Game-Theory Based Research on Oil-Spill Prevention and Control Modes in Three Gorges Reservoir Area

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Abstract. Aiming at solving the existing oil pollution in the Three Gorges reservoir, this paper makes research on oil-spay prevention and control mode based on game theory. Regarding the built modes and comparative indicator system, overall efficiency indicator functions are used to compare general effect, overall cost, and overall efficiency, which concludes that the mode combining government and enterprise has the highest overall efficiency in preventing and controlling ship oil spills. The suggested mode together its correspondingly designed management system, has been applied to practice for a year in Three Gorges Reservoir Area and has made evident improvements to the existing oil pollution, meanwhile proved to be quite helpful to the pollution prevention and control in the lower reaches of Yangtze River.

1. Introduction

In recent years, with the increasing hazard transportation, oil transportation, and nonstandard operation of non-oil ships in oily sewage, incidences of oil spills rise a lot. The present overseas researches of oil spills mainly focus on damage evolution, risk evolution, or oil-pollution prevention and control mode. The domestic researches mainly deal with oil-spill influences on ecosystem, level assessment of oil-spill damages, emergency responses to oil spills, and oil-spill clean-up. As for emergency responses, most researches mainly work on the development and application of simulation system. As for clean-up of oil spills, related researches mainly involve emergency responses, prevention and control technology, and equipments for emergencies. There are not enough researches on management modes for oil-pollution prevention and oil control. Since the optimization of such management modes can play an important role in pollution prevention of rivers and oceans, this paper, taking Three Gorges Reservoir as the example, works on designing a management mode combining efforts from both government and enterprise. This paper first analyzes the existing problems in Three Gorges Reservoir, establishes a game-theory based indicator system which refers to both oil-spill damage rules and risk evolution rules, and then builds the above mode with the calculated results from game theory model which uses data of specialist surveys and real spill cases. The designed mode has been applied to practice for a year in Three Gorges Reservoir Area and has made evident improvements to the existing oil pollution, meanwhile proved to be quite helpful to the pollution prevention and control in the lower reaches of Yangtze River.
2. Building Comparative Indicator System Based on Game Theory in Ship Oil-pollution prevention and Control Mode

2.1. Different Modes in Ship Oil-Pollution Prevention and Control

According to literatures at abroad and home and preliminary investigation, there are mainly three modes regarding ship oil-pollution prevention and control: government-dominated mode, enterprise-dominated mode, and government-enterprise mode [6, 7].

1) Government-Dominated Mode in Ship Oil-Pollution Prevention and Control

In 21st century, government-dominated mode has already made many improvements such as in pre-controlling and pre-warning, ship oil-pollution prevention and control system building, publicity and rehearsal in ship oil pollution, first-aid rescue in the aftermath, and so on. Under such mode, however, there is still little involvement of enterprises and ships which exhibit unobvious self-discipline.

2) Enterprise-Dominated Mode in Ship Oil-Pollution Prevention and Control

The enterprise-dominated mode emphasizes the self-discipline and responsibility-taking on the part of enterprises. The mode by adopting its own management regulations, technical standards, and pollution prevention technologies, carries out restrictions and assumes responsibilities on enterprise activities. In this mode, enterprises themselves make controlling and prevention beforehand, equip themselves with anti-pollution facilities, open technology symposium and do rehearsals, make internal supervision and inspection, circumvent legal liability, and even do the first-aid rescue themselves in the accidents. The government is mainly responsible for law-making and related management.

3) Government-Enterprise Mode in Ship Oil-Pollution Prevention and Control

The government-enterprise mode combines both government-dominated and enterprise-dominated mode, in which government and enterprises play distinctive roles and own different features. But this mode has the following in common: government is responsible for lawmaking, policy guidance, and supervising enterprises, while enterprises under legal requirements do self-discipline, and assume responsibilities such as prevention and control before and after the oil pollution.

2.2. Comparative Indicator System Based on Game Theory in Ship Oil-Pollution Prevention and Control Mode

In the system, general effect indicators include incidence of ship oil spills happening in the jurisdiction, quantity control of spilled oil in the jurisdiction, and time of response and intervention after the oil spills, and the overall cost indicators include public force cost by government in preventing pollution, cost by enterprises and ships in preventing pollution, main damage loss caused by oil spills, and clean-up cost.

3. Quantification of Overall Efficiency Indicator in Oil-pollution prevention and Control Mode [8-10]

3.1. Overall Efficiency Indicator in Oil-Spill Prevention and Control Mode

1) Function for General Effect Indicators of Ship Oil-Spill Prevention and Control in the Jurisdiction

The function for general effect indicators of ship oil-spill prevention and control in the jurisdiction, R, is the function including incidence of ship oil spills happening in the jurisdiction, quantity control of spilled oil in the jurisdiction, and time of response and intervention after the oil spills, as follows:

\[ R = F(R_1, R_2, R_3) \]  

(1)

2) Function for Overall Cost Indicators of Ship Oil-Spill Prevention and Control in the Jurisdiction
The function for overall cost indicators of ship oil-spill prevention and control in the jurisdiction, \( C \), is the function including public force cost by government in preventing pollution, cost by enterprises and ships in preventing pollution, main damage loss caused by oil spills, and clean-up cost, as follows:

\[
C = F(C_1, C_2, C_3, C_4, C_5, C_6)
\]  
(2)

3) General Effect Indicators of Ship Oil-Spill Prevention and Control in the Jurisdiction

According to the general meaning of efficiency in Economics, the general efficiency of ship oil-spill prevention and control in the jurisdiction, \( E \), can be presented by ratio between general effect and overall cost of ship oil-spill prevention and control in the jurisdiction, as follows:

\[
E = \frac{R}{C}
\]  
(3)

3.2. Function for Overall Efficiency Indicators of Ship Oil-Spill Prevention and Control

1) Function for Management Efficiency Indicators of Ship Oil-Spill Prevention and Control in the Jurisdiction

When the indicators such as incidence of ship oil spills happening in the jurisdiction, quantity control of spilled oil in the jurisdiction, time of response and intervention after the oil spills, public force cost by government in preventing pollution, cost by enterprises and ships in preventing pollution, main damage loss caused by oil spills, and clean-up cost, can be equivalently quantized through parameters, the corresponding general effect indicators can be described by equivalent parameters and their weight coefficients, and the corresponding overall cost indicators can also be described by equivalent parameters and their weight coefficients. Hence, function for management efficiency indicators of ship oil-spill prevention and control, can be described as follows:

\[
E = \frac{\lambda_1 \cdot R_1 + \lambda_2 \cdot R_2 + \lambda_3 \cdot R_3}{\eta_1 \cdot C_1 + \eta_2 \cdot C_2 + \eta_3 \cdot C_3 + \eta_4 \cdot C_4 + \eta_5 \cdot C_5 + \eta_6 \cdot C_6}
\]  
(4)

Function for precaution efficiency indicators of ship oil-spill in the jurisdiction, can be described as follows:

\[
E_p = \frac{\lambda_1 \cdot R_1 + \lambda_2 \cdot R_2}{\eta_1 \cdot C_1 + \eta_2 \cdot C_2}
\]  
(5)

Function for emergency control efficiency indicators of ship oil-spill in the jurisdiction, can be described as follows:

\[
E_a = \frac{\lambda_2 \cdot R_2 + \lambda_3 \cdot R_3}{\eta_2 \cdot C_2 + \eta_4 \cdot C_4 + \eta_5 \cdot C_5 + \eta_6 \cdot C_6}
\]  
(6)

2) Function for overall efficiency indicators of three ship oil-spill prevention and control modes, can be described as follows:

a) Function for management efficiency indicators of government-dominated ship oil-spill prevention and control mode

\[
E_1 = \frac{\lambda_{11} \cdot R_{11} + \lambda_{12} \cdot R_{12} + \lambda_{13} \cdot R_{13}}{\eta_{11} \cdot C_{11} + \eta_{12} \cdot C_{12} + \eta_{13} \cdot C_{13} + \eta_{14} \cdot C_{14} + \eta_{15} \cdot C_{15} + \eta_{16} \cdot C_{16}}
\]  
(7)
Function for precaution efficiency indicators

\[ E_{P} = \frac{\lambda_{11} \cdot R_{11} + \lambda_{12} \cdot R_{12}}{\eta_{11} \cdot C_{11} + \eta_{12} \cdot C_{12}} \]  \hspace{1cm} (8)

Function for emergency control efficiency indicators

\[ E_{A} = \frac{\lambda_{12} \cdot R_{12} + \lambda_{13} \cdot R_{13}}{\eta_{12} \cdot C_{12} + \eta_{13} \cdot C_{13} + \eta_{15} \cdot C_{15} + \eta_{16} \cdot C_{16}} \]  \hspace{1cm} (9)

b) Function for management efficiency indicators of enterprise-dominated ship oil-spill prevention and control mode

\[ E_{2} = \frac{\lambda_{21} \cdot R_{21} + \lambda_{22} \cdot R_{22} + \lambda_{23} \cdot R_{23}}{\eta_{21} \cdot C_{21} + \eta_{22} \cdot C_{22} + \eta_{23} \cdot C_{23} + \eta_{24} \cdot C_{24} + \eta_{25} \cdot C_{25} + \eta_{26} \cdot C_{26}} \]  \hspace{1cm} (10)

Function for precaution efficiency indicators

\[ E_{2P} = \frac{\lambda_{21} \cdot R_{21} + \lambda_{22} \cdot R_{22}}{\eta_{21} \cdot C_{21} + \eta_{22} \cdot C_{22}} \]  \hspace{1cm} (11)

Function for emergency control efficiency indicators

\[ E_{2A} = \frac{\lambda_{22} \cdot R_{22} + \lambda_{23} \cdot R_{23}}{\eta_{22} \cdot C_{22} + \eta_{23} \cdot C_{23} + \eta_{25} \cdot C_{25} + \eta_{26} \cdot C_{26}} \]  \hspace{1cm} (12)

c) Function for management efficiency indicators of enterprise-enterprise ship oil-spill prevention and control mode

\[ E_{3} = \frac{\lambda_{31} \cdot R_{31} + \lambda_{32} \cdot R_{32} + \lambda_{33} \cdot R_{33}}{\eta_{31} \cdot C_{31} + \eta_{32} \cdot C_{32} + \eta_{33} \cdot C_{33} + \eta_{34} \cdot C_{34} + \eta_{35} \cdot C_{35} + \eta_{36} \cdot C_{36}} \]  \hspace{1cm} (13)

Function for precaution efficiency indicators

\[ E_{3P} = \frac{\lambda_{31} \cdot R_{31} + \lambda_{32} \cdot R_{32}}{\eta_{31} \cdot C_{31} + \eta_{32} \cdot C_{32}} \]  \hspace{1cm} (14)

Function for emergency control efficiency indicators

\[ E_{3A} = \frac{\lambda_{32} \cdot R_{32} + \lambda_{33} \cdot R_{33}}{\eta_{32} \cdot C_{32} + \eta_{33} \cdot C_{33} + \eta_{34} \cdot C_{34} + \eta_{35} \cdot C_{35} + \eta_{36} \cdot C_{36}} \]  \hspace{1cm} (15)

4. Living Example for Quantification of Overall Efficiency Indicator in Oil-Pollution Prevention and Control Mode in Three Gorges Reservoir Area

Based on the investigations and surveys in the latest five years for the oil spills happening in Three Gorges Reservoir area and for related construction of emergency bases, the quantization parameters are as follows.
Table 1. Quantization Parameter Table

| Category                  | Project                                          | Parameter Quantization and Value Interval                                      |
|---------------------------|--------------------------------------------------|--------------------------------------------------------------------------------|
|                            | Project                                          | Value interval [1,2], [3, 5], [6, 8], [9, 10]                                  |
| General Effect R          | Incidence of Ship Oil Spills Happening in the Jurisdiction R₁ | Divided to 4-level quantization, with vale intervals respectively being beyond 10 times, 5-10 times, 1-5 times, 1 time and below. |
|                           | Quantity Control of Spilled oil in the Jurisdiction R₂ | Divided to 4-level quantization, with vale intervals respectively being beyond 700t, 7t-700t, 100kg-7t, and below 100kg. |
|                           | Time of Response and Intervention after the Oil Spills R₃ | Divided to 4-level quantization, with vale intervals respectively being beyond 1000h, 100h-1000h, 10h-100h, below 10h. |
|                           | Public Force Cost by Government in preventing pollution C₁ | Divided to 4-level quantization, with vale intervals respectively being below 0.1 million, 0.1-2 million, 2-10 million, beyond 10 million. |
|                           | Cost by Enterprises and Ships in Preventing Pollution C₂ | Divided to 4-level quantization, with vale intervals respectively being below 0.01 million, 0.01-0.1 million, 0.1-2 million, beyond 2 million. |
| Environmental Pollution Loss C₃ | Divided to 4-level quantization, with vale intervals respectively being below 0.01 million, 0.01-2 million, 2-10 million, beyond 10 million. |
| Overall Cost C            | Damage Loss of Economic Entity C₄                | Divided to 4-level quantization, with vale intervals respectively being below 0.01 million, 0.01-2 million, 2-10 million, beyond 10 million. |
| Clean-Up Cost by Government C₅ | Divided to 4-level quantization, with vale intervals respectively being below 0.01 million, 0.01-2 million, 2-10 million, beyond 10 million. |
| Clean-Up Cost by Enterprises and Ships C₆ | Divided to 4-level quantization, with vale intervals respectively being below 0.01 million, 0.01-2 million, 2-10 million, beyond 10 million. |

4.1. Game-Theory Based Analysis Results of General Effect Efficiency in Three Ship Oil-Spill Prevention and Control Modes

1) Analysis Methods of Game Model
   a) Case Analysis of Ship Oil Spills
      The indicator analysis of the three modes is based on the data from the project this paper depends on [11], the data which shows the ship oil spills having treated by maritime departments and having happened in Three Gorges Reservoir area from 1997 to 2014.
   b) Analysis of Questionnaire among Specialists
      In order to conduct surveys on the practices of ship oil-spill prevention and control in Three Gorges Reservoir area, questionnaires are designed among specialists about the following indicators: incidence of ship oil spills happening in the jurisdiction, quantity control of spilled oil in the jurisdiction, time of response and intervention after the oil spills, public force cost by government in preventing pollution, cost by enterprises and ships in preventing pollution, main damage loss caused by oil spills, and clean-up cost.
      200 sheets of questionnaire have been given out to specialists and retrieved back 168 sheets of effective questionnaires. Among the effective questionnaires, there are 46 sheets from administrative and technology staff in ship companies, 44 are from ship crew (senior sailors majoring in ship driving and marine engineering), 43 sheets from administrative and technology staff in maritime departments (including personnel in emergency base for oil spills), 35 sheets from technology staff in education and research institutes. After the sorting out of the 168 effective questionnaires, and the descriptive
analysis of the data through software SPSS, it is found that the histogram of the questionnaire data is close to normal distribution.

2) Indicator Parameter Value in Game Model
   a) Value of Each Indicator Parameter
      Specialists give scores to each quantized indicator parameter and the average value is taken as the value for corresponding indicator.
   b) Confirming the Weight of each Indicator
      Through the case analysis for oil spill accidents, the weight of each indicator is confirmed according to its corresponding ratio.
   c) Result Calculation and Analysis
      The three-mode results for general effect, overall cost, and overall efficiency do not apply to the comparison in one same mode among the artificial values of general effect, overall cost and overall efficiency calculated from scores of specialist questionnaires and indicator weights of oil spill accidents.

Table 2. Artificial Values in Three Game-Theory Based Modes

| Category                                | General Effect R | Overall Cost C/10 thousand yuan | Overall EfficiencyE |
|----------------------------------------|------------------|--------------------------------|---------------------|
| Government-Dominated Management System in Oil Pollution Prevention | Precaution of Oil Spills 5.128 | 4.764                         | 1.08                |
|                                        | Control of Oil Spills 5.25 | 4.357                         | 1.20                |
| Enterprise-Dominated Management System in Oil Pollution Prevention | Precaution of Oil Spills 5.144 | 5.724                         | 0.90                |
|                                        | Control of Oil Spills 7.525 | 3.833                         | 1.96                |
| Government-Enterprise Management System in Oil Pollution Prevention | Precaution of Oil Spills 5.986 | 5.332                         | 1.12                |
|                                        | Control of Oil Spills 7.86  | 3.316                         | 2.37                |

From above game-theory based analysis, the following can be found out:

a) Precaution of Oil Spills
   As for the general effect in oil-spill precaution (aiming at the incidence of ship oil spills happening in the jurisdiction, and quantity control of spilled oil in the jurisdiction), it reaches the best in the government-enterprise mode, and is similar in both government-dominated mode and enterprise-dominated mode.
   As for the overall cost in oil-spill precaution (aiming at the public force cost by government in preventing pollution in the jurisdiction, and cost by enterprises and ships in preventing pollution in the jurisdiction), it reaches the highest in the enterprise-dominated mode, the second in the government-enterprise mode, and the lowest in the government-dominated mode.
   As for the overall efficiency in oil-spill precaution, it reaches the highest in the government-enterprise mode, the second in the government-dominated mode, and lowest in the enterprise-dominated mode.

b) Control of Oil Spills
   As for the general effect of control after oil spills (aiming at the quantity control of spilled oil in the jurisdiction, and time of response and intervention after the oil spills), it reaches the highest in the government-enterprise mode, the second in the enterprise-dominated mode, and the lowest in the government-dominated mode.
As for the overall cost of control after oil spills (aiming at environment pollution loss caused by oil spills in the jurisdiction, entity damage loss caused by oil spills, clean-up cost by government, clean-up cost by enterprises and ship), it reaches the highest in the government-dominated mode, the second in the enterprise-dominated mode, and the lowest in the government-enterprise mode.

As for the overall efficiency of control after oil spills, it reaches the highest in the government-enterprise mode, the second in the enterprise-dominated mode, and the lowest in the government-dominated mode.

c) General effect of Oil-Spill Prevention and Control

As for the general effect of prevention and control before oil spills (aiming at the incidence of ship oil spills happening in the jurisdiction, and quantity control of spilled oil in the jurisdiction), it reaches the best in the government-enterprise mode, and is similar in both government-dominated mode and enterprise-dominated mode.

As for the overall cost of prevention and control after oil spills (aiming at the quantity control of spilled oil in the jurisdiction, and time of response and intervention after the oil spills), it reaches the highest in the government-enterprise mode, the second in the enterprise-dominated mode, and the lowest in the government-dominated mode.

d) Overall Cost of Oil-Spill Prevention and Control

As for the overall cost of prevention and control before oil spills (aiming at the public force cost by government in preventing pollution in the jurisdiction, and cost by enterprises and ships in preventing pollution in the jurisdiction), it reaches the highest in the enterprise-dominated mode, the second in the government-enterprise mode, and the lowest in the government-dominated mode.

As for the overall cost of prevention and control after oil spills (aiming at environment pollution loss caused by oil spills in the jurisdiction, entity damage loss caused by oil spills, clean-up cost by government, clean-up cost by enterprises and ship), it reaches the highest in the government-dominated mode, the second in the enterprise-dominated mode, and the lowest in the government-enterprise mode.

e) Damage Loss Caused by Oil Spills

As for damage loss caused by oil spills (aiming at environment pollution loss caused by oil spills in the jurisdiction, entity damage loss caused by oil spills), it reaches the highest in the government-dominated mode, the second in the enterprise-dominated mode, and the lowest in the government-enterprise mode.

f) Overall Efficiency of Oil-Spill Prevention and Control

The government-enterprise mode has the highest overall efficiency. As for the overall efficiency of prevention and control before oil spills, the government-dominated mode has higher overall efficiency than the enterprise-dominated mode. As for the overall efficiency of prevention and control after oil spills, the enterprise-dominated mode has higher overall efficiency than the government-dominated mode.

3) The Influence of Game-Theory Analysis on the Supervision mode of Ship Oil Pollution in Three Gorges Reservoir Area

a) Government plays an important role in policy guidance and supervision of oil-spill prevention and control. Government should introduce the good and eliminate the inferior, having a whole control in the following services such as lawmakership for preventing ship oil pollution and supervising, technology standards setting, pre-warning and pre-caution, supervision and governance, public benefit, and policy guidance.

b) Enterprises and ships, as the involved parties and the main body to control risks beforehand and deal with emergencies afterwards in oil spills, should possess the feature of responding first for emergency control and damage loss control.

How the enterprises and ships discipline themselves and assume main responsibilities has a crucial and even decisive role in ship oil-spill prevention and control in the jurisdiction.
4.2. Design of Management Mode for Ship Oil-Spill Prevention and Control in Three Gorges Reservoir Area

In view of the real practices of ship oil-spill prevention and control in Three Gorges Reservoir area, and the distinctive features of both government and enterprises in oil-pollution prevention and control, this paper put forwards a “government-dominated and enterprise-as-the main-body” management system for oil-pollution prevention and control in Three Gorges Reservoir area.

1) Design of Management System for Ship Oil-Spill Prevention and Control

The “government-dominated and enterprise-as-the main-body” management system for oil-pollution prevention and control in Three Gorges Reservoir area refers to the combination of government-dominated mode and enterprise-dominated mode.

a) Government takes the responsibilities of policy guidance and construction of public benefit, aiming at tasks including lawmaking for preventing ship oil pollution, policy guidance, technology standards setting, pre-warning and pre-caution of risk source, supervision and treatment of ship oil pollution, public force for oil clean-up and its facilities equipping, and publicity, training and rehearsing for preventing ship oil pollution as well.

The objectives of performance evaluation include incidence of ship oil spills happening in the jurisdiction, quantity control of spilled oil in the jurisdiction, time of response and intervention after the oil spill in the jurisdiction, environment pollution loss and damage loss of economic entity in the jurisdiction, cost of public force construction in preventing pollution, and clean-up cost in the jurisdiction, and so on.

b) Enterprises and ships should take the duty of self-disciplining and responsibilities of being the main body in preventing pollution, aiming at taking tasks including internal supervision and administration, control of oil-spill risk source, infrastructure and facilities equipping for preventing oil pollution, clean-up devices equipping, training and rehearsing for preventing ship oil pollution, emergency treatments.

The objectives of performance evaluation include incidence of ship oil spills, quantity control of spilled oil, time of response and intervention after the oil spill, environment pollution loss and damage loss of economic entity, cost of equipping infrastructure and facilities in preventing pollution, and clean-up cost, and so on.

![Fig. 1 “Government-Dominated and Enterprise-As-the Main-Body” Mode for Oil-Spill Prevention and Control](image-url)
2) Responsibilities and Objectives of Preventing Ship Oil Pollution
a) Responsibilities of Government

Government should take the responsibilities of administrative lawmaking, policy guidance and creating public benefits.

I) Administrative Lawmaking and Policy Guidance
Under the framework of “Regulations of Pollution Prevention and Treatment in Inland Waters in PRC” and with the real situations in Three Gorges Reservoir area into consideration, a series of specific measures are made to reinforce the government’s role as social and public administration, the enterprises’ role as main body in pollution prevention through administrative lawmaking, and enterprises’ self-disciplining in pollution prevention and treatment through policy guidance and supervision and inspection.

II) Creating Public Benefits
The government should reinforce its role in prevention and pre-warning mechanism of oil pollution, and have a whole control on the risk source and pre-warming management. Besides, it also should enhance publicity, training and rehearsing for the prevention of oil pollution, setting technology standards to prevent oil pollution and building public clean-up base and infrastructure.

b) Responsibilities of Enterprises

I) Enterprises as Main Body of Responsibilities
Under legal administration of government, enterprises, as the main body of responsibilities, should build internal management systems and shoulder oil-spill obligations like pre-control, self-restriction, emergency treatment, and civil compensation, and so on.

II) Self-Discipline of Enterprises
The self-discipline of enterprises can be achieved under policy guidance, supervision and inspection of government. To reduce the damage loss of possible oil spills to the minimum, such self-discipline includes improved management systems inner the enterprises, implementing self-consciously pre-warning mechanism, having internal supervision and restrictions, innovation in anti-pollution technologies, well-equipped infrastructure and facilities for preventing oil pollution, building mechanism of training and rehearsing on oil-pollution prevention, and measures for emergency control as well.

c) Mutual Tasks

I) Pre-Warning and Pre-Control before Oil Spills
Government should accordingly broadcast information of pre-warning and pre-control. Enterprises should implement internal supervision according to administrative legislation, technology standards and regulated practices, and improve control on risk source. In addition, government, enterprises and ships should share the information and build linkage mechanism.

II) Supervision on Ship Oil-Spill Preventing and Controlling

Government should implement management, supervision and inspection based on administrative legislations. Enterprises should make internal supervision. Ships should have self-discipline and self-restriction in terms of administrative legislations and technology standards.

III) Damage Control of Ship Oil Spills
In case of ship oil spills, ships should start procedures of emergency and control the damage to the minimum under the guidance of government and enterprises. Enterprises and ships should assume the responsibilities of being main body, and public force of government should start emergency treatments and rescues in view of how the oil spill is.

IV) Anti-Pollution and Clean-Up System Building
Government is responsible for building public anti-pollution and clean-up systems, while enterprises and ships are responsible for building their own facilities in anti-pollution and clean-up.

d) Objectives in Ship Oil-Pollution Prevention and Control
As for government, enterprises and ships, precaution aims at incidence of ship oil spills and quantity control of spilled oil; pre-control aims at quantity control of spilled oil and time of response and intervention after the oil spill; damage loss control aims at environment pollution loss, damage
loss of economic entity, clean-up cost by government in oil spills, and clean-up cost by enterprises and ships in oil spills; cost budget includes cost of building public force in preventing oil pollution, and construction cost by enterprises and ships in preventing oil pollution.

Fig. 2 Responsibilities and Objectives of “Government-Dominated and Enterprise-As-the Main-Body” Mode for Oil-Spill Prevention and Control

5. Conclusion
From above analysis and research, the following conclusions can be drawn.

1) The government-enterprise mode has the highest overall efficiency in ship oil-spill prevention and control. As for the overall efficiency of prevention and control before oil spills, the government-dominated mode has higher overall efficiency than the enterprise-dominated mode. As for the overall efficiency of prevention and control after oil spills, the enterprise-dominated mode has higher overall efficiency than the government-dominated mode.

2) This paper establishes a game-theory based indicator system and builds the game-theory model which uses data of specialist surveys and real spill cases. From the calculated results, the “government-enterprise” management mode has been designed to prevent and control oil spills in Three Gorges Reservoir area. The techniques of such mode for analysis and problem solving also apply to other reservoir waters, despite specific analysis needed for specific reservoir.

3) This paper puts forwards the “Government-Dominated and Enterprise-As-the Main-Body” Mode and its systems of responsibilities and objectives. In the real practice, the strict implementing of responsibilities and policies has exerted its large utility in oil-spill prevention and control of reservoir area.

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