

A System Dynamics Approach for Modeling a Food safety incident: Borax incident for WDL Flour Company

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ABSTRACT

With the rapid increase of food supply, food safety incidents occur frequently. Therefore, how to prevent food safety incident and improve food safety management have become an open issue. In this paper, a particular food safety incident, that is, Borax incident for WDL Flour Company, is analyzed using system dynamics approach for providing guidance for food safety management, which usually involves multiple organizations and factors. To do this, a system dynamics (SD) model including a two-way communication mechanism between five organizations is established to simulate the process of the incident and the response of the company. The results show that the present SD model is effective to simulate the actual process of the food safety incident. Further, to explore the role of two-way communication in food safety incident control, five cases that respond to the process of two-way communication are assumed and the corresponding SD models to the five cases are established. It is revealed that the two-way communication between the five organizations plays an important role in food safety incident management, and its influence on food safety is systematic and nonlinear.

Keywords: Food safety incident; Risk management; Communication; System dynamics.

INTRODUCTION

Food safety is becoming an increasingly prominent issue in China. A series of food safety incidents caused by the sale of melamine-tainted baby milk formula, gutter cooking oil, Borax-tainted flour and clenbuterol-tainted pork seriously increase public concern to the food safety and also weaken the public confidence in the government's ability to regulate food industries. As a result, the question of "what else can we eat" has been raised naturally.

The causes of food safety incidents are manifold. For example, the improper use of new food processing technologies such as crop and animal transgenic technologies in food production may cause food acceptance crisis [1-3]. The chemical, microbial or physical contamination of food may lead to public health crisis [4, 5]. The simple and unopen management by the government to the food safety incident may cause public confidence crisis [6]. So far, a lot of research on food safety have been conducted. Frewer et al [7] systematically reviewed 54 published papers and studied the extent that the current theoretical framework is applied in food risk or benefit communication and the effects of food risk or benefit communication on consumption behavior. Margôt Kuttischreuter [8] studied the risk of application of nanotechnology in food area and evaluated the factors of online information sharing on food risk. Yang et al. [9] established the Bayesian model to assess the overall food quality and safety status and to evaluate the qualified rate of food in China market.

The model can also be used to assess product quality and reduce the likelihood of food incident. Ha et al. [10] investigated the information linkages among food incidents, institutional trust, and risk perception and found that food incident information will result in a low level of institutional trust. Nayak and Waterson [11] summarized the impact of globalization on food safety and emphasized the importance to understand the interactions among different components in the global food safety system. Furthermore, Wang et al. [12] used descriptive statistics and factor analysis to analyze the influencing factors of food safety and summarized four main factors influencing food safety. Based on the food safety incidents that have occurred in China, Ma et al. [13] pointed out the main risk factors and responsible organizations of food safety. Zhang [14] analyzed the difficulties and causes of frequent food safety incidents in China and pointed out that the food safety issues are highly complex.

Because the occurrence and development of food safety incidents is a time-related systemic problem, using system dynamics (SD) method for studying food safety issue is advantageous. For example, in order to assess the policy of reducing energy consumption of food industry in United States, Xu et al. developed a SD model on energy consumption in the food industry, which can be used to predict food energy consumption in United States for more than 50 years and evaluate the effect of energy-saving policies in food industries in United States [15]. Additionally, a SD model of sustainable food supply in Indonesia was established by Findiastuti et al. [16]. The model containing economic, environmental and social elements and their relationship was used to analyze the food supply in Indonesia systematically and quantitatively. As a result, the policy of sustainable development in Indonesia was proposed. Mu et al. [17] established the SD model of the food safety culture influence mechanism of the enterprise. Based on the simulation, some relevant suggestions of promoting the development of food safety culture in enterprises and reducing the frequency of food safety incidents were put forward. All these studies indicate that the SD method is effective for modeling a complex system quantitatively. However, the study of food safety incidents using the SD method has not been reported, to the author's best knowledge. Because China's organizations related to food safety mainly include food enterprises, public, government, scientific research institutions and the media [18, 19], the communication between them forms a complex dynamic system. In this study, a flour incident from Chinese flour processing company is analyzed and the corresponding SD model, which can reflect the two-way communication, is established to simulate the process of the incident and the normal response of the company (assuming that the incident did not occur). The simulation results agree well with the actual situation and process of this food safety incident. At the same time, the characteristics of two-way communication influence on food safety incident are further studied by simulating five hypothetical situations that can reflect the effect of two-way communication.

INCIDENT DESCRIPTION AND ANALYSIS

In this section, the incident of flour safety from Wudley Company is described [20] and then it is analyzed from the different viewpoints.

Incident Background And Process

Wudley Company (WDC) is a famous flour enterprise in China. It has 14 subsidiaries in six provinces and has a daily wheat processing capacity of 20,000 tons. It has won

the title of "National key leading Enterprises of Agricultural industrialization", "National Standardization good behavior Enterprise" and "Top 100 Enterprises of China's Food Industry" and other honorary titles.

The flour safety incident of WDC occurred in 2012. On September 13, the Public Security Bureau of Cangzhou city (PSBC) issued a document which points out that according to the test results, the content of borax in three flour samples of WDC were 4.33mg, 4.56mg, and 4.66mg per kilogram, respectively. So, on September 14, Hebei Provincial Bureau of Industry and Commerce (HPBIC) issued an official document of "an emergency notice on the inspection of the Wudley flour market". This document was forwarded within the government's system, and simultaneously, HPBIC demanded that production and sale of flour containing borax must be immediately stopped.

On September 19, the government website of Handan city released the information of "Industry and commerce department quickly checked the problem of unqualified flour". On September 20, Caixin website released a news of "The country's first-selling flour enterprises was checked due to adding carcinogen borax to flour." On the same day, however, the website of WDC published an information of "To date, WDC has not received any inspection report and written notice of which their flour is unqualified." On September 22, WDC held a news conference to declare the checking results of 42 flour samples which were performed by a third-party organization and pointed out that no any carcinogenic borax was found in WDC flour product. Because the checking results were published by the company itself, and more importantly, the results are not from the official check, so the impact of the flour safety risk is still expanding. By September 24, about 100000 related information has been found through searching in Baidu using words "Wudley, flour, borax". By September 26, after confirmation by an authoritative technical department that the allowable content of borax in flour product is 16.5%, Hebei Province convoked news release conference and announced that according to the inspection results of the authoritative inspection organizations and the communication with the relevant departments, WDC did not illegally add borax in the flour production process. On October 2, the "Truth investigation" program of Oriental time and Space reported on the practical circumstances of the incident, and illustrated that WDC didn't artificially add borax to the flour. Thereafter, this fake flour safety incident was disappeared.

Analysis Of Incident

The analysis of such incident is made as follows. The incident was first caused by the local public security department. In the multi-sector and segmented food safety management model, mainly due to the inadequate communication between management organizations, lack of experience and capacity for the enterprises to respond to the crisis, and inadequate government enforcement, the incidents that should been avoided was happened indeed.

The WDC lacks the capacity and experience to deal with major crises and did not communicate with management organization, such as government, media and research institutions and so on, to obtain evidence and solutions that the flour is qualified. The WDC just declared itself that their flour is qualified. This subjective

and negative response from WDC made the "flour borax incident" worse at the beginning period.

The core media involved in this incident was an online media. At the circumstances of without finding out the facts, the media took "flour enterprises add carcinogen borax" as title to attract public attention. The report of the media used a viewpoint of certain subjective reasoning or subjective guidance.

Borax is a natural ingredient in many foods. Song et al. [21], the experts of National Institute for Nutrition and Food Safety of China, reported in 2011 that the allowable content of borax in flour is 14.6mg/kg, but the maximum borax content of WDC's flour checked by the public security department was 4.66mg/kg. Because WDC knew the fact that borax content less than 4.66mg/kg is within the permitted range, so WDC always claimed that their flour is qualified. However, because the local government departments deemed that the content of borax 4.66 mg/kg is not qualified, the incident finally happened. The WDC was punished by stopping production and selling. Actually, there is the scientific indicator that the flour in which the borax content is less than 14.6mg/kg is qualified, so the flour incident could be avoided if the management organizations of government fully communicated with the relevant departments at the beginning period of the incident.

ESTABLISHMENT OF SD MODEL FOR THE INCIDENT

Two-Way Communication Framework For Food Safety Risk

Based on the actual condition of food safety management in China [18], Liang proposed a two-way communication framework, as shown in Figure 1, to describe the interaction among different organizations [19]. The framework consists of five communication organizations, which are enterprise, public, government, scientific and research institution and media. The government refers to the relevant official departments responsible for food safety. The enterprise refers to food production manufacturer. The public refers to consumers associated with specific food. The scientific and research institution refers to professional institutes in the field of food. The media refers to newspaper, television, network, etc. Because each communication organization forms a subsystem, there are five subsystems in Figure 1, and each subsystem has a state variable. The five state variables corresponding to the five subsystems are represented by SV1, SV2, SV3, SV4 and SV5, respectively. SV1 represents the food safety risk state; which is called the probability of food safety risk. SV2 represents the effect of public opinion on food safety risk. SV3 represents the government's efficiency in managing food safety risk. SV4 represents the effect of scientific research institutions on food safety risk. SV5 represents the effect of the media on food safety risk.

The two-way arrows in Figure 1 indicate two-way communication. R_{ij} are the direct influence factors/parameters of each communication organization. K_{ij} are the influencing factors/parameters of communication among the communication organizations. The significance of R_{ij} and K_{ij} will be explained in Section 3.2.

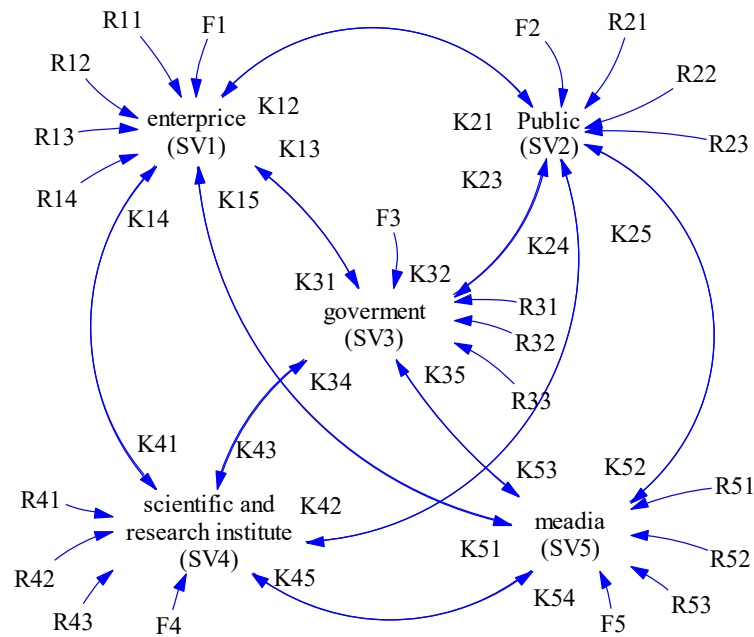


Figure 1: Two-way communication framework for food safety risk

Main Influence Factors/Parameters

In Figure 1 there are five communication organizations: government, enterprise, public, research institution and media. The influencing factors / parameters of each communication organization are divided into three categories. The first is direct influence factors / parameters of each communication organization, the second is communication factors/parameters among organizations, the third is communication coefficient.

Direct Influence Factors / Parameters

Direct influence factors/parameters are that emerged within each communication organization, which is indicated by R_{ij} as shown in Table 1. R_{ij} stands for j th direct influence factor of the i th communication organization. The values and explains of 16 direct factors/parameters are given in Table 1, in which the values are obtained by means of questionnaires and mathematical statistics [19]. For the sake of convenience, the direct factors/parameters are called as direct parameters (DPs) in the following description.

Table 1: Direct influence factors

Subsystem	Parameter	Initial value	Description
Food enterprise	R11	0.30	Risk rate from non-conforming raw material
	R12	0.30	Risk rate from failure to meet the national standards in the production process
	R13	0.20	Risk rate from the improper production technology
	R14	0.20	Risk rate from insufficient ability to deal with risks
Public	R21	0.40	Risk rate of public opinion caused by public attitude and emotion
	R22	0.30	Risk rate of public opinion due to information asymmetry
	R23	0.30	Risk rate of public opinion generated by public concern, the higher the degree of concern becomes, the higher the risk of public opinion is.
Government	R31	0.30	Influence rate of the management organization settings on the efficiency of government administration
	R32	0.30	Influence rate of the legal system of food safety on the efficiency of government administration
	R33	0.40	Influence rate of the law enforcement on the efficiency of government management
Scientific research institution	R41	0.35	Influence rate of the science and technology level on the role of the scientific research institution
	R42	0.33	Influence rate of the application of the scientific and technological achievements on the role of the scientific research
	R43	0.32	Influence rate of the fairness of scientific and technological personnel participating in communication on the role of scientific research institutions
Media	R51	0.40	Influence rate of the authoritativeness of the information publisher on the role of media
	R52	0.30	Influence rate of scientificness of expression methods on the role of media
	R53	0.30	Influence rate of timeliness of reporting on the role of the media

Communication Factors/Parameters

Communication influencing factors/parameters K_{ij} , which are listed in Table 2, represent the interaction between the communication organizations in the process of food safety risk. Because it is a two-way communication, one organization is also affected by the other four organizations when it affects the other four organizations. For example, K_{ij} ($i, j = 1, 2, 3, 4, 5$ and $i \neq j$) indicate the influence of the j th organization on the i th organization.

The values and explains of 20 communication influencing factors/parameters given in Table 2, in which the values are obtained by means of questionnaires and mathematical statistics [19]. For the sake of convenience, the communication influencing factors/parameters are called as communication parameters (CPs) in the following description.

Communication Coefficients

In order to describe the influence generated by communication between five organizations, we use five communication coefficients F_i ($i = 1, 2, 3, 4, 5$) ≥ 0 to reflect the degree of communication between the five relevant organizations. The greater the value of F_i , the better the communication effect.

Table 2: Communication influence factors

Subsystem	Parameter	Initial value	Description
Food enterprise	K12	0.20	Influence caused by public opinion on food safety risk
	K13	0.40	Influence caused by government management on food safety risk
	K14	0.15	Influence caused by scientific research institution on food safety risk
	K15	0.25	Influence caused by media on food safety risk
Public	K21	0.25	Influence caused by food enterprise on public opinion
	K23	0.40	Influence caused by government management on public opinion
	K24	0.10	Influence caused by scientific research institution on public opinion
	K25	0.25	Influence caused by media on public opinion
Government	K31	0.30	Influence caused by food enterprise on effect of government management
	K32	0.30	Influence caused by public opinion on effect of government management
	K34	0.10	Influence caused by scientific research institution on effect of government management
	K35	0.30	Influence caused by media on effect of government management
Scientific research institution	K41	0.20	Influence caused by food enterprise on effect of scientific research institution
	K42	0.15	Influence caused by public opinion on effect of scientific research institution
	K43	0.35	Influence caused by government management on effect of scientific research institution
	K45	0.30	Influence caused by media on effect of scientific research institution
Media	K51	0.30	Influence caused by food enterprise on effect of media
	K52	0.20	Influence caused by public opinion on effect of media
	K53	0.30	Influence caused by government management on effect of media
	K54	0.10	Influence caused by scientific research institution on effect of media

SYSTEM DYNAMIC MODEL

Modeling Assumptions

The aim of modeling is to establish a two-way SD model of food safety risk communication based on China's national conditions and study the change and control of food safety risk. Based on the research purpose and definition of model parameters, assuming that five state variables (SV1-SV5) vary with DPs (R_{ij}) and the CPs (K_{ij}) as shown in Table 3 and Table 4, respectively. In Table 3, state variables (SV1-SV5) vary in the same trend as that of DPs if the state variables and DPs have the same sign, and vice versa.

For example, when R11-R14 increase, it will cause an increase in SV1-SV5. Alternatively, when the R11-R14 decrease, SV1-SV5 will decrease as well. Also, when the R31-R33 increase, it will lead to a decrease in SV1-SV2 and an increase in SV3-SV4. In contrast, when the R31-R33 decrease, it will lead to the increase of SV1-SV2 and the decrease of SV3-SV4. The meanings of positive sign (+) and negative sign (-) in Table 4 are the same as in Table 3.

Table 3: Varying trends of the state variables with the DPs

DPs/vary	SV1 vary	SV2 vary	SV3 vary	SV4 vary	SV5 vary
R11- R14/+	+	+	+	+	+
R21- R23/+	+	+	+	+	+
R31- R33/+	-	-	+	+	+
R41- R43/+	-	-	+	+	+
R51- R53/+	-	-	+	+	+

Table 4: Varying trends of the state variables with the CPs

CPs/vary	SV1 vary	SV2 vary	SV3 vary	SV4 vary	SV5 vary
K12-K15/+	-	-	+	+	+
K21, K23- K25/+	-	-	+	+	+
K31,K32,K34, K35/+	-	-	+	+	+
K41-K43, K45/+	-	-	+	+	+
K51-K54/+	-	-	+	+	+

SD Model

The stock and flow diagram of the SD model of the food safety risk communication system is shown in Figure 2, which contains five subsystems: enterprise, public, government, research institutions and media. Figure 2 is a multi-loop two-way feedback system model, that is, there are many parameters that affect the change of a state variable, and there are many paths that make a state variable change. Moreover, according to the actual situation in the process of the flour incident, three table functions (R14B LOOKUP、R23B LOOKUP、R33B LOOKUP) are designed for

the three direct parameters by using the function of SD software VENSIM. In order to reflect the actual communication situation during the incident, five table functions (F1BLOOKUP、F2BLOOKUP、F3BLOOKUP、F4BLOOKUP、F5BLOOKUP) corresponding to the five communication coefficients are designed.

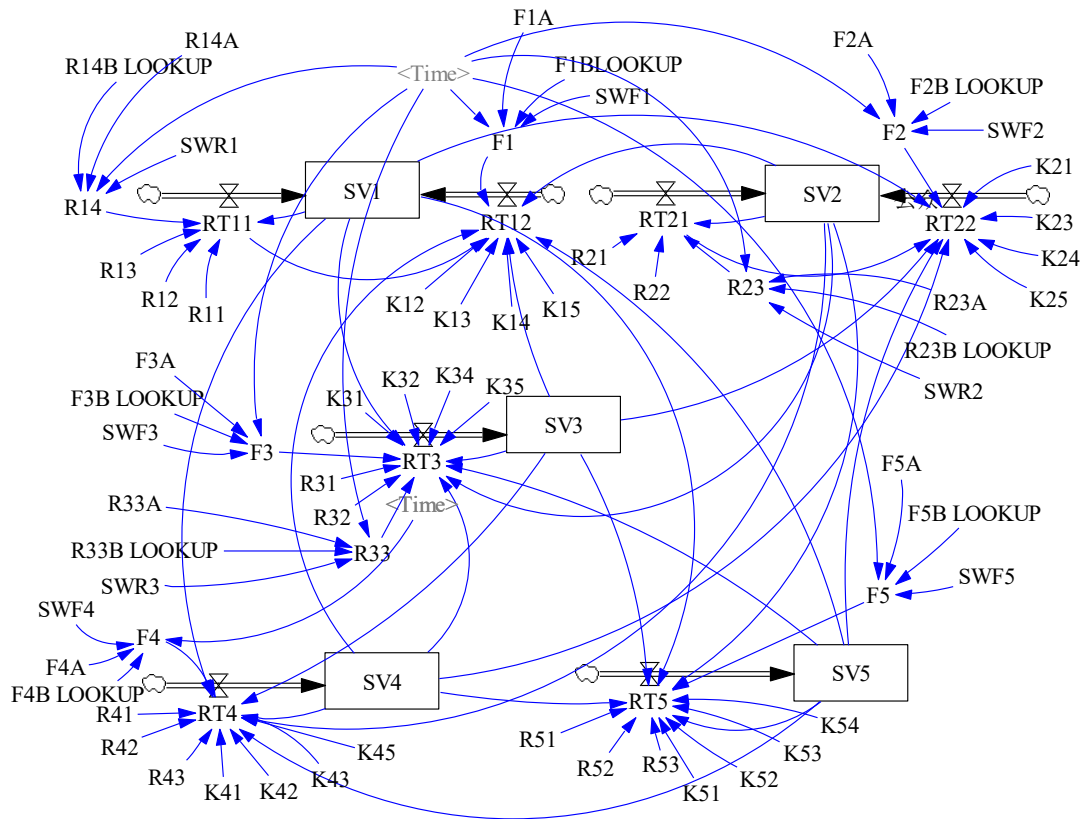


Figure 2: Stock and flow diagram of the SD model of food safety risk communication

Rate variables

The flow diagram of SD model in Figure 2 only indicates the connection relationships and qualitative interaction relationships between parameters or state variables. In order to simulate, we need to “translate” the model into mathematical expression, that is, we need to use the language of SD software to define the equations and functions needed. Based on the actual circumstances of the incident and relevant literature [17,20,22], the rate variables of the model are expressed as follows:

$$RT11=(R11+R12+R13+R14) \times SV1 \times (1-SV1) \quad (1)$$

$$RT12=DELAY1[(K13 \times SV3+K14 \times SV4+K15 \times SV5-K12 \times SV2) \times RT11 \times F1,0.2] \quad (2)$$

$$RT21=(R21+R22+R23) \times SV2 \times (1-SV2) \quad (3)$$

$$RT22=DELAY1[(K23 \times SV3+K24 \times SV4+K25 \times SV5-K21 \times SV1) \times RT21 \times F2,0.2] \quad (4)$$

$$RT3=(R31+R32+R33) \times SV3 \times (1-SV3) \quad (5)$$

$$\times DELAY1(((K31 \times SV1+K32 \times SV2+K34 \times SV4+K35 \times SV5)+1) \times F3,0.5) \quad (6)$$

$$RT4=(R41+R42+R43) \times SV4 \times (1-SV4) \quad (7)$$

$$\times DELAY1(((K41 \times SV1+K42 \times SV2+K43 \times SV3+K45 \times SV5)+1) \times F4,0.8) \quad (8)$$

$$RT5=(R51+R52+R53) \times SV5 \times (1-SV5) \quad (9)$$

$$\times DELAY1(((K51 \times SV1+K52 \times SV2+K53 \times SV3+K54 \times SV4)+1) \times F5,0.3) \quad (10)$$

Direct parameters

In general, the values of direct parameters are taken as in Table 1. Based on the actual situation in the process of flour incidents, using the function of SD software VENSIM, the following three table functions are designed. The table functions R14BLOOKUP corresponding to direct parameters R14 reflects the ability dealing with risks of WDC. The table functions R23BLOOKUP corresponding to direct parameter R23 reflects actual influence of the legal system of food safety on the efficiency of government management. The table functions R33BLOOKUP corresponding to direct parameters R33 reflects actual influence of law enforcement on the efficiency of government management. The three table functions are as follows:

$$R14 = \text{IF THEN ELSE}(SWR1 \leq 0, R14A, R14B \text{ LOOKUP}(\text{Time}))$$

$$R14A = 0.2, \quad R14B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(26,1)], (0,0.2), (3,0.6), (6,0.75), \\ (9,0.85), (12,0.9), (15,0.95), (26,0.95) \end{array} \right) \quad (6)$$

$$R23 = \text{IF THEN ELSE}(SWR2 \leq 0, R23A, R23B \text{ LOOKUP}(\text{Time}))$$

$$R23A = 0.1, \quad R23B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(26,0.9)], (0,0.1), (3,0.7), (4,0.9), \\ (6,0.3), (10,0.15), (15,0.11), (20,0.1), (26,0.1) \end{array} \right) \quad (7)$$

$$R33 = \text{IF THEN ELSE}(SWR3 \leq 0, R33A, R33B \text{ LOOKUP}(\text{Time}))$$

$$R33A = 0.3, \quad R33B \text{ LOOKUP} \left([(0,0)-(26,1)], (0,0.7), (6,0.6), (15,0.4), (26,0.2) \right) \quad (8)$$

There are three switches SWR_i ($i=1,2,3$) corresponding to the three table functions. When $SWR_i \leq 0$, the direct parameter R14, R23 and R33 take the value of Table 2, respectively. When SWR_i ($i=1,2,3$) > 0 , the direct parameter R14, R23 and R33 take the value corresponding to its table function, respectively.

Communication parameters and communication coefficients

The values of communication parameters are taken as in Table 2. Using the function of SD software VENSIM, five table functions (F1BLOOKUP, F2BLOOKUP, F3BLOOKUP, F4BLOOKUP, F5BLOOKUP) corresponding to the communication coefficients F_i are designed, respectively. These table functions reflect the degree of communication during risk incident. The five table functions are given as follows:

$$F1 = \text{IF THEN ELSE}(SWF1 \leq 0, F1A, F1B \text{ LOOKUP}(\text{Time}))$$

$$F1A = 0.2, \quad F1B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(25,2)], (0,0.1), (2,0.12), (3,0.15), \\ (4,0.2), (5,0.25), (6,0.3), (7,0.35), (8,0.45), \\ (9,0.6), (10,1.5), (11,1.7), (12,1.85), (13,1.95), \\ (14,2), (15,2), (25,2) \end{array} \right) \quad (9)$$

$$F2 = \text{IF THEN ELSE}(SWF2 \leq 0, F2A, F2B \text{ LOOKUP}(\text{Time}))$$

$$F2A = 0.2, \quad F2B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(25,2)], (0,0.1), (3,0.12), (5,0.2), \\ (8,1.3), (10,1.8), (12,1.9), (15,1.96), (18,1.98), \\ (21,2), (25,2) \end{array} \right) \quad (10)$$

$$F3 = \text{IF THEN ELSE}(SWF3 \leq 0, F3A, F3B \text{ LOOKUP}(\text{Time}))$$

$$F3A = 0.5, \quad F3B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(25,2)], (0,0.1), (1,0.12), (2,0.13) \\ (3,0.16), (4,0.18), (5,0.24), (6,0.3), (10,1.5), \\ (15,2), (20,2), (25,2) \end{array} \right) \quad (11)$$

$$F4 = \text{IF THEN ELSE}(SWF4 \leq 0, F4A, F4B \text{ LOOKUP}(\text{Time}))$$

$$F4A = 0.5, \quad F4B \text{ LOOKUP}([(0,0)-(25,2)], (0,0.1), (1,1.5), (25,1.5))) \quad (12)$$

$$F5 = \text{IF THEN ELSE}(SWF5 \leq 0, F3A, F5B \text{ LOOKUP}(\text{Time}))$$

$$F5A = 0.5, \quad F5B \text{ LOOKUP} \left(\begin{array}{l} [(0,0)-(25,2)], (0,0.1), (3,0.5), (6,0.8), \\ (9,1.1), (12,1.4), (15,1.6), (18,1.8) \end{array} \right) \quad (13)$$

There are five switches $SWFi$ ($i=1,2,3,4,5$) corresponding to the five table functions. When $SWFi \leq 0$, the communication coefficients Fi ($i=1,2,3,4,5$) take the constants as shown in table functions, respectively. When $SWFi > 0$, the communication coefficients Fi take the value corresponding to its table function, respectively. $SWFi \leq 0$ is used to simulate the case that the incident does not occur. $SWFi > 0$ is used to simulate the case that the incident happened.

Model check

The model needs to be checked, but there is no unified method for SD model check [22,23] and there is no reference for this model to be checked. J.W. Forrester, the founder of SD, pointed out that the qualitative check method of the SD model is effective [24]. Therefore dimensional consistency check and time integral step check are performed for the proposed SD model. Then the validity of the model is checked by using qualitative check method [25], i.e. the purpose and hypothesis of modeling are tested by changing the parameter values in Table 3 and Table 4. For example, the blue lines in the state variable box of Figure 3 show the variations of state variables SV1-SV5 when the values of parameters (R11, R21, R31, R41, R51) increase from (0.3, 0.4, 0.3, 0.35, 0.4) to (0.1, 0.1, 0.7, 0.7, 0.7) and the other parameters keep original values. The red lines in the state variable box represent the case that all parameters take the original value. It can be seen that the SV1 and SV2 decrease with the change of parameter R11, R21, R31, R41 and R51 while the SV3-SV5 increases. Such variations of state variables are consistent with the hypothesis given in Table 3. Table 4 is also checked similar to Table 3.

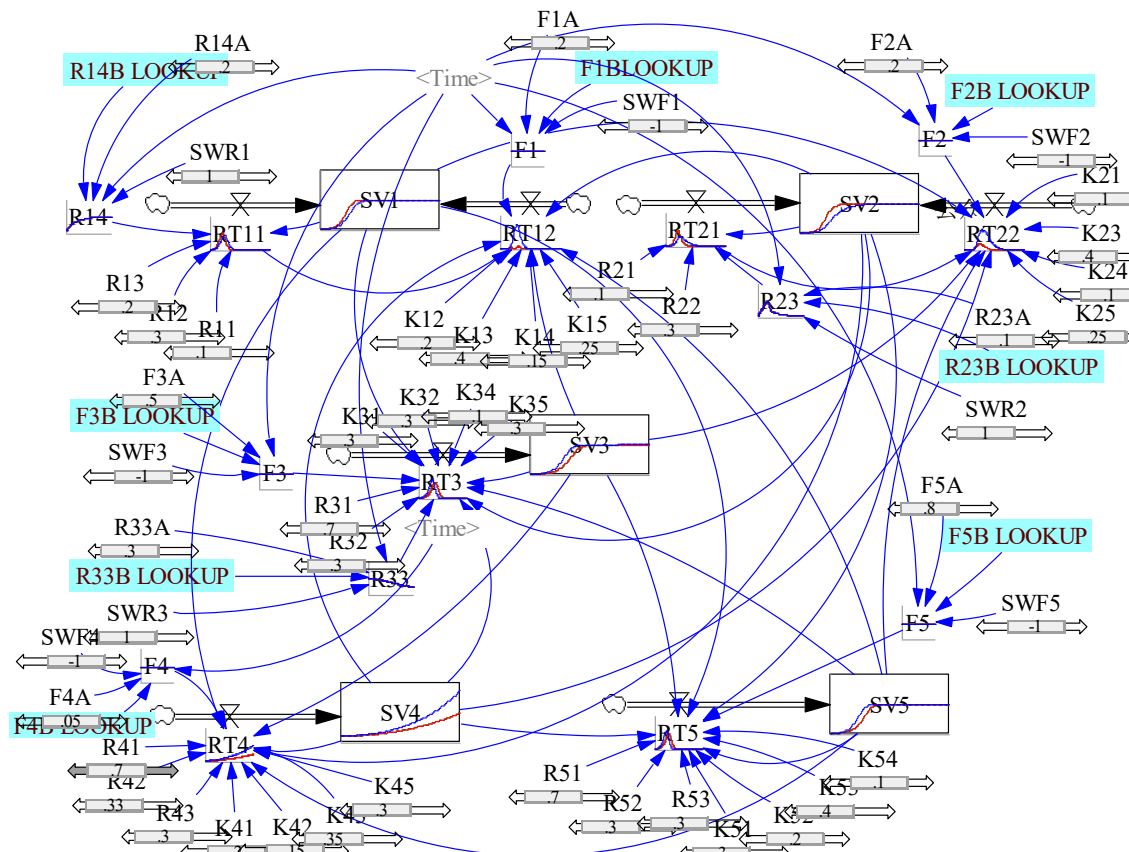


Figure 3: Model check by change of specific parameters

SIMULATION AND ANALYSIS

It took a total of 20 days from beginning to end of the incident, so the total time of simulation is 20 days and the time unit is day.

Case A-Incident Simulation

Case A is the case that the flour incident happened. When SWR_i ($i = 1, 2, 3$) > 0 , SWF_i ($i = 1, 2, 3, 4, 5$) > 0 , the established SD model corresponds to the Case A. The simulation result of case A is shown as the curve SV1:CT in Figure 4. The curve SV1:CT represents the change of the risk probability of the WDC during the incident. It can be seen from the curve that the curve went up slowly in the first 5 days. But then the curve rapidly went up after first five days. Up to the 10th day, the curve rapidly reaches a peak of 0.91, and then slowly fell to 0.312.

The simulation results show that the simulated curve is consistent with the actual process, i.e., in the first few days WDC's flour was mistaken as the unqualified food, but the incident was only under inspection and the relevant government departments asked the flour to stop selling. Although the risk had already occurred, the influence of the incident was limited to a very small range. So the curve also goes up more slowly. However, by September 19 (i.e., the sixth day), the event was published in society the by news reports of government website and other media. With the help of the rapid communication function of the new media, the risk rose rapidly, and the curve reaches its highest point on the 10th day. Then, after government-led communications, it was the government and the media finally announced that the WDC's flour qualified, so the incident was calmed down.

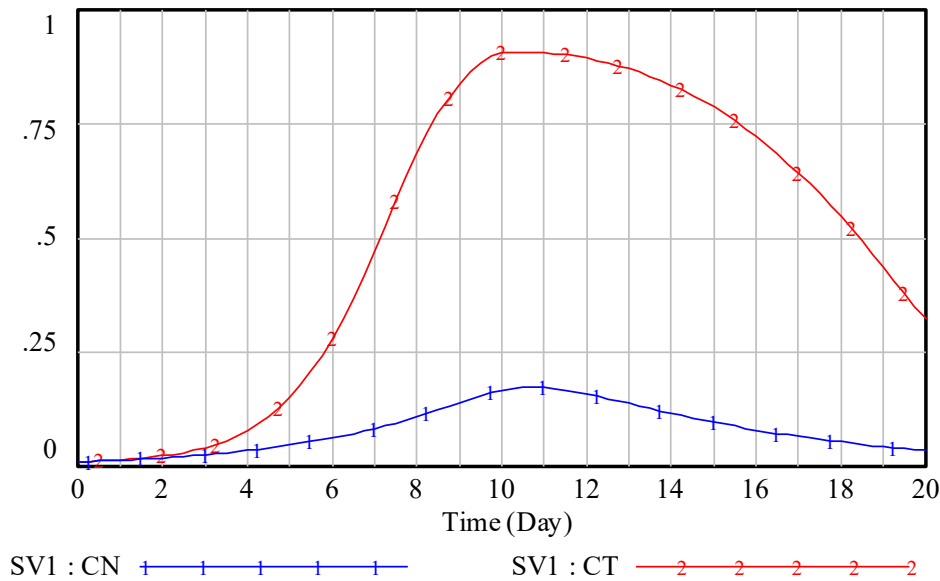


Figure 4: Risk curves

Case B-Simulation Of Supposed Normal State

Case B corresponds the case that supposing the incident of the WDC's flour did not happen. When SWR_i ($i = 1, 2, 3$) < 0 , SWF_i ($i = 1, 2, 3, 4, 5$) < 0 , the established SD model corresponds to the Case B. The simulation result of case B is shown as the curve SV1:CN in Figure 4. The curve SV1:CN represents the change of the risk probability of the WDC for case B. It can be seen from the curve SV1:CN that risk probability of WDC's flour is at low level if incident hadn't happened, which is consistent with the company's previous actual operation.

THE INFLUENCE OF TWO-WAY COMMUNICATION ON INCIDENT

Supposed Models Of Inadequate Two-Way Communication (ITWC)

In order to analyze the influence of two-way communication on this risk incident, six models as shown in Table 5 are assumed based on the case A. Model 0 of Table 5 is a model without communication among organizations. Models 1-5 are five ITWC models. For each ITWC model, one of the five communication organizations is taken as a one-way communication organization (OWCO). The OWCO only releases information to the other four organizations and does not receive information from the other four organizations.

The six ITWC models are implemented by setting the switch SWF_i ($i = 1, 2, 3, 4, 5$). For example, in the row corresponding to model 1, symbol "-1" indicates that enterprise is a one-way communication organization.

The risk curves of the six ITWC models obtained by simulation are shown in Figure 5, in which Curve SV1:C0 stands for the simulation result corresponding to model 0 and the curves SV1:C1 to SV1:C5 are the simulation results corresponding to model 1-5. It can be seen from Figure 5 that although the path of each one of model 1-5 is only one less than the model of case A, but the effect of reducing risk is much less than that of case A.

Table 5: Six ITWC models

Model/ OWCO	SWF1	SWF2	SWF3	SWF4	SWF5
Model 0/No	>	>	>	>	>
Model 1/Enterprise	-1	>	>	>	>
Model 2/Public	>	-1	>	>	>
Model 3/Goverment	>	>	-1	>	>
Model 4/Scientific and research institute institution	>	>	>	-1	>
Model 5/Media	>	>	>	>	-1

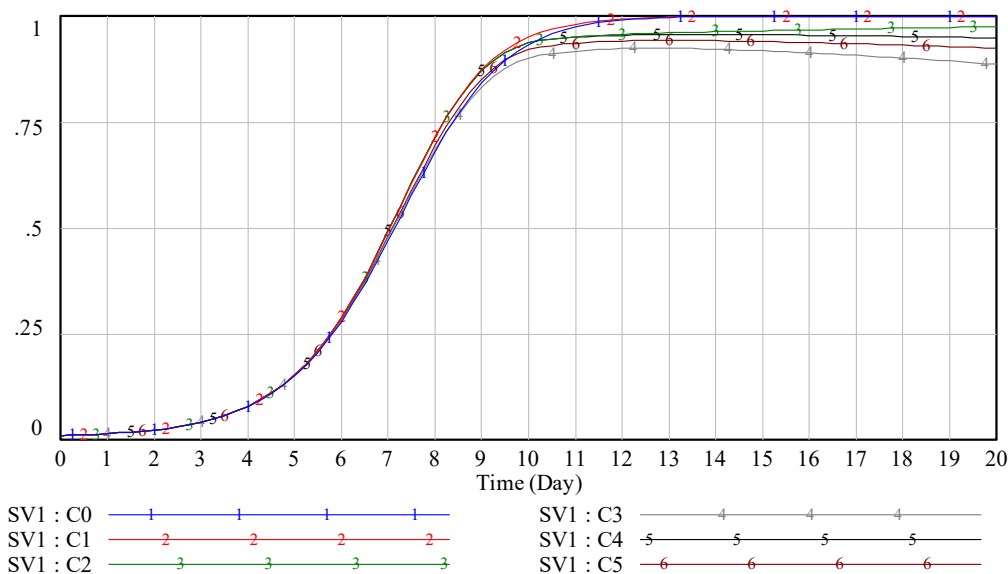


Figure 5: Risk curves of six ITWC models

In order to further analyze the influence of the communication degree on the food safety risk, the risk curves SV1:C0, SV1:CT and SV1:CS are plotted in Figure 6. The curves SV1:C0 corresponds the situation without communication. The curve SV1:CS is the superposition of difference between the curves SV1:C1-SV1:C5 and the SV1:C0, i.e., the curve SV1:CS is calculated by Eq. (14)

$$\{y_{CS}\}_{n \times 1} = \{y_0\}_{n \times 1} - \sum_{i=1}^5 (\{y_0\}_{n \times 1} - \{y_i\}_{n \times 1}) \quad (14)$$

where n stands for the number of points representing the horizontal coordinates. The $\{y_{CS}\}_{n \times 1}$ and $\{y_{C0}\}_{n \times 1}$ stand for the column matrix composed of n vertical coordinates values of curve SV1:CS and SV1:C0, respectively. The $\{y_i\}_{n \times 1}$ stands for a column matrix composed of n vertical coordinates values of curve SV1:C1-SV1:C5, as shown in Figure 6, respectively.

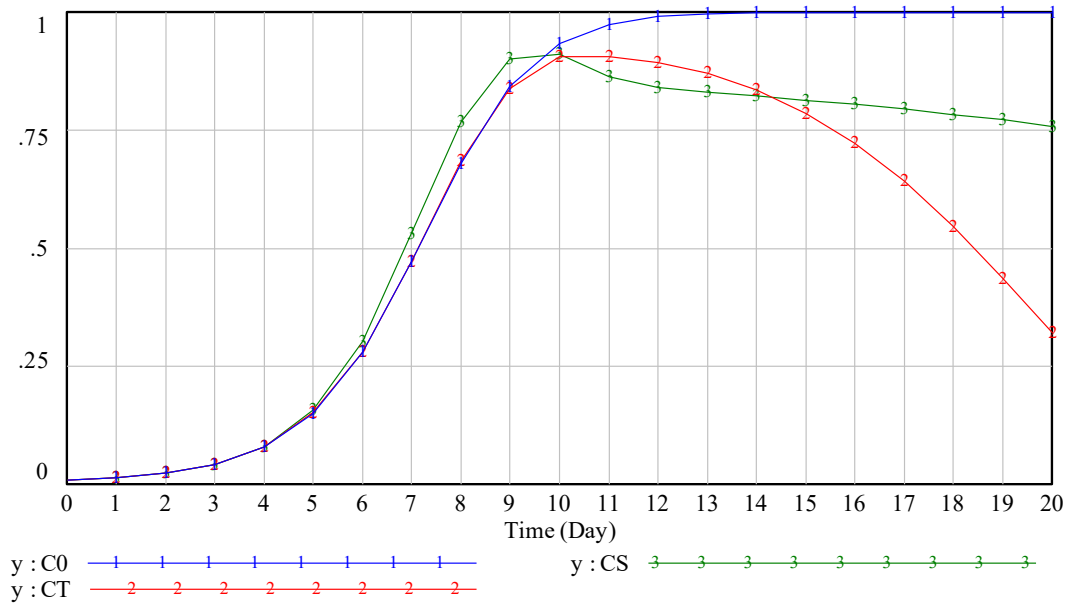


Figure 6: Influence of communication on the food safety risk

Analysis Of Simulation Results Of Supposed Five ITWC Models

Systematicness of communication effect

The incident involved five exchange organizations, all of which had an influence on the incident. Incident control is achieved under the joint action of two-way communication of five communication organizations, which shows that two-way communication is a communication system. If one organization does not communicate with other four organizations, the systematicness of two-way communication will be destroyed and the systematic and effective of communication could not be created. The curves SV1:C1-SV1:C5 in Figure 5 show such situation. Taking model 1 of Table 5 as an example, enterprise did not engage in two-way communication with the other four organizations and only repeatedly declared that its flour was qualified, even enterprise publicly declared that the reward will be given to person who proves that its flour is unqualified. Despite what the enterprise declared is truth, but enterprise is not trusted and recognized. The reason is that enterprise did not obtain and demonstrate valid evidence that the flour was qualified. In fact, there is evidence that flour is qualified and the enterprise can get it by two-way communication. Then taking model 3 as an example, without engaging in two-way communication with other departments, government subjectively ordered the enterprise to shut down only based on the incomplete and unscientific information. This situation can be said to be one-way communication. Therefore, in this case, enterprise is difficult to avoid facing high risks.

Nonlinearity of two-way communication effect

SD model is a multi-path feedback system, so a state variable is affected by multiple paths, i.e., the change of a state variable is the superposition of the effects of each path. Through comparing the curve SV1:CS and SV1:CT of Figure 6, we can see that the effect of model A is much better than that of model 1-5. For example, on the 20th day the risk values of curve SV1:CS and SV1:CT are 24.23% and 67.88% less than those of curve SV1:C0, respectively, which indicates that the effect of communication coefficients on communication effect has systematic characteristics. Therefore, the

superposition effect of multiple communication paths is nonlinear for two-way communication.

Problem-oriented comprehensive communication

The effect of communication depends mainly on two aspects, i.e. communication content should be problem-oriented and communication should be comprehensive. For example, at the beginning of the incident, determined whether the content of borax in flour is qualified is the key problem of communication. But organizations such as enterprise and government etc. did not comprehensively communicate on this issue. So the risk went up rapidly in the first few days. In addition, that the simulation results of six ITWC models and their superposition effect are very poor shows the importance of comprehensive communication.

CONCLUSION

A system dynamics model which can reflect the two-way communication is established. A flour incident happened in China was simulated by the established SD model. The simulation result coincides with the incident occurrence process, which shows that the SD model established in this paper is feasible and effective to simulate the incident. In addition, six cases of two-way communication are assumed and the corresponding six system dynamics models are established. The simulation results show that two-way communication can play an important role in food safety incident control and the effect of two-way communication on food safety incident is systematic and nonlinear. The simulation and analysis of this paper show that the SD method can evaluate the influence of different factors on food safety incident, predict the development of food safety incidents, and give management strategies of food safety incident. Therefore, the system dynamics method can be used as a method to predict, manage and control food safety incident. Although the SD method has not been applied in food safety management in China, this paper can provide a guide for future food incident management and control.

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References

- [1]. Costa-Font, et al., *Consumer acceptance, valuation of and attitudes towards genetically modified food: Review and implications for food policy*. Food Policy, 2008, 33: 99-111.
- [2]. Frewer, L.J., et al., *Consumer response to novel agri-food technologies: Implications for predicting consumer acceptance of emerging food technologies*. Trends in Food Science & Technology, 2011, 22: 442-456.
- [3]. Frewer, L.J., et al., *Public perceptions of agri-food applications of genetic modification—A systematic review and meta-analysis*. Trends in Food Science & Technology, 2013, 30: 142-152.
- [4]. Kher, S.V., et al., *Consumer perceptions of risks of chemical and microbiological contaminants associated with food chains: a cross-national study*. International Journal of Consumer Studies, 2013, 37: 73-83.
- [5]. Verbeke, W., *Beliefs, attitude and behaviour towards fresh meat revisited after the Belgian dioxin crisis*. Food Quality and Preference, 2001, 12: 489-498.

- [6]. Poortinga, W., and Pidgeon, N.F., *Trust in Risk Regulation: Cause or Consequence of the Acceptability of GM Food?*. Risk Analysis, 2005, 25: 199-209.
- [7]. Frewer, L.J., et al., *Risk/Benefit Communication about Food—A Systematic Review of the Literature*. Critical Reviews in Food Science and Nutrition, 2016, 56: 1728-1745.
- [8]. Kuttschreuter, M., and Hilverda, F., *"Listen, did you hear...?" A structural equation model explaining online information sharing on the risks of nanotechnology in food*. Food Quality and Preference, 2019, 76: 118-132.
- [9]. Yang, Y., et al., *Application of Bayesian modelling to assess food quality & safety status and identify risky food in China market*. Food Control, 2019, 100: 111-116.
- [10]. Ha, T.M., et al., *Linkages among food safety risk perception, trust and information: Evidence from Hanoi consumers*. Food Control, 2020, 110: 106965.
- [11]. Nayak, R., and Waterson, P., *Global food safety as a complex adaptive system: Key concepts and future prospects*. Trends in Food Science & Technology, 2019, 91: 409-425.
- [12]. Wang, Z.G., et al., *Study on Main Factors Affecting Food Safety in China: questionnaire survey on urban and rural residents in 21 provinces and cities (in Chinese)*. Quality and Safety of Agro-Products, 2012, 2: 11-21.
- [13]. Ma, X.N., and Du, M.H., *Analysis of risk factors and responsibility subjects for food safety in China (in Chinese)*. Journal of Food Safety and Quality, 2015, 6(8): 3167-3171.
- [14]. Zhang, E.D., *The legitimacy of the food safety compulsory liability insurance in China (in Chinese)*. Insurance Studies, 2015, 6(8): 95-101.
- [15]. Xu, Y., and Szmerekovsky, J., *System dynamic modeling of energy savings in the US food industry*. Journal of Cleaner Production, 2017, 165: 13-26.
- [16]. Findiastuti, W., et al., *Indonesian sustainable food-availability policy assessment using system dynamics: A solution for complexities*. Cogent Food & Agriculture, 2018, 4: 1455795.
- [17]. Mu, J., et al., *Influencing mechanism of food safety culture in enterprise based on system dynamics (in Chinese)*. The Food Industry, 2016, 37(8): 226-230.
- [18]. Wu, Y.N., et al., *Food safety risk assessment in China: Past, present and future*. Food Control, 2018, 90: 212-221.
- [19]. Liang, L., *Study on risk communication framework and influence factors of food safety (in Chinese)*. Journal of Henan Agricultural University, 2020, 54: 543-550.
- [20]. China Food and Drug Administration, National Center for Food Safety Risk Assessment. *Theoretical exploration of food safety risk (in Chinese)*. China Quality Inspection Press, Standards Press of China. 2015.
- [21]. Song, Y.Y., et al., *Boron background value survey of some foodstuffs in 12 provinces of China and boron primary intake estimation of Chinese habitants (in Chinese)*. Journal of Hygiene Research, 2011, 40(4): 431-433.
- [22]. Wang, Q.F., *System dynamics (in Chinese)*. Tsinghua University Press, 1994.
- [23]. Zhang, X.C., et al., *Evaluation and simulation for ecological risk based on emergy analysis and Pressure-State-Response Model in a coastal city, China*. Procedia Environmental Sciences, 2012, 13: 221-231.
- [24]. Forrester, J.W., and Senge, P.M., *Test for building confidence in System Dynamics models*, in TIMS Studies in the Management Sciences, Legasto Jnr, A.A.,

Forrester, J.W. and Lyneis, J.M. (Editors). 1980, North-Holland Publishing Company: Amsterdam. p. 209-228.

- [25]. Barlas, Y., *Formal aspects of model validity and validation in system dynamics*. *System Dynamics Review*, 1996, 12: 183-210.