# Operational Safety of Subsea Systems: pros and cons of different types of regulation

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## 1. INTRODUCTION

Carrying hazardous and highly combustible gaseous and liquid products through major pipelines at high pressure is an inherently dangerous activity involving significant potential risks to the environment and public safety.

In order to transfer oil and gas from exploration and production field, Brazil holds a vast network of subsea systems, connecting offshore platforms with onshore processing facilities. Loss of human life and environmental damage are the most serious consequences of an accident on subsea systems. Additionally, other concerns are supply shortage and economical lost. Annual losses of $ 300 million in property damage in USA caused by incidents are estimated by PHMSA [1].

The pipeline regulation plays an important role in safety of process ensuring reliable supply of products.

Gas and oil supplies are an increasingly important part of the Brazilian energy matrix. On the last 10 years, the consumption of natural gas has grown from 18.8 to 37.6 billion $m^3$. This fact made Brazil the 24th greatest consumer of natural gas in the world on 2013 [2]. Most part of the production (73.3%) is from offshore fields, therefore operational safety of subsea systems are of major importance in order to assure that needed amount of gas will be delivered.

Interruptions in the pipelines can cause gas supply problems or restrict oil availability. Ensuring that gas supplies are reliable and are delivered safely is important to meet the needs on natural gas power stations. It was especially needed on the year 2015, because of the Southeast drought, since this region concentrates a lot of important water reservoirs and Brazilian energy matrix for the region is essentially based on hydropower electricity.

The economical lost can be related to damage on the subsea system or the consequences of a leakage, regarding the interruption of fishing activities, and even the decrease on touristic activities due to the area pollution.

This paper presents an analysis of the pros and cons of different types of regulation for operational safety of subsea systems such as: prescriptive, performance-based and industry self-regulation. This analysis was originally done and documented as a Regulatory Impact Statement (RIS) of the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis – ANP) prior to the publication of a performance based regulation for operational safety of subsea systems.

The Regulatory Impact Statement evaluates the impact, considering costs, benefits and risks of regulatory proposals that can impact the society. It is a police in European Union, Australia and United Estates that all departments and agencies that have legal power and create rules that affect other entities must do a Regulatory Impact Statement [2].

The following steps must be followed during the analyses: problem identification, market failure identification, *status quo* analyses, detection and analyses of regulation options, choice of analyses criteria, involved parties consultation, consequences on parties involved, and recommendation of an action. [3]

## 2. WHAT IS THE PROBLEM?

Pipelines are critical points in the logistics of the oil industry. An accident may cause huge operational disruptions, environmental damage and people exposure to the risk of contamination, property damage, and fires and explosions. This risk is enlarged when one considers that pipelines cross immense distances, in areas where they are subjected to environment changes, soil movement and third parties actions.

### *2.1 Main Accidents in Brazil*

In 2000, a pipeline that connects Duque de Caxias Refinery (REDUC) to terminal Sudeste-DTSE / Ilha D'Água (GEGUA) collapsed, causing the leakage of 1.3 million $m^3$ of combustible oil on a mangrove. The cause of the accident was related to project deficiencies, and its maintenance. The leaked oil has caused significant environmental, economical, and social damage. It can be quoted the impact on biotic environment, and decline on fishing activities that had a direct consequence on the local communities. Around 15 thousand tons of fish couldn't be commercialized on Guanabara Bay area, harming the livelihood of 30 thousand families. As the pollution altered the water quality and sand conditions, there was also a decrease on touristic activities [4].

In 2014 there was a leakage on a gas pipeline whose damage was caused by an impact with a heavy object. In this case, the pressure on pipeline was decreased, but operations didn't stop to avoid water entrance. The area was signalized and the leakage was observed with an auxiliary boat, in order to protect the communities on coastal area.

This year there was one leakage on a rigid pipeline from the 1980s, which connected platforms. In this case, the accident happened on shallow water depths and could have caused a significant pollution on the coastal area, due to its proximity.

Those incidents have been a stimulus for ANP to study and evaluate the regulatory approaches for subsea pipelines in Europe, USA, Australia, Mexico, Norway, Argentina, Canada, among other countries, in order to propose the best way to ensure the operational safety of subsea systems in Brazil. Most of the countries have a consolidated operational safety management policy.

### *2.2 Incidents statistics worldwide*

Between 1995 and 2014, 640 incidents on subsea pipelines were reported in the United States, which are around 32 incidents per year. From these, 492 were considered significant, meaning that at least one of the following conditions were followed: fatality or injury requiring in-patient hospitalization; $50,000 or more in total costs (measured in 1984 dollars); highly volatile liquid releases of five barrels or more or other liquid releases of 50 barrels or more; or liquid releases resulting in an unintentional fire or explosion [1].

In Norway, 975 incidents were reported in risers between 1975 and 2012, on average 25 accidents per year [5]. From the accidents classified as major between 2000 and 2012, stands out 71 accidents related to flexible risers and five associated with rigid risers. In general, Sundby and Anfinsen (2014) highlighted that the main causes of accidents are due to project failure, inappropriate qualification of technology and inefficient procedures.

### *2.3 Existing Problems*

The data bellow resume the accidents reported in US, Norway and Brazil on the last years:

- US has approximately 1.7 times the number of pipelines in Brazil, and between 1995-2014 were reported 640 accidents on subsea pipelines [1].

- Norway has around 300 flexible risers and umbilicals installed, most of them in depth less than 300 m, a small amount compared to Brazil, which uses flexible pipes in deeper waters. Around 5.5 accidents per year happen in Norway in flexible risers, a number 14 times bigger than the incidents on rigid risers [5].
- In Brazil, from 2012 to 2015, 5 incidents on subsea pipelines were reported to ANP, all related to rigid pipelines, an average of 1.6 accidents per year.

Comparing the incidents statistics of US and Norway, exposed briefly above, with the incidents reported in Brazil, it is easy to conclude that there is a poor communication to ANP. If US and Brazilian accidents were similar, it would be expected around 19 incidents per year in Brazil, five of which of major gravity. The same applies to Norway statistics since there are no accidents related to flexible risers in Brazil and there is a significant amount in Norway, it is assumed that Brazilian statistics are not realistic and incidents are not efficiently communicated to ANP.

This poor accident communication is attributed to the lack of a specific regulation for subsea systems and to insufficient enforcement activities by the government. This fact happens despite the existence of ANP Resolution No. 44/2009, which sets the procedure for incident reporting to be adopted by the concessionaries and authorized companies by ANP to perform activities of the oil, natural gas and biofuels industry.

Another fact that can contribute to poor communication is the system available for incident report. That system doesn't have a list of all pipelines, as it happens with onshore and offshore production installations, and rigs. Then, sometimes, accidents on pipelines are reported but not attributed to subsea systems.

With the implementation of a specific resolution to subsea systems and the enlargement of enforcement activities a more realistic incident database is expected.

When accidents on subsea systems happen it may have some serious consequences on human life, environment pollution and also an economic impact. So far, ANP has regulatory instruments concerning permits to construct or operate pipelines, as quoted below:

- ANP Resolution n° 17/2015 that sets permit for construction and operation of gathering and transferring pipelines in Brazil, addressing the approval of the Development Plan for Oil and Natural Gas Fields; and
- ANP Ordinance n° 170/1998, which regulates the water transportation of oil, its derivatives, natural gas, biodiesel and diesel and bio diesel mixtures.

Additionally, Law 9.478/1997, Article 44, which presents the obligations of the concession contracts, establishing that dealers shall adopt, in all its operations, the necessary measures for the conservation of reservoirs and other natural resources, for the safety of people and equipment and for the protection of the environment; following international oil industry best practices

However, up to now there is no regulation related to safety that applies to the whole life cycle of a subsea system. Therefore, the intended results of operational safety and environmental protection can't be reached.

Figure 1 shows the relation of the problem to be faced (high risk of operational safety incidents) with its causes and consequences, represented by a problem tree where the trunk is composed of the diagnosis of the problem, the roots are the main causes and the branches and leaves represent the negative effects of the problem.

The main causes of accidents are: non compliance of codes, standards, safety procedures, and industry best practices; insufficient and deficient enforcement activities by the government; poor incident communication; and failure on safety management. The secondary causes are inadequate penalties, lack of safety culture, inappropriate regulation, lack of financial resources, lack of human resources, lack of operational safety prioritization, failure on operational safety management, and low implementation of incident investigation results.

The primary effects are the decrease in production and supply shortage; interdiction and fines; and safety risk. This can bring implications to Brazilian trade balance, harm to consumers, administrative and legal costs, financial losses, damage to human life, environment and properties.

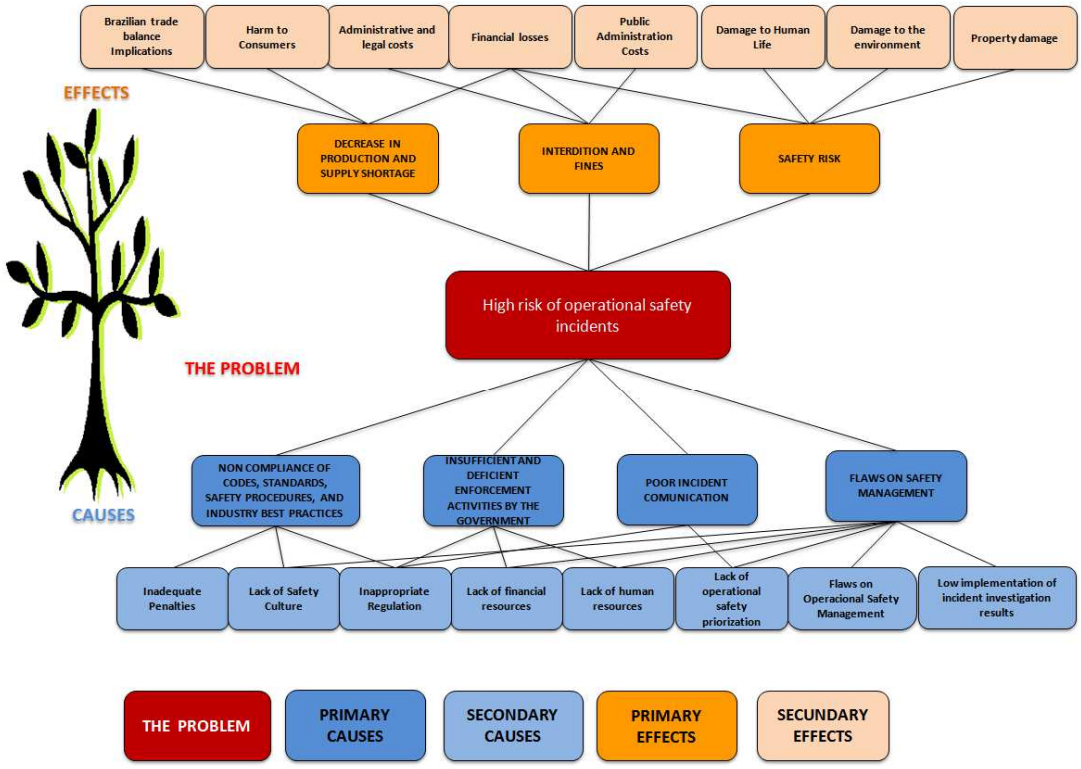


Figure 1 – Problem Tree

## 3. WHY SHOULD THE GOVERNMENT ACT?

Having identified the nature and extent of the problem and the appropriate policy solution, the threshold or preliminary question to be addressed in an RIS is: Is there a sufficient reason for further government intervention to assist in solving the problem?

Operational safety and environmental protection are of interest of subsea systems operators, in order to protect its properties and image. However, damage to society and environment might be more significant than property damage, and consequently, the interests might not be enough to ensure operational safety.

Risk level is of major importance when considering regulatory options. High risk levels of non compliance with industry best practices usually justify the use of stronger regulatory instruments. On the other hand, if the risk of non compliance with codes and standards is low, less interventionist regulations, including self-regulation, might be applied. The consequences of an accident on subsea systems are significant to the society and the environment, therefore indicating the need of a regulation.

Generally speaking, the economic rationale for government intervention in markets arises from the concept of market failure: the existence of externalities and/or public goods or common goods, including a lack of information. In other words, market forces alone would not solve the problems

identified in this RIS and a regulatory solution is necessary.

Evaluating the international regulation and consulting codes, standards and industry best practices, the deficiency on Brazilian regulation was observed, despite the fact that the operators of subsea systems follows recognized international codes and standards. Thereby, is necessary to settle a regulation for subsea systems, in order to reinforce operational safety of subsea systems.

Additionally, the Australian Regulatory Agency considers the existence of a regulation a crucial instrument to keep safety records. The Australian pipelines have a safety history better than the Europe and US. This performance is attributed to effective attendance on regulatory instruments [6].

The following main goals are expected to be achieved with the implementation of a regulatory instrument for subsea systems:

i. Ensure that the subsea system operator sets up an operational safety management system for subsea systems;
ii. Minimize the occurrence of incidents in subsea systems;
iii. Provide consistent regulatory framework for managing the technical aspects of subsea systems, thereby improving the uniformity and transparency of government action;
iv. Reduce the risk and the incidence of supply interruptions related to systems covered by the regulation, therefore promoting more reliable sources to consumers;
v. Regulate the industry best practices;
vi. Be compatible with the Petroleum Law and other regulatory instruments; and
vii. Enhance Brazil's capacity to prepare and respond to potential emergencies that affect human life and the environment.

## 4. HOW SHOULD THE GOVERNMENT ACT?

With the aim of addressing the problem, different options of regulation might be adopted such as: prescriptive, performance-based and industry self-regulation. In this section, it is presented some pros and cons of these approaches.

On the industry self-regulation option, the industry is responsible for design, construction, operation and maintenance of their subsea systems in a self-managed safety system. Therefore, the companies would be free to operate on their way and determine what performance data is collected.

Nevertheless, the regulatory agency still needs to track the performance of subsea systems on public domains because failure on facilities management might bring high consequences to society and environment.

Additionally, companies seek profit maximization, without necessarily prioritizing the best option in terms of safety. Hence, the self-regulation approach is considered of unacceptable elevated risk, bearing in mind the importance of oil and gas transfer as an essential service, and the potential of catastrophic consequences if safety management systems are not properly applied.

Without an efficient regulatory instrument to standardize industry best practices, the enforcement activities become more discretionary, hindering the judgment of fines, and the transparency of government actions.

Another option is the institution of a prescriptive regulation. In this case, specific requirements for facilities, equipment and activity that prevent accidents and mitigate the risks would be demanded. The regulatory agency would verify the adherence to these requirements from subsea systems operators.

In order to achieve a good prescriptive regulation, the regulatory agency would have to develop expertise in a great variety of subjects, such as inspection, maintenance, corrosion control, operation, design, and construction. This would take excessive time and cost, therefore the current situation of regulation absence would continue for a long time.

An alternative would be the establishment of international standards as mandatory, as it is done in some countries. For instance, in Australia it is mandatory to follow AS2885 standard that is related to

DNV-OS-F101. Norway adopts API 17J and API 17B for flexible pipes, and ISO 13263 and DNV-OS-F10 for the rigid ones. The standard CSA-Z662 is compulsory in Canada, and it combines performance based and prescriptive requirements for design. Though, the indication of standards can be ineffective once it may arise situations not covered by them. Exploration going to deeper waters and reservoirs may lead to new technological developments, which are not included in any mandatory standard, generating regulatory flaws.

The situation above does not exist in a performance-based regulation since other standards and industry best practices can be applied, as long as properly managed. Furthermore, it is an industry consensus that the establishment of specific requirements for design, inspection and maintenance may encourage a passive attitude among companies, despite the adoption of general standards. Sundby and Anfinsen (2014) justified the migration of prescriptive regulations from the 70's and 80's to performance-based ones with this argument. In Norway this migration was visible. Nowadays, Norway regulation is performance-based with general requirements for especial activities such as risk reduction, continuous improvement and maintenance. Additionally, this country adopts prescriptive rules for other subjects, such as welding and coating.

Other countries keep adopting prescriptive regulations, as it happens in Italy and Germany. However, neither of these regulations is very detailed. Argentina and Mexico have a detailed and prescriptive regulation for design. Subsection F of 49CFR–Part 195, an US regulation, determines mandatory leak detection dispositive, specifies requirements for the control room, and brings specific requirements for valves, pig launchers, and pig receivers maintenance. This regulation is more prescriptive, indicating the periodicity of inspections for some equipment and the adoption of some API standards. However, there are a few performance-based requirements and the philosophy of risk management is present.

## 5. WHAT IS THE IMPACT OF EACH OPTION?

The main analytic methods available in literature to assess the impact analysis of Regulations are: the cost-benefit analysis, cost-effectiveness analysis, multicriteria analysis and partial analysis [7].

The impact of each option on the affected parties was analyzed through a cost-effectiveness analysis, where social and environmental benefits have been identified.

Ensure public safety is the outcomes of both remain options (industry self-regulation and a performance-based regulation). Moreover, the benefits of each option could not readily be quantified, so a cost effectiveness analysis has been used to identify the minimum cost option. This allows a quantitative comparison of the options based on administrative costs and a qualitative analysis of the benefits of improving safety and reducing environmental and social impact. These benefits have not been quantified due to the wide range of values which can be attributed to them.

A preliminary analysis resulted on the elimination of the option of a prescriptive regulation, due to the reasons already discussed in Item 4 of this paper: this approach is not considered efficient by international regulators.

The following areas were considered in the evaluation of regulatory options:

- Compliance costs including resources, time and financial costs;
- Administrative costs, including potential costs and time constraints on government;
- Social costs or impacts on the community;
- Environmental impacts;
- Benefits associated with the regulation; and
- Implementation and adherence.

## 5.1 Impact Analysis of Option 1 (Performance-Based Regulation)

### 5.1.1 Compliance costs including resources, time and financial costs

These include the following direct costs imposed on the industry as a result of the regulatory requirements:

- Develop or adapt the operational safety management system;
- Implement procedures of operational safety management system;
- Develop and implement operational safety documents;
- Defining and measuring targets and performance indicators; and
- Auditing the operational safety management system.

For each operator the annual compliance cost can vary depending on the network size, location and age.

### 5.1.2 Administrative costs including potential costs and time constraints on government

Administrative costs to the Government include:

- Provision of guidance to regulator agent;
- Operator management system evaluation;
- Performance evaluation; and
- Reinforcement activities to check specific issues.

### 5.1.3 Social costs or impacts on the community

No additional major social costs or community impacts have been identified.

### 5.1.4 Environmental impacts

No negative environmental impact has been identified. The subsea pipelines will still need authorization of environmental authority and ANP, regardless of new regulation existence. In addition, the new regulation has new requirements during routing and decommissioning that are intended to prevent environmental damage.

### 5.1.5 Benefits associated with the regulation

There are three main benefits of the proposed Regulation:

- Reduced social costs and negative community impacts;
- Reduced environmental impact; and
- Increased reliability and quality of supply.

The reduced social costs and negative community impacts are related to the potential decrease on serious accidents, including fatalities, and on property damage. The two main causes of social and community impacts related to hydrocarbon transport are loss of containment and supply shortage. The loss of containment in any circumstance is a potentially dangerous and undesirable event.

The reduction on environmental impact was discussed on item 5.1.4. The increased reliability and quality of supply is directed linked with the potential reduction of accidents.

### 5.1.6 Summary of costs and benefits of the regulation

The establishment of a regulation based on performance brings some costs mainly on operator compliance. However, it is expected to reduce accidents, having clear social and environmental benefits that overcome the costs for operators.

The compliance costs on operators are not expected to be extremely high because companies already have a safety management system, although it will have to be adapted.

## 5.2 Impact Analysis of Option 2 (Industry Self-Regulation)

### 5.2.1 Compliance costs including resources, time and financial costs

Under option 2 (industry self-regulation), it is likely that companies would still develop and implement a Safety and Operating Management System as part of their risk management procedures.

Compliance cost reductions are expected in relation to Option 1. There is not mandatory emission of some documents, such as commissioning report and permanent decommissioning program, as well as audits of the compliance of its management system. However, companies may still conduct some of these activities for internal performance management requirements.

Thus, the impact of the industry self-regulation option could vary greatly between companies depending on the processes in place within each organization.

### 5.2.2 Administrative costs including potential costs and time constraints on government

It is expected that the Government would still incur administration costs under this approach, ensuring safety standards are met through failures and accidents investigations, and enforcement activities.

The lack of specific requirement in the industry self-regulation approach should result in poorer safety outcomes. On this option it's necessary to check the compliance with a variety of standards, codes and international best practice, turning in complex enforcement activities of government institutions, such as ANP and IBAMA. Thus, administrative costs are likely to be increased.

Additionally this option requires further action in investigating incidents, monitoring emergency response plans, management of integrity and permanent decommissioning plans for the facilities.

A decrease in employees safety performance may also lead to an increase in administration costs for other agencies such as Ministry of Labor and Employment (MTE - Ministério do Trabalho e do Emprego).

With this option it is expected higher employment and operating costs for the Government over the life of the Regulation. This reflects the increased number of employees (most likely public servants) required to investigate incidents and court lawsuits. The costs to the Government could be even higher, as this does not include an assessment of the impact on other agencies, such as MTE and IBAMA.

### 5.2.3 Social costs or impacts on the community

It is expected that option 2 involve significant social costs and community impacts. According to PHMSA (Pipeline and Hazardous Materials Safety Administration- US Department of Transportation), a lack of regulatory regime is not clear in identifying which party is fully covering the safety aspects. The industry self-regulation option would have even less obligations to pipeline Operators.

Brazil has a high proportion of serious accidents relative to the number of reported near misses. When compared to the ideal pyramid of Frank Bird, Brazil is statistically unbalanced since the ratio 1: 10: 30: 600 isn't observed. This fact may be related to regulatory failure.

The statistic analysis of Frank Bird's pyramid means that the ability to develop realistic and favorable plans to avoid accidents, and give proper treatment to near misses, reducing the proportion of these to fatal accidents, is impaired in the Option "industry self-regulation". The costs associated with a serious injury or fatality are very difficult to accurately quantify as they can never capture the true social cost of such events, which include the pain and suffering of the injured party, as well as the indirect impact on family members and the community. This cost item provides the strongest argument against adopting the industry self-regulation approach in this area.

Performance-based regulations provide procedures, inspections and maintenance to ensure the

integrity of the installation, as well as concerns about the workplace, the employees and the environment. Additionally it requires more effective management action on the behavior of the employees, focused on safety culture. Thus, it is understood that the option "self-regulation" will generate higher social costs as it will reduce the organization's commitment to safety and thus will maintain unbalance the ideal Frank Bird's pyramid.

### *5.2.4 Implementation and adherence*

Implementation of a "industry self-regulation" approach may initially result in some impact of both Government and industry workforce. In addition, as previously stated, it is inevitable that Government would need additional compliance inspectors to ensure integrity of subsea systems and public safety.

Furthermore, it is forecast that the Operator of subsea system would also need to allocate increased resources in order to satisfy their obligations to comply with codes, guides, and industry best practices, increasing resources to monitor numerous standards and international guides and evaluate the most appropriate to maintain. This increased resource would be needed as it is generally accepted that compliance is more difficult for companies to achieve in the absence of Government Regulation.

### *5.2.5 Summary of costs and benefits of the regulation*

The benefits under this option are largely related to increased flexibility for companies to choose their own methods for ensuring subsea systems operational safety.

However, it brings higher costs for government enforcement activities and could increase the number of accidents, resulting on social and environmental costs.

## 6. CONCLUSIONS

Evaluating worldwide regulations, it is noticed that there is a tendency on demanding a management safety system or an integrity management program. Additionally, it is observed the increasing number of risk management regulations.

Self-regulation is often quoted as an alternative to regulation. However, this option is only effective if a high percentage of people whose behavior needs to be modified are relevant private organizations members with a well-established safety culture and whether there are sufficient government sanctions to ensure compliance with internationally recognized codes and standards.

Based on the evaluations of pros and cons of different types of regulations, ANP decided to establish a performance based regulation for subsea systems operational safety, seeking to maximize the transparency of government actions and to ensure effective and efficient protection of operational safety and the environment. It holds decision-making autonomy within the industry best practices and aims safety and continuous improvement.

While the industry self-regulation option may go some way towards meeting these objectives, it is not only considered less effective but more costly in terms of social and environmental impacts.

The impact (cost effectiveness) analysis indicates that while the two options have similar identified cost impacts, the benefits for performance-based options are likely to be much greater than industry self-regulation.

The new regulatory instrument, called Technical Regulation for Operational Safety Management of Subsea Systems (SGSS), also specifies minimal criteria to be covered in the subsea system lifecycle. However, it does not determine any mandatory code or standard.

The SGSS is robust, with management practices and technical chapters working together, with risk management philosophy. While it does still contain some prescriptive elements, it is primarily a performance based instrument providing industry with considerable scope to best achieve desired safety

and network management outcomes.

Adoption of the Regulation provides the Government a satisfactory level of assurance that the interests of the society and the environment will be considered, without placing unreasonable obligations on operators.

There is no intention in overcharging the operators of subsea systems with the implementation of the SGSS because it is assumed all operators have a management system already running.

With the implementation of SGSS it is expected to achieve a better result on safety and also a more reliable incident database.

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