Opinion Leader Participation: Opinion leaders with strong appeal and influence drive netizen emotions; their participation affects the overall crisis evolution situation and advances the arrival of the crisis peak.

Government Special Rectification of Animal Epidemics: Government intervention reflects emergency management capacity, including epidemic monitoring, isolation and culling, harmless disposal, and punishment of illegal acts to improve crisis governance capacity and safeguard public interests.

Government Public Opinion Guidance: Governments have the obligation to release information timely and accurately, disclose the truth, control network information, resolve incidents and reduce hazards. In the face of complex false online information, governments need to investigate facts, clarify rumors and guide public opinion rationally.

2.4 Variable Assignment

Under the guidance of the binary membership principle, the outcome variable of this study—crisis outbreak and abatement process—together with eight conditional variables derived from the four dimensions of crisis subject, crisis object, crisis carrier, and crisis inducer (i.e., consumer risk perception, producer legitimacy, animal epidemic scale, network public opinion scale, online media linkage, opinion leader involvement, and government supervision and guidance) are processed by four-point scaling. Both the outcome variable and conditional variables adopt four assignment values: a value of 1 indicates that all corresponding conditions are fully present; 0.670 indicates two conditions are satisfied; 0.330 indicates only one condition is satisfied; and 0 means none of the conditions are met. Detailed assignment rules are shown in Table 2.

Table 2 Variable Assignment Rules

Variable Type	Theoretical Dimension	Variable Name	Abbreviation	Specific Connotation	Assignment Rules
Outcome Variable	-	Crisis Outbreak/Abatement	RES	Whether the crisis breaks out with huge impact; massive online negative emotions; government credibility loss; media trust loss; consumers refusing to buy meat products; producers suffering economic losses	1.000 for full compliance with three criteria; 0.670 for two criteria; 0.330 for one criterion; 0 for none
		Consumer Risk Perception	Con	Consumers' awareness and perception of epidemic risks	1 for high perception; 0.670 for medium; 0.330 for low; 0 for others
		Producer Legitimacy	Pro	Producers' false publicity or illegal sales	1.000 for full compliance with three illegal behaviors; 0.670 for two; 0.330 for one; 0 for none
		Animal Epidemic Scale	Epi	Scope of animal epidemic outbreak	Divided into four levels by harmless disposal quantity: 1 for high risk; 0.670 for medium; 0.330 for low; 0 for others
		Network Public Opinion Scale	Opi	Scale of online public opinion	Divided into four levels by Baidu Index: 0.670 for large scale; 0.330 for small scale; 0 for others
Conditional Variable	Crisis Carrier	Online Media Linkage	Med	Whether online media form joint reports	1 for more than 10 national media reports/reposts; 0.670 for 5–10; 0.330 for 3–5; 0 for less than 3
		Opinion Leader Participation	Lea	Attention and reports by opinion leaders/influencers	1 for influencers with over 500,000 followers; 0.670 for 100,000–500,000; 0.330 for less than 100,000; 0 for less than 10,000
	Crisis Inducer	Government Special Rectification	Reg	Government performance efficiency	1.000 for full implementation of three governance links; 0.670 for two; 0.330 for one; 0 for none
		Government Public Opinion Guidance	Gui	Multi-subject participation in public opinion management	1.000 for full compliance with three guidance criteria; 0.670 for two; 0.330 for one; 0 for none

2.5 Truth Table Construction

After determining outcome and explanatory variables, data coding and sorting are conducted for 30 African swine fever cases to obtain the original data of outcome and conditional variables (see Table 3). Tosmana 1.6 qualitative analysis software is adopted to generate a contradiction-free truth table with crisis diffusion evolution as the outcome variable. The case frequency threshold is set to 1 and the consistency threshold to 0.8 when simplifying the truth table.

Table 3 Raw Database of African Swine Fever Cases

case	Con	Pro	Epi	Opi	Med	Lea	Reg	Gui	RESULT
case1	1	0.33	1	1	1	1	1	0	1

case	Con	Pro	Epi	Opi	Med	Lea	Reg	Gui	RESULT
case2	0.67	0.33	1	1	1	1	1	0	1
case3	1	1	1	1	1	1	0.67	0	1
case4	1	1	1	1	1	0.67	0	0	1
case5	1	1	1	1	1	0.67	0	0	1
case6	1	0.33	0.67	1	1	0.67	0	0	1
case7	1	0.33	1	0.67	1	0.67	0	0.33	1
case8	1	1	1	1	1	0.67	0	0.67	0.67
case9	1	1	0.67	0.67	1	0.67	0	0.33	1
case10	1	1	0.33	1	1	0.67	0	0.67	0.67
case11	1	1	0.33	0.33	1	0.67	0	0.67	1
case12	1	1	0.67	1	1	0.67	0.33	0	1
case13	1	0.67	0.33	1	1	0.67	0	0.33	1
case14	1	0.67	0.67	1	1	0.67	0	0.67	0.67
case15	1	1	0.67	0.33	1	1	0	0.33	1
case16	1	1	0.67	1	1	0	0	0	1
case17	0.67	0.67	0.67	1	1	0.33	0	0.67	1
case18	0.33	0.67	0.33	1	1	0.33	0	0.67	0
case19	1	1	0.67	1	1	0.33	0	0.67	1
case20	0.33	1	0.33	1	1	0.33	0	0.67	0.67
case21	1	1	0.33	1	1	0	0.33	0	1
case22	0.67	0.33	0	1	0.67	0	0	1	1
case23	1	0.33	0.33	1	1	0.67	0	1	1
case24	0.33	0.67	0.33	1	1	0.33	0	0.67	0.33
case25	0.67	0.67	0	1	0.67	0.33	0	1	1
case26	1	0.33	0.33	1	1	0.33	0	0	1
case27	1	0.33	0	0.33	0.67	0.33	0	1	0
case28	0.67	1	0	0.33	0.33	0.67	0	1	0.67
case29	0.33	0.33	0	0	0.33	0.67	0	0	0.33
case30	1	0.33	0	1	0.33	0.33	0	1	0

By adopting the qualitative analysis software Tosmana 1.6, a truth table without contradictory configurations is generated, with crisis diffusion and evolution set as the outcome variable. The truth table contains outcome variables with different results as well as multiple conditional variable configurations corresponding to various outcome scenarios. It can calculate the frequency of different crisis evolution path combinations and their matched case information, thereby revealing how the joint effects of conditional variables lead to either crisis occurrence or non-occurrence. In the process of truth table simplification, the case frequency threshold is set to 1 to eliminate unobservable cases and their conditional configurations. Meanwhile, the consistency threshold is set at 0.8. The corresponding results are presented in Table 4.

Table 4 Truth Table

Con	Pro	Epi	Opi	Med	Lea	Reg	Gui	number	RESULT	raw consist.	PRI consist.
1	0	1	1	1	1	1	0	2	1	1	1
1	1	1	0	1	1	0	0	1	1	1	1
1	1	1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	0	4	1	0.95675	0.944816
1	1	1	1	1	0	0	0	1	1	0.950076	0.933468
1	1	1	1	1	1	0	1	2	1	0.937736	0.909589
1	1	0	1	1	0	0	0	1	1	0.937618	0.916877
1	1	1	1	1	0	0	1	2	1	0.933602	0.900602
1	1	0	1	1	1	0	0	1	1	0.933468	0.909341
1	0	1	1	1	1	0	0	2	1	0.900602	0.87594
1	0	0	1	1	0	0	0	1	1	0.875472	0.834171
1	1	0	0	1	1	0	1	1	1	0.834171	0.801205
1	1	0	1	1	0	0	1	1	1	0.823843	0.75063
1	1	0	1	1	1	0	1	1	1	0.823843	0.75063
1	0	0	1	1	0	0	1	1	0	0.728022	0.667785

3 EMPIRICAL ANALYSIS RESULTS

After completing case selection, variable screening, variable assignment based on case characteristics, and truth table calibration, this study conducts an empirical analysis on the evolution of animal epidemic public crises under network public opinion by adopting the crisp-set Qualitative Comparative Analysis (csQCA). The fsQCA 3.0 software is employed to analyze the necessary and sufficient conditions of variables based on the constructed truth table. By identifying the configurational combinations of necessary and sufficient conditions among variables, this paper further extracts the core influencing factors and typical evolution paths of crisis evolution.

3.1 Univariate Necessity Analysis: Key Influencing Factors of Crisis Evolution

The logical operation of QCA suggests that different conditional variables present a nonlinear and multi-conjunctive causal relationship, indicating that the same outcome can be achieved through multiple alternative factor configurations. For instance, the simultaneous occurrence of X and Y leads to outcome Z, and the combination of V and W can also produce Z. Thus, the integrated logical expression is $X*Y+V*W \rightarrow Z$. Meanwhile, a condition that consistently appears in all configurations leading to a certain outcome is defined as a necessary condition—the outcome cannot occur without the presence of this condition. For example, in the logical formula $X*Y+V*W \rightarrow Z$, condition X is a necessary condition for outcome Z, as X exists in all valid configurations. In QCA, Consistency and Coverage are two core indicators used to examine the sufficient and necessary relationships between outcome variables and conditional variables, so as to explore the influencing factors of animal epidemic public crisis evolution under network public opinion. A conditional variable is regarded as a sufficient condition when its consistency is no less than 0.8, and it is identified as a necessary condition when the consistency reaches 0.9 or above [20]. Coverage adopted in this study refers to raw coverage, which reflects the explanatory power of conditional variables for outcome variables. The symbol $\sim$ represents logical negation, denoting the absence or opposite state of a variable. The calculation formulas are presented as follows.

$$\text{Consistency}(X_i \leq Y_i) = \frac{\sum [\min(X_i, Y_i)]}{\sum X_i} \quad (1)$$

$$\text{Coverage}(X_i \leq Y_i) = \frac{\sum [\min(X_i, Y_i)]}{Y_i} \quad (2)$$

This paper conducts a univariate necessity analysis on eight conditional variables covering the crisis subject, object, carrier and inducer, namely consumer risk perception, producer legitimacy, animal epidemic scale, network public opinion scale, online media linkage, opinion leader involvement, and government regulation and guidance, together with their respective negation terms. The results are shown in Table 5. According to the necessity analysis taking crisis occurrence as the outcome variable, the consistency values of consumer risk perception and online media linkage both exceed 0.9, indicating that the two single variables constitute necessary conditions for the occurrence and evolution of the crisis. Their corresponding coverage values are 0.870666 and 0.852222 respectively, demonstrating that both variables possess strong explanatory power for crisis evolution. Among other variables, the consistency of network public opinion scale is 0.888796, and the consistency of $\sim$ government special rectification on animal epidemics is 0.861308. Both values are close to the necessary condition threshold of 0.9 and serve as sufficient conditions for crisis formation and evolution, suggesting that these two conditional variables also exert indispensable effects throughout the process of crisis development.

Table 5 Univariate Necessity Analysis

Conditional Variable	Outcome = Crisis Occurrence		Outcome = Non-Crisis Occurrence	
	Consistency	Coverage	Consistency	Coverage
Con	0.930862	0.870666	0.774624	0.180756
$\sim$ Con	0.124115	0.688222	0.445743	0.616628
Pro	0.763432	0.859756	0.664441	0.186679
$\sim$ Pro	0.277801	0.768433	0.500835	0.345622
Epi	0.610995	0.956947	0.330551	0.129159
$\sim$ Epi	0.443982	0.726653	0.889816	0.363327
Opi	0.888796	0.831645	0.776294	0.181216
$\sim$ Opi	0.124948	0.691244	0.278798	0.384793
Med	0.958351	0.852222	0.776294	0.172222
$\sim$ Med	0.069138	0.553333	0.333890	0.666667
Lea	0.625573	0.918654	0.607679	0.222630
$\sim$ Lea	0.470637	0.827839	0.777963	0.341392
Reg	0.138692	1.000000	0.000000	0.000000
$\sim$ Reg	0.861308	0.775403	1.000000	0.224597
Gui	0.416910	0.749813	0.833055	0.373783
$\sim$ Gui	0.651812	0.939940	0.442404	0.159159

(1) High consumer risk perception: It serves as the fundamental necessary condition for crisis evolution. The public forms subjective risk judgments based on limited cognition. A high level of risk perception easily triggers anxiety and panic, disrupts rational consumption decisions, induces collective stress responses, and directly fosters the budding of a crisis. The absence of targeted government rectification aggravates public panic and amplifies the negative effects of risk perception.

(2) High online media linkage: It acts as an essential necessary condition for crisis dissemination and diffusion. Local animal epidemics achieve cross-regional transmission through the coordinated linkage of online media, and online public opinion overlaps with offline real-life situations, further magnifying the social influence of incidents. Opinion leaders leverage their public appeal to guide netizens' emotions, becoming a critical driving force for the fermentation of online public opinion.

3.2 Conditional Configuration Paths of Crisis Evolution

To present the analytical results more intuitively and clearly, this paper adopts the nested relationship between intermediate solution and parsimonious solution in QCA. By means of comparative analysis, the core conditions of crisis evolution paths are identified. Conditional variables that appear in both intermediate paths and parsimonious paths are defined as core conditions of evolution paths, while those only appearing in intermediate paths are regarded as peripheral conditions [21]. As shown in Table 6: the symbol ● denotes a present core condition; the hollowed dot ○ denotes a present peripheral condition; ⊗ denotes an absent core condition; crossed hollow ⊗ denotes an absent peripheral condition; blank cells indicate irrelevant conditions whose presence or absence exerts no influence on the outcome. There are three paths (S1, S2, S3) driving the evolution of public crises, which share identical core conditions: consumer risk perception, network public opinion scale, and online media linkage. The configuration of each crisis evolution path is analyzed in detail below.

Table 6 Conditional Configurations of Crisis Evolution in fsQCA

Variables	Conditional Paths of Crisis Evolution			Conditional Paths of Non-crisis Evolution	
	S1	S2	S3	NS1	NS2
Con	●	●	●	⊗	●
Pro			●	⊗	⊗
Epi	●	⊗	●	⊗	⊗
Opi	●	●		⊗	⊗
Med	●	●	●	⊗	●
Lea	●	⊗	●	●	⊗
Reg		⊗	⊗	⊗	⊗
Gui	⊗	⊗	⊗	⊗	●
CS	1	1	1	1	1
CV	0.429821	0.220741	0.318201	0.111853	0.111853

Boolean minimization was performed on the previously constructed truth table using fsQCA 3.0 software. The case frequency threshold was set to 1 and the raw consistency threshold to 0.8. Given the lack of theoretical and empirical evidence to clarify the exact direction of each conditional variable's influence on the outcome, this study assumed in the counterfactual analysis that the presence or absence of a single conditional variable could affect crisis evolution. Three types of solutions were obtained from the QCA analysis: Complex Solution, Intermediate Solution and Parsimonious Solution [22]. As presented in the table, this study finally generated 5 complex paths, 5 intermediate paths and 4 parsimonious paths. Since no directional assumptions were made in counterfactual judgments and the intermediate solution excludes logical remainders, the configurations of the complex solution and the intermediate solution are identical. Scholars generally hold that the conclusions derived from complex and intermediate solutions are highly enlightening and universal, which are regarded as the optimal interpretable solutions in QCA research. The consistency values of the five intermediate configuration paths in the table are 0.892227, 0.969014, 0.941385, 0.958595 and 0.833893 respectively. Among them, three paths have a consistency above 0.9, which serve as the sufficient and necessary conditions for crisis evolution and can reasonably explain the crisis evolution in this chapter. Therefore, these three intermediate paths were selected for interpretation to ensure strong robustness of the analytical results.

The first configuration is $\text{Con}^*\text{Epi}^*\text{Opi}^*\text{Med}^*\text{Lea}^*\sim\text{Gui}$, with a raw coverage of 0.429821. It indicates that the combination of high consumer risk perception, large-scale animal epidemic, massive online public opinion, strong online media linkage, high-level opinion leader involvement and absence of government supervision and guidance can explain approximately 42% of the cases. The second configuration is $\text{Con}^*\sim\text{Epi}^*\text{Opi}^*\text{Med}^*\sim\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui}$, with a raw coverage of 0.220741. This path, characterized by high consumer risk perception, small-scale animal epidemic, massive online public opinion, strong online media linkage, low-level opinion leader involvement, absence of government special rectification and absence of government supervision and guidance, can explain roughly 22% of the cases. The third configuration is $\text{Con}^*\text{Pro}^*\text{Epi}^*\text{Med}^*\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui}$, with a raw coverage of 0.318201. The combination of high consumer risk perception, illegal sales by producers, large-scale animal epidemic, strong online media linkage, high-level opinion leader involvement, absence of government special rectification and absence of government supervision and guidance can explain about 31% of the cases, see Table 7 and Table 8.

These three parallel paths feature equifinality. Expressed by the Boolean operator "+" [23]:

$\text{RESULT} = \text{Con}^*\text{Epi}^*\text{Opi}^*\text{Med}^*\text{Lea}^*\sim\text{Gui} + \text{Con}^*\sim\text{Epi}^*\text{Opi}^*\text{Med}^*\sim\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui} + \text{Con}^*\text{Pro}^*\text{Epi}^*\text{Med}^*\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui}$

After simplification:

$\text{RESULT} = \text{Con}^*\text{Med}^*\sim\text{Gui}^*[\text{Epi}^*\text{Lea}^*(\text{Opi} + \text{Pro}^*\sim\text{Reg}) + \sim\text{Epi}^*\text{Opi}^*\sim\text{Lea}^*\sim\text{Reg}]$

Table 7 Output Results of QCA Configuration Paths for Crisis Evolution

Path Type	Configuration	Consistency	Coverage
COMPLEX SOLUTION	$\text{Con}^*\text{Pro}^*\text{Opi}^*\text{Med}^*\sim\text{Reg}$	0.892227	0.56893
	$\text{Con}^*\text{Epi}^*\text{Opi}^*\text{Med}^*\text{Lea}^*\sim\text{Gui}$	0.969014	0.429821
	$\text{Con}^*\sim\text{Epi}^*\text{Opi}^*\text{Med}^*\sim\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui}$	0.941385	0.220741
	$\text{Con}^*\text{Pro}^*\text{Epi}^*\text{Med}^*\text{Lea}^*\sim\text{Reg}^*\sim\text{Gui}$	0.958595	0.318201
	$\text{Con}^*\text{Pro}^*\sim\text{Epi}^*\text{Med}^*\text{Lea}^*\sim\text{Reg}^*\text{Gui}$	0.833893	0.206997
INTERMEDIATE SOLUTION	$\text{Con}^*\text{Pro}^*\text{Opi}^*\text{Med}^*\sim\text{Reg}$	0.892227	0.56893

Path Type	Configuration	Consistency	Coverage
PARSIMONIOUS SOLUTION	Con*Epi*Opi*Med*Lea*~Gui	0.969014	0.429821
	Con*~Epi*Opi*Med*~Lea*~Reg*~Gui	0.941385	0.220741
	Con*Pro*Epi*Med*Lea*~Reg*~Gui	0.958595	0.318201
	Con*Pro*~Epi*Med*Lea*~Reg*Gui	0.833893	0.206997
	Con*Pro*Med	0.914508	0.73511
	Con*~Gui	0.978914	0.638067
	Opi*~Gui	0.978445	0.623907
	Med*~Gui	0.979349	0.651812

Table 8 Output Results of QCA Configuration Paths for Non-Occurrence of Crisis

Path Type	Configuration	Consistency	Coverage
COMPLEX SOLUTION	~Con*~Pro*~Epi*~Opi*~Med*Lea*~Reg*~Gui	1	0.111853
	Con*~Pro*~Epi*~Opi*Med*~Lea*~Reg*Gui	1	0.111853
INTERMEDIATE SOLUTION	~Con*~Pro*~Epi*~Opi*~Med*Lea*~Reg*~Gui	1	0.111853
	Con*~Pro*~Epi*~Opi*Med*~Lea*~Reg*Gui	1	0.111853
PARSIMONIOUS SOLUTION	~Pro*~Opi	0.802395	0.223706

3.3 Robustness Test

Robustness testing is an essential procedure in the application of the fsQCA method. There are multiple testing approaches, among which adjusting the minimum case frequency and changing the consistency threshold for logical minimization are commonly adopted to evaluate the stability and reliability of analytical results [24]. This paper conducts the robustness test on the results of crisis evolution by raising the consistency threshold. When the consistency threshold is increased from 0.8 to 0.9 and the calculation is rerun, no substantial changes are observed in the configurational relationships, evolution paths, consistency values and coverage values. It verifies that the analytical results are robust and credible, see Table 9.

Table 9 Output Results of QCA Configuration Paths

Path Type	Condition Configuration	Raw coverage	unique coverage	consistency
COMPLEX SOLUTION	Con*Pro*Opi*Med*~Reg*~Gui	0.415244	0.0420658	0.967961
	Con*Pro*Epi*Opi*Med*~Reg	0.443565	0.0703874	0.941645
	Con*Epi*Opi*Med*Lea*~Gui	0.429821	0.125781	0.969014
	Con*Pro*Epi*Med*Lea*~Reg*~Gui	0.318201	0.0141608	0.958595
	Con*Pro*Opi*Med*~Reg*~Gui	0.415244	0.0420658	0.967961
INTERMEDIATE SOLUTION	Con*Pro*Epi*Opi*Med*~Reg	0.443565	0.0703874	0.941645
	Con*Epi*Opi*Med*Lea*~Gui	0.429821	0.125781	0.969014
	Con*Pro*Epi*Med*Lea*~Reg*~Gui	0.318201	0.0141608	0.958595
PARSIMONIOUS SOLUTION	Epi	0.610995	0.168263	0.956947
	Pro*~Gui	0.526031	0.0832986	0.974537

3.3.1 Online media-dominated evolution path

The first driving path follows the logic of animal epidemic-network public opinion-opinion leader, expressed as Con*Epi*Opi*Med*Lea*~Gui. It indicates that crisis evolution is highly likely to occur when all conditional variables are satisfied simultaneously: high consumer risk perception, large-scale animal epidemic, massive network public opinion, intensive online media linkage, active intervention of opinion leaders, and the absence of targeted special rectification by regulatory authorities on the animal epidemic. This path can explain 9 cases in the sample, corresponding to Case 1, Case 2, Case 3, Case 4, Case 5, Case 6, Case 7, Case 9 and Case 12 in the case database. A typical example is the African swine fever public opinion incident of Sanquan Dumplings in Xiangxi. Dense coverage by mainstream media and secondary dissemination by self-media rapidly accumulated negative sentiment among netizens, pushing public opinion popularity to a peak within a short period and triggering industry trust crisis as well as market consumption panic.

3.3.2 Government guidance absence-induced evolution path

The second driving path is a compound evolution path of animal epidemic- opinion leader-government, denoted as Con*~Epi*Opi*Med*~Lea*~Reg*~Gui. Crisis evolution tends to take place under the combined conditions of strong consumer risk perception, small-scale animal epidemic, large-scale network public opinion, high-intensity online media linkage, in-depth non-intervention of opinion leaders, inadequate special rectification by regulators on the epidemic, and ineffective guidance on network public opinion. This path covers 2 cases, namely Case 21 and Case 26. The African swine fever incident in Taojiang County, Yiyang City of Hunan Province serves as a typical representative. Local involved enterprises concealed the epidemic information and illegally transported live pigs, while governmental investigation and rectification lagged at the initial stage. After public opinion fermented, government departments at all levels intervened promptly. A series of measures including epidemic zone blockade, compulsory culling, harmless disposal, full-range disinfection and market supply guarantee were implemented to effectively curb the further spread of the crisis.

3.3.3 Producer-driven evolution path

The third driving path is a multi-dimensional evolution path of producer-animal epidemic-opinion leader-government, formulated as Con*Pro*Epi*Med*Lea*~Reg*~Gui. The superposition of high consumer risk perception, illegal sales behaviors of producers, large-scale animal epidemic, strong online media linkage, high participation of opinion leaders, as well as the lack of governmental special rectification and public opinion guidance will greatly boost the evolution of public crisis.

This path applies to 5 cases: Case 4, Case 5, Case 9, Case 12 and Case 15. Producers engaging in breeding, slaughtering and circulation links conduct illegal and irregular business activities, such as arbitrary disposal of sick and dead livestock and illegal cross-regional transportation of live pigs, which become the fundamental source of epidemic transmission. The coupling of multiple factors including media linkage, remarks by opinion leaders, public panic and government regulatory deficiency jointly fuels the escalation of the crisis.

The "Pig Speculation Group" incident in Yunnan Province is highly representative. Unscrupulous traders illegally transported diseased pigs across provinces and spread rumors to suppress purchasing prices. Irregular quarantine work and regulatory failure aggravated the cross-regional spread of the epidemic, severely impacting the live pig breeding industry and the stability of market supply order.

4 RESEARCH CONCLUSIONS

Taking 30 African swine fever epidemic cases as samples, this paper adopts the QCA method to systematically analyze the evolution mechanism and configuration path of animal epidemic public crises under network public opinion, drawing the following core conclusions:

The evolution of animal epidemic public crises presents the characteristics of multiple concurrency and configuration-driven development; a single factor cannot independently trigger crisis diffusion, and the coupling and superposition of multiple conditional variables are the core inducement of crisis escalation.

High consumer risk perception and high online media linkage are the core necessary conditions for crisis evolution; epidemic scale, public opinion momentum, opinion leader participation, producers' irregular behaviors and the absence of government supervision and guidance are key catalytic factors.

There exist three typical equivalent evolution paths for animal epidemic public crises: online media-led path, government absence-induced path, and producer-driven path, with significant differences in core driving subjects, inducing conditions and evolution logic among paths.

This study clarifies the internal evolution logic of animal epidemic crises in the network public opinion environment, providing practical references for the government to accurately identify crisis inducements, conduct targeted public opinion guidance, strengthen source supervision of breeding and circulation, grasp the time window of emergency control, and improve the multi-subject collaborative governance system.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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AUTHOR CONTRIBUTION

ZL participated in data curation, methodology, validation, resources, funding, writing (original draft preparation conceptualization and review and editing), formal analysis, screening questionnaires, and tables. LS and AL participated in conceptualization, supervision, and project management, and all authors have read and agreed to the published version of the manuscript.

REFERENCES

- [1] Lee M, Ju Y, You M. The Effects of Social Determinants on Public Health Emergency Preparedness Mediated by Health Communication: The 2015 MERS Outbreak in South Korea. *Health Communication*, 2020, 35(11): 1396-1406.
- [2] Ruthven I. An Information Behavior Theory of Transitions. *Journal of the Association for Information Science and Technology*, 2022, 73(4): 579-593.
- [3] Livorati A L P, Caldas I L, Dettmann C P, et al. Crises in a dissipative Bouncing ball model. *Physics Letters A*, 2015, 379(43-44): 2830-2838.
- [4] Peng Y, Hu Z, Xi G. Research on the Evolution Law and Response Capability Based on Resource Allocation Model of Unconventional Emergency. *Journal of Computers*, 2010, 5(12): 1899-1906.
- [5] Li N, Sun N, Cao C, et al. Review on visualization technology in simulation training system for major natural disasters. *Nat Hazards*, 2022, 112: 1851-1882.

- [6] Pan J, Shen H. Analysis of mass incident diffusion in Weibo based on self-organization theory. *Physica A: Statistical Mechanics and its Applications*, 2017, 491.
- [7] Kim J, Hastak M. Social Network Analysis: Characteristics of Online Social Networks After a Disaster. *International Journal of Information Management*, 2018, 38(1): 86-96.
- [8] An L, Shen Y, Tao Y F, et al. User Profiling and Role Evaluation of Government Microbloggers in the Context of Public Emergencies. *Online Information Review*, 2023, 47(6): 1116-1133.
- [9] Bakar U A, Jabar M A, Sidi F, et al. Crisis Informatics in the Context of Social Media Crisis Communication: Theoretical Models, Taxonomy, and Open Issues. *IEEE Access*, 2020, 8: 185842-185869.
- [10] Bakar U A, Sidi F, Jabar M A, et al. A Multistage Analysis of Predicting Public Resilience of Impactful Social Media Crisis Communication in Flooding Emergencies. *IEEE Access*, 2022, 10: 57266-57282.
- [11] Zhao X. A Multilevel Perspective to Social Media Influentials' Frame Building Across Crises. *Social Science Computer Review*, 2022.
- [12] Yuan J, Shi J, Wang J, et al. Modelling network public opinion polarization based on SIR model considering dynamic network structure. *Alexandria Engineering Journal*, 2022, 61(6): 4557-4571.
- [13] El Sawy O A, Malhotra A, Park Y K, et al. Seeking the configurations of digital ecodynamics: it takes three to tango. *Information Systems Research*, 2010, 21(4): 835-848.
- [14] Hino A. Time-Series QCA: Studying Temporal Change through Boolean Analysis. *RirontoHoho*, 2009, 24(2): 247-265.
- [15] Andrews R, Beynon M J, McDermott A M. Organizational capability in the public sector: A configurational approach. *Journal of Public Administration Research and Theory*, 2016, 26(2): 239-258.
- [16] Oana I E, Schneider C Q, Thomann E. *Qualitative Comparative Analysis Using R: A Beginner's Guide*. Cambridge: Cambridge University Press, 2021.
- [17] Wang W J. Exploring the determinants of network effectiveness: The case of neighborhood governance networks in Beijing. *Journal of Public Administration Research and Theory*, 2016, 26(2): 375-388.
- [18] Wagemann C, Schneider C Q. Transparency standards in qualitative comparative analysis. *Qualitative & Multi-Method Research*, 2015, 13(1): 38-42.
- [19] Du Y, Liu Q, Kim P H, et al. Riding the waves of change: Using qualitative comparative analysis to analyze complex growth patterns in entrepreneurship. *Entrepreneurship Theory and Practice*, 2025, 49(1): 312-353.
- [20] Kroglund C, Choi D D, Poertner M. Fuzzy Sets on Shaky Ground: Parametric and Specification Sensitivity in fsQCA. *Political Analysis*, 2015(1): 21-41.
- [21] Chen L, Li Y, Fan D. How Do Emerging Multinationals Configure Political Connections across Institutional Contexts? *Global Strategy Journal*, 2018, 8(3): 447-470.
- [22] Ragin C C. *The Comparative Method: Moving beyond Qualitative and Quantitative Strategies*. Berkeley: University of California Press, 1987.
- [23] Fiss P C. Building better causal theories: a fuzzy set approach to typologies in organization research. *Academy of Management Journal*, 2011, 54(2): 393-420.
- [24] Morgan S L. Redesigning social inquiry: Fuzzy sets and beyond. *Social Forces*, 2010, 88(4): 1936-1938.