

## Identification of Global Indicators for Regulatory Risk Management in Production Platforms - Case Study of Brazilian Industry

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### Abstract

This study aims to analyze different indicator's programs from regulators and other organizations, select and apply methods to normalize and compose global indicator. Using obtained information related to risk management system and incidents from 67 oil and gas production platforms in Brazil, the results show a new method to follow offshore performance and its companies, in lagging and leading focuses, showing a tool to improve Regulator's overview.

*Keywords:* offshore platforms, process safety, leading indicator, lagging indicator, global indicator

### 1. Introduction

The selection and monitoring of performance indicators, both in a leading focus to monitor the performance of safety barriers, as in lagging focus to monitor precursors events of major accidents, are the best tools to provide information about how a risk management process is conducted [4][5][6]. It can indicate if corrective actions are needed to achieve management goals at various levels, and, in the end, monitor the risk of major accidents. [7].

The experience of industry shows that without an effective regulatory oversight at oil and gas industrial activities, the risk of accidents will not be reduced, nor will industry prepare effectively to respond to major emergencies [8]. To be sure that all actions are going in

a right direction, regulator's can use safety indicators to follow safety performance and show deviations and the need to add corrective actions. As examples of this approach, the project Trends in Risk Level (RNNP) [9] and the United Kingdom Health and Safety Executive (HSE) [10] are nowadays in use. In this context, it becomes reasonable that in the regulatory level that exist tools for monitoring the platform's performance and oil companies' risk management to have a correct approach to set rules to regulated activities. All of it in sense to achieve sustainable industry's growth ensuring a good level of safety in regulated activities and applying regulators efforts in a reasonable.

The Brazilian regulator offshore authority<sup>1</sup> released in 2007 a non prescriptive regulation based on a safety management system and has been implementing actions to increase industry's risk awareness and lead a safety continuous improvement environment of all offshore activities, as regular regulator's audits, accident investigations, reports, meetings and workshops. This regulatory risk control regulation based on a Process Safety Management System (PSMS) allows to achieve an indicators monitoring program for a new step on this development, giving information to improve the results evaluation of regulatory activities.

## 2. Process Safety Management Systems

The PSMS have a variety of meanings and purposes. The AIChE defines PSMS as a management system focused on prevention, preparedness, mitigation, response and recovery from catastrophic events associated with plant processes [3]. Also according to the AIChE, the PSMS is the discipline for managing the integrity of the operation of systems and processes that handle hazardous substances by applying good engineering practices, operation and maintenance [7]. It can be translated into the prevention and control of risks that have the potential for release of hazardous substances and energy. The organization of procedures, behaviors and actions to be taken and checked for systematic implementation of an effective process risk management is usually done by adoption of a management practices in a PSMS format<sup>2</sup>.

### 2.1. Performance Indicators used in risk management

The majority of indicators definitions tells that they are mainly used to information aquisition for management decision making related to a relevant issue [11]. For the word "performance", it is indicated that it contains the idea of something that has already been done, executed or performed [12]. Therefore, performance indicators have the function to transmit information about processes that occurred in the past for adoption of actions to follow an objective.

Frequently, a retrospective analysis shows that early signs arising from safety indicators could avoid major

accidents if detected and managed timely [13]. Thus, safety performance indicators or just "safety indicators" are measures that seek to give information if a system is operating within chosen safety bounds to ensure that major accident risks are under control. Anyway, they intend to indicate that the preventive and mitigative safeguards and assumptions considered for risk acceptance process are applicable, reliable and active. In the other hand can denounce irrelevance, unreliability or inactivity for an early detection of a non tolerable risk to demand pro-active actions to its reduction.

#### 2.1.1. Leading indicators

According to Hopkins [14], leading indicators are able to measure the ongoing risk management process and make predictions at sufficiently early stages to enable interruption of evolution course, reverse the process and avoid the fact. Another definition describes leading indicators as a type of accident precursors and reports that this kind of indicators are conditions, events and actions that precede an undesirable events and which have value in predict the proximity of an accident, near miss incident or undesirable safety condition. In this sense, leading indicators are related to proactive activities that identify and evaluate hazards, eliminate, control, or mitigate the risk [15].

HW Heinrich in 1931 introduced the widespread accident pyramid based on his experience with the insurance industry (Fig. 1). It has two basic concepts: one is that accidents can be placed on a scale representing the degree of impact and the other is that many precursors incidents occurs with minor

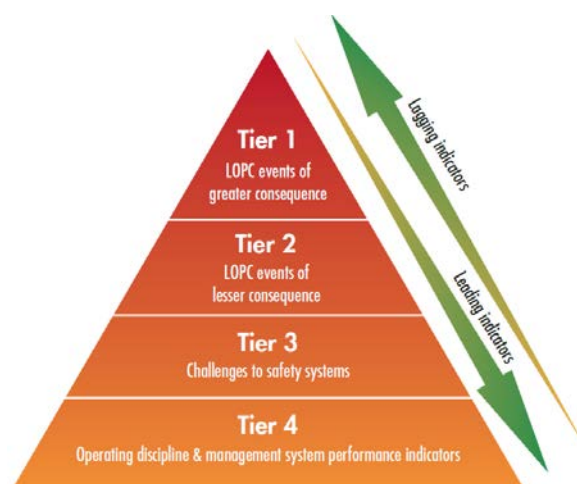


Fig. 1. Process Safety Indicator Pyramid [15].

<sup>1</sup> Agência Nacional de Petróleo, gás natural e biocombustíveis (ANP)

<sup>2</sup> More information in SEPEDA, Adrian L.; Understanding Process Safety Management, CEP Magazine, Aug. 2010, AIChE, 2010.

consequences compared to accidents with large consequences. This representation establishes a predictive relationship between minor and major incidents [16]. Large explosions and other disasters are rare events and many companies did not record any event or only few were recorded in the last 50 years at the same industry (top of the pyramid of accidents). Thus, the number of occurrence of these events is not a good indicator of the probability of occurrence of major accidents [6].

### 2.1.2. Lagging indicators

The lagging indicators generally reflect past experience and are associated with undesirable events and adoption of corrective actions to avoid the recurrence of such events. These indicators are often not sufficient for a preventive program, because the accidental events that generate this type of measure indicators are rare and do not allow a statistical prediction [17]. Lagging indicators are generally viewed as direct measures of damages, however, may also be included incidents of unexpected losses of containment and failure on demand of safety critical systems. The fact is that not all damages and failures are recorded as lagging data, which complicates the design of a boundary between different types of indicators [18].

### 2.2. Global indicators

The search for global indicators has been currently quite intensified as a way to manage different activities using the lowest possible number of information, or an indicator that integrates different information, allowing a responsible decision making to manage applied resources. In the chemical and petrochemical industries, the implementation of global indicators is already an established fact [16].

A global indicator represents a way to specify the evaluation of organizational performance, based on indicators combined and grouped for a determined focus. Global indicators allow us to conclude about implementation effectiveness measurement of an aspect and can be a tool to correlate complex concepts and translate this in simple numerical information [19].

## 3. Methodology

### 3.1. Identification of requirements to be considered in the formation of global safety indicators

The platforms that are in operation in Brazil are required to comply with a safety regulation established by ANP Regulation 43/2007 [20] (also called SGSO). It demands the implementation of a set of good practices developed as a PSMS focused operational risk control. It relies on the adoption of seventeen management practices, showed in Table 1, that are interrelated and are incorporated into all phases of a project from its conception until its decommissioning [20].

Table 1. Management Practices (MP) required by SGSO [19].

MP	Description
MP 1	Safety Culture, Commitment and Responsibility Management
MP 2	Personnel Involvement
MP 3	Personal Qualification, Training and Performance
MP 4	Working Environment and Human Factors
MP 5	Selection, Management and Control of Contractors
MP 6	Monitoring and Continuous Improvement Performance
MP 7	Audits
MP 8	Management of Information and Documentation
MP 9	Incident Investigation
MP 10	Project, Construction, Installation and Deactivation
MP 11	Operational Safety Critical Elements
MP 12	Risk Identification and Analysis
MP 13	Asset Integrity
MP 14	Planning and Management Major Emergencies
MP 15	Operational Procedures
MP 16	Management of Change
MP 17	Work Safety Practices and Control Procedures for Special Activities

#### 3.1.1. Identified leading indicators

Checking guidelines and reports of safety indicators key programs already disclosed by regulatory authorities [21], it was observed that information taken from leading indicators contribute to act in a preventive way, to identify and correct non acceptable behaviors aiming to follow risk acceptance criteria in a regulatory point of

view prior to the occurrence of major accidents [6]. As SGSO is a regulatory instrument of risk control and has a primarily preventive focus, leading indicators was settled based on information acquisition through specific parameters and sub groups as shown in Table 2.

Table 2. Subgroups and parameters to be monitored under leading focus.

INDICATORS RELATED TO LEADING FOCUS	
Subgroup	Parameters
LEADERSHIP, MANAGEMENT AND PERSONNEL	Involvement of Personnel Qualifications, training and personal performance Monitoring and Continuous Performance improvement Audits Accident investigation
SYSTEMS AND TECHNOLOGY	Identification and Risk Analysis Mechanical Integrity and Safety Critical Systems Planning and Management of Major Emergencies
OPERATIONAL PRACTICES	Change Management Safe work practices

Beaconed in leading focus established subgroups and considering identified parameters based on SGSO, indicators were identified for each subgroup.

### 3.1.2. Identified lagging indicators

Accidental events classified as catastrophic, involving the death of many people, severe environmental and other damage to businesses rarely occur, not allowing to perform a statistical analysis. However, prior to these disasters, less damage incidents (precursor events) occur and are good indicators for monitor and prevent major accidents. Thus, in this text, lagging indicators were grouped according to their kind and characteristics in order to support its proposition, from less to more severe events [22] [23]. The groups defined are shown in Table 3 and are divided into Operational Deviations; Loss of Primary Containment; Fires and Collisions.

Table 3. Parameters identified for indicators related to the acquisition of lagging focus.

SUBGROUP RELATED TO LAGGING FOCUS	
Subgroup	Parameters
Operational deviations	Emergency Shutdowns
Loss of Primary Contention	Oil spills without fire Oil spills with fire Major spills Significant spills

	Major Natural Gas Leaks Significant Natural Gas Leaks H <sub>2</sub> S release
Fires	Major fire Significant fire
Collisions	Major collision Significant collision

### 3.2. The global indicator indicators related to leading and lagging focus

The first step to create global indicators was the validation of chosen indicators by experts in the field of risk management in offshore activities. Each subgroup was evaluated by 9 skilled professionals, with plenty of knowledge in SGSO and risk management of offshore activities which evaluated the significance of the proposed indicators. This validation was made together to the prioritization evaluation, using criteria showed in tables 4 and 5 [24][25].

Table 4. Grades used in validation of the indicators.

Criteria	Note	Justifications
Not relevant	1,0 - 2,5	The proposed indicator has no relevance in the composition of a global indicator.
Low relevance	2,6 - 6	The proposed indicator has low relevance in the composition of a global indicator even though related to risk area
Average relevance	5,1 - 7,5	The proposed indicator is important in composing a global indicator related risk area
High relevance	7,6 - 10	The proposed indicator is very relevant in the composition of a global indicator related to risk area

Table 5. Weights used for prioritization of indicators.

Criteria	Wheight	Justifications
Hardly relevant	1,0	The indicator derives from subjective assessments or have an history of low frequency of occurrence
Relevant	3,0	The indicator stems from objective assessments with lower severity
Very relevant	5,0	The indicator runs from objective assessments with high severity

For this purpose, it was established a prioritization matrix composed of columns and rows which was prepared for each subgroup related to both preventive and reactive focus. In columns were listed for each subgroup indicators, and for each one were assigned

grades and weights. This methodology adaptation was already tested in the environmental area for the global suitability indicators and proved to be satisfactory [25].

This method allows separate evaluations on criteria that point the relevance of each indicator through grades and use this value associated to given weights (weighted by multiplying), we have direct relationship with its importance in a general scenario, i.e., the higher these factors, the greater relative importance of such a specific indicator [26].

### 3.2.1. Normalization

The normalization of the indicators used in each subgroup was conducted according to procedures established by the United Nations (UN) in the composition of the Human Development Index (HDI) for the data comparison between different countries. It consists in adjust data within interval [0,1] and make it comparable to each other so that they can compose a global indicator, as showed in equation 1 [27] [28] [29].

$$\overline{X}_w^{i,j} = \frac{X_w^{i,j} - \min(X_w^{i,j})}{\max(X_w^{i,j}) - \min(X_w^{i,j})} \quad (1)$$

The meaning of variables is:

$i$  : platform

$j$  : company

$w$  : index of specific indicator:

$X_w^{i,j}$  specific indicator  $w$

$\overline{X}_w^{i,j}$  : normalized indicator derived from specific indicator  $X_w$

$\min(X_w^{i,j})$  : minimum value of the specific indicator  $w$  across all platforms

$\max(X_w^{i,j})$  : maximum value of the specific indicator  $w$  across all platforms

### 3.2.2 The global indicators

The leading and lagging variables were incorporated, respectively, as Global Leading indicator (IGPRV) and Global Lagging Indicator (IGRTV) through a sum according to Equation 2.

$$IG_{i,j} = \sum_{n=1}^n V^{X_w} * \overline{X}_w^{i,j} \quad (2)$$

The meaning of variables is:

$IG$  : Global Indicator for the company's  $J$  and platform  $I$

$V^{X_w}$  :Coefficient contribution percentage assigned to specific indicator within the prioritization performed for the respective segment;

$\overline{X}_w^{i,j}$  : Normalized indicator derived from specific indicator  $X_w$ ;

$n$  : number of specific indicators of the respective segment.

## 4. Results and Discussion

The table 6 and 7 shows a summary of prioritization results obtained in leading and lagging indicators, showing the relative importance of specific indicators using the methodology already presented.

The tables 6 and 7 show the relative importance of information raised by a specific indicator compared to others. Each one has a weight that put it in a position that will impact on the final result of the respective global indicator and its position was obtained based on opinion of specialists that are the most used method for this kind of hierarchy process [29].

To analyze the results, real data from 2011 was used in 67 offshore production platforms and after normalization of specific indicators using equation 1, equation 2 was applied. The previous obtained values ( $\overline{X}_w^{i,j}$ ) have been multiplied by respective weighting values ( $V^{X_w}$ ) to achieve both global indicators that add the contribution of each specific indicator to achieve one final number. The final results were divided into quartiles as shows figure 2.

For IGPRV case, the greater value of the indicator, better is the platform safety practices compared to others. In a opposite way, as higher is the IGRTV, worse is the results of the risk management for the specific platform.

As presented, the IGPRV and IGRTV are showed respectively at upper and lower part of figure 2 and allow the behavior identification of implementation effort to follow SGSO requirements (IGPRV) and also give us information about the precursor events of major accidents (IGRTV), based on the lowest and highest values of specific good safety practices indicators.

As IGRTV exhibits low values for a considerable number of platforms, it can deliver a false output that might indicates that no further actions are needed. However, if this kind of data is used alone in a safety analysis, it may lead actions that are not enough to avoid major accidents. This results may indicate that the cut lines established in the lagging approach may need a

further stratification to incorporate a greater number of related events or a more extended period of time [31]. In the other hand, it is not possible aim a good safety performance analysis looking just at leading indicators and forget the results showed by lagging indicators [6].

However, important management information can be raised from global indicators like showed in Fig. 2. For instance, if a non desirable performance is identified, the weakness in risk management can be analyzed as showed in Fig. 3.

Table 6. Prioritization Results of indicators in the leading focus.

Indicator	Results	Normalized value ( $V^{X_w}$ ) (%)
Compliance with recommendations of risk assessments	367,0	6,35
Risk assessment in change management	324,0	5,61
ESDVs Tests	323,2	5,60
PSVs Tests	323,2	5,60
BDVs Tests	322,0	5,58
Fire detections System test	317,3	5,49
Gas detections System Test	317,0	5,49
Risk Assessment in the Work Permits	284,5	4,93
Personal Qualification	283,1	4,90
Start up testing of fire pumps	280,6	4,86
Deluge System Test	273,3	4,73
Implementation of audit corrective actions	263,1	4,56
Implementation of incident investigations corrective actions	258,5	4,48
Awareness and Participation	248,8	4,31
Risk analysis recommendations acceptance	367,0	3,90
Temporary Management of changes	219,0	3,79
Accidental Scenarios drills	215,0	3,72

Level of investigation	214,0	3,71
Goal attainment	212,7	3,68
Deadline Attendance for corrective actions of audits	180,6	3,13
Evaluation level	172,5	2,99
Work permits	150,0	2,60
Total / normalized	5775,4	100

Table 7. Prioritization Results of indicators in the lagging focus.

Indicator	Results	Normalized Value ( $V^{X_w}$ ) (%)
H <sub>2</sub> S release	420,5	10,32
Major Natural Gas Leaks	419,0	10,29
Major fire	419,0	10,29
Oil spills with fire	406,0	9,97
Major spills	405,0	9,94
Significant fire	360,0	8,84

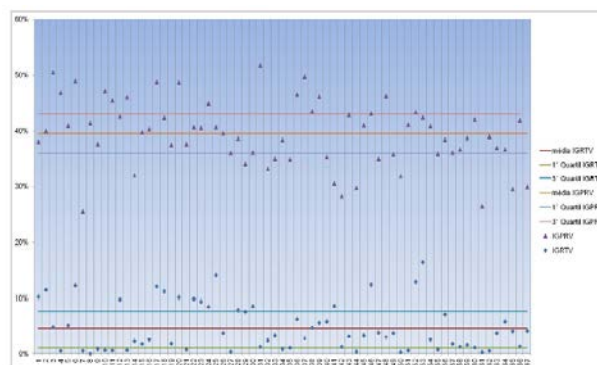


Fig. 2. Leading Global Indicator (IGPRV) and Lagging Global Indicator (IGRTV) to 67 production platforms.

Major collision	339,1	8,32
Significant Natural Gas Releases	282,5	6,94
Significant spills	278,0	6,82
Oil spills without fire	264,8	6,50
Significant collision	245,5	6,03
Plant shutdowns in emergency	234,0	5,74
Total / normalized	4073,4	100

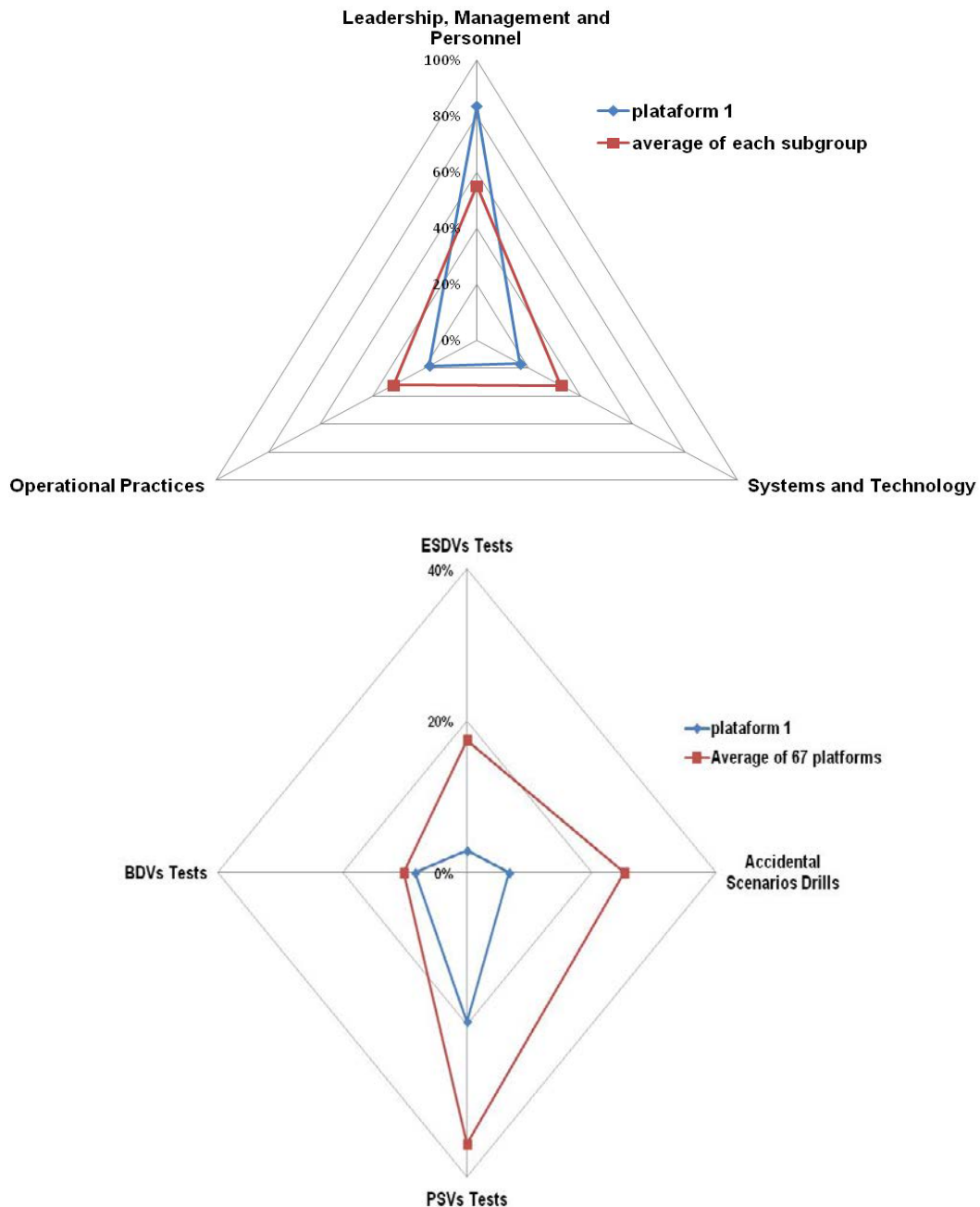


Fig. 3. Analyses of one specific result for IGPRV for a chosen platform.

Fig. 3 shows that once a bad result is identified for a specific platform, the global information can be analysed in a more deep perspective, looking for the causes of this output. On the left it shows the subgroups of IGPRV results compared to a general average. After finding the lower performance subgroup, the specific indicators can be analysed as shown on the right side of figure 3 and specific actions can be addressed to improve these

results. Furthermore, this kind of analysis can be expanded to an oil company by adding the different results of their own platforms for a more applied scope.

## 5. Conclusions

This study aimed to generally discuss the topic of process safety in offshore oil and gas production platforms in order to propose a model of global

indicators to turn easier to regulators to identify weaknesses in a process safety management based regulation. It can be useful to point possible improvement opportunities, optimize regulators resources finding inspection opportunities and enforce an operational safety continuous improvement environment.

Thus, from a leading point of view, it was found that knowing the real position of companies in meeting the need of implementing a regulatory PSMS, identifying key practices for the adoption of such a system and, therefore, measuring the implementation ongoing efforts has direct impact in avoiding major accidents. In other hand, measuring the occurrence of minor damage precursors events (near misses) and accidents has to be the focus to a lagging monitoring.

The adequacy of the proposed indicators as instruments of information and evaluation came from numerous studies that incorporated different perceptions and different methods of analysis and safety monitoring, enabling the proposal of a mechanism for the safety assessment process [30].

In this context and within analyzed data, it was found that the proposed global indicators allow weaknesses identification at individual platforms level, which can be expanded to oil companies and platform operators, allowing regulatory and other management levels to act aiming to avoid undesirable behaviors and, in the end, avoid main situations that can lead a major accident.

In this aspect, the indicators used and normalization procedure allow different levels of comparisons analysis and lead to compare platforms inside an oil company, platforms from different companies and even companies. It turns easier the establishment of performance goals and proactive regulatory oversight of the industry.

It was found in the data analysis, confirming texts that performance monitoring programs based on purely leading or lagging data can lead weak or insufficient outputs, which do not allow a proper conclusion of the current status of safety of ongoing processes [6] [31]. On this way and to improve results analysis was found a need to improve lagging data analysis, maybe changing the data horizon, expanding the analysis period. Other study opportunity is try to find the best fit to correlate both leading and lagging global indicators.

As result of this research, considering the methodology procedure, it has allowed to measure the performance of global indicators in a given period of time, observing their variations in a large number of production platforms operating in Brazil. In this same perspective, it could be seen that the use of global indicators proposed can address the proposal needs. However, a demand of this kind of method is the adoption of continuous improvement safety culture for companies which data are required and for regulator's analysis mechanisms, in order to maintain the characteristics, sensitivity, robustness and simplicity in the conditions of measurement and analysis to reach desirable results [6] [29].

In this sense, it is expected that the evaluation of data from IGPRV and IGRTV may be added with additional information from other processes such as information audits conducted by the regulator and causes of incidents correlated to PSMS, among others, could significantly improve the regulatory management process. It can lead a designing of companies risk management profiles, or other results outside the scope of this text, but preliminarily discussed in the data analysis.

The presented indicators are designed to simplify analysis by quantifying subjective and complex concepts for establishing goals and to allow assess performance in regulated industry. As showed, it can be used to articulate concepts of process safety and regulatory action to allow identification and dissemination of best practices in risk management [5] [9] [10] [32]. This perception aims to improve resources destination in regulatory bodies improving actions to achieve the main focus of avoid major accidents.

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