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Blowout fire probability prediction of offshore drilling platform based on system dynamics

Blowout Fire Probability Prediction of Offshore Drilling Platform Based On System Dynamics

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Abstract: A Barrier Failure Model of offshore platform fire is proposed based on the analysis of historical accidents. On this basis, a fault tree is built to analyze the causes of fire accidents and the Fussell Vesely importance method is used to compare the contributions degree of the basic events. However, it is known that the traditional fault tree method has some limitations on predicting the dynamic probabilities of accidents. To improve the situation, a dynamic probability prediction model is proposed by integrating fault tree with a system dynamics model. Firstly, the dynamic probability of blowout fire for offshore drilling is predicted using the proposed model. Secondly, sensitivities of causal factors are analyzed based on mutual information to find out the key contributory factors to blowout fire. The research results provide safety managers with reliable and effective risk control strategies for preventing the occurrence of accidents.

Key words: Offshore drilling platform; Probability of blowout fire; System dynamics; Sensitivity analysis

1. Introduction

Oil and gas drilling operations have accounted for the highest rate of critical accidents compared to other domains in the petroleum industry (Vandenbussche et al., 2012). Geological uncertainties, high pressure flammable fluids in the presence of ignition sources, complicated structural layouts, limited response time allowance and the difficulties of communication are some of the critical factors that pose clear threats toward safety operations and may result in serious consequence events (Nafiz et al., 2017). Under such environments, the leakage of oil and gas may cause uncontrollable fire accidents, not only causing casualties and great economic losses, but also leading to serious pollution and ecological damage (Wang et al., 2015).

Many accident modelling methods, such as System Hazard Identification, Prediction and Prevention (SHIPP) (Rathnayaka et al., 2011), Functional Resonance Accident Model (Hollnagel, 2004), simulator-based simulation (Chen et al., 2018), Systems-Theoretic Accident Model (Leveson, 2004) and Fault tree and Bayesian Network (BN) have been developed over the last several decades. SHIPP is a systematic methodology to identify, evaluate, and model the accident process, thereby predicting and preventing accidents in a process facility (Rathnayaka et al., 2011). In this methodology, process hazard accidents were modeled using safety barriers rather than causal factors. The fault tree and event tree analysis techniques enhance the accident model. They gave researchers a holistic picture on the cause-consequence mechanism of the accident process. Quantitative analysis of BN has two aspects: updating and prediction. The Bayesian theory updates failure probability and consequence occurrence probability when there is a new observation. Traditional accident models normally use a fault and event tree sequential approach to predict cause-consequence relationships, which are unable to capture the real nonlinear interactions of several

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accident contributory factors.

Recently, some studies have been carried out in dynamic risk assessment of offshore drilling. Safety and reliability assessment of a managed pressure drilling operation by investigating the kick control operation of the constant bottom hole pressure technique is explored(Sule et al., 2018). Abimbola introduced the loss function approach into the risk analysis of drilling operations to address the drawbacks of static consequence analysis (Abimbola and Khan, 2016). Perez proposed an Accident Precursor Probabilistic Method that aims to overcome the usual limitations of existing Quantitative Risk Analyses and assessing the risk of blowouts in offshore hydrocarbon drilling projects (Perez and Tan, 2018). Adedigba presented a data driven risk assessment methodology for offshore drilling operation, from which the dynamic risk profile generated is useful in operational decision making to prevent accidents and enhance the safety of drilling operations (Adedigba et al., 2018).

Some researchers attempted to analyze the effect of human factor in quantitative risk analysis for drilling operation. Strand and Lundteigen presented a human reliability analysis (HRA) method for the qualitative and quantitative analysis of human factor influences on the blowout risk (Strand and Lundteigen, 2016). Strand and Lundteigen presented a novel method that combines the well accident report reviews and analysis with the probabilistic well risk assessment (Strand and Lundteigen, 2017). Zhang presented a method for the dynamic and quantitative risk assessment of MPD operations in the offshore oil and gas field by translating the Bow Tie model to Dynamic BNs (Zhang et al., 2018). Sun applied the hybrid method of Analytic Network Process and Structural Equation Modelling to evaluate the importance of human factors in an oil drilling work system (Sun et al., 2018).

Existing methods have their own strengths and weakness which depend mainly on the areas of their application. What is missing in the literature is a simplified time dependent blowout fire accident modelling approach considering holistic view of causal and non-causality-based factors. In this paper, a dynamic probability prediction model is proposed by integrating Fault Tree (FT) with System Dynamic (SD) theory to handle both the complexity and changes in a system over time. The methodology is grouped into two main activities including system dynamic modeling of a sociotechnical system and a dynamic probability analysis. The objective is to provide theoretical support for safety managers to reduce the probability of blowout fire accidents and to improve the overall safety of offshore drilling platforms. The novelty is proposing a simplified time dependent blowout probability prediction model, which can be used to predict the dynamic probability of blowout fire on offshore drilling platforms.

2 Causal analysis of blowout fire and importance analysis

2.1 Methodology

Firstly, the fire accidents of offshore drilling platforms are statistically analyzed. Secondly, a Barrier Failure Model for blowout fire is proposed based on the above analysis of historical accidents. This model can be used to define the causal relationship among factors, which is useful to draw a complex causal relationship of FT and SD. Thirdly, a fault tree is established to analyze the causes of blowout fire and provide guidance to define the hierarchical structure diagram of System Dynamics model. The root causes of the offshore platform blowout fire could be determined. Based on this, the causal loop diagrams of SD model is built to predict the dynamic probabilities of blowout fire.

2.2 Barrier failure model of blowout fire

A blowout is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems failed (Westergaard, 1987). The down-hole fluid pressures are controlled in modern wells through the balancing of the hydrostatic pressure provided by the mud column. Should the balance of the drilling mud pressure be incorrect, the formation fluids may start flowing into the wellbore and filling up the annulus or going inside the drill pipe. This is commonly called a kick. Ideally, mechanical barriers, such as blowout preventers, can be closed to isolate the well while the hydrostatic balance is regained through circulation of fluids in the well. Improper handling of kicks in oil well control can result in blowouts with very serious consequences. A blowout fire is an accident that the formation fluids is ejected from the wellbore and subsequently ignited.

The occurrence of an accident is not only a reaction chain of time itself, but also in a penetrated set of organization defects (Vinnem et al., 2010). If the organization defects at different levels are triggered by an accident factor at the same time or in sequence, entire multi-level blocking barriers will fail and an accident will potentially occur. According to the process of blowout fire, the barrier failure model of blowout fire for offshore drilling platforms is constructed as shown in Fig. 1. The four large rectangles represent physical or operational barriers to reduce hazards.

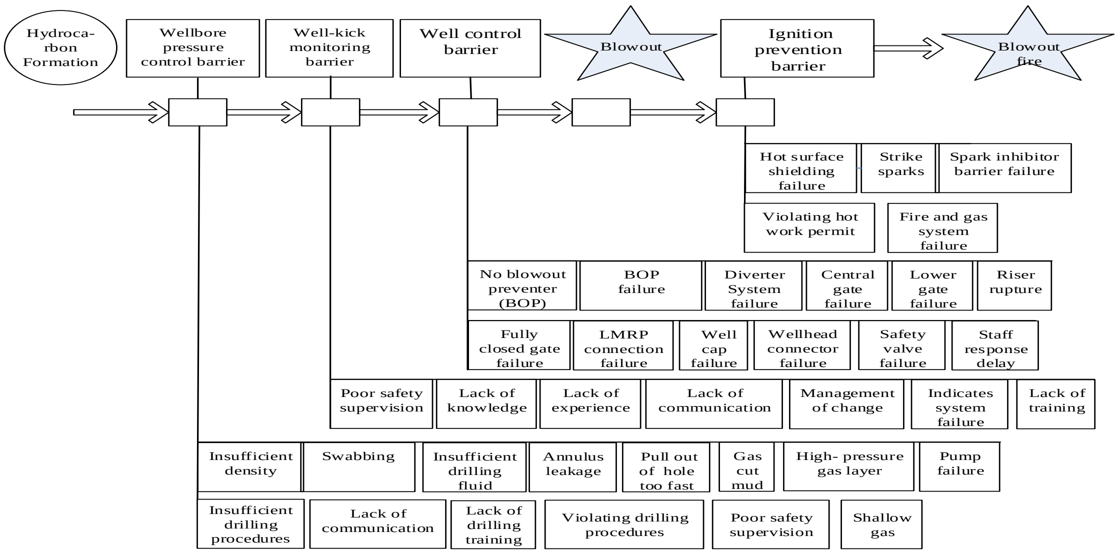


Fig. 1 Barriers Failure model of blowout fire accident

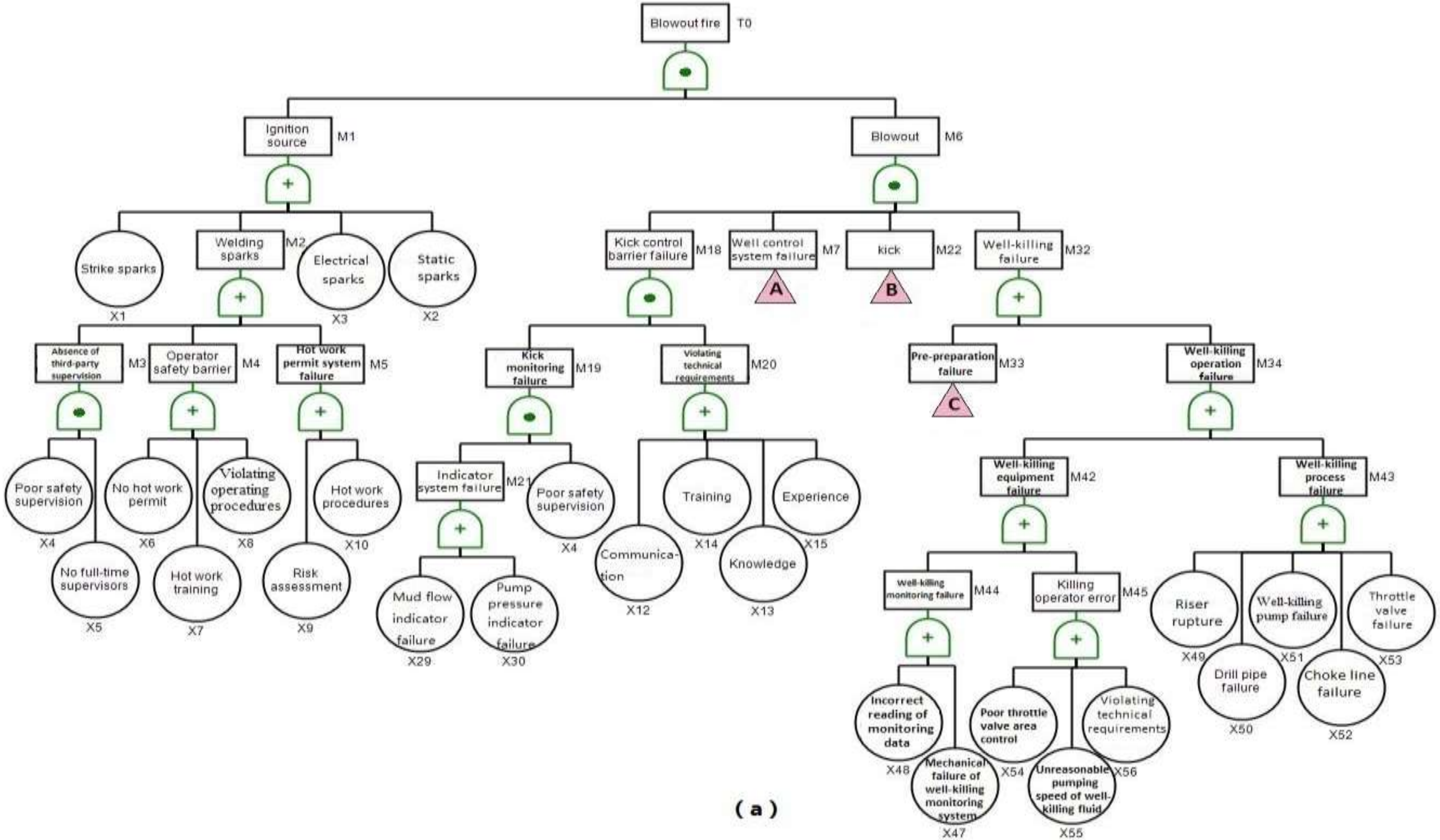
From Fig. 1, it can be seen that safety measures to prevent blowout fire are divided into four levels, which consist of wellbore pressure control barrier, well kick monitoring barrier, well control barrier and ignition prevention barrier. The first barrier is mainly used to balance the pressure inside the wellbore and prevent the occurrence of the well kick. The well kick monitoring barrier is used to timely detect the precursors of well kick before the occurrence of the blowout. The well control barrier is the emergency response measures after blowout. The last level of the model is the ignition prevention barrier, which is used to eliminate the potential ignition source and prevent the blowout from escalating to blowout fire.

2.3 Fault tree model of blowout fire

The 2837 fire accidents of offshore platforms in the Gulf of Mexico during the period from 1976 to 2015 are analyzed to determine the main causes and processes of fire accidents [18]. The FT of blowout fire is proposed as shown in Fig. 2, which is constructed based on the above barrier failure model and the statistical analysis of historical accident. There are 58 basic events that contribute to the occurrence of blowout fire accidents. Their occurrence probabilities are determined according to the statistics of historical data from Offshore Reliability Data, Health and Safety Executive and Bureau of Safety and Environment as shown in Table 1(Holland, 1997; Engevik, 2007; Jyoti et al., 2015; BSEE, 2019).

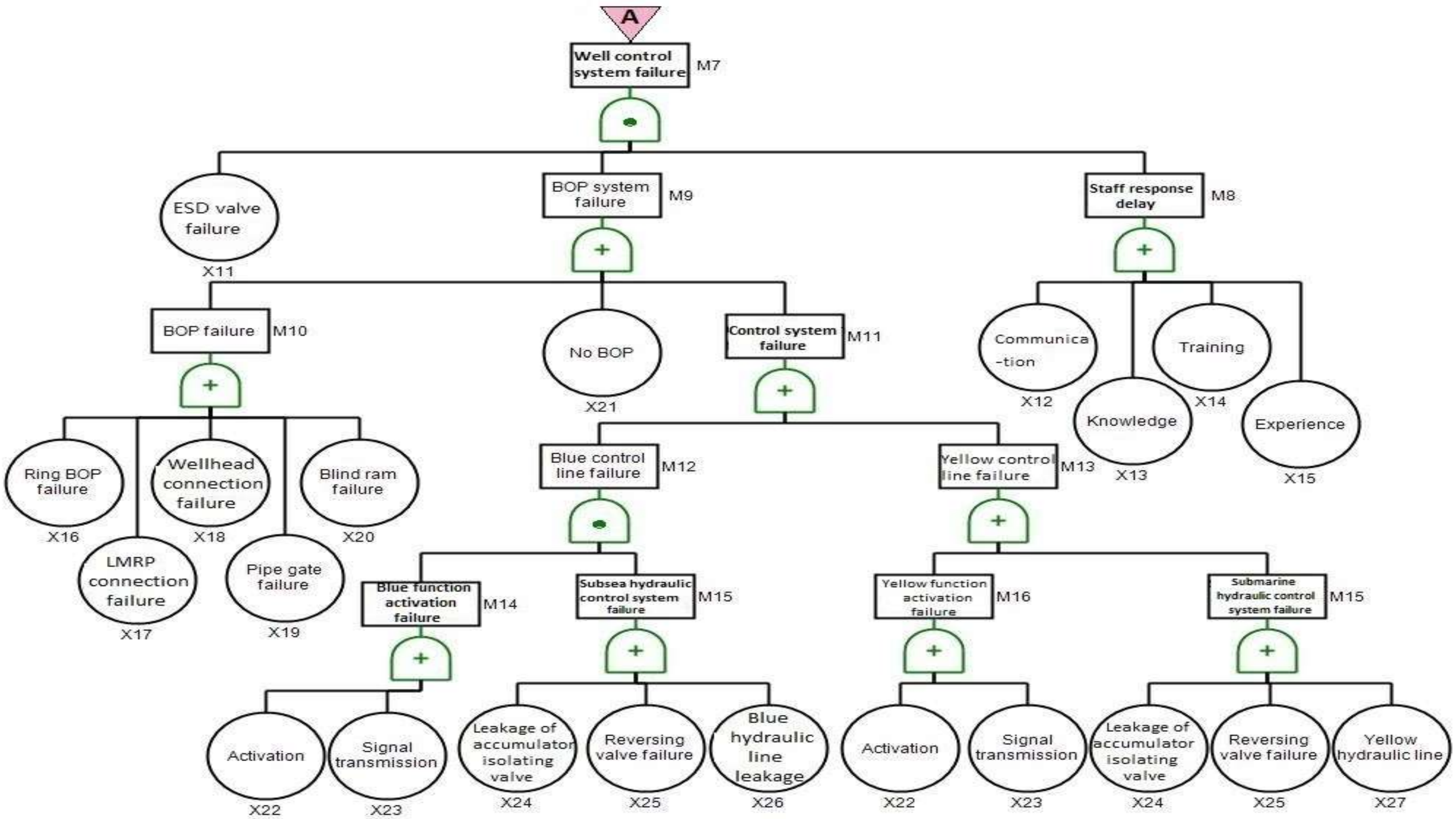
Table 1 Probability of basic events (Holland, 1997; Engevik, 2007; Jyoti et al., 2015; BSEE, 2019)

Basic events	Probability (10^6 hour)	Basic events	Probability (10^6 hour)
Strike sparks (X1)	6.3E-3	Well leakage (X32)	2.7E-3
Static sparks(X2)	1.1E-3	Killing pump failure(X33)	4.3E-3
Electrical spark(X3)	1.1E-3	Clogged pipeline (X34)	5E-5
Poor safety supervision(X4)	4.6E-4	Drilling procedure (X35)	7E-4
No full-time supervisor(X5)	7.4E-4	High-pressure gas layer (X36)	1.5E-2
No hot work permit(X6)	5.5E-3	Insufficient technical handover(X37)	6.3E-3
Hot work training(X7)	8.6E-3	Insufficient equipment safety check(X38)	2.5E-2
Violating operating procedures (X8)	1.7E-4	Unfamiliar with wellbore(X39)	5.6E-3
Risk assessment(X9)	1.8E-4	Lack of well-killing experience(X40)	1.25E-3
Hot work procedures (X10）	3E-6	Insufficient reserve plan (X41)	3.5E-3
ESD valve failure(X11)	1.3E-4	No periodic inspection of well-killing material(X42)	2.5E-2
Communication(X12)	1.89E-3	Invalid daily record(X43）	5.6E-3
Knowledge(X13)	1.2E-3	Inadequate well-killing technology(X44)	1.25E-3
Training(X14)	1.89E-3	Inadequate emergency well-killing plan (X45）	5E-4
Experience(X15)	1.1E-3	Design error of operator(X46）	2.2E-3
Ring BOP failure(X16)	3E-5	Killing monitoring system failure (X47）	5E-4
LMRP connection failure(X17)	1E-6	Fail to read the monitoring data correctly (X48）	2.5E-3
Wellhead connection failure(X18)	3E-5	Riser rupture(X49)	1.25E-3
Pipe gate failure(X19)	3E-5	Drill pipe failure(X50)	1.25E-3
Blind ram failure(X20)	1E-5	Well-killing pump failure (X51）	3.5E-3
No BOP (X21)	3E-5	Choke line failure(X52）	2.2E-3
Activation(X22)	2.37E-5	Throttle failure(X53)	1E-2
Signal transmission (X23)	3.35E-5	Poor throttle valve area control(X54)	5E-4
Leakage of accumulator isolating valve(X24)	1.03E-5	Unreasonable pumping speed of well-killing fluid(X55)	4.3E-3
Reversing valve failure (X25)	1.32E-5		
Blue hydraulic line leakage(X26)	2.08E-5	Failed to follow the technical requirements (X56)	1.92E-4
Yellow hydraulic line leakage(X27）	2.08E-5	Groundwater intrudes into mud (X57)	3E-5
Display wrong mud flow (X29)	2E-3	Shallow gas (X58)	3E-5
Display wrong pump pressure (X30)	2E-3		
Gas gut mud (X31）	3E-5	Violating the technical requirements(X59)	1.92E-4

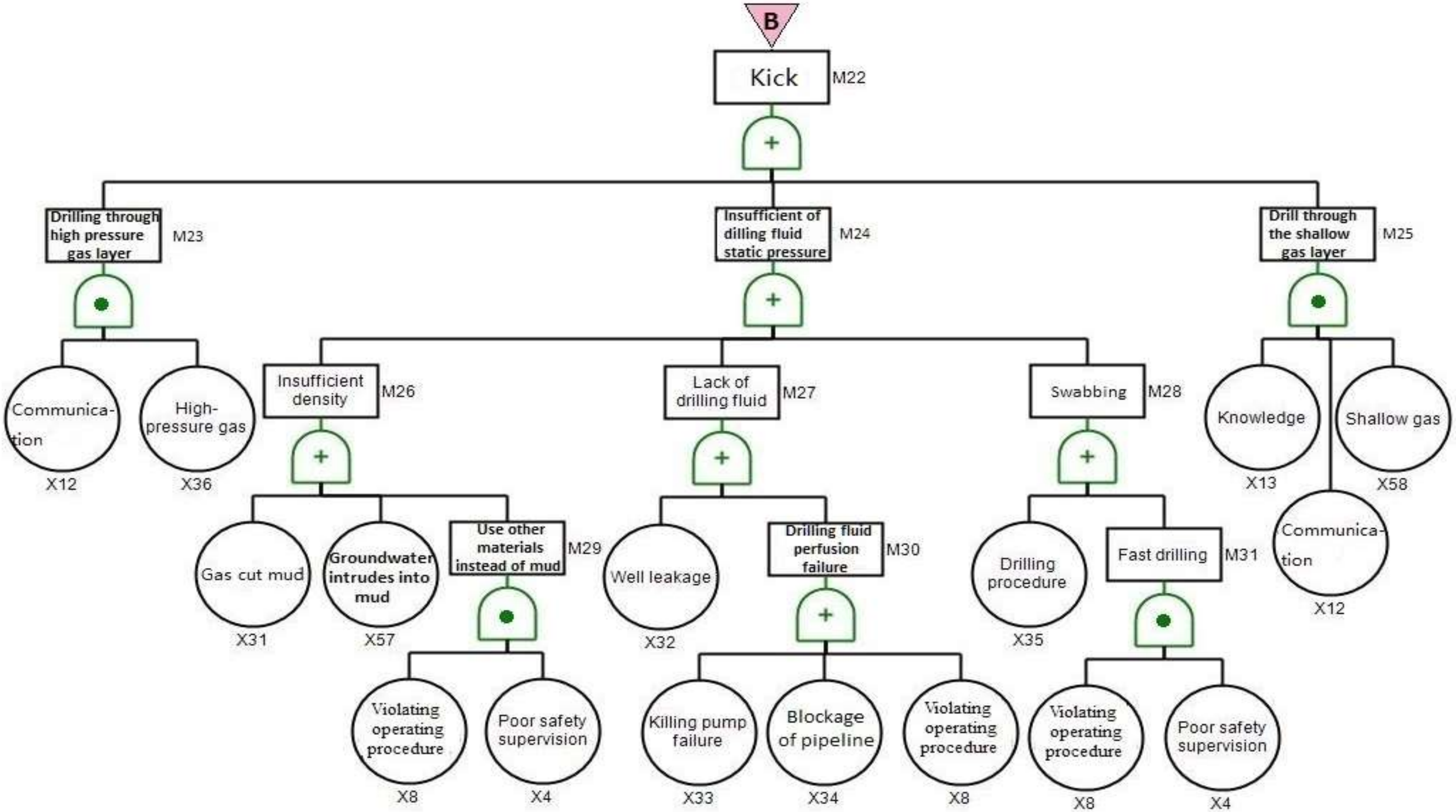


Blowout fire
T0
Ignition source
M1
Blowout
M6
Strike sparks
X1
Welding sparks
M2
Electrical sparks
X3
Static sparks
X2
Absence of third-party supervision
M3
Operator safety barrier
M4
Hot work permit system failure
M5
Poor safety supervision
X4
No full-time supervisors
X5
No hot work permit
X6
Hot work training
X7
Violating operating procedures
X8
Risk assessment
X9
Hot work procedures
X10
Kick control barrier failure
M18
Well control system failure
M7
A
kick
M22
B
Well-killing failure
M32
Kick monitoring failure
M19
Violating technical requirements
M20
Indicator system failure
M21
Poor safety supervision
X4
Mud flow indicator failure
X29
Pump pressure indicator failure
X30
Communica-tion
X12
Training
X14
Knowledge
X13
Experience
X15
Pre-preparation failure
M33
C
Well-killing operation failure
M34
Well-killing equipment failure
M42
Well-killing process failure
M43
Well-killing monitoring failure
M44
Killing operator error
M45
Incorrect reading of monitoring data
X48
Mechanical failure of well-killing monitoring system
X47
Poor throttle valve area control
X54
Unreasonable pumping speed of well-killing fluid
X55
Violating technical requirements
X56
Riser rupture
X49
Drill pipe failure
X50
Well-killing pump failure
X51
Choke line failure
X52
Throttle valve failure
X53

(a)


A
Well control system failure
M7
ESD valve failure
X11
BOP system failure
M9
Staff response delay
M8
BOP failure
M10
No BOP
X21
Control system failure
M11
Communica -tion
X12
Knowledge
X13
Training
X14
Experience
X15
Ring BOP failure
X16
LMRP connection failure
X17
Wellhead connection failure
X18
Pipe gate failure
X19
Blind ram failure
X20
Blue control line failure
M12
Yellow control line failure
M13
Blue function activation failure
M14
Subsea hydraulic control system failure
M15
Yellow function activation failure
M16
Submarine hydraulic control system failure
M15
Activation
X22
Signal transmission
X23
Leakage of accumulator isolating valve
X24
Reversing valve failure
X25
Blue hydraulic line leakage
X26
Activation
X22
Signal transmission
X23
Leakage of accumulator isolating valve
X24
Reversing valve failure
X25
Yellow hydraulic line
X27

(b)



B
Kick
M22
Drilling through high pressure gas layer
M23
Insufficient of dilling fluid static pressure
M24
Drill through the shallow gas layer
M25
Communica-tion
X12
High-pressure gas
X36
Insufficient density
M26
Lack of drilling fluid
M27
Swabbing
M28
Knowledge
X13
Shallow gas
X58
Communica-tion
X12
Gas cut mud
X31
Groundwater intrudes into mud
X57
Use other materials instead of mud
M29
Well leakage
X32
Drilling fluid perfusion failure
M30
Drilling procedure
X35
Fast drilling
M31
Violating operating procedure
X8
Poor safety supervision
X4
Killing pump failure
X33
Blockage of pipeline
X34
Violating operating procedure
X8
Violating operating procedure
X8
Poor safety supervision
X4

(c)

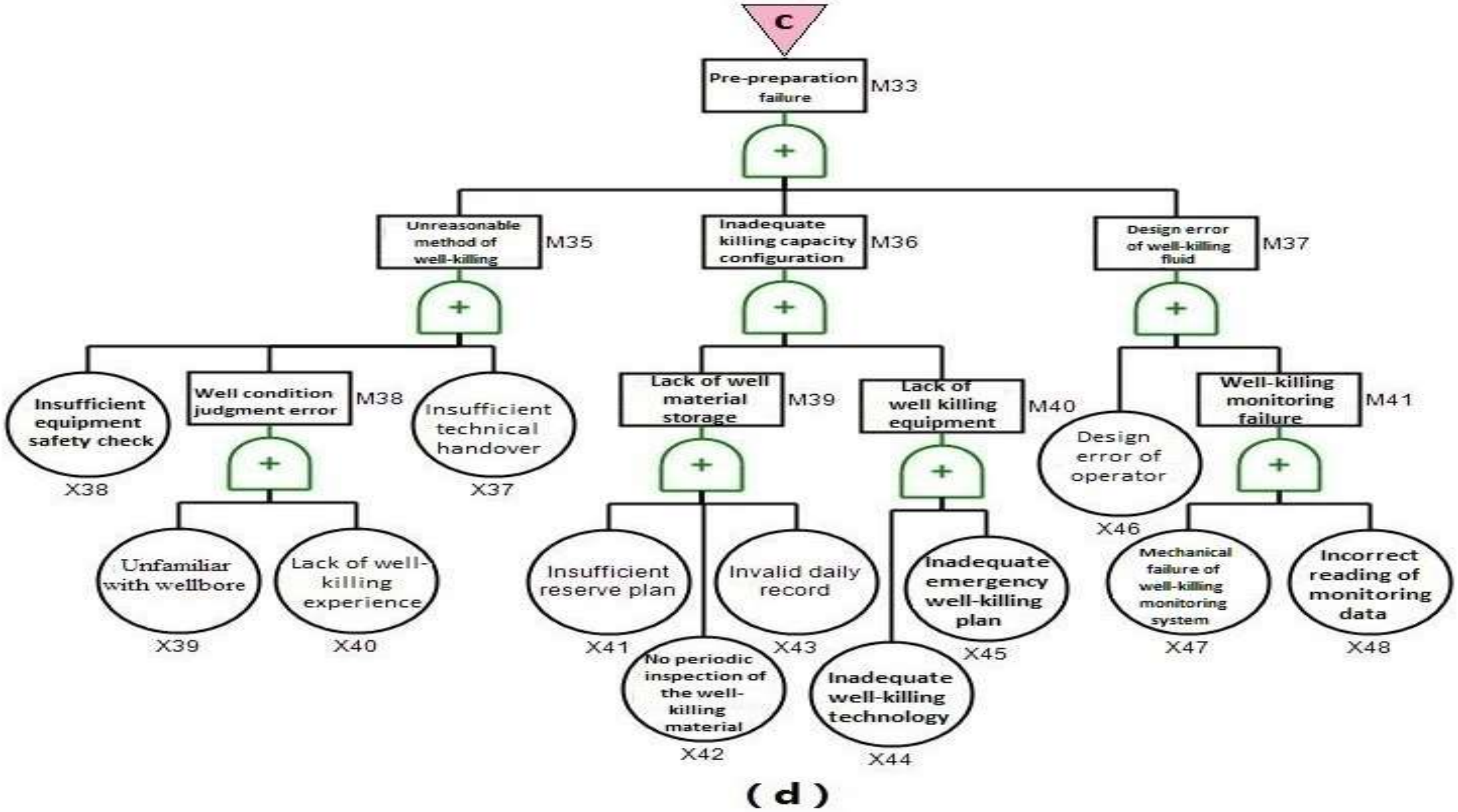


Fig. 2 Fault Tree of blowout fire on offshore drilling platforms

Seen from Fig. 2, both blowout and ignition source are the coupling interactions of human errors, organizational defects and equipment failures. There are 60 basic events contributing to the blowout fire as shown in Table1. There are 57 minimal cut sets as shown in Table 2. The probability of blowout fire is estimated as 4.748E-10.

2. 4 Fussel-Vesely measure of importance

In this section, the Fussel-Vesely method is adopted to measure the importance of the basic events and minimum cut sets. Fussel-Vesely measure of importance for basic events is defined as the ratio of the occurrence probability of the union of the minimum cut sets containing event X_i over the occurrence probability of the top event.

The importance of X_i is represented by I (X_i).

$$I(X_i) = P(U \text{ (cut sets containing } X_i)) / P(\text{top event}) \tag{1}$$

where, U stands for “union” or “OR” operation.

The importance of minimum cut sets is defined as the ratio of the occurrence probability of minimum cut set i (i.e. MC_i) over the occurrence probability of the top event (Andrews,1993).

The importance of MC_i is represented by $I(MC_i)$:

$$I(MC_i) = P(MC_i) / P(\text{top event}) \tag{2}$$

The Fussell-Vesely importance order of the minimal cut sets are listed as follows: IFV(43)>IFV(53)>IFV(9)=IFV(42)>IFV(54)=IFV(13)>IFV(44)>IFV(55)>IFV(46)>IFV(25)>IFV(29)=IFV(35)> IFV(51)>IFV(47)=IFV(2)>IFV(48)>IFV(4)=IFV(20)>IFV(26)>IFV(5)>IFV(41)>IFV(49)>IFV(3)=IFV(57)>IFV (56)>IFV(37)>IFV(52)>IFV(16)>IFV(38)>IFV(33)>IFV(18)>IFV(50)>IFV(10)IFV(12)>IFV(14)>IFV(39)>IFV(6)>IFV(27)>IFV(45)>IFV(8)>IFV(23)>IFV(1)>IFV(34)>IFV(17)>IFV(32)>IFV(19)>IFV(28)>IFV(24)>IFV(56)>IFV(21)>IFV(11)>IFV(15)>IFV(30)>IFV(22)>IFV(31)>IFV(7).

The Fussell Vesely importance order of the main basic events are listed in descending order as follows: I(X12)> I(X38)> I (X8)> I (X14)> I (X36)> I (X7)> I (X33)> I (X1)> I (X13)> I (X49)> I (X 6)> I (X15)> I (X32)> I (X37)> I (X39)> I (X51)> I (X47)> I (X3)> I (X42)> I (X35)> I (X48)> I (X2)= I (X43)= I (X44)= I (X40)> I (X41)= I (X45)= I (X52)= I (X9)> I (X46)= I (X54)= I (X55)= I (X56)= I (X34)= I (X53)= I (X31)= I (X57)> I (X50)= I (X10)= I (X4)= I (X5)> I (X58)> I (X29)= I (X30)= I (X11)> I (X23)= I (X21)= I (X16)= I (X18)= I (X19)= I (X22)= I (X25)= I (X24)= I (X20)> I (X17)> I (X26)= I (X27).

3 Dynamic probability analysis of blowout fire based on System Dynamics

3.1 System Dynamics Method

A SD is an analytical method of combining qualitative analysis, quantitative analysis and synthesis reasoning, which is regarded as an effective approach for nonlinear complex systems and scientific decision-making. The SD modeling is useful for understanding the underlying behavior of complex systems over time, taking into account time delays and feedback loops (Calvo and García, 2013). Unlike traditional approaches that place an emphasis on linear cause-and-effect, the SD focuses on feedback between variables in a system. The focus on feedback enables a more holistic view of the real world and places emphasis on the complex dynamics that invariably exist within systems. Some of the reported benefits of SD include dynamic and nonlinear analysis (Schade and Rothengatter, 2003) and a platform for policy makers and stakeholders to understand the possible impacts of policies and strategies over a period of time (Maalla and Kunsch, 2008). In this section, the dynamic relationship among the equipment, organizational function and human behavior is studied through the establishment of the SD model using Vensim software. Vensim is a simulation software tool developed by Ventana Systems (Vensim, 2019). It primarily supports continuous simulation (SD), with some discrete event and agent-based modelling capabilities. Vensim provides a graphical modeling interface with stock and flow and causal loop diagrams, on top of a text-based system of equations in a declarative programming language. It includes a patented method for interactive tracing of behavior through causal links in model structure, as well as a language extension for automating quality control experiments on models called Reality Check (Peterson and David, 1994). Sensitivity analysis options provide a variety of ways to test and sample models, including Monte Carlo simulation with Latin Hypercube sampling.

3.2 Dynamic probability prediction model of blowout fire

It is difficult to directly build the causal loop diagrams of the SD model of blowout fire due to the complexity of offshore drilling and the complicated causality between their technical, human, and organizational factors. However, it is easier to draw the causal loop diagrams of a SD model by integrating FT with the SD (Mohaghegh et al., 2009). The SD model is proposed, as shown in Fig. 3, according to the causal relationship of FT in Section 2.2. The occurrence probabilities of causal factors are presented in Table 1.

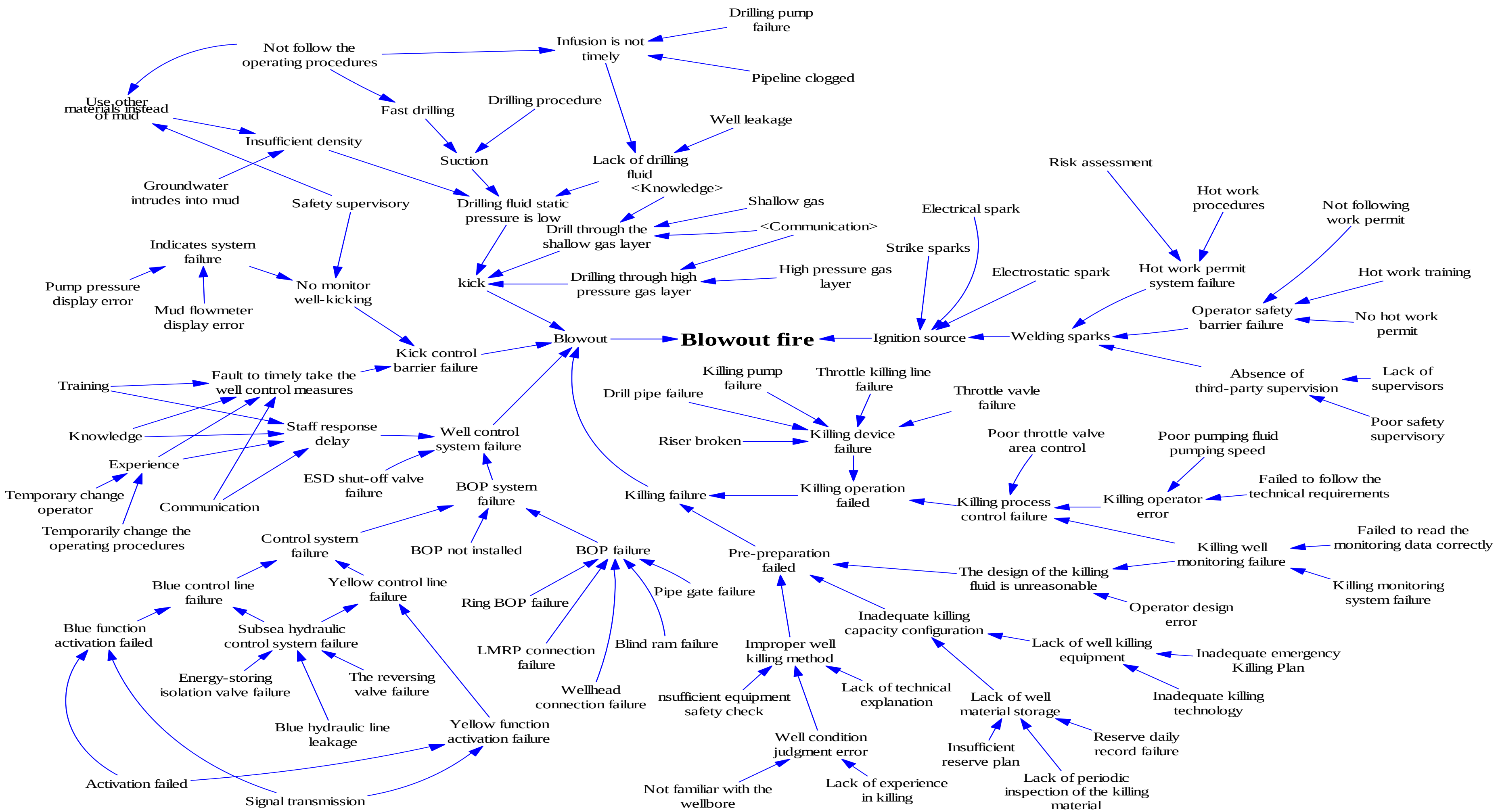


Fig. 3 System dynamics model of blowout fire for offshore drilling platform

4. Simulation Results and Analysis

4.1. Dynamic Probability of Blowout Fire

The time boundary condition is set to display the dynamic change trend of blowout fire probability for each month within 48 months: INITIAL TIME=0；FINAL TIME=48；TIME SETP=1；Units for Time=month. The occurrence probability of each basic event in Table 1 is put into the established simulation model. Thereafter, time series data sets can be generated through the dynamic analysis of the simulation model. The dynamic probability of blowout fire for an offshore drilling platform is shown in Fig. 4.

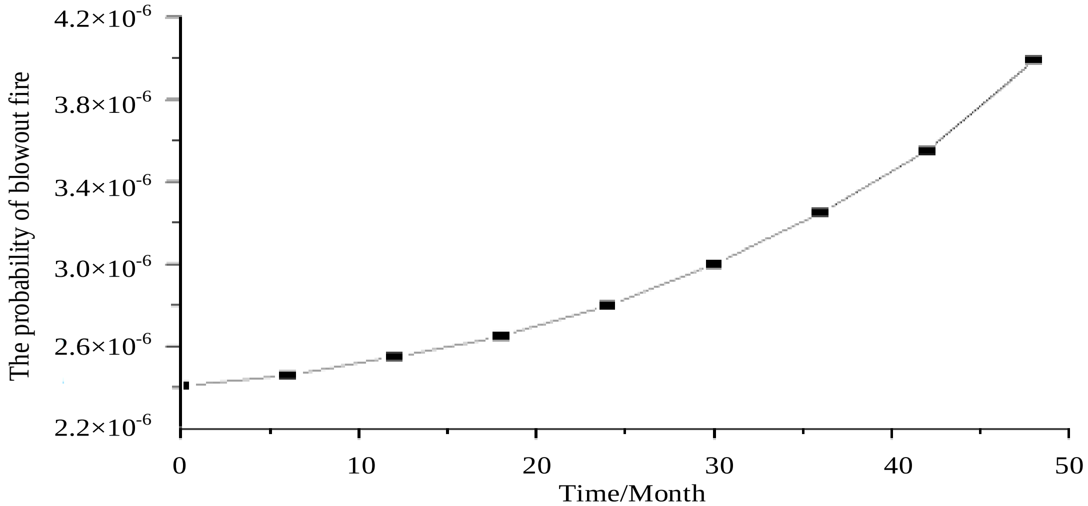


Fig. 4 Dynamic blowout fire probability of an offshore drilling platform

As shown in Fig. 4, the blowout fire probability of an offshore drilling platform is between 2.41E-6 and 3.997E-6 within four years. The corresponding historical data from the statistics of the Bureau of Safety and Environmental Enforcement (BSEE, 2019) is around 3.18E-6 (Wang et. al, 2016). From the comparison of simulation results with the real data, it can be seen that the proposed model can be used to reliably predict the dynamic probability of blowout fire. The fire probability in 48 months will increase with time due to the ignorance of safety management. This is because the fire probability is predicted without considering the effect of strengthening safety management. If the above identified contributing factors of the blowout fire are managed to a reasonable level, the fire probability should be reduced correspondingly.

4.2. Sensitivity Analysis Based on Mutual Information

In probability theory and information theory, the mutual information of two variables is a measure of the mutual dependence between the two variables. More specifically, it quantifies the "amount of information" obtained about one variable, through the other variable. The concept of mutual information is intricately linked to that of entropy of a variable, a fundamental notion in information theory that defines the "amount of information" held in a variable. The information entropy is the expected value of the information contained in each message, which can be used to characterize the uncertainty about the source of information. The entropy is expressed by Eq. (3) (Borda and Monica, 2011).

$$H(Y) = -\sum_{t} P(y)\log P(y) \tag{3}$$

where, $P(y)$ is the probability mass function.

The mutual information of two discrete variables X and Y can be defined as:

$$H(X:Y)=\sum_{y\in Y}\sum_{x\in X}P(x,y)\log_2\left(\frac{P(x,y)}{p(x)p(y)}\right) \tag{4}$$

where, $P(x,y)$ is the joint probability distribution function of X and Y, while $P(x)$ and $P(y)$ are the respective marginal probability distribution functions of X and Y.

The sensitivity analysis is carried out to determine the impact of the contributory factors on blowout fire. The results of sensitivity analysis for well kick, the failure of the well control barrier, the failure of the well control system, blowout and fire are shown from Fig. 5 to Fig. 9 respectively.

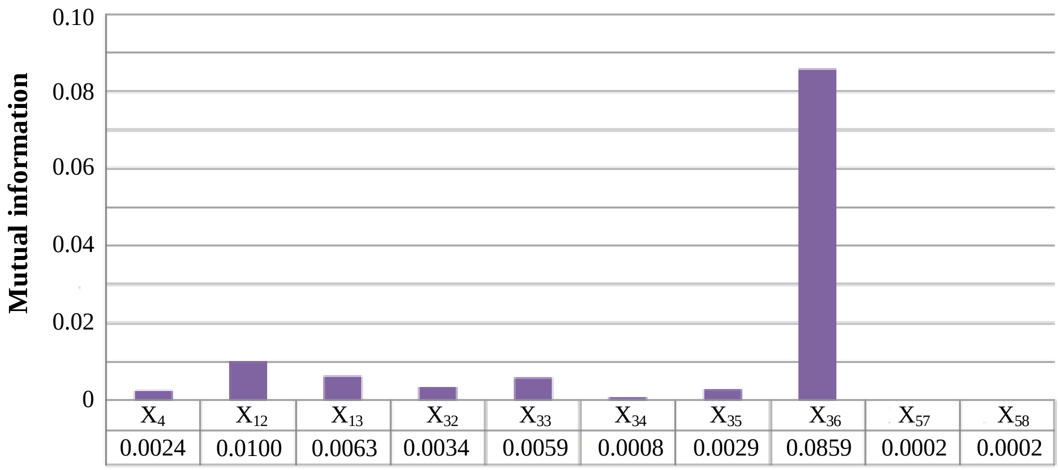


Fig. 5 Mutual information of basic events and well kick

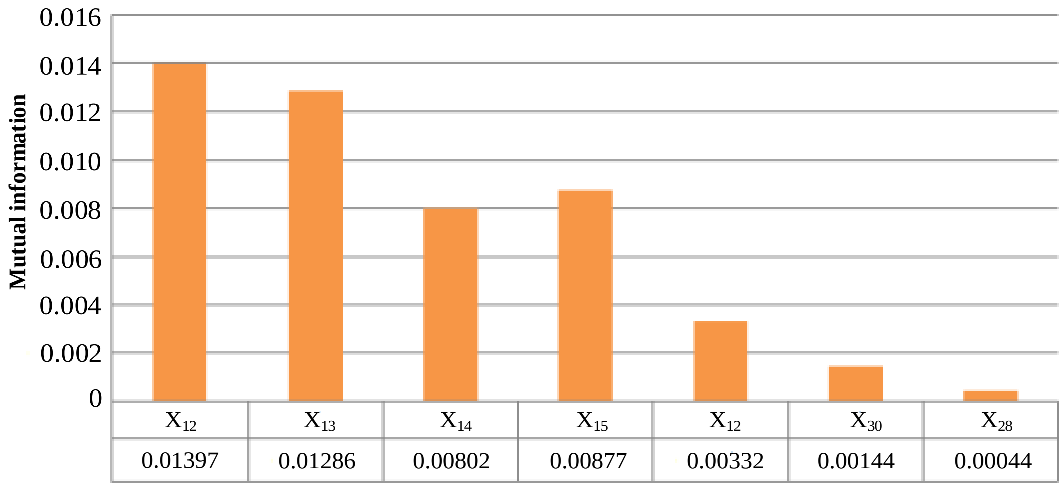


Fig. 6 Mutual information of basic events and well kick control barrier failure

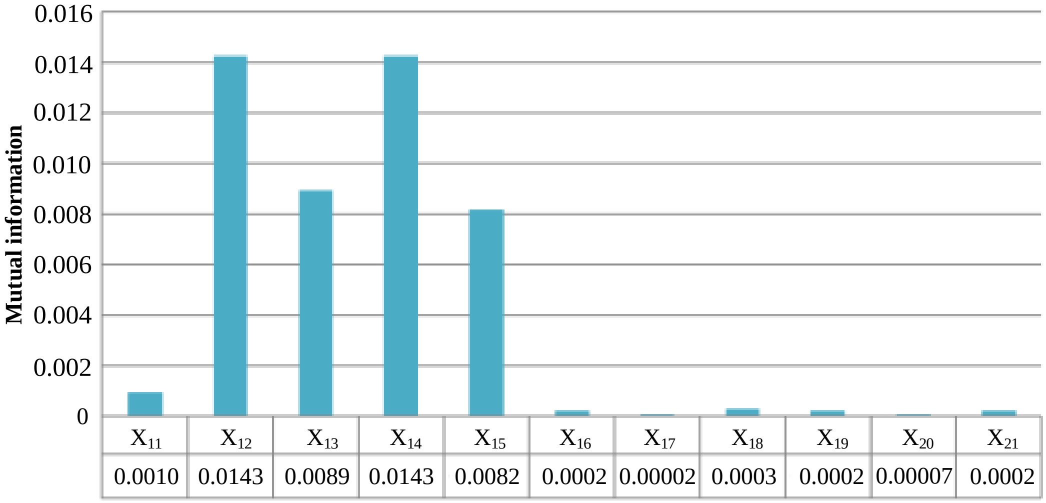


Fig. 7 Mutual information of basic events and well-control system failure

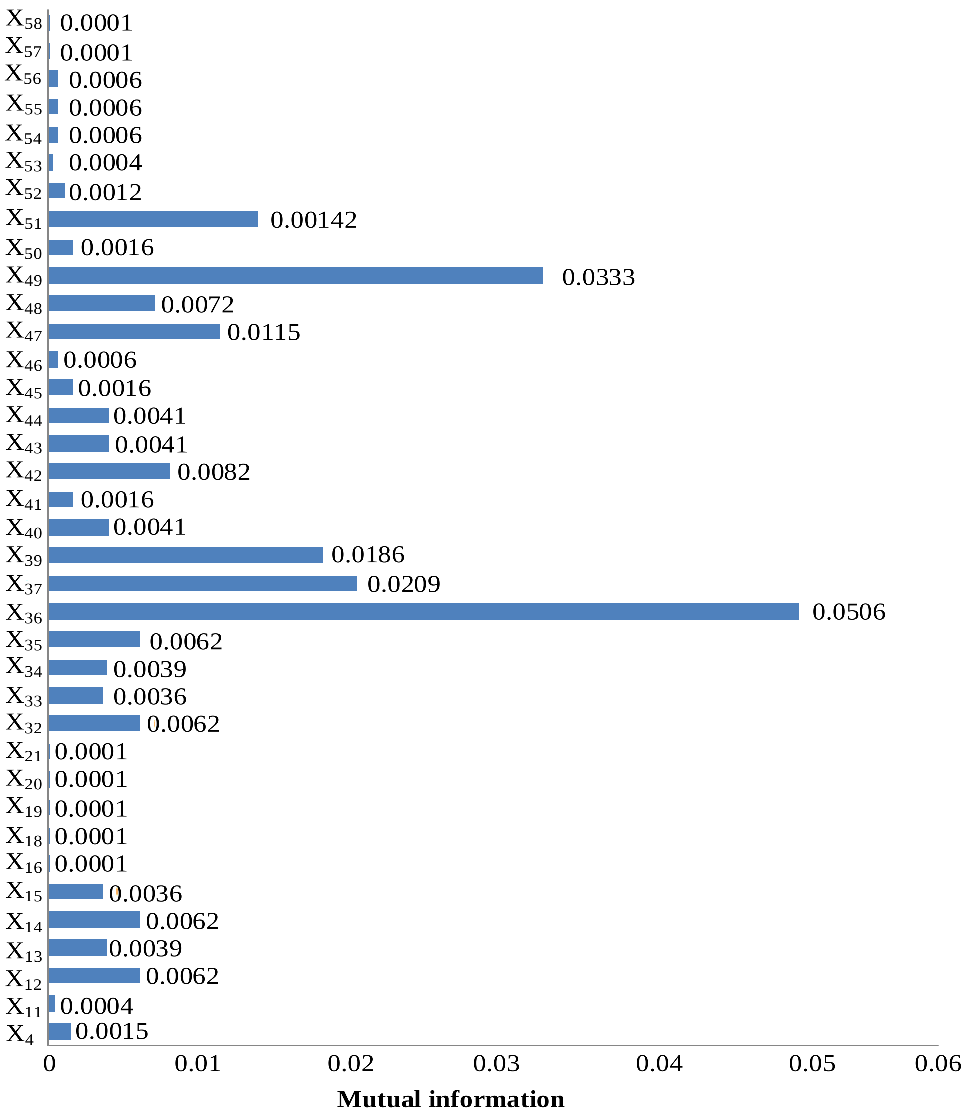


Fig. 8 Mutual information of basic events and blowout

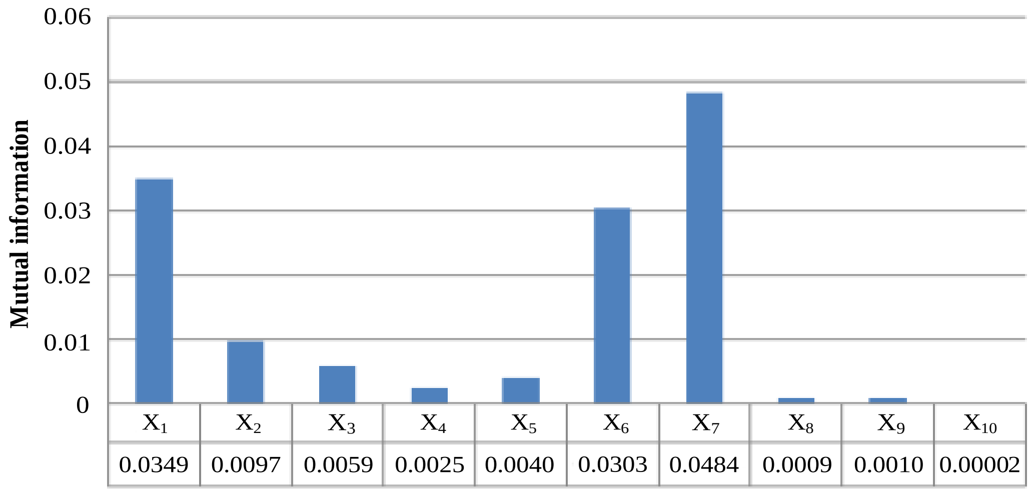


Fig. 9 Mutual information of basic events and fire

From Fig. 5, it can be seen that X36 High-pressures gas, X12 Communication, X13 Knowledge and X33 Drilling pump failure are the main contributing factors of well kick.

Seen from Fig. 6, the sensitivity of node variable in descending order are X12 Communication, X13 Knowledge, X15 Experience, X14 Training and X30 Pump pressure indicator failure. Insufficient communication, knowledge, experience and training contribute more to the failure of well kick control barrier.

As shown in Fig. 7, the sensitivity of node variables in descending order are X12 Communication, X14 Training, X13 Knowledge, X15 Experience, X11 ESD valve failure, X18 Wellhead connection failure, X16 Annular BOP failure, X19 Pipe gate failure, X21 No BOP, X20 Blind ram failure and X17 LMRP connection failure. The result shows that insufficient communication, training, knowledge and experience are the main contributing factors that lead to the delay response of personnel. The failure of ESD valve and wellhead connection contribute more to the failure of well-control system.

From Fig. 8, it can be seen that X36 High-pressure gas, X49 Riser rupture, X37 Insufficient technical handover, X39 Unfamiliar with the wellbore, X51 Well-killing pump failure, X47 Mechanical failure of well-killing monitoring system are the main contributing factors of blowout.

As shown in Fig. 9, the sensitivity of variables in descending order are X7 Hot work training, X1 Strike sparks, X6 No hot work permit, X2 Electrical sparks, X3 Static sparks, X5 Lack of supervisors, X4 Poor safety supervision, X9 Risk assessment, X8 Violating standard operation procedures and X10 Hot work procedures separately. Therefore, hot work training, Strike sparks, No hot work permit, Electrical sparks, Static sparks and Lack of supervisors are the main contributing factors for blowout fire.

5. Conclusions

1）The Barrier Failure Model is constructed to analyze the process and the potential pathways of blowout fire. The FT model of blowout fire for offshore drilling platforms is built based on the statistics analysis of historical data. The probability of blowout fire is estimated as 4.748E-6 using the built FT model.

2) The dynamic probability prediction model of blowout fire is proposed by integrating FT with a SD model.

From the simulation results of SD, it can be seen that the probability of blowout fire increases from 2.41E-6 to 3.997E-6 within 48 months. The comparison results between the simulation data and historical data show that the proposed model can be used to predict the dynamic probability of blowout fire on offshore drilling platforms.

3) The proposed methodology can be used to develop some targeted safety precautions to prevent the occurrence of similar accidents because the main contributing factors can be identified. X36 High-pressure gas, X7 Hot work training, X1 Strike, X49 Riser rupture, X6 No hot work permit, X37 Insufficient technical handover, X39 Unfamiliar with the wellbore, X12 Communication, X13 Knowledge, X47 Mechanical failure of well-killing monitoring system, X15 Experience and X14 Training are the main contributing factors of blowout fire.

4) By comparing sensitivity analysis with importance analysis, the Fussell Vesely importance method can be used to compare the basic events in terms of their contribution to the accident.

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