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The application of CBA in FSA

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The Application of CBA in FSA

By

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Dedicated to:

My dear wife, Chen Xiaojie

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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Abstract

Formal Safety Assessment is a proactive, comprehensive and structured methodology of risk analysis for assessing the risk relating to maritime safety and maritime environment protection through evaluating the costs and benefits of IMO's options for reducing these risks. CBA is a decision-supporting technique normally used to evaluate the economic desirability of public programs. It also can be used to evaluate the economic efficiency of applying regulations on maritime safety and marine environment protection. Now it becomes the forth part of formal safety assessment. So the features of cost-benefit analysis would impact the application of formal safety assessment.

In this paper the advantages and limitations of cost-benefit analysis have been discussed. Through analysis the cause of limitations of cost-benefit analysis, it is found that the uncertainty is a very necessary thing for analysts to dealing with. From the study of how to dealing with uncertainty on other industries, three approaches are proposed: expected value analysis, sensitivity analysis and quasi-option value. After analyzing the advantages and disadvantages of each approach, the suggestions on how to dealing with the uncertainty in formal safety assessment was proposed.

Key words: FSA, CBA, uncertainty, expected value analysis, sensitivity analysis, quasi-option value

Table of contents

List of Figures and Tables

Abbreviations

FSA: Formal Safety Assessment

CBA: Cost-benefit Analysis

CEA: Cost- effectiveness Analysis

IMO: International Maritime Organization

UK: United Kingdom

OECD: Organization for Economic Co-operation and Development

WTP: Willingness to Pay

WTA: Willingness to Accept

VTS: Vessel Traffic Service

IC: International Collaborative

EPA: Environmental Protection Agency

NCEDR: National Center for Environmental Decision-making Research

USDA: United States Department of Agriculture

PSA: Probabilistic Scenario Analysis

NPV: Net Present Value

CAF: Cost of Averting a Fatality

IACS: International Association of Class Society

Chapter I

Introduction

Formal Safety Assessment (FSA) represents an approach that is rapidly gaining international acceptance as a solution enabling the application of risk-based techniques to international shipping, especially on regulations of maritime safety and marine environment protection.

Application of FSA may be particularly relevant to proposals for regulatory measures that have far reaching implications in terms of costs to the maritime industry or the administrative or legislative burdens that may result.

1.1 Importance of the study

Formal Safety Assessment (FSA) was first submitted to IMO in 1993 and was deemed helpful in the rule-making process. Several States applied this method to proposals for regulatory measures, such as the bulk carrier safety problems. In spite of the general acceptance and recognition, FSA is not perfect and needs to be assessed to ensure the application in a proper way.

Cost-benefit analysis (CBA) is a policy assessment method that quantifies in monetary terms the value of all policy consequences to all members of society. The broad purpose of cost-benefit analysis is to help social decision making. Now, the cost-benefit analysis is incorporated into formal safety assessment and become one of important parts of FSA. It is useful to evaluate the costs and benefits of each alternative of policy and can facilitate more efficient allocation of society's resources.

1.2 Objective of study

The objectives of this dissertation are as follows:

(1) To discuss the advantages of formal safety assessment;

(2) To discuss the merits of using cost-benefits analysis in formal safety assessment;

(3) To discuss advantages and limitations of cost-benefit analysis;

(4) To analyze the cause of limitations of cost-benefit analysis;

(5) To analyze and find the proper way of dealing with uncertainty;

(6) To identify how to dealing with uncertainty in formal safety analysis

1.3 Order of presentation

In this presentation, the objective is focused and achieved by using a logic sequence order. In Chapter II, the salient feature of formal safety assessment will be discussed. FSA is not a reactive risk assessment after the casualty but a forward looking way of risk analysis. FSA is also a comprehensive methodology for risk assessment concerning with organizational, management, operational, human, hardware and other aspects. Furthermore, FSA is a system for risk analysis with a well structured organization.

The cost-benefit analysis is the forth step of formal safety assessment. In Chapter III, the steps of doing CBA will be presented. In additional, the effect of CBA after used in formal safety assessment will be discussed. After monetizing, CBA provides the relative definite costs and benefits of each alternative, so CBA can easier facilitate the decision-maker to choose the most appropriate one and can accelerate the implementation of flag State. After incorporating the CBA, FSA is more scientific and feasible.

The awareness of the advantages and limitations of cost-benefit analysis is one of keys to apply the formal safety assessment properly. The advantages and limitations of CBA will be discussed in Chapter IV. CBA has many advantages such as comprehensiveness and monetization. CBA also has some limitations. Uncertainty is one of important limitations of CBA and most of other limitations of CBA can also contribute to uncertainty.

Through the analysis of the limitations of cost-benefit analysis, the uncertainty is the main cause of them. So in Chapter V, how to dealing with uncertainty will be discussed. Expected value analysis, sensitivity analysis and quasi-option value are used in many other industries. In formal safety assessment, these ways also can be used and they all have own advantages and limitations.

1.4 Scope and methodology

A literature search was undertaken to examine what findings have been got by research. IMO relevant resolutions, FSA reports and related papers as well as some FSA proposals submitted by IMO Party States were collected and examined to support the study. The research papers about CBA applied in other fields were also collected and examined.

Chapter II

Introduction of Formal Safety Assessment

2.1 Introduction

According to IMO (2002), Formal Safety Assessment (FSA) is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment. It is a methodology for assessing the risk relating to maritime safety and maritime environment protection through evaluating the costs and benefits of IMO's options for reducing these risks. FSA also can be used as a tool to help in the evaluation of new regulations.

Adopting FSA the decision makers at IMO, will be able to appreciate the effect of proposed regulatory changes in terms of benefits (e.g. expected reduction of lives lost or of pollution) and elated costs incurred for the industry as a whole and for individual parties affected by the decision.

2.2 The salient features of FSA

FSA is a rational， structured and systematic process for the proactive and comprehensive management of safety and environment protection through hazard identification, risk analysis and cost-benefit/cost-effectiveness evaluation. Three most conspicuous merits can be achieved by the application of FSA.

2.2.1 A proactive methodology of risk management

'Safe, secure and efficient shipping on clean oceans' is the tenet of IMO. The safety and environmental issues are the permanent topic of maritime community.

Previously, the accidents impelled us to consider assessment and control of the risk, and it is passive. Some marine disasters have a far-reaching impact on developing new safety standards. These disasters include, but not limited to, Titanic, Amoco Cadiz, Herald of Free Enterprise, Exxon Valdez, Estonia and Prestige. Making reference to one of the most important IMO's conventions, it can be concluded that about half of amendments to SOLAS Convention are derived from the findings of investigation of marine accidents and statistics studies of marine accidents, either directly or indirectly.

In May 1993, the framework of FSA was initially submitted by UK MCA at the IMO Maritime Safety Committee (MSC) meeting 62. FSA introduced the precautionary principle in the process of risk management. FSA not only use the historical data, but also some models such as probabilistic model and accident scenarios to evaluate rare events where there is in adequate data. FSA is an initiative method to assess and prevent the risk.

2.2.2 A comprehensive methodology of risk management

As Soares and Teixeira (2001) said:

> 'The FSA is not to be applied to a ship in isolation but rather to a

collection of systems including organizational, management, operational, human, and hardware, which fulfils specific functions. It recognizes that the human element is one of the most important contributory aspects to the causation and avoidance of accidents and thus should be treated systematically in the FSA.'

Safety case approach is another method for risk management. Wang (2001) argued that a safety case approach is applied to a particular ship. Compared with safety case approach, FSA is designed to safety issues for a larger range such as a ship type. Now the FSA reports of IMO members and IACS are concerned about many aspects, such as Fore-end watertight integrity by IACS (IMO, 2001a), life saving appliances for bulk carriers by Norway and ICFTU (IMO, 2001b) and so on.

FSA facilitates to achieve as much practical safety as possible by risk control options that give an overall reduction of risk and good value for money. FSA evaluates not only that a certain measure will improve maritime safety or pollution prevention but also by how much and at what cost. It provides regulators with better information on the full implications of their decisions and indicates whether or not the benefits obtained from the regulations overweigh the costs entailed (Ma, 2002, p420).

2.2.3 A structured and systematic methodology

FSA is an approach to the maritime safety and environmental protection which involves using the techniques of risk analysis and cost benefit assessment to assist in the decision-making process. It is a structured and systematic methodology.

According to IMO (2002), FSA consists of five steps as shown in Figure 1:

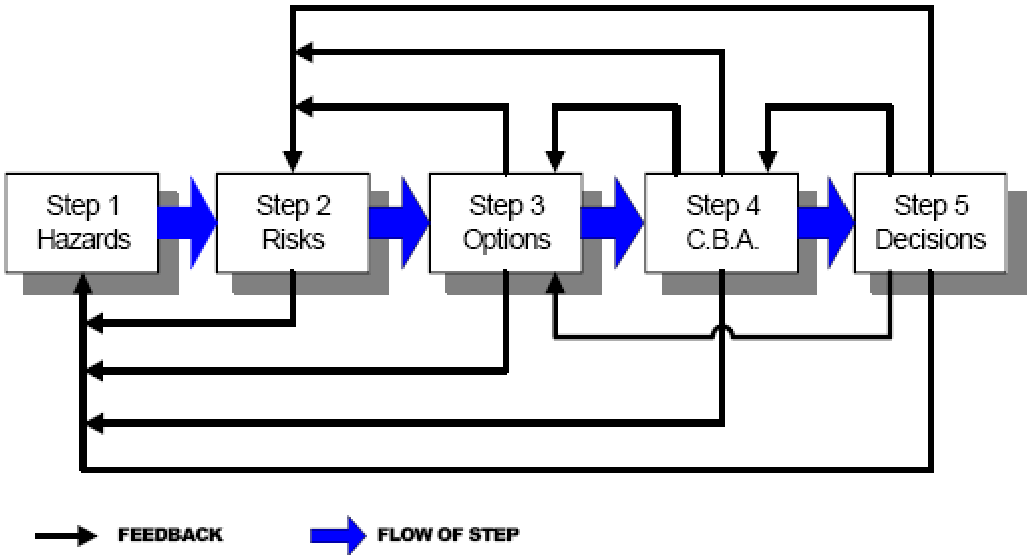

Figure 1: The steps of FSA (Dasgupta, 2004)

1. Identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes);
2. Assessment of risks (evaluation of risk factors);
3. Risk control options (devising regulatory measures to control and reduce the identified risks);
4. Cost benefit assessment (determining cost effectiveness of each risk control option); and
5. Recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided).

Chapter III

Introduction of Cost-benefit Analysis

3.1 Introduction

> 'Benefit-cost analysis is a method of evaluating the relative merits of alternative public investment projects in order to achieve efficient allocation of resources. It is a way of identifying, portraying and assessing the factors which need to be considered in making rational economic choices. It is not a new technique. In principle, it entails little more than adjusting conventional business profit-and-loss calculations to reflect social instead of private objectives, criteria, and constraints in evaluating investment projects.'
>
> (Treasury Board, 1998)

Cost-Benefit Analysis (CBA) estimates and totals up the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile. These projects may be dams, highways and maritime transportation or can be training programs and health care systems.

CBA is a policy assessment method that quantifies in monetary terms the value of all policy consequences to all members of society and can improve the quality of public policy decisions. The net social benefits measure the value of the policy. Social benefits minus social costs equal net social benefits:

Net social benefits = social benefits – social costs

3.2 The revolution of CBA

The idea of cost-benefit analysis originated with Jules Dupuit, a French engineer. The British economist, Alfred Marshall, formulated some of the formal concepts that are at the foundation of CBA. But the practical development of CBA can be said to date from the impetus provided by the Federal Navigation Act of 1936 (Pearce, 1983, p14). This act required that the U.S. Corps of Engineers carry out projects for the improvement of the waterway system when the total benefits of a project to whomsoever they accrue exceed the costs of that project. Thus, the Corps of Engineers had created systematic methods for measuring such benefits and costs. With assistance from the economics profession the engineers of the Corps did this. It wasn't until about twenty years later in the 1950's that economists tried to provide a rigorous, consistent set of methods for measuring benefits and costs and deciding whether a project is worthwhile.

According to Pearce (1983, p15), the next landmark was the ‘Green Book’ of 1950 which was produced by the US Federal Inter-Agency River Basin Committee and attempted to instill some agreed set of rules for comparing costs and benefits. These were early attempts, and they were followed by the general introduction of economic techniques into budget management in the USA across many areas of expenditure. Here the benefits were expressed in terms of ‘national security’ or destructive capability. The important development was in the use of procedures for minimizing the money cost of a given level of activity – the beginnings of ‘cost-effectiveness analysis’ (CEA), by which the benefit is measured in some physical units, or is simply stated as a policy objective, and the costs are expressed in monetary units. From that time, both CBA and CEA began their practical lives as aids to government decision-making.

In 1960s, United Kingdom began to use CBA with the application of the technique to the London – Birmingham highway. In 1967 a UK Government White Paper gave formal recognition to the existence of cost-benefit analysis and assigned it a limited role for nationalized industries (UK Government, 1967). In the late 1960s CBA was extended to less developed counties with the publication or a Manual of Industrial Project Analysis (Little and Mirrlees, 1969). The Manual was prepared for the Organization for Economic Co-operation and Development (OECD). In 1975, the World Bank's guidelines came which were heavily relied on the earlier work of Little and Mirrlees (Squire and Tak, 1975). From then on the CBA became a useful tool for executive decision making used in many areas and CBA also gained additional impetus with the environmental revolution.

3.3 The steps of cost-benefit analysis

According to Boardman (2001), Oxenfeldt (1979), Pearce (1983) and Treasury Board of Canada Secretariat (1998), the CBA process can divided into nine major steps:

1. Specify the set of alternative projects. In formal safety assessment, this step is done in Risk Control Options.
2. Decide whose benefits and costs count. Analyst should consider all the costs and benefits which are relative to the project.
3. Catalogue the impacts and select measurement indicators. This step requires the analyst to list the physical impacts of the alternatives as benefits or costs and to specify the impact's measurement units.

4. Predict the impacts quantitatively over the life of the project. In this step, the analyst should quantify all impacts for each RCOs over the life of the project.

5. Monetize all impacts.

6. Discount costs and benefits to obtain present values. Because many projects would last for long time, so the analyst needs a way to aggregate the costs and benefits that occur in different years.

7. Compute the net present value (NPV) of each alternative.

   NPV = present benefits – present costs

8. Perform sensitivity analysis. There are so many uncertainties in analysis, so the analyst should consider the predicted impacts and the appropriate monetary valuation of each unit of uncertainty.

9. Make a recommendation based on the NPV and sensitivity analysis. This is the last step and analyst should make a recommendation to the decision-maker.

3.4 The merits when cost-benefit analysis is used in formal safety assessment

Cost-benefit analysis is an effective way to identify, quantify and evaluate all the consequent benefits and costs for the achievement of the optimal safety and environment regulations. By the introduction of CBA, FSA can help in the evaluation of new maritime regulations or in making a comparison between existing and possibly improved regulations, with a view to reaching a balance between the various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs (IMO, 2002).

Although decisions should not be based solely on a simple cost-benefit test, a cost-benefit analysis should be one of the important factors in the decision. With the application of cost-benefit analysis in formal safety analysis, the following merits can be gained:

First, using cost-benefits analysis can make the formal safety assessment more scientific and feasible. CBA is a transparent method that the results of a well-executed CBA can be clearly linked to the assumptions, theory, methods, and procedures used in it. 'This transparency can add to the accountability of public decisions by indicating where the decisions are at variance with the analysis.'(Kopp, R et al, 1997)

Second, cost-benefits analysis gives a definite ranking of every alternative. CBA could be used to rank policies on the basis of their improvements or reductions in well-being. It is a value judgement with a "norm" according to which one project is said to be better or worse than another. Cost-benefit analysis is vital as a decision tool, though economic performance as measured by net benefit should not be the sole determining factor in decisions. But people always make choices through comparison of alternative states of affairs, such that choices are judged by their relative values to one another by way of "ranking". Although the real purpose of CBA is not to compare with precision the cost and benefit of each regulatory item but rather to have an overall feel for the rightfulness of the regulation concerned and to trade off between the alternative policy programs (Arrow et al, 1996), but if there is a definite ranking of each alternative, the decision-maker can do the decision-making more easily. Economic efficiency, measured as the difference between benefits and costs, ought to be one of the fundamental criteria for evaluating proposed environmental, health and safety regulations (Arrow et al, 1996)

Third, cost-benefit analysis can accelerate the implementation of flag State. Because the cost-benefit analysis can give relative precise costs and benefits of each regulation, the flag State can know what they should burden and if it is worthy. Through the CBA, FSA can be more practicable and the regulations could be easily accepted by flag State, so the implementation can be accelerated.

Chapter IV

Advantages and limitations of CBA

4.1 Introduction

Cost-benefit analysis is a very important step of formal safety assessment, so the advantages and limitations of cost-benefit analysis would be parts of the advantages and limitations of formal safety assessment. Analyzing the advantages and limitations can help the analysts to comprehend the formal safety assessment well so as to use it in a proper way and the analysts can make a good proposal for the decision-maker. The appropriate decision-making can be made if the advantages and limitations of cost-benefit analysis are realized by decision makers.

4.2 The advantage of cost-benefit analysis

4.2.1 Comprehensiveness

As Boardman et al (2001, p25) said, CBA can be thought of as providing a framework for measuring efficiency. CBA provides a method for making direct comparisons among alternative policies. Potential Pareto efficiency provides the practical basis for actually doing CBA. Potential Pareto efficiency means that a project should be considered if, by undertaking it, the gainers from the project can compensate the losers and still remain better off in their economic conditions than they were before. It distinguishes CBA from other analytical frameworks and it also provides a basis for understanding the various philosophical objections commonly made against the use of CBA for decision making.

Because Potential Pareto efficiency is the practical basis for actually doing CBA, so the net social benefit of a policy should be positive. But how can we calculate the net social benefit? Except the direct cost, Boardman et al (2001, p27) said that in particular it requires one to consider willingness-to-pay as the method for valuing the outputs of a policy and opportunity cost as the method for valuing the resources required to implement the policy. Both economic benefits broadly defined (willingness to pay) and opportunity costs are expressed in comparable monetary units, making possible the calculation of net benefits that can be compared across different policies. Except WTP and opportunity, the externalities also should be considered.

Willingness-to-pay (WTP)

OKA (2001) stated that the WTP means that ‘there is an upper limit to the amounts of money a buyer is willing to relinquish in exchange for obtaining the goods.

When analysts monetize all impacts, there are some non-marketed things such as safety, environmental protection and so on which should be considered. In order to find the net benefit of these, analysts need to find WTP of the policy. Here, WTP can be defined as that people put a particular economic value on reduce safety risk level that they are willing to give up that amount of other beneficial consumption opportunities.

Opportunity cost

Opportunity cost measures the value of what must be forgone to use the input to implement the policy. The implementation of policies almost always requires the use of some inputs that could be used to produce other things of value. For example, the money for implementing a policy to equip ships with AIS could be used to produce other value for safety. The opportunity cost of using an input to implement a policy is its value in its best alternative use. From economic view, the analysts must consider the opportunity cost when calculate the costs of the policy.

Externalities

According to the classical economic, the market can allocate all resources efficiently called Invisible Hand. But only when the ownership is clearly defined, the Invisible Hand could operate well. Otherwise the costs and benefits can not be priced accurately and would be treated as incidental or external. ‘A technical term used to describe this situation is externality.’ (Hussen, 2004, p54). An externality is an effect that production or consumption has on third parties – people not involved in the production or consumption of the good. We can say the externality is arisen when one individual causes an effect on welfare to other individuals. It is a by-product of production or consumption for which there is no market. The externalities may be positive or negative. As professor Ma (2002, p402) said, ‘Maritime transport does cause negative externalities, mainly in relation to the pollution of the environment and safety threat to the health and/or life of seafarers and dockworkers.’ When we consider the externality, we can find that the equilibrium point is different to the pure market. As shown in figure 2, in a competitive market in the externality is internalized, the equilibrium point changes from M to N.

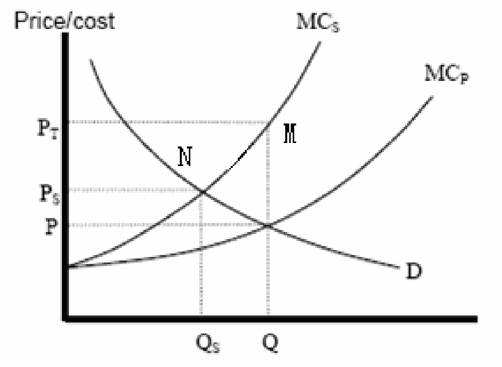

Figure 2: The effect of externality in a competitive market (Ma, 2002)

When we think about the maritime safety and environment regulations, we should consider the externalities, because the government intervention through regulations is a method to solve the problem of externalities of economics of safety and environment.

> ‘An attempt should be made to take into account all of the allocate effects in evaluations of the efficiency of government expenditures, some of which may be less obvious than others... Such implicit effects may be internal (to direct actors in the project) or external (to persons not directly acting in the project but included in the group whose point of view is being taken in the analysis). An example of internal implicit effects is foregone wages during education... External implicit effects (also referred to as spillovers, social effects, or third party effects) are commonly things like pollution or congestion…Ignoring implicit costs or benefits could lead to major errors in analysis.’
>
> (Treasury Board, 1998)

4.2.2 Monetization

Monetization is a feature of cost-benefit analysis and it also be a feature of formal safety assessment.

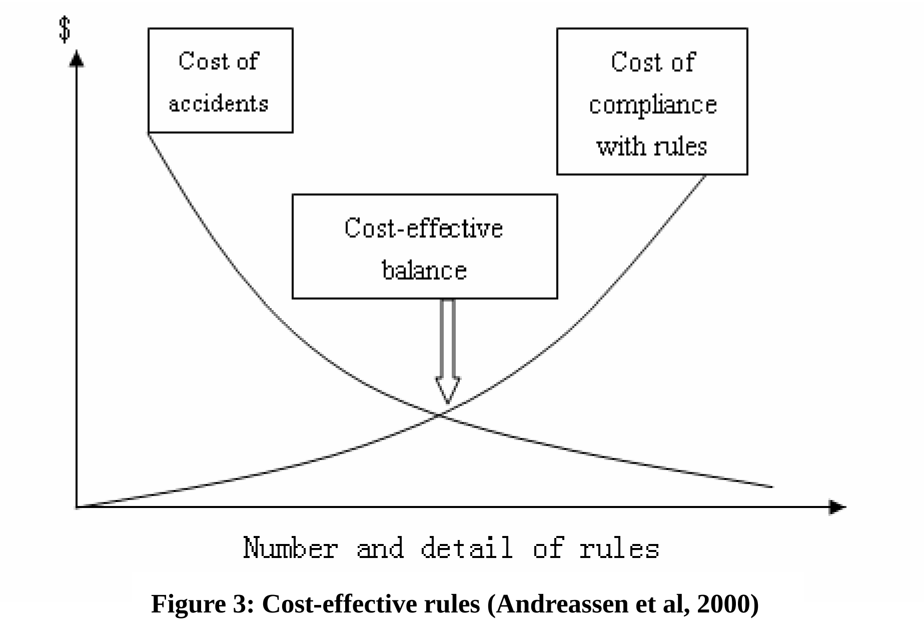

Figure 3: Cost-effective rules (Andreassen et al, 2000)

Before putting the regulation into force, we should analysis the costs of it. Then FSA can help us. FSA is to 'achieve a suitable balance between the level of safety and reliability and cost to shipowner to achieve it', (Andreassen et al, 2000) (Figure 3) and uses Cost-Benefit Analysis.

CBA is normally used to evaluate the economic desirability of public programs. It also can be used to evaluate the economic efficiency of applying regulations on maritime safety and environment protection. CBA is one of the methods and techniques used in decision-making procedures and 'the systematic estimate of all benefits and all costs of a contemplated course of action in comparison with alternative courses of action' (Seneca et al. 1984, pp. 10).

When we want to evaluate the worthiness of a project of applying regulations, we should weigh the benefit of project against its cost. In CBA, the marginal changes in costs and benefits as a result of the regulation are the only thing to be care for. Because almost all externalities should be considered, so we should compute both direct and indirect costs and benefits. Ships have long lifetime, so both short term and long term effects should be taken into account. As Mr. Hussen said (2004, p177) that people prefer their benefit now rather than later. So CBA uses discounting techniques to deal with these costs and benefits to calculate out their Net Present Value.

But in fact, many costs and especially benefits can not be quantified in monetary terms, such as environment pollution and life. So the cost efficiency analysis (CEA) is used in FSA. The use of CEA is often justified when the identification and measurement of benefits are difficult.

Through the monetization, the CBA can give a definite ranking of each alternative. Although the ranking would not be the only criteria for the decision-maker, it is very useful to help the decision-maker to make the decision.

4.2.3 Discounting

In many applications of cost-benefit analysis, the analyst must measure the net benefits of projects or policies that generate costs and benefits over a period of time, with costs and benefits often occurring in different time periods.

There are two reasons for using the discount rate. The first is the inflation and the second is that the people prefer to make payments later and receive benefits sooner. Discounting reflects the time period impacting on the projects and also reflects the opportunity cost of not getting the benefits immediately.

4.2.3.1 Future benefits and costs

In many situations, the policy can have important consequences that extend over time. For example, the project of VTS needs several years to be accomplished. The analyst should compare projects with benefits and costs that arise in different time periods. The analyst should discount future costs and benefits so that all costs and benefits are in the present value. The value of the unit of measurement itself also changes over time because of inflation leading to loss of the purchasing power of the currency. Thus, the analyst can measure and compare the net social benefits of each policy alternative using the net present value criterion.

4.2.3.2 The social discounting

In most case of public projects (policies), especially most projects of environmental nature, the social discount rate should be used. Social discounting reflects the generally accepted idea that a given amount of resources available for use in the future is worth less than the same amount of resources available today. As Boardman (2001, p227) said, this is because through investment one can transform resources that are currently available into a greater amount of resources in the future. The need of social discounting is also because people prefer their benefit now rather than later (Ma, 2002) that is to say that people prefer to consume a given amount of resources now rather than in the future because people are impatient (Mishan 1988) and people are uncertain about the future (Mishan 1988; Pearce and Nash 1981). So the social discount weights decline over time. The weight represents how much current consumption society is willing to give up now in order to obtain a given increase in future consumption.

4.3 The limitations of CBA

The limitations are represented by the problems of: (1) trying to evaluate what are often 'invaluable,' i.e., non-economic values; (2) limited considerations regarding distributional equity (including inter temporal equity); (3) political bias often present in the application of CBA; (4) Uncertainty.

4.3.1 Monetization of non-market value

The environmental protection and safety are the central works of IMO, so when analyst use FSA to access the risk, in step of CBA, there are many costs and benefits which are difficult to monetize, such as value of life, environmental protection and human right. Arrow (1997) refers these as invaluable goods which are not subject to a calculation of costs and benefits.

CBA requires that all impacts relevant to efficiency be quantified and made commensurate through monetization. Only when all the costs and benefits are expressed in monetization can the potential Pareto principle be applied through the calculation of net benefits. Boardman (2001, p40) said that ‘limitations in theory, data, or analytical resources, however, may make it impossible for the analyst to measure and value all impacts of a policy as commensurate costs and benefits.’

Hauer (1994, p12) argues that trying to put a monetary value on human life is impossible, because it is ‘impossible to have preferences for an option involving the death of the deciding organism and it is meaningless to speak about them’.

OKA (2001) states that monetary appraisal of any benefit from environmental improvement has been said to be difficult, because it consists of “intangible values.” Environmental economists have been spending much energy in appraising it, although the estimation is difficult since opportunities to observe WTPs are limited in actual market transactions.

The difficult calculation of benefits can be attributed to a few of special features of safety and environment. First, the total value of an environmental asset comprises the use value and nonuse value. To ignore this fact and focus exclusively on the use value could lead to severe underestimation of benefits. The contingent valuation approach is one way to tackle the nonuse value. However several potential biases could undermine its validity, such as the strategic bias, information bias, hypothetical bias and difficulties with the reference group for pricing. (Hussen, 2004, p135) Second, the characteristic of public goods contributes to the complexity of quantification of the full benefits. Public goods are non-exclusive and non-rival in consumption. In a safer working environment at sea, all the seafarers will benefit, and the reduction of NO_X from ships will improve the environment quality and benefit the whole ecological system. Third, the benefits from the reductions in fatalities, injuries and casualties are quite difficult to give an exact estimation. It goes without saying that human life is invaluable. Even if life has to be valued from an economic perspective, the two normally-used methods, namely human capital and willingness to pay, have major deficiencies (Ma, 2002, p417). It is also need to consider whether the lives saved now or in the future have the same value (Rolf, 2002, p15). In addition, in the calculation of the benefits, many assumptions and hypotheses are controversial, which may lead to significant difference. For example, the assumptions made by the International Collaborative (IC) FSA study during the calculation of benefits have no explicit or reasonable foundations and are controversial, which make the majority of benefits is significantly overestimated (IMO, 2004).

From the CBA study of other industry, there are a lot of environmental regulations that cannot be justified when cost-benefit analysis is applied. And the policy concerned with the life-saving has the same condition. In maritime community, now the regulations of IMO related with environmental protection and safety have occupied the prominent status, so it is important for analyst to treat the value of environmental protection and safety.

The cost-effectiveness analysis (CEA) is a way to treat the value of environmental protection and safety. It ranks policies by priority in order of efficiency according to unit cost.

CEA is a particular form of CBA, and based on the same principle of economic efficiency with CBA. It compares alternatives on the basis of the ratio of their costs and a single quantified but not monetized effectiveness measure, such as money per lives saved. CEA concerns about finding the least costly alternative for achieving the specific physical or social goals. (Tietenberg, 2000, p379-380; Dorfman, 1993, p306) Obviously, CEA can also 'be a useful tool when two or more regulation options have a similar or very close economic benefit level.'(Ma, 2002, p409) Of course, cost-effectiveness analysis is not the only method for policy appraisal, but it is promising as a steady and highly reliable method. It is a restrictive application of efficiency criteria and is easy to harmonize with values other than efficiency. It does not directly allow the analyst to conclude that the highest-ranked policy contributes to great efficiency.

Although the CEA has been applied in FSA, two factors affect the accuracy of estimation of costs. On one hand, the cost data are too fluctuating in time and variable geographically. That makes the result less reliable between one country and another or at different time. On the other hand, different users will emphasize different parts of the costs and this will also cause the calculation of cost greatly different. The discount rate is also problematic at the calculation of the costs and benefits in the long-run effects. It may influence the results to a considerable degree as the discounting effect will grow exponentially over time. The choice of a suitable discount rate is a hard problem and no consensus view exists (Hussen, 2004, p183-186).

Except the factors mentioned above, there is also another problem: Willingness to Accept (WTA) of every country is different. It is well known from the research that there is a relationship between purchasing power and WTA. Because of the imbalance of the world economic, the purchasing power of every States of the world is different. So the WTA of every States is different.

For example, let us look at value of life. Figure 4 indicates an optimum acceptable NACF between OECD countries in evaluation criteria. From this figure, we can found that the NACF between OECD countries is different. So, if we look into all countries, the difference would be very large.

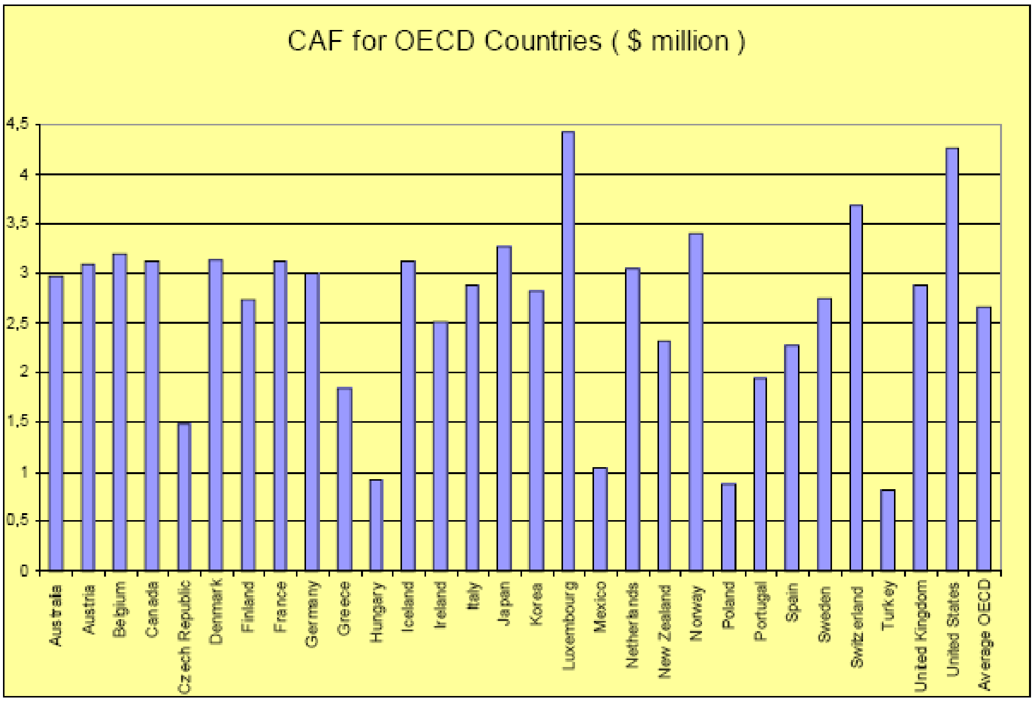

Figure 4: Comparison of values of implied cost of averting a fatality between 1984 and 1994 and between various countries (Skjong and Ronold, 2002).

As the implementation of mandatory safety regulations, it is the fact that the regulations would be offered regardless of purchasing power. As Skjong (2003) said there will be a limit to the cost effectiveness of such expenses whenever decisions by individuals are more cost effective to every State.

4.3.2 Distribution of equity

> ‘All public policy decisions result in a distribution of benefits and burdens, some gain and others lose from a decision.’
>
> (Merkhofer, 1987)

Being a monetary-based analysis, as general, CBA does not take into account any moral issues, such as distributional equity. CBA is based on a potential Pareto efficiency, so it may cause inequality of distribution of benefits and costs.

Efficiency focuses on the size of benefits and costs, not how these impacts are distributed between various groups of the population. Unlike efficiency, which seeks aggregate gains, equity seeks to determine if costs and benefits are systematically reallocated between stakeholders. In reality, the distributional equity is a very important issue that the efficiency and the equality of distribution are two independent criteria of economic welfare (OKA, 2003). It also could impact the acceptance degree of a policy.

4.3.2.1 Global equity

IMO is an international organization, and its policy would impact the world maritime community. Every member States is the stakeholder of the policy of IMO. So the globe equity should be considered by IMO.

The globe equity concern raised from such an exercise where those people with lower incomes may suffer from environmental deterioration as they cannot express a high 'willingness to pay' although their 'desire' to prevent such states may be at the same degree as those of rich people (Jacobs 1991, pp. 197-198).

The inequity of distribution could cause two consequences. The first is as Omura (2004) argues that ‘For global matters, such differences in income levels actually cause the export of ‘dirty industries’ from rich nations to poor nations because the costs of setting them up and the resulting pollution in these developing countries are much less than in developed countries, regardless of their intrinsic preference.’ We can found that the most scrap yards which have high pollution risk are located in the developing country, such as China.

The second is that many polices would not be accepted by the developing countries.

As discussed in 4.3.2.1, there is a relationship between purchasing power and WTA. There is a difference of criteria of life and environmental protection between developing countries and developed countries. From the view of developing countries, many policies may be inequity to them, and then they would not approve them. It will be trace back to the problem we have discussed above: the acceptable criteria (Willingness to Accept) of every country are different.

In order to correct this deficiency, we can first use a stakeholder analysis (SHA) to identify the key players, their roll in project, and their social utility. Stakeholder analysis is the identification of a project's key stakeholders, an assessment of their interests, and the ways in which these interests affect project risk and viability. After SHA, the gainers of project may compensate the losers through a side-payment system which ‘are known politely as gain sharing and pejoratively as bribery, and are prevalent in marketing’. (Hauser et al, 1997)

4.3.2.2 Future Generations

> ‘The existing valuations of fuels and minerals, and their current rates of consumption, cannot be justified by reference to any criterion that would exclude the opinions of future generations.’
>
> (Mishan, 1980)

To maritime community, the environmental protection is not only benefits us but also benefits our future generations. And many resources we consumed not only belong to us, but also to our future generations. Some policies adopted today, such as the disposal of nuclear or the restoration of wilderness areas and virgin forests may have impacts on the future generations. So when the policy is made, the sustainability should be considered.

Application of CBA/CEA and 'willingness to pay' techniques which rest on efficiency criterion will result in discrimination against people in the future as well as in inferior circumstances which has been discussed above. The most environmental burdens will end up being imposed on them.

How to treat the costs and benefits to the future generations? The social discount rate would be a way. As above has mentioned, the social discounting reflects that a given amount of resources available for use in the future is worth less than the same amount of resources available today. The social discount rate also can be used in the maritime policy making.

4.3.3 Politic

> ‘Political controversies cannot be resolved by resorting to calculations of how much various policy objectives are ‘worth’ in monetary terms.’
>
> (Rune Elvik, 2001)

The political forces influenced all decision about whatever kind of environmental impacts, such as land use and habitats, pollution and health, resource consumption, visual recreational and other forms of amenity and almost without an exception. And whatever techniques used in CBA, the ultimate decision-making is always a political issue since CBA cannot escape informational constraints and uncertainty, under which policymakers routinely make decisions.

The economists claim that CBA enables a more rational and objective way of making such decisions, that ‘instead of politicians or experts simply indicating what is good for people, account can be taken of the expressed interests and preferences of all those affected by the decision’ (Jacobs 1991, pp. 196). However, such “claimed rationality" or "objectivity" of a CBA is much dependent upon the techniques/methods used in the analysis, which are generally based on the value judgement of those who are interested in carrying out the projects, and thus are likely to give a lesser weight to environmental disbenefit which could be disregarded as "intangibles" (Omura 2004).

As mentioned by Davies (1997, pp. 209), CBA may lend a "pseudo-scientific authority" to government to rationalize and pursue its own agenda regardless of its moral responsibility. It is often for a country, especially developing countries, to grant little importance to environmental effects because government decision-makers are much more concerned with economic growth and are more impressed by a project with high financial returns, although its major environmental costs may be significant higher than its environmental benefits even than its financial returns.

Pearce (1997, pp. 210) notes that 'the whole process of policy priority setting is all too often ad hoc, reactive, crisis-based and over-responsive to often ill-informed pressure groups (of all kinds)'. As Ray (1997, pp. 217) indicates, it would indeed be futile to expend much resources and efforts in conducting CBA, 'only for this work to be nullified by some arbitrary, if not capricious, amendments of the final results'.

4.3.4 Uncertainty

Cost-benefit analysis always requires analysts to predict the future, but the future is uncertainty. Uncertainty means an inability to predict accurately and it is the lack of knowledge concerning the probability distribution of future events. Uncertainty refers to lack of knowledge about specific factors, parameters, or models.

EPA (1997), argues that 'uncertainty includes parameter uncertainty (measurement errors, sampling errors, systematic errors), model uncertainty (uncertainty due to necessary simplification of real-world processes, mis-specification of the model structure, model misuse, use of inappropriate surrogate variables), and scenario uncertainty (descriptive errors, aggregation errors, errors in professional judgment, incomplete analysis).'

When CBA is presented without effective characterization of the uncertainties associated with the results, cost-benefit studies can be used in highly misleading and damaging ways (EPA, 2003, p10). CBA is one of important pasts of FSA, so FSA is also subject to uncertainties which are the main causes of limitations. These uncertainties mainly arise from two parts.

The uncertainties pertinent to the risk reduction rate which include:

- Uncertainty in the application of historical data because of the ever-changing situations and the completeness and inaccuracy of data.
- Uncertainty in the process and the outcomes of expert judgment about the risk level and risk reduction.
- Uncertainty in the quantification of the effects of human factors.

The uncertainties relevant to the quantification of the costs and benefits are due to:

- The characteristics of the non-market products of safety and environment and the existence of externalities.
- The hard prediction of the shipping market and the effects of technology in the life cycle of a ship.
- The differences of economic level between regions and countries.

From above analysis, it is found that other limitations of CBA also may be influenced by uncertainty, or we can say the uncertainty is the main cause of other limitations of cost-benefit analysis. The non-market value is one of aspect of uncertain factors so monetization of non-market value is one kind of uncertainty. The difference of economic level between regions and countries is one reason of globe inequity, and the uncertainty of costs and benefits of each country can make the police harder to be accepted. The unfairness to future generations can be solved by using social discount rate, but how to confirm it? The social discount rate is also an uncertain issue. To some extent, the uncertainty also could impact the political aspects of decision-making. The ultimate decision-making is always a political issue since CBA cannot escape informational constraints and uncertainty (Omura, 2004). So treating the uncertainty is useful to cost-benefit analysis as well as formal safety assessment.

Chapter V

The approach to the dealing with uncertainty

5.1 Introduction

> 'Uncertainty means an inability to predict accurately. As it applies to business decision, uncertainty means that decision makers cannot forecast what will happen if they select any of the alternatives among which they are choosing.'
>
> (Oxenfeldt, 1979)

It is essential that the analyst must take into account uncertainty when performing the cost-benefit analysis and that the decision maker must pay attention to this problem as well because the uncertainty is the main cause of limitations of cost-benefit analysis.

Somebody has said: 'In CBA, the only certainty is uncertainty.' This statement clearly describes cost-benefit analysis, where lack of information about the consequences of actions and the benefits and costs of these consequences often confounds the analysis. So the key factor for a successful application is how to make the impact of uncertainty to the minimum level.

5.2 The ways of treating uncertainty in CBA

5.2.1 Expected value analysis

Expected value analysis is designed to deal with risk and uncertainty by assigning probability estimates to alternatives and then using these probability estimates to compute an expected value. One limitation of CBA is that the consequence of the policy is uncertainty. Analysts can not be able to specify the full range of relevant circumstances that may occur. Indeed, the human and natural worlds are so complex that we can not hope to anticipate every possible future circumstance. But in many situations of relevance to the policy, it is reasonable to characterize the future in terms of a number of distinct contingencies. For example, after set up the place of refuge, we might reasonably divide the future into three contingencies of distressed ship: badly damaged, considerate damaged and non-damaged.

Expected values take account of the dependence of benefits and costs on the occurrence of specific contingencies to which analysts are able to assign probabilities of occurrence. If analysts assign probabilities of occurrence to each of the contingencies, then the uncertainty about the future becomes a problem of dealing with risk. In relatively simple situations, risk can be readily incorporated into CBA through expected value analysis (Boardman et al, 2001, p157).

According to Boardman et al (2001, p57), the beginning of modeling uncertainty as risk is the specification of a set of contingencies that are exhaustive and mutually exclusive. Contingencies can be thought of as possible events, outcomes, or states of the world such that one and only one of the relevant set of possibilities will actually occur.

When analysts make the model, two things should be considered. One important consideration is that the contingencies capture the full range of likely variation in net benefits of the policy. We also look the example of the place of refuge. We should consider two extreme situations: one is the best situation – non-damaged and the other is the worst situation – badly damaged. Another consideration is how well the contingencies represent the possible outcomes between the extremes. Analyst should list the possible contingencies exhaustively so that they are fully representative. After specified representative set of contingencies, analysts should assign an infinite number of probabilities of occurrence of each of them. To be consistent with the logical requirement, the probabilities must be nonnegative and sum to exactly one. If the badly damaged, considerate damaged and non-damaged assign corresponding probabilities p1, p2 and p3, then p1+p2+p3=1. If B1, B2, B3 represent the benefit and C1, C2, C3 represent the cost of the policy, analysts can calculate the expected value of net benefits (ENB) of the policy:

$$ENB = p1\ (B1 - C1) + p2\ (B2 - C2) + p3\ (B3 - C3)$$

If the number of contingencies is n then the formula will be:

$$ENB = p1\ (B1 - C1) + p2\ (B2 - C2) + p3\ (B3 - C3) + \cdots + pn\ (Bn - Cn)$$

Let's expand the example of place of refuge. Suppose there are three policies we can choose: doing nothing to the place of refuge; doing some general service such as tug service; doing some special service such as crude oil feeding. The table shows the analysis of expected value of net benefits of each policy. (In this table, all numbers are supposed, not fact) From the Table 1, we can found the general service is the best choice.

Possible	badly	considerate	non-damaged	

contingencies	damaged	damaged		
Probabilities	0.1	0.35	0.55	
Policy				expected value
Doing nothing	100	70	0	34.5
General service	500	200	-100	65
Special service	700	100	-200	-5

Table 1: Comparison of expected values of different service

The above is the basic procedure for expected value analysis. In this procedure, the risks in each year are independent of the realizations of risks in previous years. So it can be directly extended to situations in which costs and benefits accrue over multiple years but the risks are independent.

The basic expected value procedure cannot be so directly applied when either the net benefits accruing under contingencies or the probabilities of the contingencies depend on the contingencies that have previously occurred. Such situations require a more flexible framework for handling risk than basic expected value analysis. Decision analysis can provide the need framework.[1]

From above analysis, it is found that now a key question here is how to formulate the probability estimates. For variables such as energy prices and population growth, one can look to well developed forecasting models that predict these variables and

[1] Please see the detail of decision analysis in 'Cost-Benefit Analysis: Concepts and Practice' (Boardman et al, 2001, p162-166)

have standard errors associated with the estimates. However, many times the analyst or decision maker will be confronted with variables for which there are no such forecasting models, such as applying some new technology in maritime transportation. In this case, the analysts (or experts that the analyst recruits) will need to make subjective probability estimates. The analyst or the expert would take into account various factors such as the changing age distribution of the population, predicted changes in income, and how they feel attitudes will change towards the environment and towards convenience products and make forecasts or future garbage streams and subjectively attach probability estimates to those forecasts.

According to NCEDR (2005), the expected value analysis has three limitations. The first is that the expected value analysis does not usually incorporate all of the information that is known about the uncertainty of the variable. The probabilities in expected value analysis are estimated. Although expected value analysis incorporates aspects of the probabilistic nature of important variables, but it does not seek to evaluate the quality of the information underlying the probability estimates. Thus, although the development of subjective probabilities in expected value analysis is one way of treating uncertainty, it is not a complete treatment.

The second limitation is that expected value analysis assumes that the decision maker places the same weights on gains as on losses whereas, but in fact, in almost time the weights may be different. For example, whereas an individual may place an equal value on saving 100$ or wasting 100$, but when she buying a TV set, it will be different between having more 100$ or lacking 100$. The analysis must also be careful to specify the source of harm or well being properly.

The last limitation is that individuals may evaluate risky situations differently than certain ones. An individual who declines a "fair" wager, for example, is said to be risk averse. In general, individuals tend to be risk averse. Nevertheless, it can be argued that society as a whole should be risk neutral in evaluating uncertain events.

5.2.2 Sensitivity analysis

5.2.2.1 Introduction

> 'Sensitivity generally refers to the variation in output of a mathematical model with respect to changes in the values of the model's input. A sensitivity analysis attempts to provide a ranking of the model's input assumptions with respect to their contribution to model output variability or uncertainty.'
>
> (EPA, 1997)

Sensitivity is measured by how much change in a parameter is required to change the alternative selected in the original analysis. In formal safety assessment, analyst can use sensitivity analysis to test the sensitivity and reliability of the results obtained from the cost-benefit analysis. Sensitivity analysis identifies those input parameters that have the greatest influence on the outcome, repeats the analysis with different input parameter values, and evaluates the results to determine which, if any, input parameters are sensitive. If a relatively small change in the value of an input parameter changes the alternative selected, then the analysis is considered to be sensitive to that parameter. If the value of a parameter has to be doubled before there is a change in the selected alternative, the analysis is not considered to be sensitive to that parameter. The estimates for sensitive input parameters should be re-examined to ensure that they are as accurate as possible.

5.2.2.2 The steps of sensitivity analysis

Based on NCEDR (2005) and USDA (2005), Sensitivity analysis includes four steps: The first step is identifying all of the important parameters that affect the cost-benefit flows. The second step is defining the range of every important parameter. The third step is repeating the cost-benefit analysis Choose either the minimum or maximum value as the new parameter value (the number selected should be the one that most differs from the value used in the original analysis). Repeat the CBA with the new parameter value and document the results. The last step is evaluating results—Compare the original set of inputs and the resulting outcomes to the outcomes obtained by varying the input parameters.

5.2.2.3 Incorporating with scenario analysis

> 'Scenario analysis is a process of analyzing possible future events by considering alternative possible outcomes (scenarios). The analysis is designed to allow improved decision-making by allowing more complete consideration of outcomes and their implications.'
>
> (Forrester, 2005)

As Oryang (2002) mentioned, scenario analysis also can be called as Probabilistic Scenario Analysis (PSA). It is a methodology for quantitative risk assessment that has been used for a long time. It was first used in the 1940's to assess the risks associated with the development and use of the atomic bomb. In the 1950's it was used to assess the-what if scenarios of nuclear proliferation. By 1960 it was being used in financial analysis, engineering applications and general economic evaluations.

Scenario analysis is the method most frequently used in conducting quantitative risk assessments. It has been well tried, and has proved useful in many fields. We can test plans against various possible scenarios to see what might happen and not go as you hope. Scenario analysis is an important technique in risk management, helping us to ensure that we do not take on too much risk. Its usefulness does of course depend on risk managers coming up with the right scenarios.

According to Oryang (2002), the PSA methodology has the following steps:

- Identify the hazard of interest.
- State the question to be investigated.
- Develop a success or as planned scenario.
- Develop an "event tree" or "scenario tree"
- Collect evidence to evaluate the nodes of the event tree
- Quantify the nodes of the event tree
- Link the information generated by the scenario analysis with the empirical evidence

NCEDR (2005) states that scenario analysis is based on the assumption that factors affecting cost-benefit flows do not operate independently of one another as is assumed in the sensitivity analysis approach. Scenario analysis is very useful to the sensitivity analysis. It is a process of analyzing possible future events by considering alternative possible outcomes or scenarios. In particular, it provides a notion of where the impacts of uncertainty are important for the analysis and where they are not.

5.2.2.4 Three approaches to doing sensitivity analysis

There are three approaches to doing sensitivity analysis: partial sensitivity analysis, extreme-case analysis and Monte Carlo sensitivity analysis. (Boardman et al, 2001).

5.2.2.4.1 Partial sensitivity analysis

Partial sensitivity analysis is the most commonly used method. It focuses on the key parameters and the consequences of alternative polices. It is most appropriately applied to what the analyst believes to be the most important and uncertain assumptions.

5.2.2.4.2 Extreme-case analysis

The extreme-case analysis considers the uttermost situations of parameters. It includes worst-case and best-case analysis. Worst-case analysis is generally most valuable when the Net CAF is negative; best-case analysis is generally most valuable when the Net CAF is negative. (Boardman et al, 2001, p171).

In FSA report of Greece about double-side of bulk carrier, the extreme-case analysis can be found. In this report, the sensitivity analysis on risk reduction was undertaken. From Figure , we can found that ‘even with 100% risk reduction rates through the introduction of the DSS RCO, economic arguments still render DSS not cost-effective (Gross and Net CAF well above US$10M).’ (IMO, 2004)

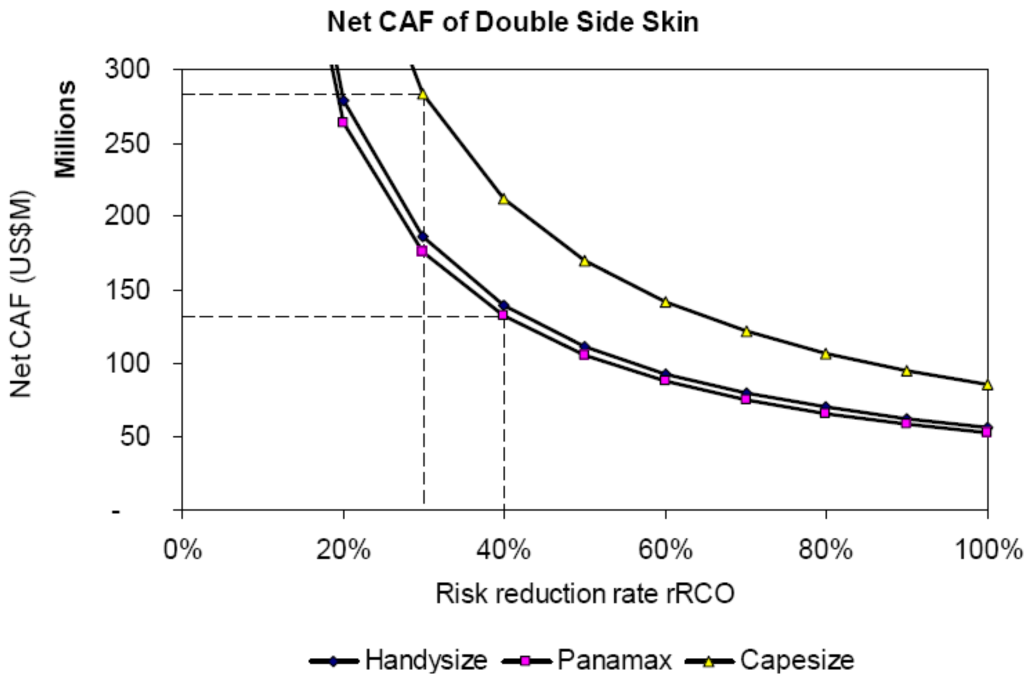

Figure 5: The sensitivity analysis of risk reduction (IMO, 2004)

5.2.2.4.3 Monte Carlo Sensitivity Analysis

Both partial and extreme case sensitivity analysis have tow limitations. First, they may not take account of all the available information about assumed values of parameters. Second, they do not directly provide information about the variance, of spread, of the statistical distribution of realized net benefits (Boardman et al, 2001). So the analysts can use Monte Carlo sensitivity analysis to overcome these problems.

Monte Carlo Analysis is a general technique to aid in decision making in complex situations. The basic goal of a Monte Carlo analysis is to quantitatively characterize the uncertainty and variability in estimates of exposure or risk. A secondary goal is to identify key sources of variability and uncertainty and to quantify the relative contribution of these sources to the overall variance and range of model results. (EPA, 1997, p3)

Monte Carlo analysis has played an important role for many years in the investigation of statistical estimators whose properties cannot be adequately determined through mathematical techniques alone. Monte Carlo methods have been used for centuries, but only in the past several decades has the technique gained the status of a full-fledged numerical method capable of addressing the most complex applications. The falling opportunity cost of computing, especially the greater availability of flexible spreadsheet software for microcomputers, makes Monte Carlo analysis feasible for an ever increasing number of practicing policy analysis (EPA, 1997). Monte Carlo is now used routinely in many diverse fields, from the simulation of complex physical phenomena such as radiation transport in the earth's atmosphere and the simulation of the esoteric sub-nuclear processes in high energy physics experiments, to the life sciences such as DNA sequence assembly. In recent years, the Monte Carlo analysis is applied in the economic domain such as project management.

Monte Carlo Analysis is a computer-based method of analysis that uses statistical sampling techniques in obtaining a probabilistic approximation to the solution of a mathematical equation or model. Monte Carlo methods can be loosely described as statistical simulation methods, where statistical simulation is defined in quite general terms to be any method that utilizes sequences of random numbers to perform the simulation. Summering the point of Wajs et al (2000) and Boardman et al (2001), the benefits of Monte Carlo analysis are: (1) an understanding of the probability of a specific outcomes; (2) the ability to pinpoint and test the driving variables within a model (e.g. what factors most affect the NPV); (3) a far more flexible model; and (4) elicit a distribution of outcomes.

According to Boardman et al (2001), EPA (1997), Wajs et al (2000) and Frenkel

(2004), the steps of Monte Carlo analysis are:

First, specify probability distributions for all important uncertain quantitative assumptions.

Second, executing a trial by taking a random draw from the distribution for each parameter to arrive at a set of specific values for computing realized net benefits.

Third, repeating the trial described in the second step many times to produce a large number of realizations of net benefits.

Last, analyzing the results by using histograms, summary statistics, confidence intervals, etc.

The Monte Carlo sensitivity analysis also can be used in maritime risk analysis. The Monte Carlo analysis uses statistical sampling techniques in obtaining a probabilistic approximation. It is not like many other methods which use the mathematical models to analysis the probability. Monte Carlo analysis attempts to estimate the distribution of net benefits by explicitly treating assumed parameter values as random variables. 'It is especially useful when the risk of the policy is of particular concern and the parameters have non-uniform distributions or the formula for the calculation of net benefits involves the parameters in other than simple sums.'(Boardman et al, 2001, p184) Many polices which the FSA are used to assess have the random distribution of risk probability, so the Monte Carlo analysis is useful for analysis the sensitivity of these polices.

Monte Carlo analysis is a computer-based analysis. It uses computer to generate enough large number of data. The more number of data we can get, the more precise Monte Carlo analysis can do. In many policies of maritime, analysts can not collect the enough data to set mathematical model. But use Monte Carlo analysis, analysts could generate enough data to risk analysis.

5.2.2.5 Advantages and disadvantages of sensitivity analysis.

Sensitivity analysis has several advantages. First, because the sensitivity analysis is used, the decision-maker can get more information about all alternatives. In particular, the analysts and decision-makers can know where the impacts of uncertainty are important for them and where are not. This could cause the analyst to gather additional information. Second, because the process requires a careful examination of the factors most likely to influence the cost-benefit flows, the analysts are better informed as to what the results of the analysis truly represent. (NCEDR, 2005) Finally, because scenario analysis is incorporated, the potential interaction of key parameters is revealed, and it is very useful for decision-making.

Several disadvantages are also gone with sensitivity analysis. The determination of values that correspond to variations in key factors is based upon the best information at the disposal of the analyst. Although Monte Carlo analysis can generate many random data of key parameters, it also based on the data which is collected from the reality or predicted by experts. Inevitably, this implies the reliance on ad hoc methods for determining pessimistic, optimistic and most likely estimates. So the scenario analysis is very important for sensitivity analysis. Also, the lack of a systematic method for determining the appropriate combination of parameters used to define given scenarios limits the reliability of sensitivity analysis. (NCEDR, 2005)

5.2.3 Quasi-option value

The concept of quasi-option value was originally explored by Arrow and Fisher (1974) and Henry (1974). It can be used whenever uncertainty is assumed in a decision making problem involving restriction on reversibility of acts.

It would be wise that decision-makers should delay a decision if better information relevant to the decision will become available in the future. The expected value of information gained by delaying an irreversible decision is called quasi-option value. (Arrow and Fisher, 1974) Although now the quasi-option value is most used in the project concerned with the environmental protection because 'the interplay between irreversibility and uncertainty has been a central issue in environmental Economics' (Ha-Duong 1998), the quasi-option value also can be used in any project which has two features: irreversibility and uncertainty. Option value is related to potential, but uncertain, future resource uses and is likely to be small in the presence of close substitutes.

Arrow and Fisher (1974) and Henry (1974) indicated that for certain events it may be beneficial after postponing actions if delaying the action can optimize conditional on improved information. Indeed, the availability of new information may partially resolve uncertainties over time, thus making project profitable to wait and act in the light of it. When the irreversible decisions are faced with, this flexibility becomes even more valuable. 'In order to take into account the level of flexibility of different investment strategies, analysts will use the concept of the quasi-option value, which is the extra value that can be captured by performing a fully dynamic analysis of the decision problem.' (Messina and Bosetti, 2002)

If the quasi-option value analysis applied, there should be four preconditions: First, the project is irreversible. That means the project may have large initial costs which include fiscal costs and environmental costs. Second, at least one of key parameter is uncertainty and it make the net benefit with high uncertain. Third, the project can be delayed. And the last, more information about the key parameters can be got during the delay.

To most projects of maritime, the irreversible is the main feature of them because the environmental protection is one of mission of IMO and the many environmental resources are irreversible such as virgin wilderness, fringing coral reefs and mangrove forests. So before the decision is made, the quasi-option value should be considered. If the project can be subdivided into several parts, and more information can be gained during the early parts of the activity can be used to reduce the uncertainty in the later parts of the activity, the project should be executed periodically. After getting more information, the uncertainty could be reduced and more profit could be got. If uncertain projects prove unfavorable, the value of the investment may be totally lost, whereas the cost of waiting may be only the savings given up until the decision is finally made, we should waiting. It can be applied to environmental decisions that are irreversible, in the sense that they require the sacrifice of some irreplaceable environmental asset. 'Hence, if science is uncertain about the role of a particular element of a larger ecosystem, with the potential for high costs if uncertainty resolves unfavorably, there can be significant value to waiting until uncertainty is resolved.' (NCEDR, 2005)

5.3 Treating uncertainty in FSA

Uncertainty is a feature of cost benefit analysis, so it is also a feature of formal safety assessment. Treating uncertainty is an important work to formal safety assessment.

In maritime community, many projects are related with the environmental protection and most of them are irreversible. So it is necessary to use quasi-option value in the projects which has two features: irreversibility and uncertainty. We should execute the project step by step and after each step we should re-assess the next step according the information got in previous step if the project can be subdivided into several parts, and more information can be gained during the early parts. If the uncertainty would cause total loss, we should postpone the project until the uncertainty is resolved.

Expected value analysis can be used if the uncertainty has no fundamental influence to the results. But because expected value analysis does not seek to evaluate the quality of the information underlying the probability estimates, so when more careful treating uncertainty is need, the sensitivity analysis is a useful method. The scenario analysis has been incorporated in formal safety assessment. Using fault tree analysis and event tree analysis can make FSA more precise. The sensitivity analysis with key parameters is very useful but few FSA approach has use it. Only from the IMO (2004) FSA report which was presented by Greece on double-side of bulk carrier we can find the sensitivity analysis. Usually partial sensitivity analysis or extreme-case analysis is used. But if we want to take account of all the available information about assumed values of parameters and the distribution of uncertainty of key parameters, the Monte Carlo sensitivity analysis should be applied. By using Monte Carlo sensitivity analysis, we also can get more data and it can make the prediction more precise. But the Monte Carlo sensitivity analysis is a computer-based method, and it needs the analysts to build the statistic model and program to run on computer. So the cost of Monte Carlo sensitivity analysis would be higher.

Chapter VI

Conclusion

Through discussion of this paper, the findings of author can be briefly summarized as follows: Formal safety assessment is very useful to maritime affaires especially on regulations of safety and environmental protection. Cost-benefit analysis is a decision-making tool and with the incorporation into FSA, it makes FSA more scientific, feasible and highly practicable. But the CBA also has some limitations which can attribute to uncertainty. So dealing with uncertainty is one of important jobs of CBA so as FSA.

6.1 The merits of FSA by using CBA

FSA is a proactive, comprehensive and structured methodology for risk assessment. It is not reactive to marine accidents and applied to not only an isolated ship, but a collection of systems.

CBA is a comprehensive methodology measuring efficiency. As being a part of FSA, CBA makes the FSA more scientific and normative by monetizing each of alternatives and discounting every costs and benefits. After doing CBA, it is clear for each member States to find what costs they should burden and what benefits they can get. They can rank the alternatives by Gross CAF or Net CAF although the Gross CAF and Net CAF should not be the sole decisive factor in decision-makings.

So CBA makes the member States easily to choose the alternatives and can accelerate the implementation of flag States.

6.2 The necessity of treating the uncertainty.

Although CBA has many advantages and is a useful tool for risk analysis, it also has some limitations which can weaken its functions for risk analysis. CBA wants to monetize all costs and benefits, but not all of them can be easily and definitely monetized, such as value of life and environment. These costs and benefits are uncertainty and make the result uncertain.

The inequity in the globe and unfairness to the future generation may be given rise to during the calculation of costs and benefits. Although the stakeholder analysis and side payment can be used to treat globe inequity and social discount rate would be a way to deal with the unfair to the future generation, the uncertainty of costs and benefits of each member States and social discount rate also need to be solved.

Uncertainty itself is also the limitation of CBA. So to treat uncertainty properly is very useful and important to CBA and FSA

6.3 Dealing with uncertainty in FSA

From the experience of other fields, three methods can be used to deal with uncertainty: expected value analysis, sensitivity analysis and quasi-option value. Not all of them are used under the same conditions. Quasi-option value is often used in the maritime project management which is related with the environmental protection and most of them are irreversible and uncertainty. And the quasi-option value should be used in FSA before these projects begin. Expected value analysis can be used if the uncertainty f the uncertainty has no fundamental influence to the results. Although the scenario analysis has been incorporated into FSA, in general, the sensitivity analysis is also needed. The partial sensitivity analysis or extreme-case analysis is used when single key parameter is needed to analysis or the parameters which are need to analysis are not so closely co-related. Monte Carlo sensitivity analysis should be applied when the distribution of uncertainty of key parameters and all the available information about assumed values of parameters are taken into account.

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