NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF NAVAL ARCHITECTURE

AND MARINE ENGINEERING

POLYMENOPOYLOY AIKATERINI MARIA

DIPLOMA THESIS

‘‘Estimation of Tanker Vessel’s Performance through Key Performance Indicators using Fuzzy Logic Models’’

SUPERVISOR PROFESSOR NIKOLAOS VENTIKOS

Athens, 2016

ΕΥΧΑΡΙΣΤΙΕΣ

Ξεκινώντας τη διπλωματική μου εργασία θα ήθελα κατ'αρχάς να ευχαριστήσω τον καθηγητή μου και επιβλέπων της διπλωματικής μου εργασίας κ. Νικόλαο Βεντίκο τόσο για την ανάθεση του θέματος όσο και για την επίβλεψη του και τη συνεργασία μας.

Επίσης θα ήθελα να ευχαροστήσω την υποψήφια διδάκτωρα κα. Ειρήνη Σταμαοπούλου για τη βοήθεια που μου πρόσφερε και τη συνεχή της προσπάθεια να βοηθήσει στη διεκπεραίωση του θέματος. Καθώς και όλους τους καθηγητές μου που με βοήθησαν τα προηγούμενα χρόνια της φοίτησης μου στο Πολυτεχνείο να μάθω και να αγαπήσω το αντικείμενο των σπουδών μου.

Τέλος, θα ήθελα να ευχαριστήσω τον πιο σημαντικό παράγοντα που συνέβαλε στην ολοκλήρωση τσν σπουδών μου, την οικογένεια μου. Θα ήθελα λοιπόν να ευχαριστήσω την μητέρα μου Γεωργία, τον πατέρα μου Τάσο την αδελφή μου Ελένη και τους φίλους και συμφοιτητές μου που με στήριξαν όλα τα χρόνια των σπουδών μου και συνεχίζουν να με στηρίζουν καθημερινά.

Πολυμενοπούλου Αικατερίνη Μαρία

Αθήνα, 2016

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ΠΕΡΙΛΗΨΗ

Στόχος της παρούσας διπλωματικής εργασίας είναι η δημιουργία τεσσάρων μοντέλων αξιολόγησης της απόδοσης πλοίων μεταφοράς πετραλαίου-δεξαμενοπλοίων. Τα τέσσερα μοντέλα αναφέρονται στη απόδοση των δεξεμενοπλοίων ως προς τις ακόλουθες τέσσερις κατηγορίες:

1. Ασφάλεια (safety)
2. Ασφάλεια (security)
3. Υγιεινή και ασφάλεια (health & safety)
4. Περιβάλλον (environment)

Τα μοντέλα δέχονται σαν πληροφορίες εισόδου τις τιμές των δεικτών απόδοσης (key performance indicators) και δίνουν σαν αποτέλεσμα την τιμή απόδοσής του βασιζόμενα στο μαθηματικό μοντέλο της ασαφούς λογικής. Πέρα από την εκτίμηση της απόδοσης ενός δεξαμενοπλοίου με χρήση των τεσσάρψν αυτών μοντέλων, μέσα από την παρουσα διπλωματική εργασία, η τιμή της απόδοσης μπορεί επίσης να αξιολογηθεί. Η αξιόγηση επιτυγχάνεται με βάση την μέση τιμή της απόδοσης για κάθε μία από τις παρα[άνω 4 κατηγορίες στην οποία καταλλήγουμε με χρήση του μοντέλου μας σε ένα στόλο 30 δεξαμενοπλοίων.

Ξενικώντας την παρούσα διπλωματική στα πρώτα κεφάλαια γίνεται μία πρώτη αναφορά στην έννοια της απόδοσης, πόσο αυτή επηρεάζει τις επειχηρήσεις, τα είδη της απόδοσης αλλά και του δείκτες που χρησιμοποιούνται για την μέτρηση της. Ένα θεμελιώδες μέρος της διπλωματικής εργασίας είναι η επιλογή των κατάλληλων δεικτών απόδοσης που θα χρησιμοποιηθούν στο μοντέλο που θα κατασκευαστεί. Λόγω της σοβαρότητας αυτού ένα μεγάλο κεφάλαιο της διπλωματικής είναι αφιερωμένο την εύρεση, μελέτη, σύκγριση και αξιολόγησης των δεικτών απόδοσης για τις κατηγορίες που μας ενδιαφέρουν σε ένα εύρος βιομηχανιών. Οι βιομηχανίες που μελετήθηκαν είναι οκτώ (8) και αφαρούν τους ακόλουθους τομείς:

1. Δρόμους (Road)
2. Τρένα (Rail)
3. Αεροπλάνα (Aviation)
4. Πυρηνική Ενέργεια (Nuclear Power Plant)
5. Χημικά (Chemical)
6. Εξόρυξης Πετρελαίου (Offshore)
7. Λιμάνια (Ports)
8. Πλοία (Shipping).

Σύμφωνα με την αξιολόγηση των δεικτών απόδοσης σε κάθε βιομηχανία μπορέσαμε σε επόμενο κεφάλαιο να βρούμε την τάση κάθε μίας με βάση ποια κατηγορία δεικτών αντιμετωπίζει πιο σημαντική και ποια λιγότερο. Αποτέλεσμα αυτού είναι να καταλλήξουμε σε βιομηχανίες με κοινή τάση και δείκτες. Στη διπλωματική που αναλύεται στις επόμενες σελίδες εστιάζουμε στη βιομηχανία της ναυτιλίας. Επομένως, για την επιλογή των κατάλληλων δεικτών απόδοσης θα βασιστούμε στην πληροφορία που παίρονουμε για τους πιο κοινά χρησιμοποιούμενους από όλες τις υπό μελέτη βιομηχανίες, από εκείνους που προτείνει ένας διεθνής ναυτιλιακός οργανισμός, που ονομάζεται BIMCO, και τέλος από εκείνους που χρησιμοποιεί μία ήδη υπάρχουσα ναυτιλιακή εταιρία με δεξαμενόπλοια. Συγκρίντας τους παραπάνω φορείς καταλλήγουμε στο set των δεικτών απόδοσης που θα

χρησιμοποιηθεί σαν είσοδος στα μοντέλα που θα δημιουργήσουμε στα επόμενα κεφάλαια. Τα ονόματα των δεικτών, η μαθηματική έκφραση υπολογισμού του, οι μονάδες μέτρησής τους αλλά και η περίοδος υπολογιμού τους είναι συγκεντρωμένα στις επόμενες σελίδες του κεφαλαίου 3.

Το θεωρητικό- μαθηματικό υπόβαθρο πάνω στο οποίο βασίστηκε η υλοποίηση των συγκεκριμένων μοντέλων ονομάζεται ασαφής λογική ή αλλιώς fuzzy logic. Μία από τις χαρακτηριστικές ιδιότητες της ασαφούς λογικής είναι η ικανότητά της να δέχεται σαν δεδομένα λογικές τιμές και όχι αριθμητικές. Για παράδειγμα στην ασαφή λογική η αριθμητική τιμή μία μεταβλητής εισόδου μετατρέπεται σε λογική, όπως είναι για παράδειγμα οι τιμές ΚΑΛΟ, ΚΑΚΟ, ΜΕΤΡΙΟ. Μία άλλη σημαντική ιδιότητα της είναι η ικανότητα που έχει να συνδυάζει δεδομένα εισόδου (περισσότερα από 1) και να δίνει μία ή περισσότερες εξόδους.

Λόγω των παραπάνω χαρακτηριστικών της γνωρισμάτων η ασαφής λογική, επιλέχθηκε από εμάς και χρησιμοποιήθηκε στην παρουσα διπλωματική εργασία για την υπολοποίηση του στόχου της. Λόγω της σημασία της και των πλεονεκτημάτων που προσφέρει στο χρήστη, έχουν αναπτυχθεί για το συκεκριμένο μαθηματικό μοντέλο κατάλληλα προγραμμτατικά περιβάλλοντα για την εφαρμογή της. Ένα από αυτά, το οποίο μάλιστα χρησιμοποιείται στην παρούσα διπλωματική εργασία και αναλύεται στις επόμενες ενότητες είναι εκείνο της Matlab, με την ονομασία Fuzzy Matlab Toolbox. Μέσω του μοντέλου αυτού ο χρήστης μπορεί να κατασκευάσει το δικό του fuzzy μοντέλο, βαζόντας τα δικά του δεδομένα εισόδου και εξόδου,τις συναρτήσεις και τα όρια κάθε εισόδου και εξόδου χωριστά και να ορίσει τους δικούς του κανόνες σύφωνα με τους οπόιους οι είσοδοι συνδυάζονται για να παραχθούν σε κάθε περίπτωση οι αντίστοιχοι έξοδοι.

Τα μοντέλα που αναπτύχθηκαν στην παρούσα διπλωματική έχουν σαν δεδομένα εισόδου τις τιμές των αντίστοιχων δεικτών απόδοσης (key performance indicators) για κάθε μία από τις κατηγορίες απόδοσης που έχουμε μελετήσει και σαν έξοδο την τιμή της απόδοσης του. Οι χαρακτηριστικές συναρτήσεις των δεδομένων εισόδου σε κάθε μοντέλο και σε σχεδόν σε κάθε είσοδο είναι διαφεορετικά μεταξύ τους και έχουν επιλεχθεί μετά από μεγάλη μελέτη και με τέτοιο τρόπο ώστε να έχουν φυσικό νόημα και να ανταπορκίνονται στην παραγματικότητα όσων σχετίζονται με τα πλοία μεταφοράς πετρελαίου. Για την έξοδο ωστόσο των μοντέλων θα παρατηρήσουμε ότι έχει και στα τέσσερα μοντέλα την ίδιες χαρακτηριστικές συναρτήσεις. Το γεγονός αυτό δεν είναι καθόλου τυχαίο, αφού θέλουμε τα αποτελέσματα των αποδόσεων αν και δεν μορούν να συνδυαστούν, να είναι συγκρίσιμα και επίσης πρόκειται για μία τιμή που αντιπροσωπεί ένα δείκτη χωρίς μονάδες, άρα χωρίς συφική σημασία, σε αντίθεση με τις τιμές των δεδομένων εισόδου. Τέλος, οι κανόνες που θέσαμε σε κάθε μοντέλο διαφέρουν τόσο σε αριθμό όσο και σε σημασία. Η αιτία ξανά είναι προφανής αν σκεφτεί κανείς ότι κάθε δείκτης αντιπροσωπεί κάτι διαφορετικό, με διαφορετική σημασία τόσο για το ίδιο το δεξαμενόπλοιο όσο και για την κοινωνία. Δεν θα μπορούσε για παράδειγμα ο αριθμός των θανάτων(δεδομένο 1) και ο αριθμός των παρολίων ατυχημάτων (δεδομένο 2) να έχουν την ίδια βαρύτητα στην εκτίμηση της απόδοσης ως προς την Υγεινή και ασφάλεια ενός πλοίου. Συμπερασματικά λοιπόν ανάλογα με τη φύση κάθε δεδομένου και την εκτίμηση της βαρύτητας του έχουν τεθέι οι κανόνες συσχετισής του. Τέλος, ο αριθμός τους είναι ίσος με εκείνον που απαιτείται για να ικανοποιηθούν όλοι οι πθιανοί συνδυασμοί ανάλογα με τον αριθμό των συναρτήσεων μεταφοράς των δεδομέων εισόδου.

Έχοντας ολοκληρώσει την ‘’κατασκευή ‘’ των τεσσέρων μοντέλων εκτίμησης της απόδοσης, θα εφαρμόσουμε στα παραπάνω μοντέλα 30 διαφορετικά δεξαμενοπλοία με στόχο την απόκτηση των 30 αντίστοιχων αποτελεσμάτων απόσοδης σε κάθε μοντέλο. Σε κάθε ένα από τα δεξαμενόπλοια που εφαρμόστηκε το μοντέλο είχε πριν συπληρωσει το σχετικό ερβτηματολόγιο έτσι ώστε να υπολογιστούν τα απαραίτητα δεοδομένα εισόδου- δείκτες απόδοσης. Τα δεδομένα εισόδου υπάρχουν συγκεντρωμένα στο τελευταίο κεφάλαιο της διπλωματικής εργασίας μαζί με το απότέλεσμα απόδοσης κάθε μοντέλου. Στη συνέχεια από τα 30 αυτά πλοία οι αποδόσεις τους καταγράφονται ανα κατηγορία και με χρήση του μέσου όρου καταλλήγουμε στην τιμή της μέσης απόδοσης για ένα δεξαμενόπλοιο ως προς τις κατηγορίες που μελετώνται. Με την ενέργεια αυτή καταφέρνουμε να αξιολογούμε την απόδοση των υπολοίπων δεξαμενοπλοίων αφού εκτιμηθεί με τα παρόντα μοντέλα, συγκρίνοντας τα με την μέση απόδοση που προκύπτει από το στόλο των 30 πλοίων που χρησιμοποιήσαμε.

Συμπερασματικά, τα τέσσερα δημιουργηθέισα μοντέλα, είναι τελέιως ανεξάτρητα με διαφορετικά δεδομένα εισόδου και διαφορετική έξοδο. Χρησιμοποιέται σαν κοινή βάση η ασαφής λογική και η επιλογη των δεδομέων εισόδων από την ανάλυση που γίνεται στα πρώτα κεφάλαια για τους δείκτες απόδοσης αλλά διαφοροποιούνται με βάση τη φυσική σημασία κάθε δείκτη-δεδομένο εισόδου για τη δημιουργία μοντέλων με φυσική σημασία.

ABSTRACT

Performance is nowadays a meaning that everyone wants to estimate in his everyday life and especially in his carrier. Both for humans but mainly for companies and industries the sense of performance is crucial them for them and many efforts have been made in order to evaluate and improve it.

The progress of performance evaluation can be succeeded through the use of well known Key Performance Indicators (KPIs). KPIs can be used for evaluating all types of performance according to each organization's scope and nature. In the specific diploma thesis we will focus exclusively to safety, health and safety, security and environmental KPIs. With aim to investigate throughout the above fields of KPIs in the subject diploma thesis we will present eight different industries concerning the above fields, safety, health and safety, security and environment. The main reason of this is to find out which KPIs are in used by every industry, which are the common ones and how the examined industries differs or resembles with each other. The examined industries are road, rail, aviation, chemical, nuclear power plan, offshore, ports and shipping.

After having completed the KPIs investigation in all the mentioned industries, the subject diploma thesis focuses in the shipping industry and more specific to tanker vessels in order to create a model which will combine at each field a set of KPIs and to produce a total estimation of the performance of one tanker vessel. This progress will be completed through Fuzzy Logic and more specific through Matlab Fuzzy Logic Toolbox. Through this, we will produce four different Fuzzy Models, which will evaluate safety, health and safety, security and environmental performance respectively. The produced models can be used from a shipping company for every tanker vessel separately. The first step in order to create the mentioned models is the selection of the right KPIs. Having them selected you will find next the use of Fuzzy Models in 30 different tanker vessels in order to conclude to an average performance. By this way each tanker's performance can not only to be evaluated by our created models but also to be compared with the average performance.

CHAPTER 1: "INTRODUCTION"

1.1 PERFORMANCE

Nowadays everyone, in order to measure his/her success and progress is trying to find out how his performance is. It is essential now to give the definition of this word, ‘‘Performance’’, that everyone cares so much about it.

Performance can be assumed as the accomplishment of a given task, the fulfillment of an obligation, measured against present known standards of accuracy, completeness, cost, and speed. [1]

It is obvious that in everyday life, all humans are trying to improve their performance concerns all of their tasks, both their business performance and their performance as parents as husbands or wives.

1.2 BUSSINESS PERFORMANCE

The same as above holds for business performance. Every industry, every field, every company has the need to examine its progress and that can be accomplished only by measuring its performance. This has got three steps in order to be completed:

Initially, company has to specify the desired goals that want to achieve in a specific period (annually, quarterly etc). Both goals and period can be unique for every company, even though between companies which are part of the same industry. The reason for that is that performance is a complex concern, that is affected from many factors such as the type of industry, the size of the company, the capabilities of the employees in that company etc. For example, it is impossible for two companies, both in shipping industry, the one that is new in the field and has got 10 or less employees to have the same goals in the same period with one other company that has been established to the field and has 100 employees. In the first case, the goals that the company will select would be more simple and easy to achieve, needed more time, comparing to those that the second company select. The goals setting by a company have to be specific, measurable, attainable, relevant, time related. [2] If they do not so, it makes it straggling for the company to believe and follow them as there is nothing demoralizing that a moving target.

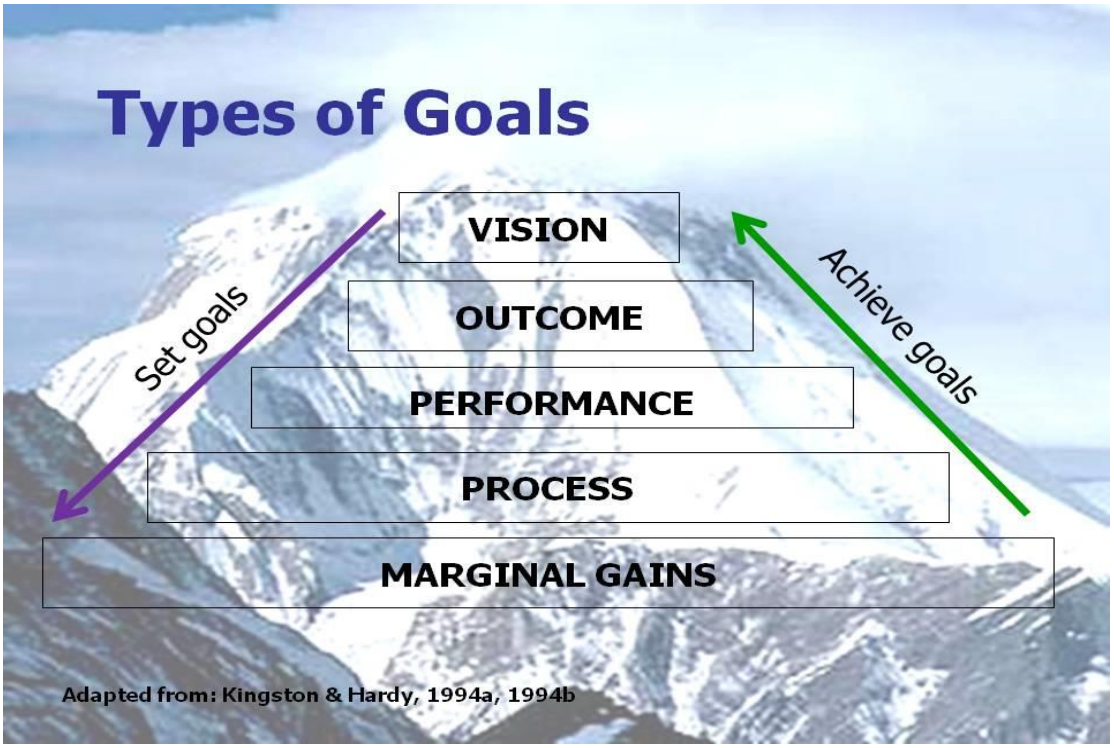
Picture 1. Definition of SMART goals, Source: Goal Setting, (2015)

After deciding goals and period, the next step for a company, is to measure its progress is the consolidation of measurement information relevant to the company's progress against its previous goals. For this task companies usually monitor indicators linked to strategy, called Key Performance Indicators and it is necessary for the company before selecting the appropriate KPIs to have well understand its goals. These indicators, we are going to analyze them in the next paragraphs as they are essential for the company and also they constitute the main subject of our research.

Last but not least, is to evaluate the results given by the Key Performance Indicators. When a result is not satisfactory enough for the company, managers intervene, make the necessary changes with a view to improve future performance against these goals.

Collecting of all the previous information about business performance we can now give to this quantity the following definition:

Business Performance management consist a set of management and analytic process, supported by technology, used to access how well an organization/ business is achieving its desired objectives. Business performance management process include financial, operational planning, business modeling, consolidation and reporting of the results, analyzing them and monitor Key Performance Indicators, in order to get a more objective sense of how business is operating and whether improvement is required. [1],[3].



Picture 2. Business Performance Management Source:Sarah Ferwick, (2012)

1.3 KEY PERFORMANCE INDICATORS (KPIs)

Apart from the attention every company has to pay at its goals it is also necessary to pay the same or even more at defining which indicators is going to use to help it estimate its progress. This procedure is difficult and takes a lot of time as these indicators are essential for giving the right results to the company and helps it understand if it complies with its primary desired goals. In order to continue with explaining them, we have first of all, to give a definition for these indicators.

1.3.1 DEFINITION OF KEY PERFORMANCE INDICATORS (KPIs)

Many efforts have been made from various and different researchers to provide bibliography with the most successful and comprehensive definition of Key Performance Indicators all these years. According to Peternsen (2012), he has gathered twelve (12) expert's definitions that are the most reliable and follow below:

1. "A metric that helps you understand how you are doing against your objectives." – *Avinash Kaishik*
2. "Measures that help decision makers define and measure progress toward business goals. KPI metrics translate complex measures into a simple indicator that allows decision makers to assess the current situation and act quickly." –*KAIZEN Analytics*
3. "A KPI: 1) Echoes organization goals, 2) is decided by management, 3) provides context, 4) creates meaning on all levels of the all organizational levels, 5) is based on legitimate data, 6) is easy to understand and 7) leads to action!" –*Dennis Mortensen*
4. "The most important performance information that enables organizations or their stakeholders to understand whether the organization is on track or not." –*Bernard Marr*
5. "The selected measures that provide visibility into the performance of a business and enable decision makers to take action in achieving the desired outcomes." –*Aurel Brudan*
6. "The data necessary to understand the implications of whatever he/she sees and the wherewithal to take appropriate action." – Shalin Shah
7. "Measurable industry, department or task relevant performance metrics that are evaluated over a specified time period, and compared against acceptable norms, past performance or targets." – *Allan Willie*
8. "Measurements of activity that is a vital gear in your business machine." – *John Standaloft*

9. "Help organizations achieve organizational goals through the definition and measurement of progress. The key indicators are agreed upon by an organization and are indicators which can be measured that will reflect success factors." –*Bruce Clay*
10. "A set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals." –*James Oh*
11. "High-level snapshots of a business or organization based on specific predefined measures." - *Avinash*
12. "Should not constitute every company metric for analysis and evaluation. Rather, KPI's should reflect the most important objectives of the business." – *Avinash* [4]

Each one of the above definitions, give something new and helpful in understanding what a Key Performance Indicator is. Trying to give ours definition, we have taken all the above into consideration and we concluded to the following expression:

Key Performance Indicator is a specific metric or quantifiable measurement, used to express the performance against objectives and pre-defined goals, within a specific area. They are also known as performance drivers, metrics, business indicators, performance ratios or critical success factors. [5], [6], [7], [8]

Source : Bonnie Moedano, (2014)

1.3.2 SCOPE OF KEY PERFORMANCE INDICATORS (KPIs)

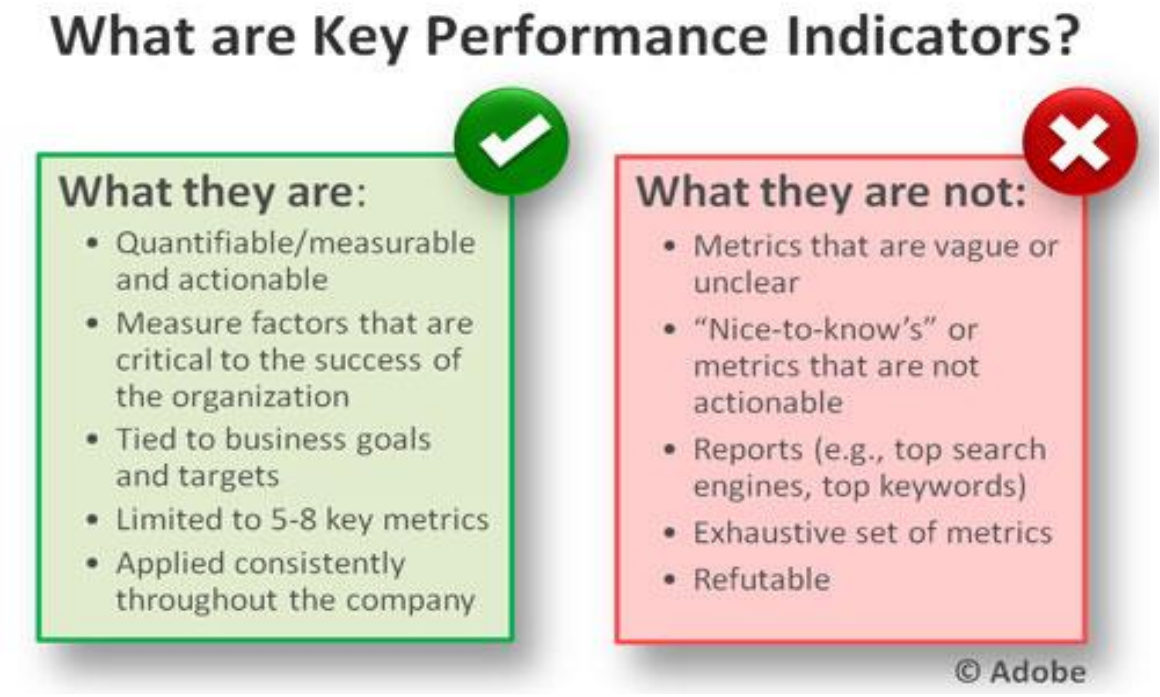
The scope of a Key Performance Indicator as it can be understood from the previous definitions is to provide a quantifiable and measurement indicator of the organization progress towards achieving its goals. Through a Performance Indicator a company can measure its performance in order to achieve continuous improvement, internal and external benchmarking and finally to set incentives.

1.3.3 CARACTERISTICS OF KEY PERFORMANCE INDICATORS (KPIs)

As their definition proves, Key Performance Indicators could be number or ratios and so we have both number and ratio metrics. They are actionable, influenced and accountable by the manager or the stakeholder and they can be used both for internal and external benchmarking. There are two categories of KPIs, the internal and the external ones. The internal are internally used by team members to measure and optimize their company's performance and they are not always reported to clients, boss or senior managers. On the other hand external KPIs are those which are in general reported to clients, boss or senior managers. One other characteristic of them is that they are output oriented and not focus on specific input or activity. They have to be possible calculated with limited effords in limited time and have important results for the company.

Also, attention has to be paid on the number of indicators a company decides to use. There shouldn't be a huge number of them but to separate the important ones from the trivial and to measure only them. [5], [7], [9]

Finally, as the goals setting from the company have to be specific, measurable, attainable, relevant, time related, the same characteristics are important and essential for KPIs too. We have already analyzed the meaning of a specific KPI. Next characteristic is to be available and measurable. We can only use those which are possible to measure, so before using an indicator we have to be sure that there is a mechanism or tool that is available to measure and report this specific indicator. Furthermore, all the KPIs must have the ability to provide recommendations for action which can hugely impact the business and for that reason KPIs must to be relevant to our business objectives. Other else if KPI is irrelevant will not be able to impact business. Finally time is one other factor must take into consideration. KPIs should be available to us in a timely manner so we can take timely decisions [7].



Picture 3. Characteristics of Key Performance Indicators (KPIs) Source: John Hingley, (2014)

1.3.4 CATEGORIES OF KEY PERFORMANCE INDICATORS (KPIs)

It is obvious that every company, according to its operation, decides the number of the indicators is going to use, the number of fields that use indicators and which fields are them. However some fields in a company are usually to use a set of KPIs in order to estimate their progress. Examples of these are the following categories:

Health and Safety Performance

Environmental Performance

Human Resources Performance

Security Performance

Safety Performance

Operational Performance

Technical Performance

1.3.5 CATEGORIES OF BUSINESS PERFORMANCE

At this point we have to remind, that as have already mentioned in the abstract, in our research we have examine only Key Performance Indicators in the fields of

- ***Safety***
- ***Security***
- ***Health and Safety***
- ***Environment***

For that reason, in the next paragraph we not occupied with all the above categories of Key Performance Indicators but only with those which we examine. In the following paragraphs the policies mentioned, report to all industries. (Afterwards we are going to examine safety, environment, health and safety and security policies in different industries).

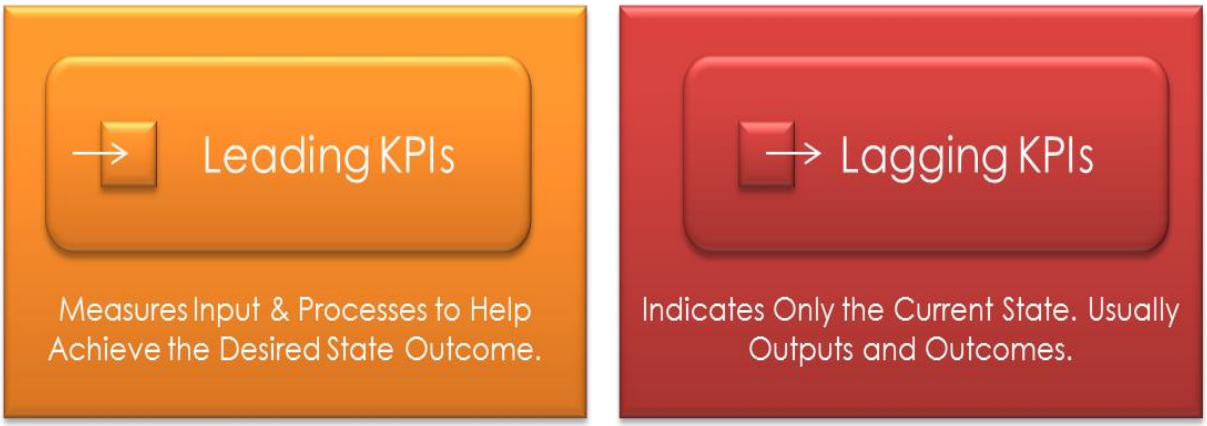
1.3.6 LEADING & LAGGING KEY PERFORMANCE INDICATORS

In an attempt to define what kind of Key Performance Indicators could be used for any business or company or industry we came into a realization, that KPIs can be divided into two categories, those which are estimated before any incident occur and those which are estimated after.

The first category is related to LEADING Key Performance Indicators. This category is typically input oriented, hard to measure and easy to influence. They change quickly and are generally seen as a precursor to the direction something is going. For example, changes in building permits may affect the housing market, an increase in new business orders could lead to increased production, interest rate changes will impact spending and investments, a diminishing of demands for natural resources will often indicate work slowdowns, and aging

baby boomers may indicate future stresses on the healthcare system. Because leading indicators come before a trend, they are considered business drivers. Identifying specific, focused leading indicators should be a part of each business's strategic planning [10].

The second category called LAGGING Key Performance Indicators. There are indicators that are typically "output" oriented, easy to measure but hard to improve or influence. Are used to measure performance and allow the business leadership team to track how things are going. Because output (performance) is always easier to measure by assessing whether your goals were achieved, lagging indicators are backward-focused or "trailing"—they measure performance data already captured. Just about anything you wish to monitor will have lagging indicators: returns on investments, a budget to plan variances, number of sick days, bags moved per day and equipment support incidents [11]



Picture 4. Leading vs Lagging of Key Performance Indicators (KPIs) Source: mONDAYBI, (2015)

CHAPTER 2 : " INDUSTRIES KPIs"

2.1 ROAD INDUSTRY

The first industry we are going to examine as concerns the Key Performance Indicators is using for its Environmental, Safety, Health and Safety and Security Performance is the Road Industry. By Road means a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, bicycle, or motor vehicle. It is a line of communication open to public which includes bridges, tunnels, supporting structures, junctions, crossings, interchanges, and toll roads, but not cycle paths.

For this industry we have collected data from 18 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.1.1 SAFETY Key Performance Indicators at ROAD Industry

Road traffic is a transport that consists of many vehicles, such as cars, motorbikes, tracks, motorbikes, bikes. As the number of vehicles rises the same raises the safety risk for all vehicles' users and every person using the road network such as pedestrians or animals. The major risk for the above categories of persons is to be killed or injured. In order to raise safety levels it is necessary to provide a road environment which ensures the appropriate meters are taken such as vehicle limits, signals, and use of seat belts or hamlets.

In order to inform road users about the laws they have to obey as concerns the use of road, ISO 39001 has been enacted. It is an ISO standard for a management system, similar to ISO 9000, for road safety, called ''Road Traffic Safety Management''. The role of this ISO is to provide a continuous improvement of the traffic safety, observing and evaluating events that are in connection with road, such as the accident numbers, the number of killed/ injured persons and by this process to reduce the number of persons killed or been severely injured.

ISO 39001 enters all public and private organizations interacting with the road system and torn in the following parts:

- Introduction
- Scope
- Normative References
- Terms and Conditions
- Context of the organization
- Leadership
- Planning
- Support
- Operation

- Performance Evaluation
- Improvement
- Annex: Guidance on the use of this International Standard [12].

In particular for the road condition, KPIs in use, are the number of road signs and traffic measures and its repair rate, emergency accident rescue movement, the number of damaged or collapsed roads with potholes and bridges, the number of consecutive accesses and finally the rate of inadequate headways [13],[14]. Other KPIs relative to vehicle's selection and maintenance are given by Mooren [15] such as the crashworthiness of vehicles, the percentage of old or mechanically deficiency vehicles still in use, defects of vehicles, and the vehicle's size [13], [14]. These all can be reduced by the right maintance, so it is also necessary to be used as a KPI the percentage of vehicles having the appropriate maintance and those which have the deferred maintance.

According to the work by Rosolino [14] on road safety it is clear that the factors that influence road comprise the condition of the road, the driver's attitude, the vehicle's condition, and the number of accidents themselves. To analyze each of the above factors we get more information from some other sources of the international literature.

Another very important parameter concerns driver's attitude (selectivity, management, discipline, tenure and training) [15], the one that we call traffic psychology. It is about a discipline of psychology that studies the relationship between psychological process and the behavior of road users. Driver's behavior consists of three motivations, the reasoned or planned behavior, impulsive or emotional behavior and finally the habitual behavior. In order to measure driver's attitude a set of Key Performance Indicators are commonly used. According to Poots [16], very important is the rate of driver's inexperience, so he suggests as KPIs the number of incidents involving drivers under the age of 25 or above the age of 70 and the number of incidents within 6, 12 and 24 months of passing test. These drivers can call them as High Risk Drivers and the total number of them is also a KPI. With Poots agrees also NETs [17] who also suggests as KPI the percentage of trained or certified or classified drivers.

Knowing the impact of driver's at road safety we have to add some more possibilities leading to a crash, or generally to an incident serious enough for the road safety. Driver's capabilities can be adversely affect from a range of parameters, such as drugs or alcohol. Here, KPIs are the number of incidents of exceeding speed limit, of no using seat belts or clash helmets, driving under the influence of alcohol or drugs, red light running and non stopping in yielding in junctions or at pedestrian crossings [13], [14], [18], [19]

Last but not least are the KPIs which associate with accidents[13], [18],[19],[20] and as Nikolson [21] refer are the number of fatal incidents, injuries (non-fatal, lost time, medical treated and restricted work), reported injuries, diseases, dangerous occurrences regulations (RIDDOR incidents) and the number of damage only without injury. The above are calculated per 1000 employees off road and per 1600000 km on road. The number of incidents (deaths, collisions and injuries) can be divided by many parameters such as 100,000 registered motor vehicles [16] or per kilometer travelled known as Collisions per million miles (CPMM) which shows the total number of collisions in a given period of time x 1,000,000)/ Total number of miles driven during that period and injuries per million miles (IPMM) which is the same indicator for injuries. [15], [17] or during the school year as Clarke refers to school buses [22]. For more detail analysis we use kpis measuring the number of death and injury for

pedestrians, pedal cyclists, motorcyclists, car users, collisions per 100 million kilometers. Also the number of death and injuries of pedestrians (both adults and children) in rural roads and in per capita in 10% of the most deprived areas compared to the 10% of the developed ones [13].

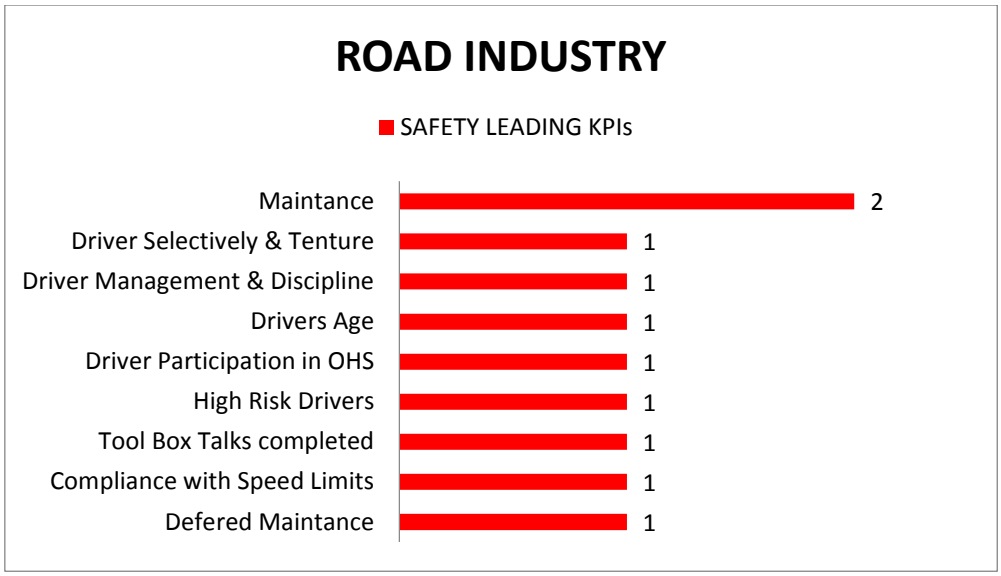


Diagram 1. Safety Leading Key Performance Indicators- Road Industry

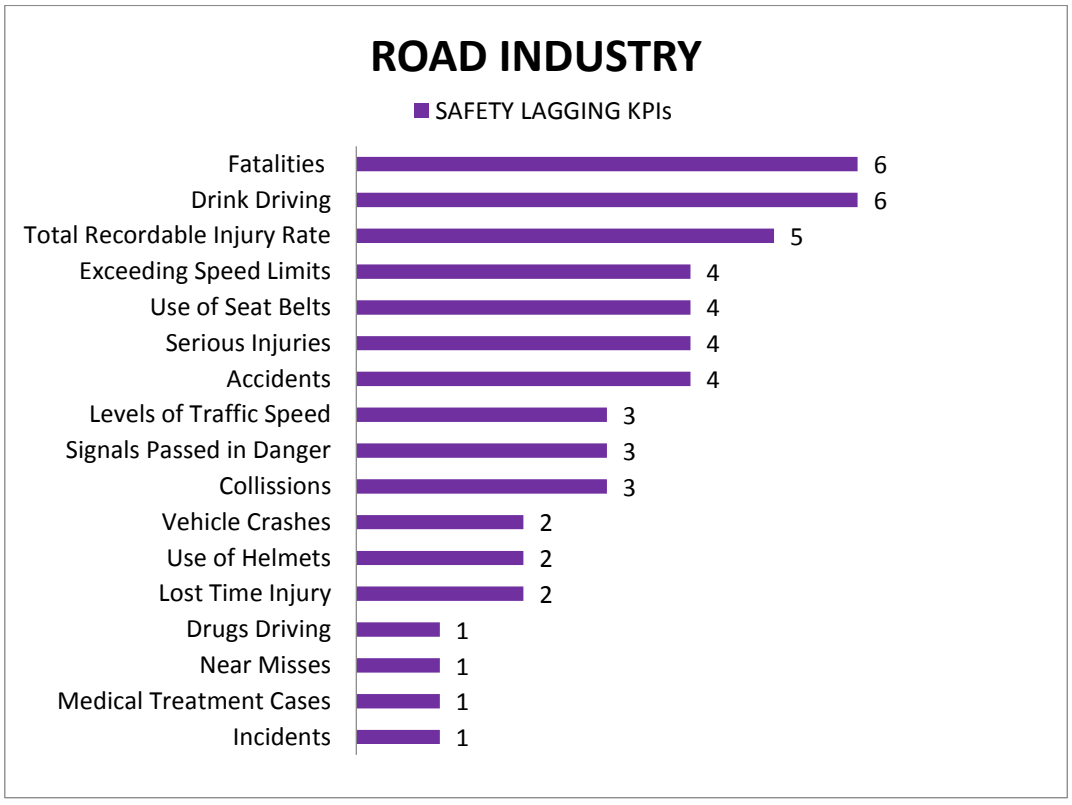


Diagram 2. Safety Lagging Key Performance Indicators- Road Industry

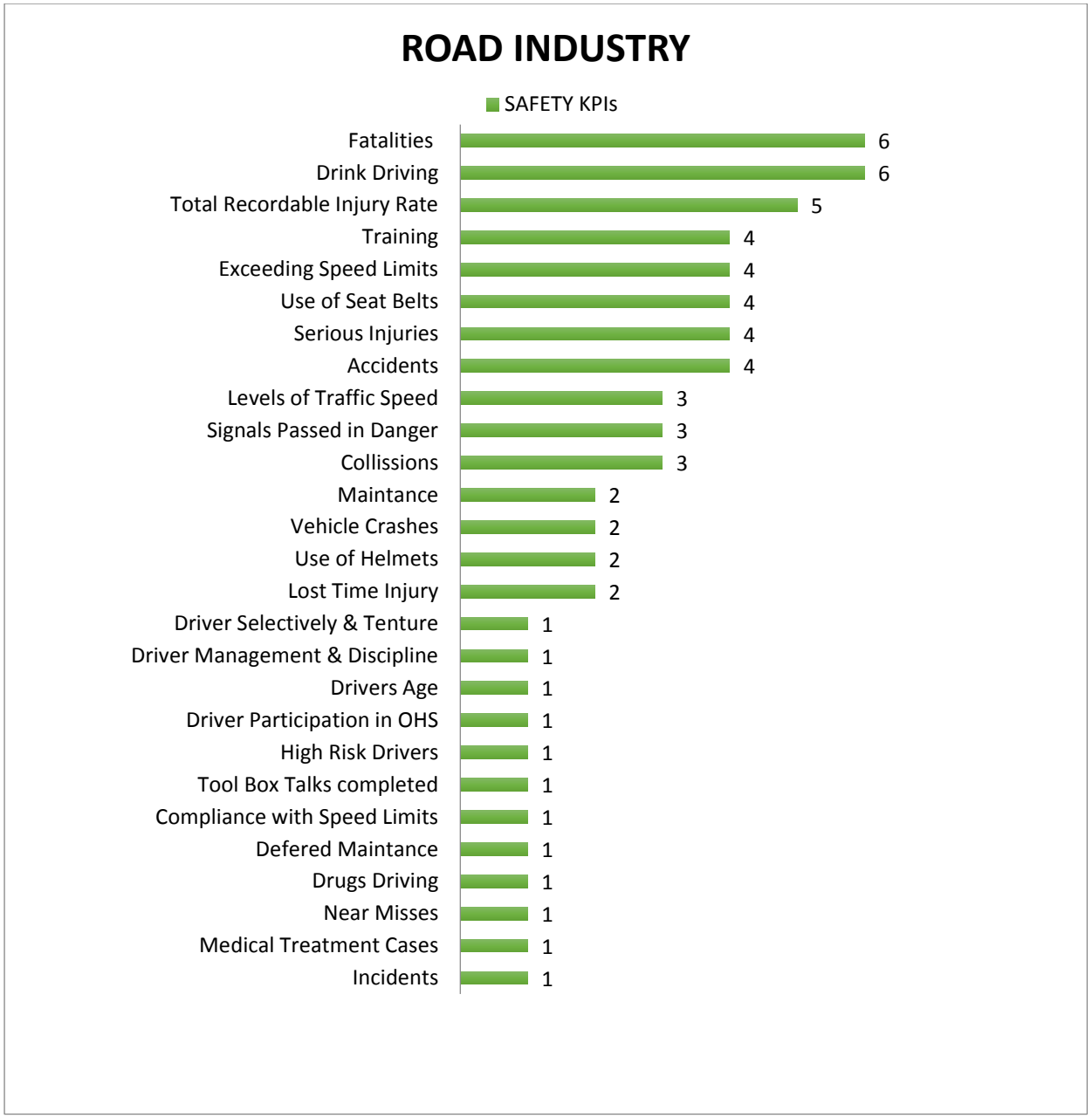


Diagram 3. Safety Key Performance Indicators- Road Industry

2.1.2 SECURITY Key Performance Indicators at ROAD Industry

Security in general refers to crimes (robberies, theft objects) and damages. Every industry trying to keep its safety levels in a good level has to take also measures for the above possible crimes. Every industry has to face different hazards as far as security and in this paragraph we are going to present security hazards at the Road Industry.

Possible hazards in this field can be assumed any damages on the road, robberies on the road, cars or car equipment. It I important to how police has worked on these subjects. For that reason according to Brebbia [13] as security key performance indicators on road it is believed to be the number of effective police patrol teams, the number of illegal taxicab operations and the number of incidents of commuters being attacked by armed robbers. The last indicator help us to calculate the road's Crime Rate, which estimates the number of crimes such as homicide, violence rape, aggravate assault, robbery, theft, car theft, burglary and arson per one million passengers [12]. Other indicators which inform us about the security level on road are the number of incidents like fender-benders, traffic accidents and operator accidents per 100.000 miles that can lead a bus or a car to go out of its course and shows the Bus/Mobility Collision Rate respectively [12]. Finally Matthews [23] refers as key performance indicator community's satisfaction with police services and its satisfaction during their most recent contact with road traffic police.

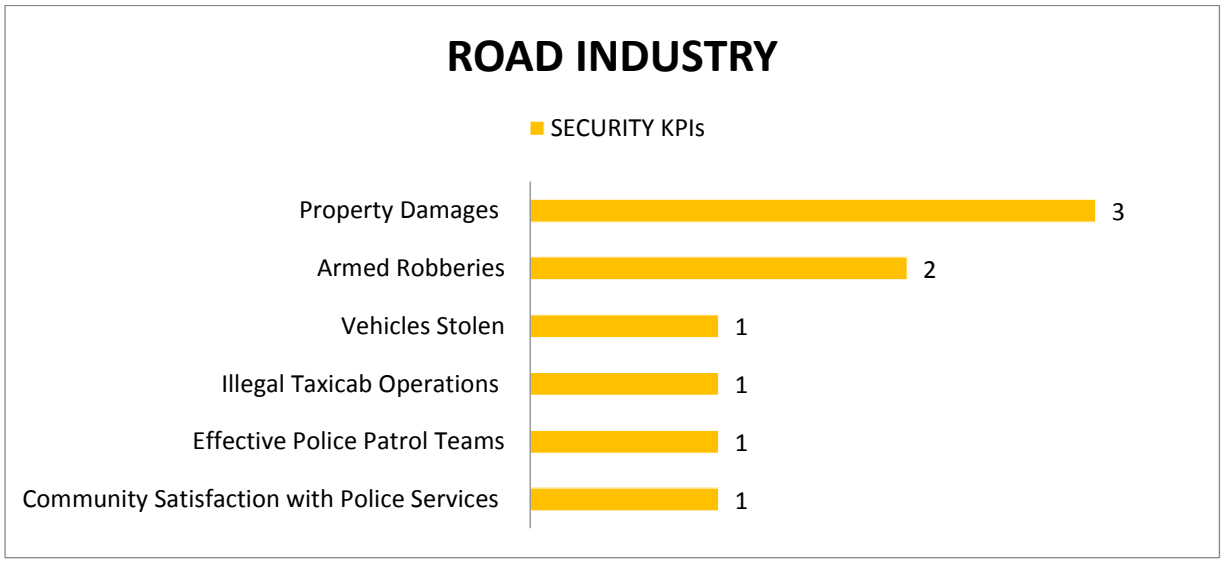


Diagram 4. Security Key Performance Indicators- Road Industry

2.1.3 HEALTH & SAFETY Key Performance Indicators at ROAD Industry

Apart from the safety and security matters we have to deal with on road, health and safety matters are equally important. To improve the safety of health of the employees working on road as drivers, Annan [24] suggests as KPIs the number of road accidents and injuries (medical treated, first aid, occupational illness) per region per year and also the fatality rate and frequency per month and also for the whole country.

More specific, TNT Express [25] separates the fatal accidents and the collisions in those which occur in the workplace and moreover those in which the road traffic is blameworthy or subcontractor per 100,000 km. In agreement to the previous ones Saracino [26] also suggests to use as KPIs the percentage of prevention and protection measures, training, health monitoring and the innovation.

We can observe that many of the Key Performance Indicators used for health & safety performance are also used in other categories. For example the number of injuries, accidents and training courses can be assumed also as safety indicators. The difference can exists between the same indicators is the form of evaluation or the time limits in which we measure each indicator.

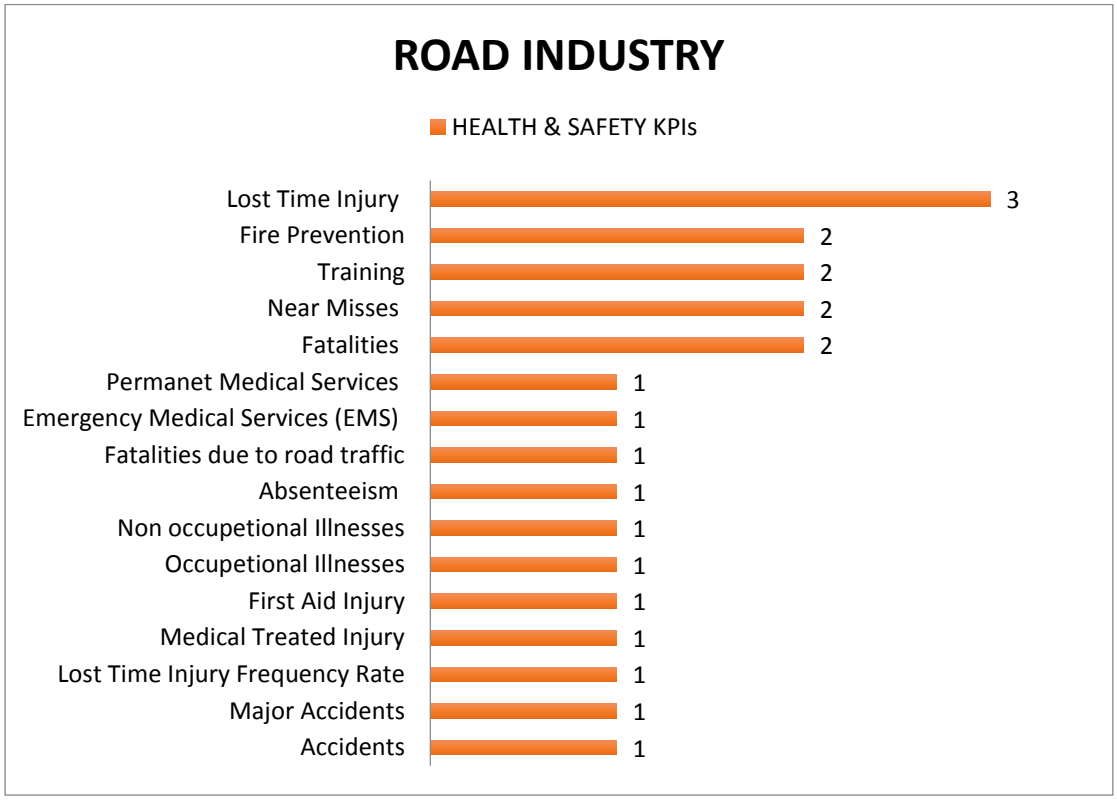


Diagram 5. Health and Safety Key Performance Indicators- Road Industry

2.1.4 ENVIRONMENTAL Key Performance Indicators at ROAD Industry

The use, design, construction and management of roads affect badly the environment in a great degree. The effects are not limited to the local environment of the roads such as the levels of noise, water pollution or air pollution but can extend and have a wider effect, such as the climate change from vehicle's emissions [17]. As EVITA [27] recommends, necessary KPIs for environment performance are the levels of noise produced per day and the levels of smog , as the number of days with smog per total number of days per year.

The road industry plays a significant part in emissions production and more specific emissions from volatile organic compounds, Carbon monoxide and various other hazardous air pollutants including benzene. Roads are an important factor in CO2 production, contributing around 20% of the UK's total carbon emissions a year, with only the energy industry having a larger impact at around 39%. Despite the fact that CO2 is not a toxic emission for health, it is the major greenhouse gas and so roads are a important contributor to greenhouse warning [2]. It also plays a significant part in NOx production from diesel engines , in lowest levels of production. For that reason the Innovation of Chemistry [28] and Transport Strategy Group report [20] suggest as KPIs the amount of CO2 and VOx emissions coming from road uses. Concentrations of air pollutants and adverse respiratory health effects are greater near the road than at some distance away from the road.

In order to define what water pollution is we have to explain that rainwater and snowmelt running off of the roads tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants. Road salts (primarily chlorides of sodium, calcium or magnesium) can be toxic to sensitive plants and animals. As a result, another suggested KPI is the number of water emissions [29].

Having as scope to prevent all the above causes of environment damage, some energy is required, such as training and surveys. Training courses that could inform adults and children how to use raw materials and recycle waste regarding staff related to road could be helpful. Toray Global [28] suggests the number of surveys for environmental incidents and the percentage of used raw materials as useful KPIs and also the Network of Employers for Traffic Safety [17], suggests as KPI the number of related to environmental protection training courses. Last KPI we have been suggested is the percentage of using fire fighting and reflected appliance and the time needed for respond to an emergency situation, as fire can also be very harmful to health also [13].

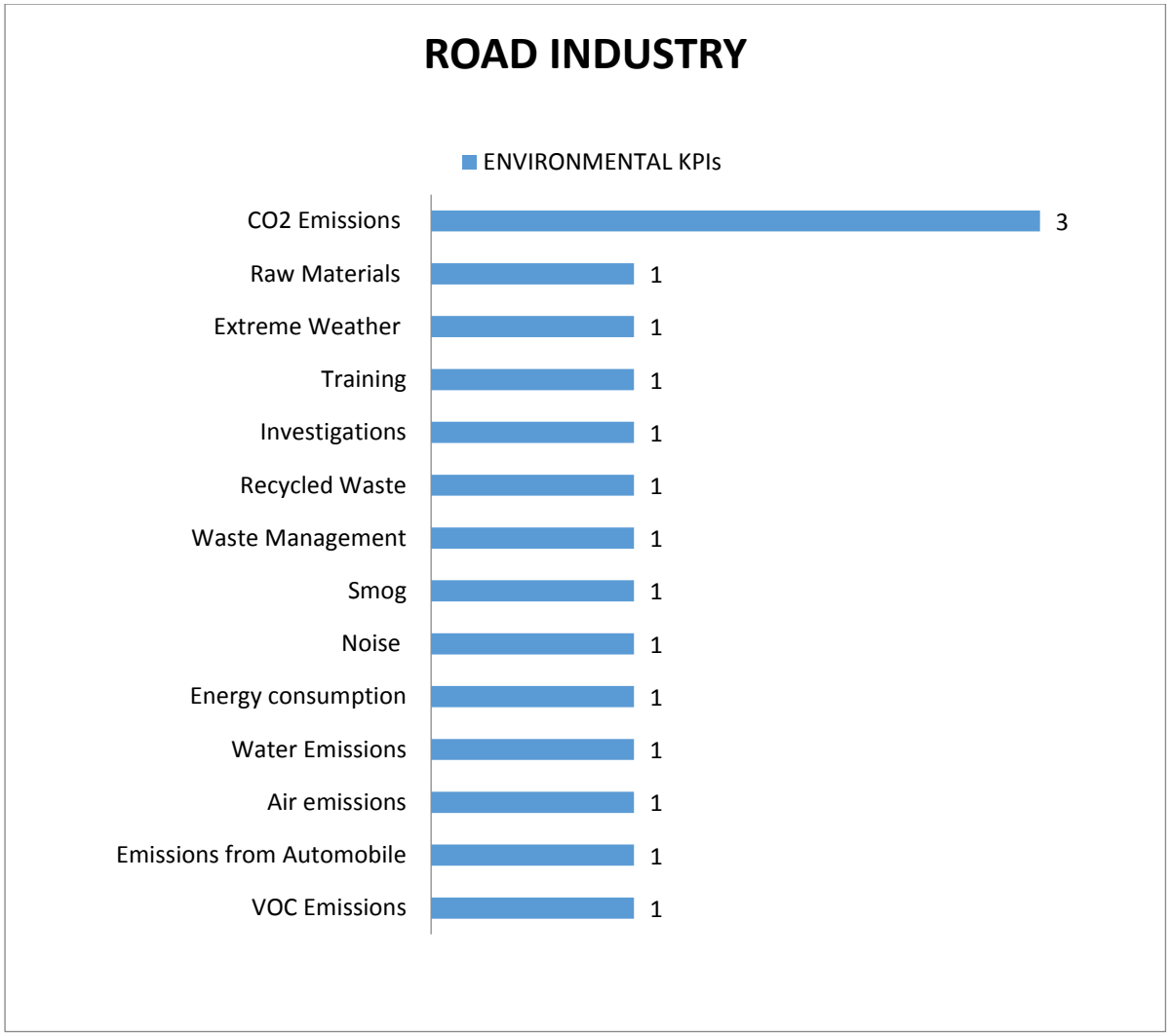


Diagram 6. Environmental Key Performance Indicators- Road Industry

2.1.5 KPIs BUBLE DIAGRAM at ROAD Industry

Having collected all the using Key Performance Indicators at the ROAD Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 18) it has been referred. With green colour appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- ROAD	CATEGORIES	PAPERS	OTHER
S1	Training	3	6	HS,E
S2	Fatalities	2	8	HS
S3	Accidents	2	5	HS
S4	Drink Driving	1	6	
S5	Total Recordable Injury Rate	1	5	
S6	Serious Injuries	1	4	
S7	Exceeding Speed Limits	1	4	
S8	Use of Seat Belts	1	4	
S9	Collissions	1	3	
S10	Levels of Traffic Speed	1	3	
S11	Maintance	1	2	
S12	Use of Helmets	1	2	
S13	Vehicle Crashes	1	2	
S14	Driver Management & Discipline	1	2	
S15	Driver Selectively & Tenture	1	2	
S16	Drivers Age	1	2	
S17	Incidents	1	1	
S18	Signals Passed in Danger	1	1	
S19	Drugs Driving	1	1	
S20	Tool Box Talks completed	1	1	
S21	Defered Maintance	1	1	
S22	Driver Participation in OHS	1	1	
S23	High Risk Drivers	1	1	
S24	Compliance with Speed Limits	1	1	
E1	CO2 Emissions	1	3	
E2	VOC Emissions	1	1	
E3	Emissions from Automobile	1	1	
E4	Air Emissions	1	1	

E5	Water Emissions	1	1	
E5	Energy consumption	1	1	
E6	Waste Management	1	1	
E7	Recycled Waste	1	1	
E8	Investigations	1	1	
E9	Raw Materials	1	1	
E10	Extreme Weather	1	1	
E11	Noise	1	1	
E12	Smog	1	1	
HS1	Lost Time Injury	2	5	S
HS2	Near Misses	2	3	S
HS3	Medical Treated Injury	2	2	
HS4	Fire Prevention	2	2	E
HS5	Major Accidents	1	2	
HS6	Lost Time Injury Frequency Rate	1	1	
HS7	First Aid Injury	1	1	
HS8	Occupetional Illnesses	1	1	
HS9	Non occupetional Illnesses	1	1	
HS10	Absenteeism	1	1	
HS11	Fatalities due to road traffic	1	1	
HS12	Emergency Medical Services (EMS)	1	1	
HS13	Permanet Medical Services	1	1	
SEC1	Property damages	1	3	
SEC2	Armed Robberies	1	2	
SEC3	Community Satisfaction with Police Services	1	1	
SEC4	Effective Police Patrol Teams	1	1	
SEC5	Illegal Taxicab Operations	1	1	
SEC6	Vehicles Stolen	1	1	

Matrix 1. KPIs in ROAD : Number of Categories & Number of Papers

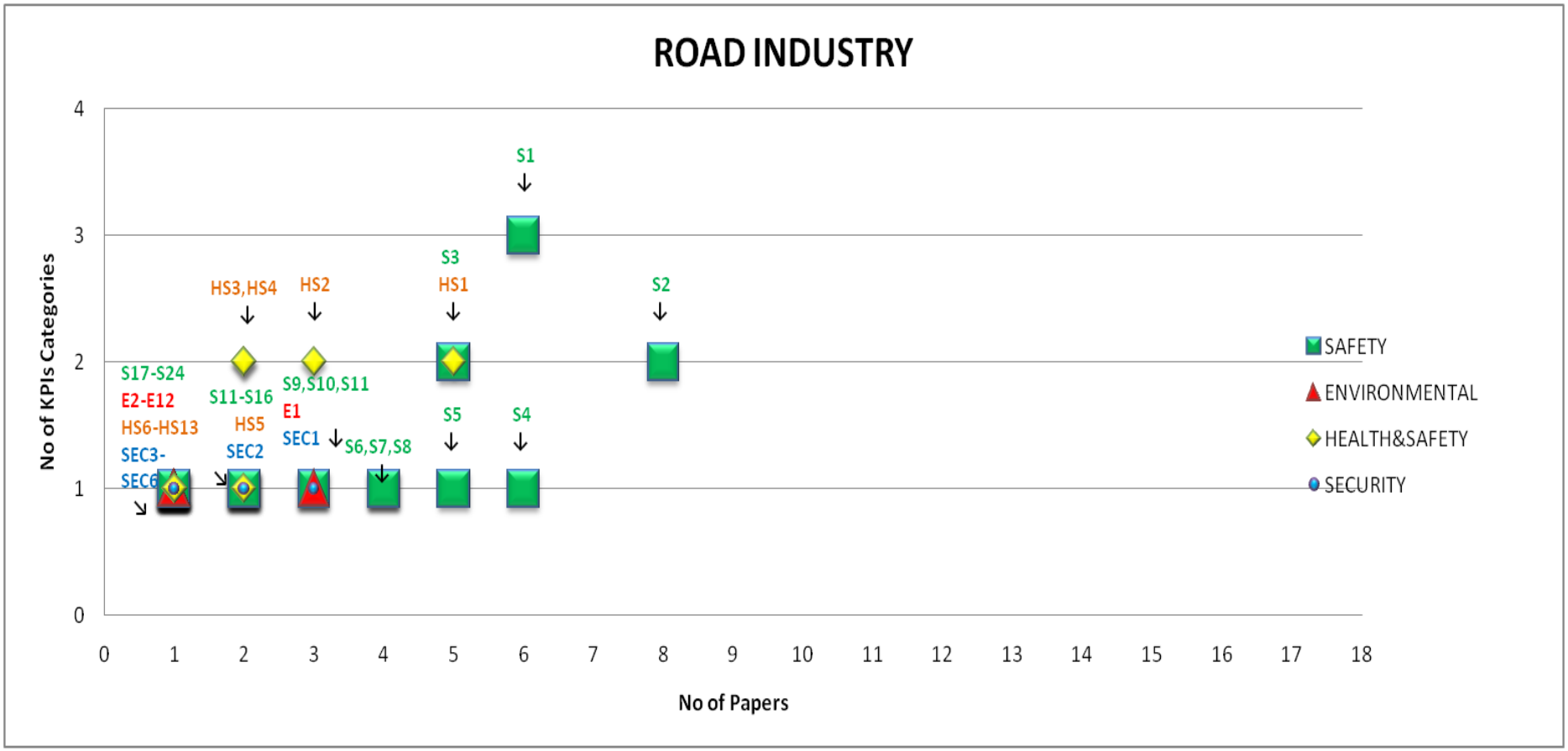


Diagram 7. All KPIs at Road Industry

2.2 RAIL INDUSTRY

After we have completed our research about the road industry, we continue with the most similar to the previous one, the rail industry. A train is used in order to connect series of train vehicles moving along the track. It has got a great part of today's transportation both for passenger's transport and products. Propulsion for the train is provided by a separate locomotive or from individual motors in self-propelled multiple units. As we can imagine the road and rail industries have a lot in common so we can easily predict that they should use many common Key Performance Indicators.

For this industry we have collected data from 20 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.2.1 SAFETY Key Performance Indicators at RAIL Industry

As we have already mentioned, train is a mean of transport both products and passengers. So, as it happens to every field that associates with human the most important part is safety. Train Industry in order to secure passenger's safety has instituted measures against its most possible hazards. These include derailments, collisions with another train or with automobiles, other vehicles or pedestrians at level crossings, which is the majority of rail accidents casualties. The above accidents happen due to train's characteristics. Trains can travel at very high speed, but they are heavy, are unable to deviate from the track and require a great distance to stop. The most important safety measures to prevent the above accidents are railway signalling and gates or grade separation at crossings. Train whistles, bells or horns warn of the presence of a train, while trackside signals maintain the distances between trains.

Since 2006, it has been enacted a law by the Parliament of the State of Victoria, Austalia regarding the safety of rail operations named the Rail Safety Act 2006 (the Act) which aimed to prevent deaths and injuries arising from rail operations. The Act establishes a scheme with the following key- elements:

- number of performance based safety duties applying to a broad range of parties who can affect rail safety outcomes
- an accreditation scheme concentrating on key rail industry operational parties
- a requirement that rail operators have a safety management system in place
- a broad range of sanctions and penalties
- cost benefit protections against excessive action by the regulator against industry participants
- alcohol and drug controls on rail safety workers
- Provision for the making of codes of practice to give guidance to regulated rail industry parties.

The Rail Safety Act is divided into ten parts

1. Preliminary
2. Principles of Rail Safety
3. Rail Safety Duties and Other Safety Requirements
4. Protection and Control of Rail Operations
5. Accreditation of Rail Infrastructure and Rolling Stock Operations
6. Alcohol and Other Drug Controls for Rail Safety Workers
7. Review of Decisions
8. Codes of Practice
9. General
10. Other Amendments to Acts, Savings and Transitional [2]

Rail industry concerns about safety, as we mentioned, and apart from protection it is also cares about measuring its safety performance. This scope can be achieving using the proper indicators, Key Performance Indicators. All the above accidents may have as result, deaths, injuries or damages, so the most common one is the number of incidents such as death, injury, damages and near-misses per million train kilometers [22], [30], [31]. In accordance to the European Railway Industry [32] each one of these incidents can be divided into categories for different type of accidents and persons. So we have serious accidents, fatalities and injuries by type of person such as passengers, employees, level crossing users, unauthorised persons, other persons or total persons, per train kilometer or per million miles .Concerning fatalities, is common to be used an indicator named Fatality Weighted Injury (FWI), which is going to be analyzed in the following paragraphs.

Other important KPIs are associating with the type of accidents. More specific, as KPIs for rail industry are used the number of collisions (with road vehicles) and derailments of trains as Elm [33] and Evans [34] have mentioned. The same important are the KPIs that measures the number of level crossing accidents, accidents of persons caused by rolling stock in motion, fires in rolling stock, crossing events, and finally the number of near misses both with road vehicle and with non-vehicle users . According to VIA Rail Canada [30], all the above accidents apart from separately, can also be summed and measured as a total KPI, named incidents per million miles and includes any incident that could cause any problem at railways safety. In addition to them other KPIs are the total number of suicides per train km [32] and the number of signals passed at danger (SPADs) per million miles. We also care about the location in which the majority of SPADs occur at low speed where braking distance has been misjudged and the train is stopped by automatic warning systems and therefore the likelihood of an accident is very low [35], [36]. The last indicator and the number of close call can be used as KPIs for both safety and health and safety for trains [36], [37].

In the previous we separated safety Key Performance Indicators to leading and lagging depending on the subject of their measurement. All of the mentioned indicators belong to the lagging category as they deal with accidents. We have also to mention these indicators used by Train Industry in order to prevent an accident and so they called leading KPIs.

The most common used safety leading KPI is the number of inspections done on a train. The inspection of railway equipment is essential for the safe movement of trains. Many types of defect detectors are in use on the world's railroads. These devices utilize technologies that vary from a simplistic paddle and switch to infrared and laser scanning, and even ultrasonic audio analysis. Their use has avoided many rail accidents. [12] In addition, as Go Ahead [35] group mentions other important KPIs are the number of audits and safety tours and the percentage of inspections, audits, and safety tours that have been completed on time. Last but not least, crew and officers training is an essential Key Performance Indicator and the number of safety communications and meetings.

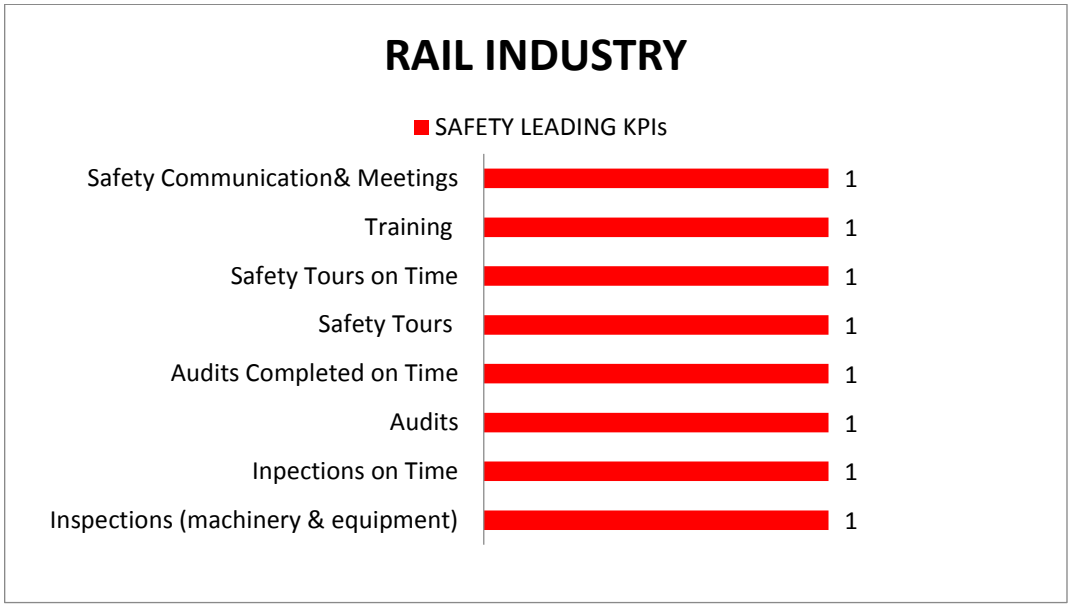


Diagram 8. Safety Leading Key Performance Indicators- Rail Industry

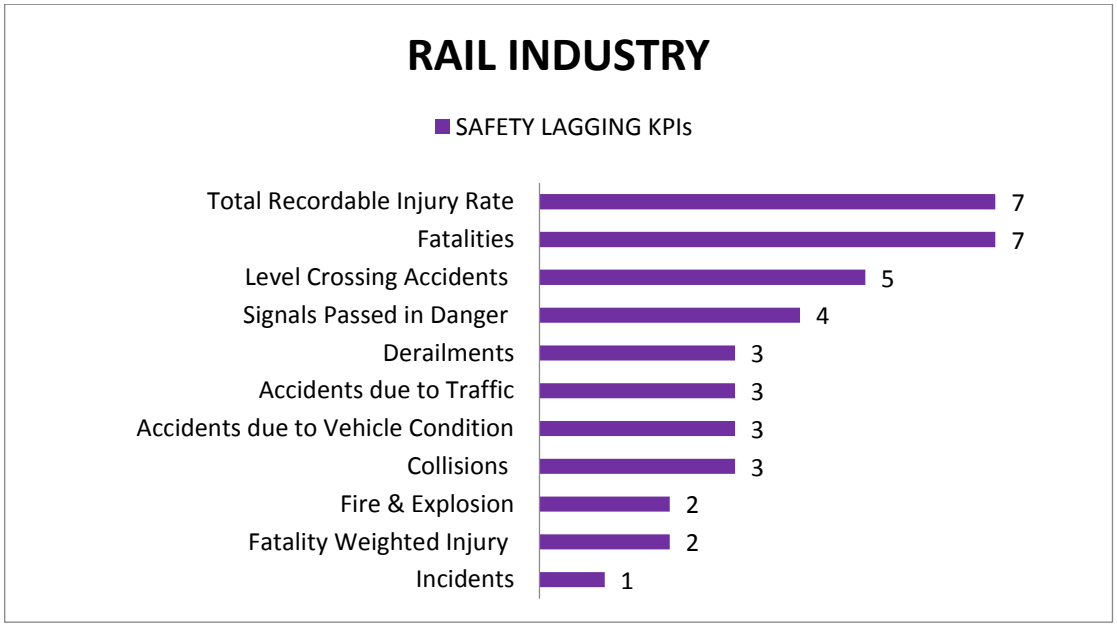


Diagram 9. Safety Lagging Key Performance Indicators- Rail Industry

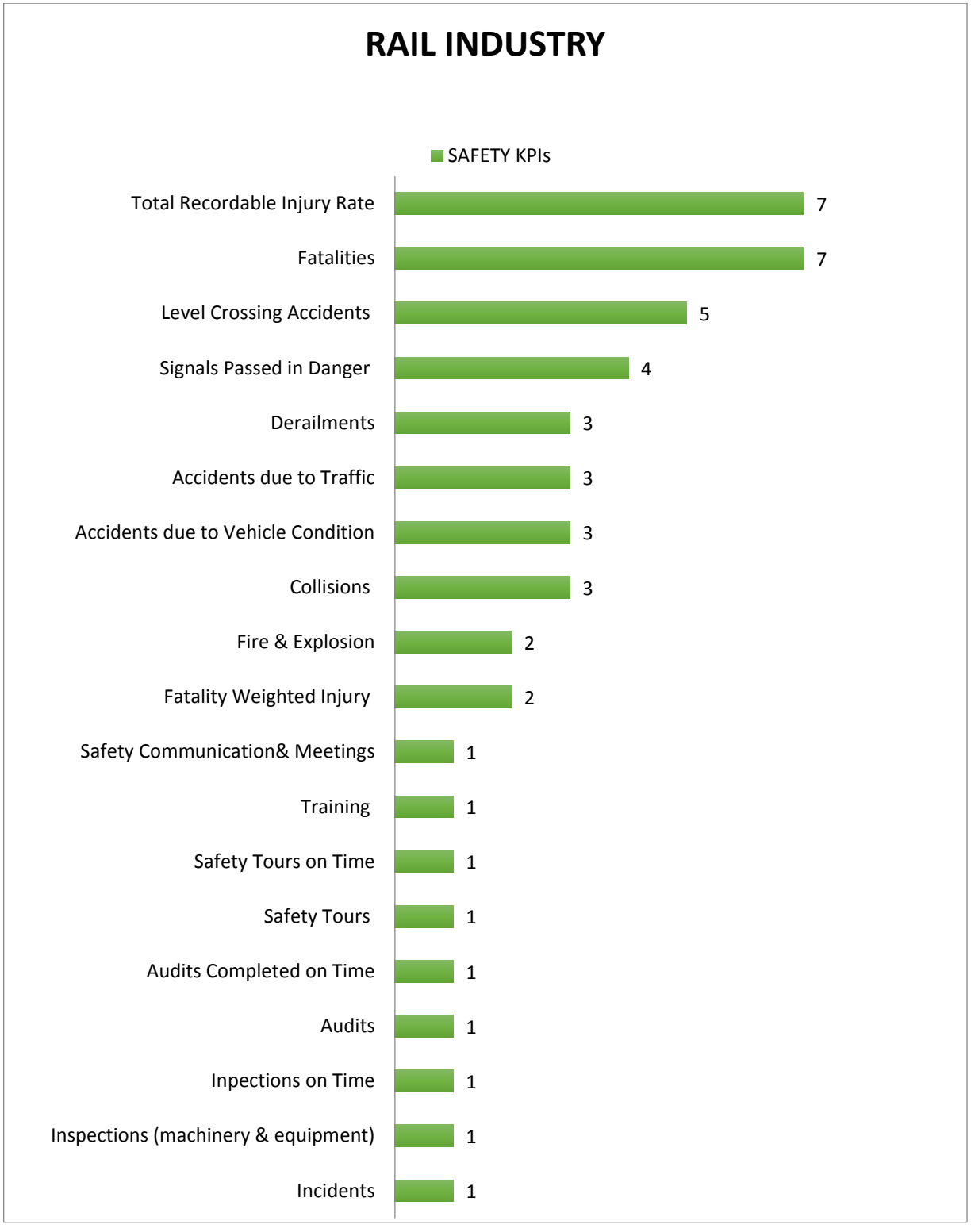


Diagram 10. Safety Key Performance Indicators- Rail Industry

2.2.2 SECURITY Key Performance Indicators at RAIL Industry

Apart from the safety, Train industry, also pays attention to strengthen its security protection against the hazards it faces. The most serious hazards are suicides, homicide, electromagnetic attacks and malicious acts. Measuring its security performance can be achieved by selecting the proper Key Performance Indicators.

These according to Metropolitan Atlanta Rapid Transit Authority [38] involve the criminal rate for crimes such as homicide, violence rape, aggravated assault, robbery and four property crimes (theft, car theft, burglary, and arson) per one million passengers. Moreover, criminal damage is taken into consideration through another indicator which estimates malicious acts per 100 route miles [36]. As we have already mentioned fire protection is very important as fire is one of the most significant dangers that a train has to deal with as escape routes are limited. So as Capote [39] mentions it is needed to be a right evacuation time in case of fire. In order to avoid such difficult situations, Elm [33] makes it clear that is important to monitor and control train movements and lines and check on the railroad interaction with highway. Finally, human factor is the last but not least indicator because the level of training and all train driver operational responsibilities have to be undertaken [40], as the rate of influence of culture and the human factor plays a role in control maneuvering of the train. The last factor that interests us is the organizational structure as Evans [34] concludes the privatization of railways has improved the security levels in railways.

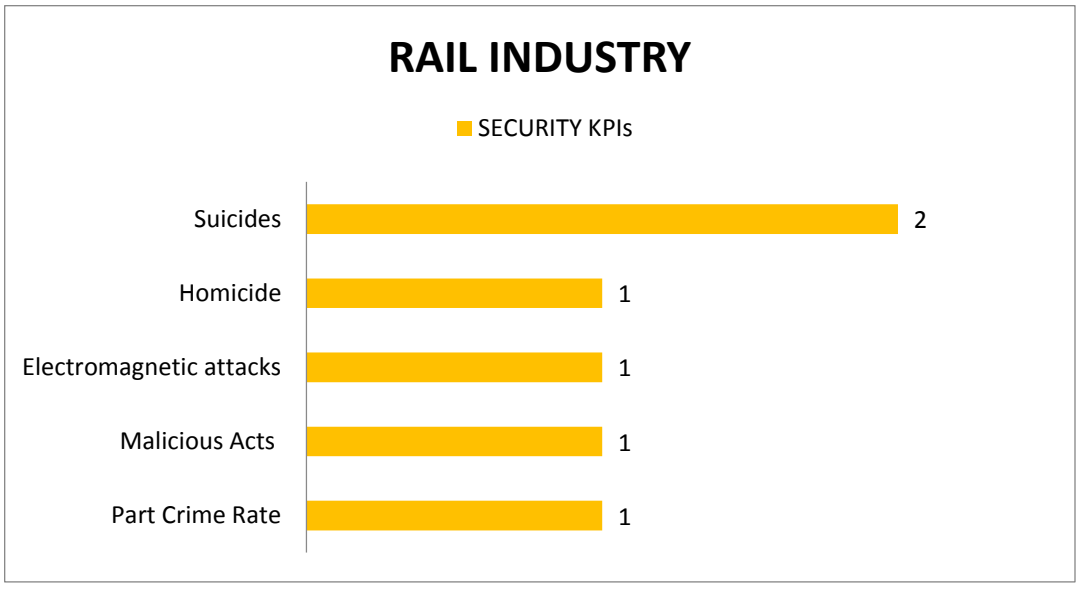


Diagram 11. Security Key Performance Indicators- Rail Industry

2.2.3 HEALTH & SAFETY Key Performance Indicators at RAIL Industry

Apart from safety KPIS we have to examine also the health and safety KPIs. These two categories of KPIs used to have a lot in common and many times one indicator to be used both at the two categories. This happens also at this Industry, Rail Industry. We mentioned in the beginning that rail and road industries have a lot in common and that can be easily understood if we examine the Key Performance Indicators used from both industries.

In order to be that proved, we examined some typical sources of the international literature which use as KPIs the number of fatal accidents, the injury rate (non lost time and lost time) and the number of near misses accidents as they were used for the road industry as well [35],[37],[41],[42].

More specific, in this industry, the number of injuries can be counted by a specific indicator, called Reportable Injuries Diseases Dangerous Occurrences (RIDDOR), which selects the total number of workplace injuries and divide it per 100 employees. [35], [37], [41]. Rail Industry uses this KPI separate as a number and also add it to other quantities, (other KPIs) in order to create a more complete indicator that enclose all the possible incidents that can effect health and safety. These KPIs divide RIDDOR reported injuries to major, non major and lost time and sums them with the number of fatalities. Any of the mentioned parts of the total Key Performance Indicator could also be used as a separate indicator.

Nowadays there are two well known mathematical equations which can be used to calculate this indicator, called Fatality Weighted Indicator and is also used as a safety lagging indicator, as we mentioned in the above paragraph. The mathematic equations are the following:

$$\mathrm{WI} = \mathrm{F} + \left(\frac{\mathrm{M}}{10}\right) + \left(\frac{\mathrm{L}}{200}\right) + \left(\frac{\mathrm{N}}{1000}\right), \text{ or}$$

$$\mathrm{FWI} = \mathrm{YF} + \left(\frac{\mathrm{YM}}{10}\right) + \left(\frac{\mathrm{YL}}{200}\right) + \left(\frac{\mathrm{YN}}{1000}\right),$$

where,

F = Number of fatalities,

M = Number of major RIDDOR reportable injuries,

L = Number of Lost time RIDDOR reportable injuries,

N= non major RIDDOR reportable injuries and

Y = 13 Period Summation of Injuries and fatalities [37].

Using the same symbols we can calculate some other useful indicators by the following equations:

$$\mathrm{AFR} = \left(\frac{\mathrm{F} + \mathrm{M} + \mathrm{L}}{\mathrm{H}}\right) \times 100000 \text{ , or}$$

$$\mathrm{AFR} = \left(\frac{\mathrm{YF+YM+YL}}{\mathrm{YH}}\right) \times 100000 \text{ , where}$$

H= Number of worked hours [37].

For both injuries, fatal incidents, trauma and shock, FWI indicator- fatality and weighted injury- is used for many categories of person related to train work such as trespassers, passengers at stations, members of the workforce working on the infrastructure and members of the public using level crossings [40], [41].

As in safety category there are the lagging and leading indicators, the same separation can be assumed that there is also in the health and safety field, though we cannot use this terminology. So, as apart from the ‘‘lagging’’ indicators, there are also some well known ‘‘leading’’ indicators. Very important Key Performance Indicator is the number of inspections, so according to the Network Rail [37] we have to take into consideration the number of planned safety tours, the number of planned general inspections and the percentage of them which had been closed on time.

Last indicator for health and safety issues is suggested by Cox [43] and it is related to levels of crowding and density of passengers which could lead to psychological and physical discomfort, and could also cause long-term health problems as stress.

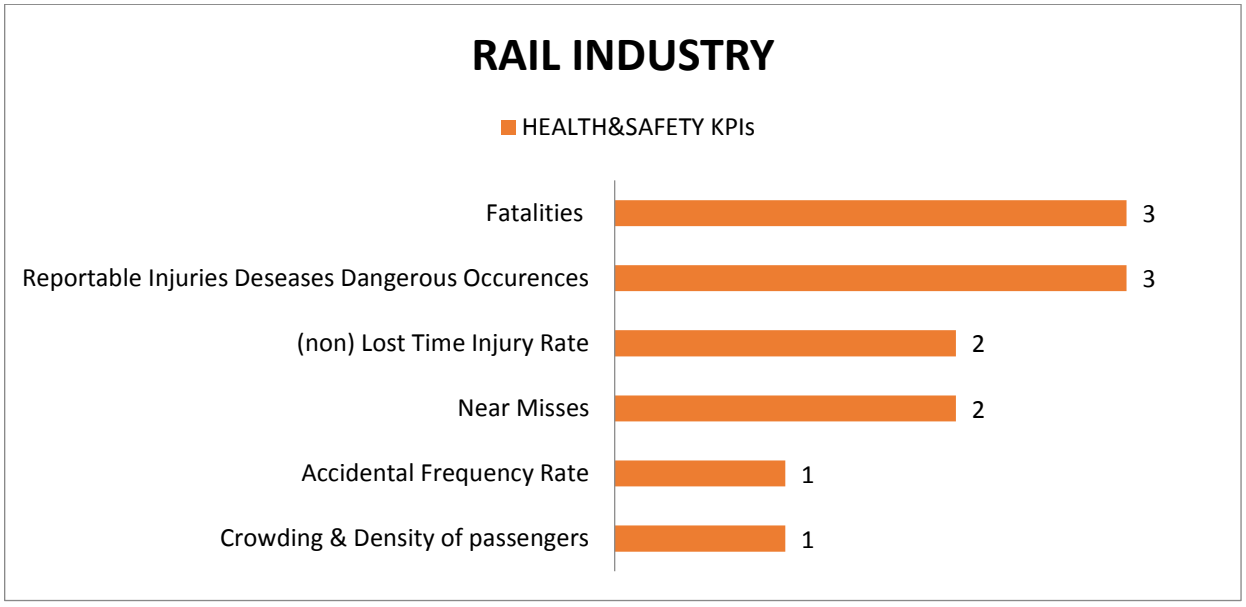


Diagram 12. Health and Safety Key Performance Indicators- Rail Industry

2.2.4 ENVIRONMENTAL Key Performance Indicators at RAIL Industry

The environmental impact of train industry to the environment is usually portrayed in a positive light since it is considered to impact the environment less than other modes of transport. However, train operations lead to negative impacts including local air pollution, climate change and noise.

As concerns air pollution, the most harmful pollutants are sulphur dioxide (SO2) and nitrogen oxides (NOx). These levels depend mainly on the share of coal used to generate the electricity. For that reason, the first Key Performance Indicators proposed by many experts are the number of tones of that emissions and also the number of complaints of people influenced by these emissions. Other important emissions are those of Carbon dioxide (CO2) that even it is lower that the emissions of other industries, it remains one of the major factors that pollute air. For that reason, the number of tones or grams of emitted CO2 also used as a KPI at rail industry. Finally, concerning people's health and the quality of the air very important are the emissions of smoke, the volume of dust and odours produced every day. Morson Group [41], proposed to every company in the train industry to evaluate its performance using as KPIs the volume of smoke emissions and the number of days with fumes and odours.

As concerns the noise nuisance from High Speed Train operations it can be considered as the main environmental impact of them. The level of noise generated depends mainly on the speed of the train. At speeds between 50 and 300 kph, rolling noise is the most important noise source and it depends mainly on the smoothness of the wheels and railhead. The high standards of the High Speed Trains (HST) infrastructure probably leads to less noise generated from their operations in comparison with conventional trains running at the same speed. At high speeds HST operations result in high levels of noise, yet the impact of this (the actual noise heard and number of people exposed to it) is lower than can be expected since in densely populated areas the speed of the HST is usually at its lowest (due to the distance required for the HST to stop, which means speed is reduced far from the station). In addition, it is possible to 'protect' people from railway noise by building barriers, trenches or tunnels [44]. The same can be considered also about the vibration levels produced from train operation. As a result the level of noise and vibration are used from Rail industry, as environmental KPIs.

In addition, other KPIs in used concerning consumption are water consumption, oil gas consumption and electricity consumption. High Speed Trains are predominantly electric powered and therefore emissions from HST operations are considered to be linearly related to energy consumption and the sources used to generate the electricity. The higher the level of renewable sources and nuclear power used to generate the electricity, the lower the level of emission associated with HST operations [44]. In order to have a more environmentally management, every company in the rail industry uses as KPIs the paper consumption and the volume of papers it is using so as to minimizing them. For the same reason every company also has a waste strategy. As Northern Rail [45] and DEFRA [46] refers companies use as KPIs the amount of their waste and call it waste management and also the percentage of their waste that is recycled. The recycling rate and the renewable energy are the key elements for a company in rail industry, or even to every industry generally to be considered as an environmental friendly one. [47],[48]

Last but not least, as we have already seen to other categories, all the above indicators can be summed and create a new Key Performance Indicator, called number of environmental incidents that can be refers to every incident could cause damage to the environment. Finally the percentage of complying with the Environmental Management System (EMS) could be a great KPI for every company wants to estimate its environmental performance.

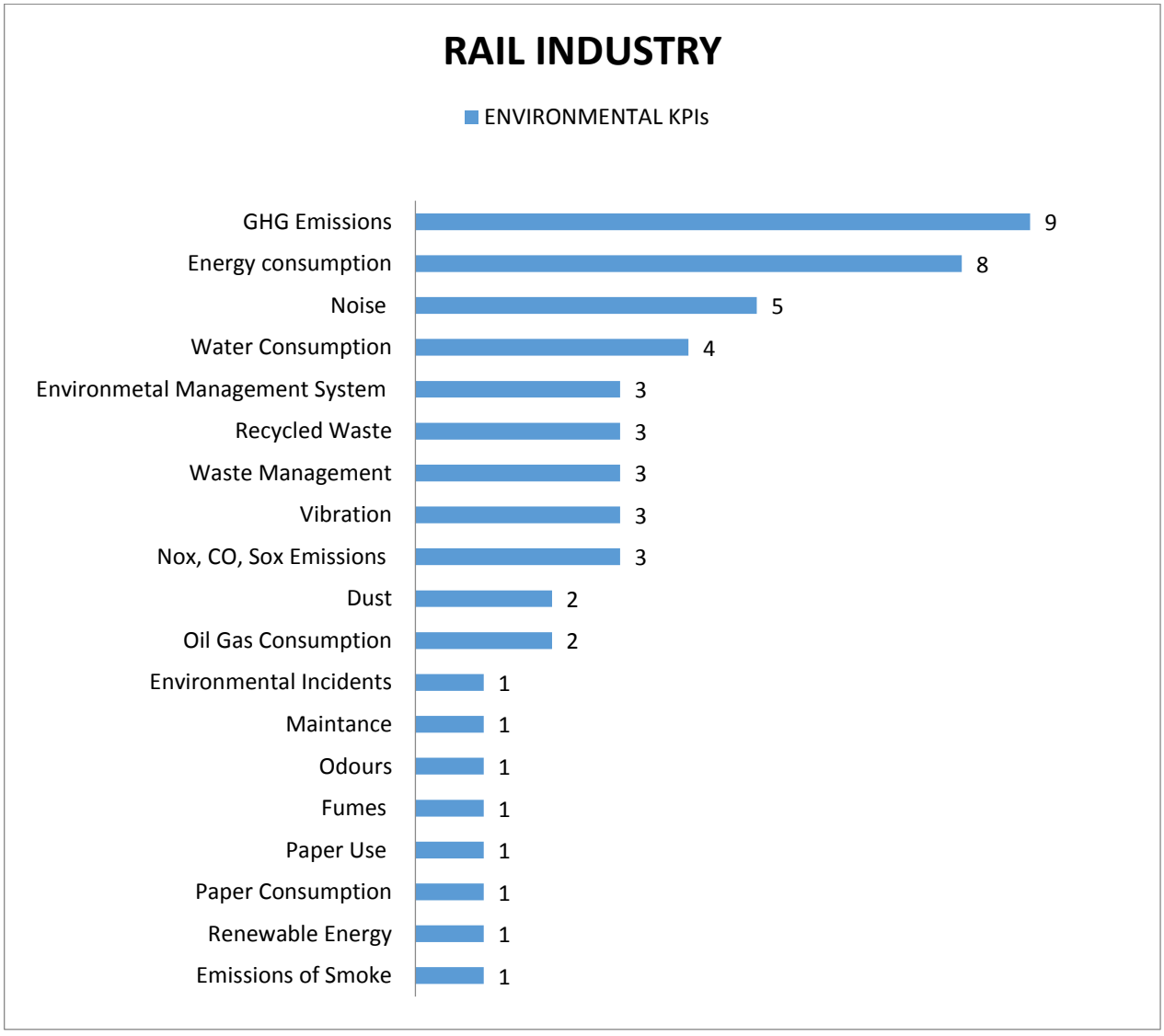


Diagram 13. Environmental Key Performance Indicators- Rail Industry

2.2.5 KPIs BUBLE DIAGRAM at RAIL Industry

Having collected all the using Key Performance Indicators at the ROAD Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 20) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- RAIL	CATEGORIES	PAPERS	OTHER
S1	Fatalities	1	5	
S2	Total Recordable Injury Rate	1	5	
S3	Signals Passed in Danger	1	4	
S4	Level Crossing Accidents	1	4	
S5	Accidents due to Traffic	1	3	
S6	Collisions	1	3	
S7	Derailments	1	3	
S8	Fire & Explosion	1	2	
S9	Accidents due to Vehicle Condition	1	3	
S10	Audits	1	1	
S11	Audits Completed on Time	1	1	
S12	Inspections (machinery & equipment)	1	1	
S13	Inpections on Time	1	1	
S14	Safety Tours	1	1	
S15	Safety Tours on Time	1	1	
S16	Training	1	1	
S17	Safety Communication& Meetings	1	1	
E1	GHG Emissions	1	9	
E2	Energy consumption	1	8	
E3	Noise	1	5	
E4	Water Consumption	1	4	
E5	Nox, CO, Sox Emissions	1	3	
E6	Waste Management	1	3	
E7	Recycled Waste	1	3	
E8	Vibration	1	3	
E9	Environmetal Management System	1	3	
E10	Dust	1	2	
E11	Oil Gas Consumption	1	2	
E12	Renewable Energy	1	1	
E13	Paper Use	1	1	
E14	Paper Consumption	1	1	
E15	Emissions of Smoke	1	1	
E16	Fumes	1	1	
E17	Odours	1	1	
E18	Environmental Incidents	1	1	
HS1	Fatality Weighted Injury	2	4	HS,S
HS2	Reportable Injuries Deseases Dangerous Occurences	1	3	
HS3	Near Misses	1	2	
HS4	Accidental Frequency Rate	2	2	HS,S
HS5	(non) Lost Time Injury Rate	1	2	
HS6	Crowding & Density of passengers	1	1	
SEC1	Suicides	1	2	
SEC2	Part Crime Rate	1	1	
SEC3	Malicious Acts	1	1	
SEC4	Electromagnetic attacks	1	1	
SEC5	Homicide	1	1	

Matrix 2. KPIs in RAIL : Number of Categories & Number of Papers

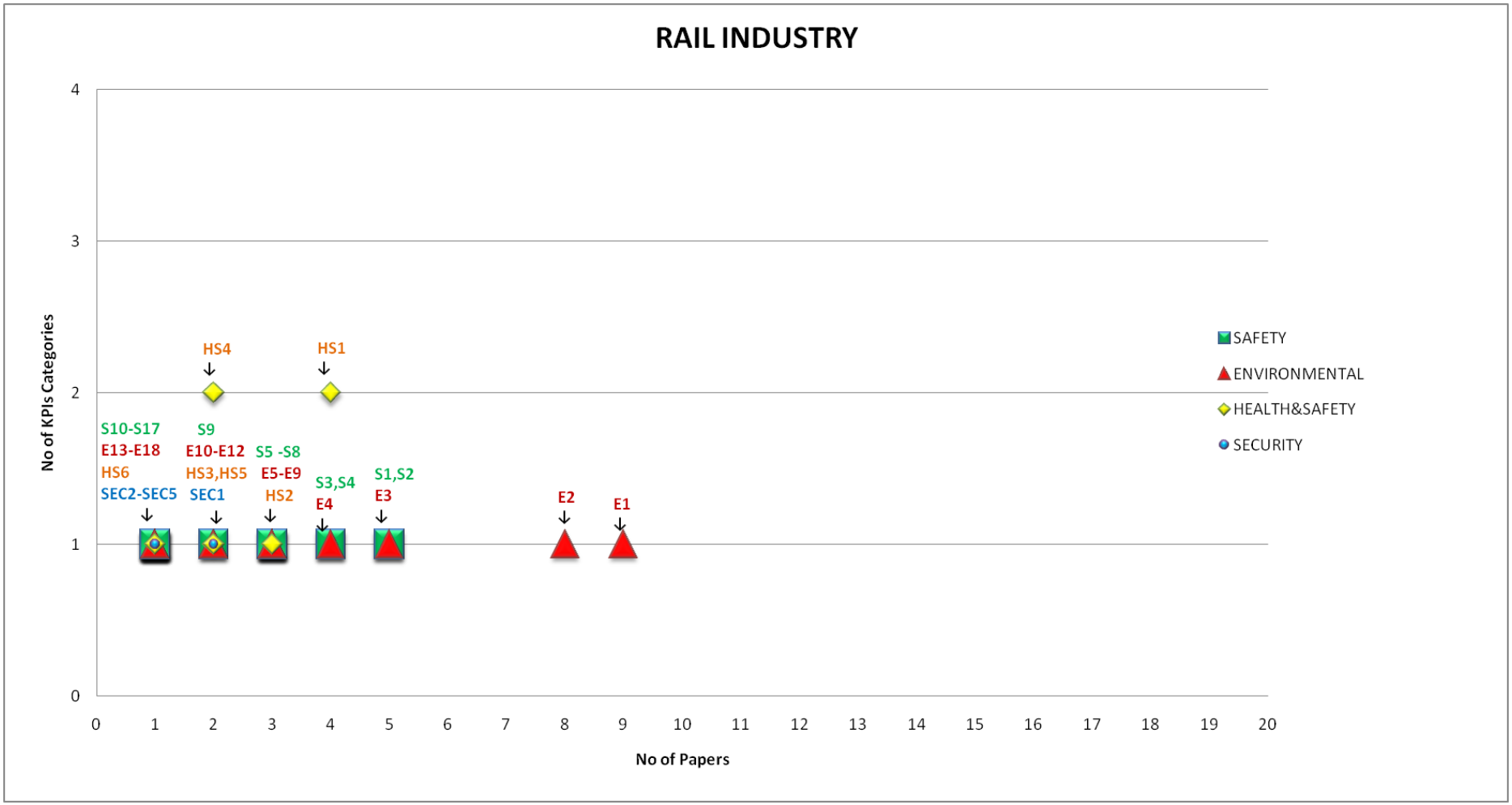


Diagram 14. All KPIs at Rail Industry

2.3. AVIATION INDUSTRY

We are going now to examine one other industry a little different from the previous two as it evolves action on air. Despite of their differences it has got the same goal, to provide safety to their customers, employees, and product transfer. In order to observe how safety this industry is, we have examined the most common and efficient KPIs (safety, security, health and safety and environment).

For this industry we have collected data from 17 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.3.1 SAFETY Key Performance Indicators at AVIATION Industry

To begin with safety at aviation industry, it focuses in encompassing the theory, investigation and to categorize the flight failures. Scope of that industry in order to be safer and prevent safety failures is to increase regulation, education and training.

The need for safety laws especially for the aviation industry began during the 1920, when passed the first laws in USA which emphasized the meaning of examination and investigation. The Aeronautics Branch of the United States Department of Commerce obligated pilots and aircraft to be examined and if an incident occurs to be investigated. However, despite the above laws in 1926 and 1927 noted 24 fatal commercial airline crashes, 16 in 1928 and finally 51 in 1929. The above incidents lead to huge number of deaths and until now is the 1929 remains the worst year record at an accident rate. [2]

The above crashes and other safety incidents lead the aviation industry to examine again its rules and laws and nowadays aviation industry sticks to International Civil Aviation Organization (ICAO). ICAO Council adopts standards and recommended practices concerning air navigation, its infrastructure, flight inspection, prevention of unlawful interference, and facilitation of border-crossing procedures for international civil aviation. ICAO defines the protocols for air accident investigation followed by transport safety authorities in countries signatory to the Convention on International Civil Aviation (*Chicago Convention*) and it is constituted by 19 Annexes, which are the following ones :

- Annex 1 - Personnel Licensing
- Annex 2 - Rules of the Air
- Annex 3 - Meteorological Services
- Annex 4 - Aeronautical Charts
- Annex 5 - Units of Measurement
- Annex 6 - Operation of Aircraft
- Annex 7 - Aircraft Nationality and Registration Marks
- Annex 8 - Airworthiness of Aircraft
- Annex 9 - Facilitation
- Annex 10 - Aeronautical Telecommunications
- Annex 11 - Air Traffic Services

- Annex 12 - Search and Rescue
- Annex 13 - Aircraft Accident and Incident Investigation
- Annex 14 - Aerodromes
- Annex 15 - Aeronautical Information Services
- Annex 16 - Environmental Protection
- Annex 17 - Security
- Annex 18 - The Safe Transportation of Dangerous Goods by Air
- Annex 19 - Safety management [49]

Having the ICAO organization to comply with, aviation safety is getting easily to estimate. Like every industry in order to improve safety levels we use safety KPIs such as the number of issues reported. A large amount of sources of the international literature suggests KPIs as the number of deaths, near misses, injuries (lost time, first aid, serious, medical treated) and other dangerous occurrences (equipment property damage) [50], [51], [52], [53]. In accordance to International Civil Aviation Organization [49], the total rate of deaths is counted per 1000 departures and the rate of accidents and incidents is counted per year. Equally important as a key performance indicator is the number of bird strikes, which are an aviation term for a collision between a bird and an aircraft. Fatal accidents have been caused by both engine failure following bird ingestion and bird strikes breaking cockpit windshields. The highest risk of a bird strike occurs during takeoff and landing [2], [50],[51].

Also we need to know the number of months reporting and the average number of issues which have been reported each month. [50], [53]. Time in general is very important to that industry so some other KPIs we usually use concern the time delay (average minutes delay, operational delay, percentage of flights delayed > 15 minutes, percentage of flights delayed due to technical or commercial reasons), average turnaround time [52], available flying time and average block hours per day [51]. It is also important to know, if an incident occurs, the needed time it takes to be solved. For that reason we use KPIs like the number of days to resolve issues [50], [53], to close reported issues and to start investigations on reported issues [53]. In that industry we have observed that cost also pays a significant role. Finally we conclude to estimate the cost for every incident (maximum, minimum, average, total) [50], [53].

Another very important field in aircrafts is the maintenance of them. As Quinlan [54] reports, while the overall performance of safety of air travel has been improved, concerns have been raised that the increased offshore aircraft maintenance can contribute to a dangerous relationship between reduced costs and weaker supervision with negative consequences for the future of aviation security. For that reason, parameters such as economic pressures, distribution of work, cuts in staffing levels, deterioration in the level of trainee staff, and changes either in the work place or in the type of the work arrangement have been used as safety KPIs. Moreover, it is important for the maintenance to be on time so other KPIs are the rate of insurance that aircraft maintenance is conducted or completed on a timely basis in accordance to the scheduled maintenance program and the rate of insurance that aircraft is returned to service within timelines set for task [55].

For the same reason we must be aware of the number of safety visits, safety meetings and attendance levels , audit findings, and finally which were the safety observations [53]. After having the data we can estimate the performance which in accordance to Verstraeten [56] it's a type of KPIs. More specifically, KPIs that he recommends, are the total number of formal safety related meetings involving at least two different types of organizations (e.g. an aerodrome and ANSP) per year, the total number of formal meetings of network of analysts to discuss safety performance measurement, and the actual safety impact of each significant airport infrastructural change is evaluated at most after 3 years of implementation of the change. Last but not least are the following KPIs, the number of flights and the distance in which aircraft flies and which must be minimized when it is going high [50], [52], [56]

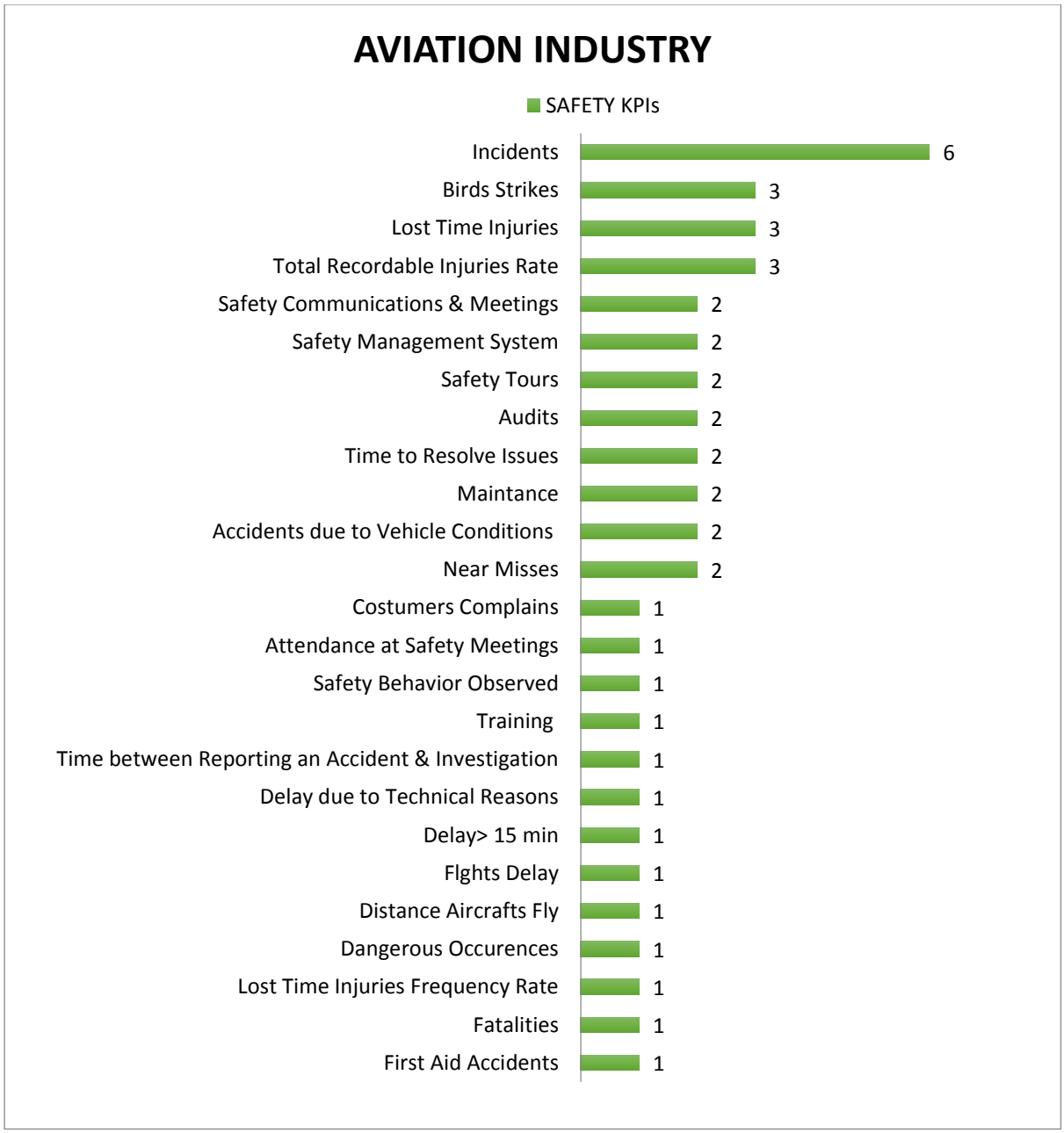


Diagram 15. Safety Key Performance Indicators- Aviation Industry

Diagram 16. Safety Leading Key Performance Indicators- Aviation Industry

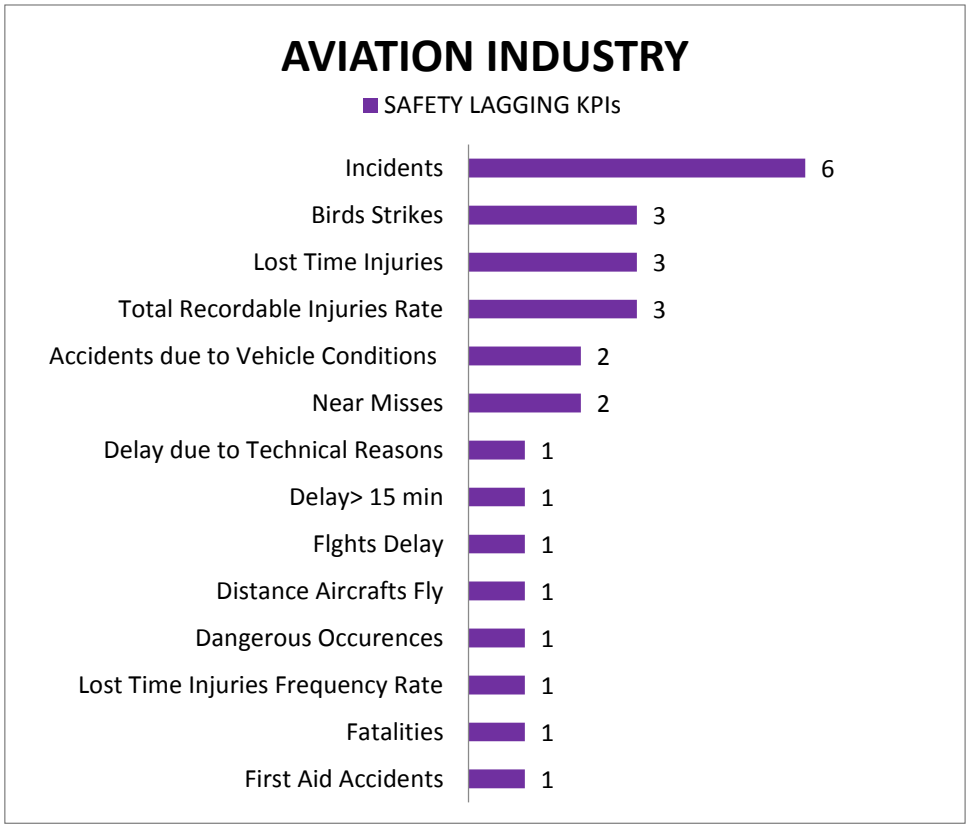


Diagram 17. Safety Lagging Key Performance Indicators- Aviation Industry

2.3.2 SECURITY Key Performance Indicators at AVIATION Industry

Apart from safety, we have to pay attention also to the security of the employees and of the airport departments including pavements. In general, aviation industry's security adheres to Annex 17 of International Civil Aviation Organization (ICAO). It is useful to know that although airports themselves do not have the complete control because of the surveillance that government has, they can monitor violations and take corrective action within the areas they control.

The major security KPIs are given by Airport council international [57] and Granberg [58] papers are the number of aircraft accidents in general, and number of terrorism acts with the most common Hijackings. Aircrew are normally trained to handle hijack situations and in order to raise the security levels at airports, stricter airport and airline security measures are in place to prevent terrorism since September 2011 [2]. These measures can be security checkpoints and locking the cockpit doors during flight. Terrorism is maybe the most major security threat for aviation industry and for that reason KPIs that are common to used are the number of hijackings and the number of incidents at security checkpoints.

Furthermore as security associates with crimes one major KPIs is the number of acts of unlawful interference against civil aviation worldwide [49]. Examples of these acts are emergency fire, bomb threat, thefts, attack on airport facilities, incidents with lost baggage and criminal behavior by passenger on board aircraft or at cargo on board aircraft. Granberg [49] and Enoma [59] inform us in their papers that as KPIs can be used the number of the above acts and also the time for normal service and operation to resume after such an incident occurred. Also we focus on the time it takes to business operations to begin in case of evacuation and between shut down and reopening in case of breach of security [58], [59]. Finally, Enoma [59] apart from the time needed uses also as KPI the rate of hysteria control-effectiveness and efficiency of handling and resolving such an incident in order to let everything returns to normal within the shortest possible time.

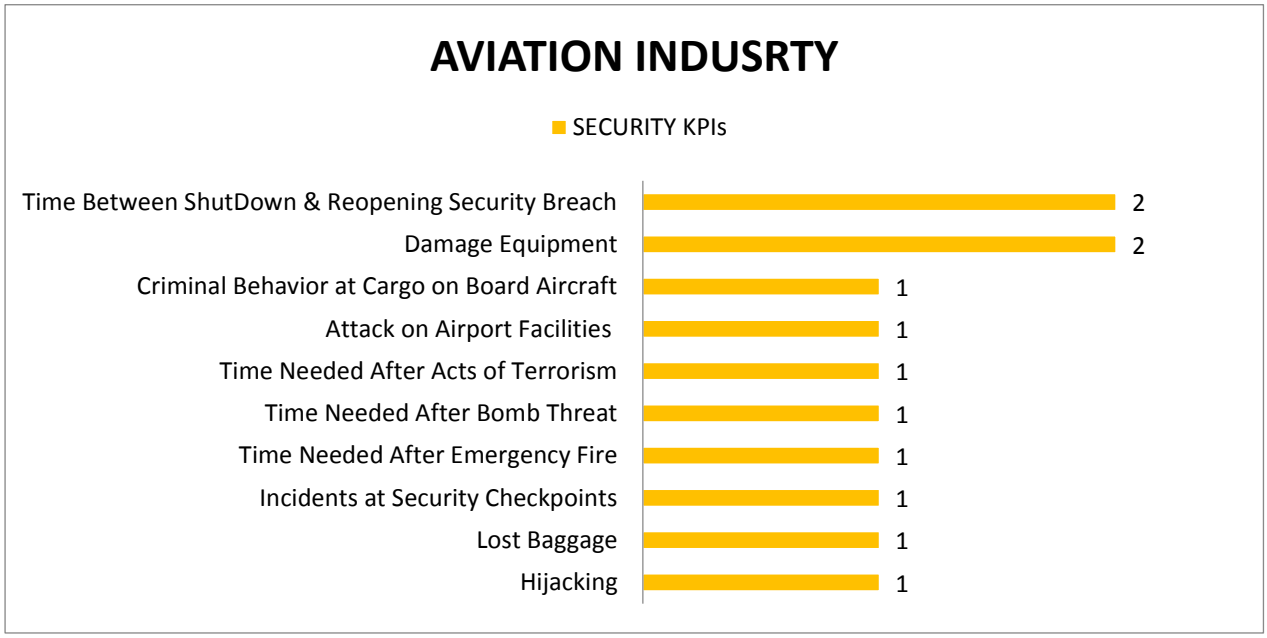


Diagram 18. Security Key Performance Indicators- Aviation Industry

2.3.3 HEALTH & SAFETY Key Performance Indicators at AVIATION Industry

As far as health and safety KPIs, both Phipps [60] and BBA aviation [61] mention the Recordable Incident Rate (RIR), which measures the number of full time employees out of every 100 that sustain a recordable injury or illness. Injuries are slept into two categories, those which lead to medical treatment, and those which need First Aids. Phipps [60] considers equally important the recordable near misses rate and also the rate of health and safety audits and global charter for the employees. Fatalities have already mentioned in the above paragraph in the safety section as it can be considered both as safety and health indicator. The number of deaths during a travel with airplane can be measured by three different ways. These are by dividing the number of fatalities per total number of journeys or per kilometers travelled or finally by the total number of travelers.

Noise is one of the major hazards for people's life who are working at airports facilities or even for those who are living or employee nearby the airports. In every case noise must be taken into consideration, measure and ways must to be found so as to reduce its levels. Very useful in order to show the affection of noise to human's health is the implementation of the appropriate Key Performance Indicators, These are the number of people and also the number of areas which are exposed in nose levels >65 db. Finally, KPIs that we are familiar with, are also used in this industry such as Lost Time Injury and the percentage of Absenteeism due to injury or illness caused by work activities.

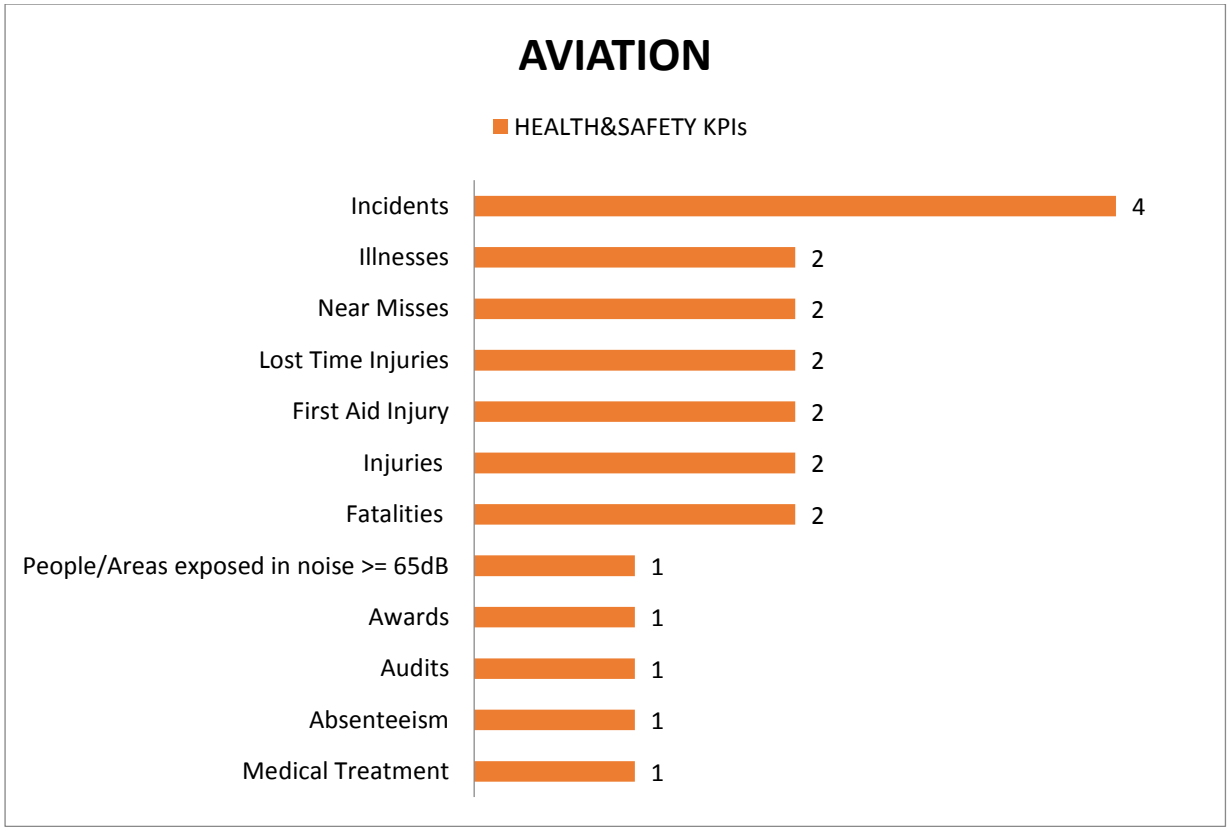


Diagram 19. Health and Safety Key Performance Indicators- Aviation Industry

2.3.4 ENVIRONMENTAL Key Performance Indicators at AVIATION Industry

There are some hazards issued from aviation industry that influence both health and safety and also the environment. One of these hazards is noise which has been mentioned above. As environmental KPIs are used not only the number of people and areas which are exposed to noise levels greater that 65db, but also the noise levels and finally the number of incidents that noise levels are out of limits. Apart from noise, another hazard both for the environment and the people's health is the vibration levels [52], [53].

Another factor that influences negatively both environment and health is the body chemistry of emissions. Aviation Industry mainly complies with the regulations of Annex 17 of ICAO, as concerns the environmental management. Emissions from aircrafts consist of CO2 per 71%, water per 28%, and CO, HC, Sox, Primary PM25 < 1% [62]. Based on this, the International Civil Aviation Organization [49], mentions as necessary KPI the number of tons of fuel burned (and CO2 generated) per 100 RTK/ATK. CO_2 emissions from aircraft-in-flight are the most significant element of aviation's total contribution to climate change. The level and effects of CO_2emissions are currently believed to be broadly the same regardless of altitude (i.e. they have the same atmospheric effects as ground based emissions). In 1992, emissions of CO_2 from aircraft were estimated at around 2% of all such anthropogenic emissions, and that year the atmospheric concentration of CO_2 attributable to aviation was around 1% of the total anthropogenic increase since the industrial revolution, having accumulated primarily over just the last 50 years, [2]. Once again according to [49] , another significant indicator is the number of distribution of aircraft in the in-service fleet by NOx characteristics. Emissions of NO_x are particularly effective in forming ozone (O_3) in the upper troposphere. High altitude (8-13km) NO_x emissions result in greater concentrations of O_3 than surface NO_x emissions, and these in turn have a greater global warming effect. [2]
Furthermore, these emissions could be the cause of spills both at land and at water. The number of those spills is used of many aviation companies and organizations as Key Performance Indicators. [52], [53], [63]

Environmental impact of the aviation industry is affiliated with consumptions. As BBA aviation [61] mentions as Key Performance Indicators are used water and electricity consumption. The last one is counting per kilowatt-hours. In agreement with BBA aviation is the Airport Council [57] and the UPS Corporate Sustainability [63] who also advances water consumption as KPI. Moreover they recommend fuel and energy consumption as indicators. The last one is of the most common used environmental indicators on all industries and would be a surprise if it would not appear in this industry. [57], [58] Energy plays a significant role in environmental management and nowadays there have been a huge attend to supplant energy with renewable sources of energy [57]. Finally the large amount of waste produced during an aircraft's fly, which some of them are toxic, is really dangerous for the environment. So, as Airport Council [57], Granberg [58], Erdogan [64] agree, the necessary key performance indicators are the waste recycling rate and the waste management.

Last but not least are the environmental Key Performance Indicators which are used to prevent form incidents could cause damage to the environment. First of all is the number of environmental incidents in which comprehended all the possible incidents could cause damage to the environment, as every company has defined them, [60]. In order to prevent these incidents is it obligatory to occur the right and appropriate training courses to the employees and next the appropriate number of audits both to the aircraft and to the employees in order to find out if they obey with the regulations. The number of training

courses, the percentage of them which have completed on time, the number of audits, and the number of inspections are used as KPIs in the aviation industry according to environmental protection and management. [60], [63], [65], [66]

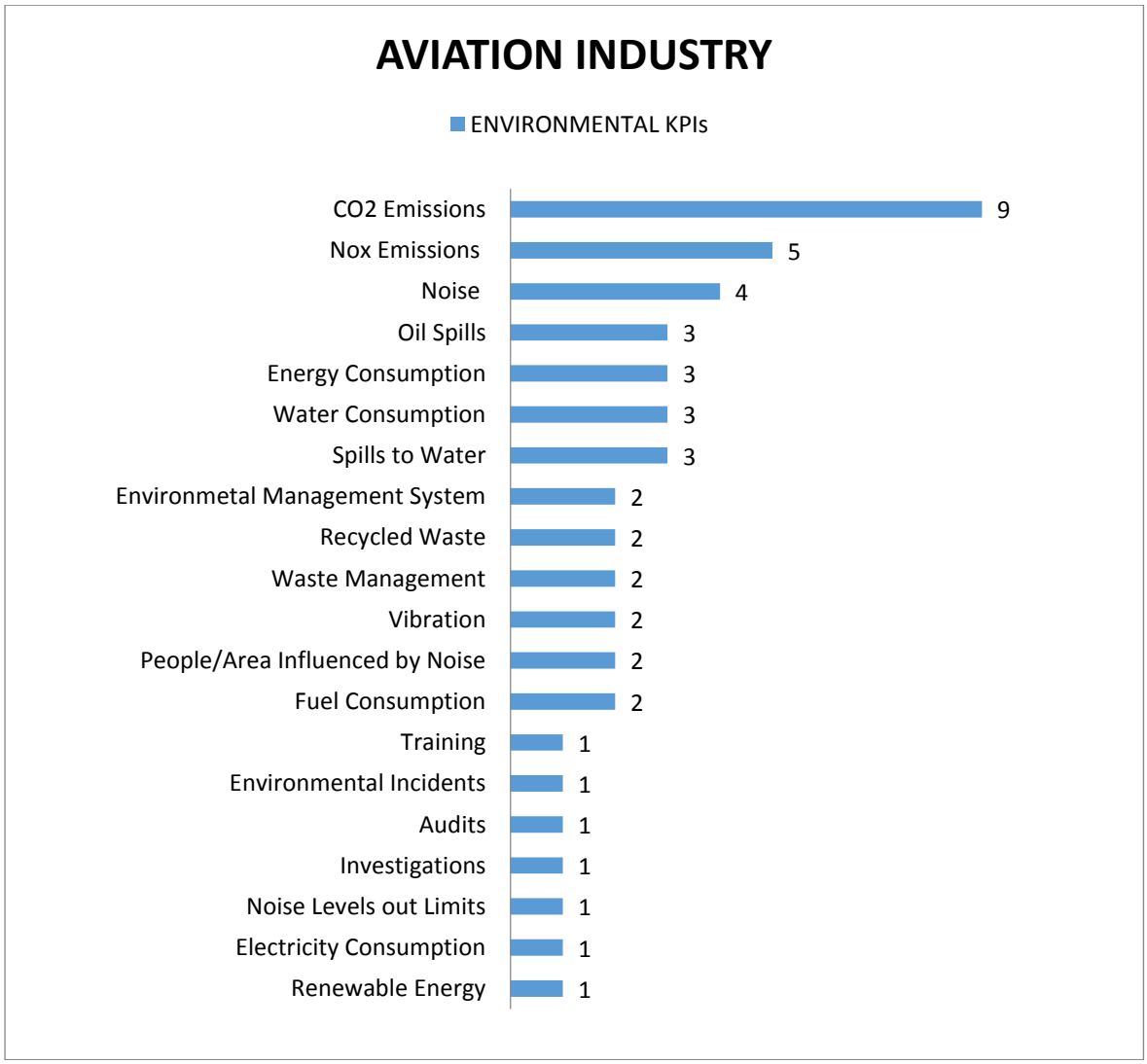


Diagram 20. Environmental Key Performance Indicators- Aviation Industry

2.3.5 KPIs BUBLE DIAGRAM at AVIATION Industry

Having collected all the using Key Performance Indicators at the Aviation Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 17) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- AVIATION	CATEGORIES	PAPERS	OTHER
S1	Incidents	3	10	E, HS
S2	Total Recordable Injury Rate	2	4	HS
S3	Lost Time Injury	2	4	HS
S4	Birds Strikes	1	3	
S5	Near Misses	2	4	HS
S6	Accidents due to Vehicle Conditions	1	2	
S7	Fatalities	2	3	HS
S8	Lost Time Injuries Frequency Rate	1	1	
S9	Maintance	1	2	
S10	Safety Management System	1	2	
S11	Safety Tours	1	2	
S12	Safety Communications & Meetings	1	2	
S13	Audits	3	3	E, HS
S14	Time to Resolve Issues	1	2	
S15	Training	2	2	HS
S16	Dangerous Occurences	1	1	
S17	Flghts Delay	1	1	
S18	Delay> 15 min	1	1	
S19	Delay due to Technical Reasons	1	1	
S20	Distance Aircrafts Fly	1	1	
S21	Attendance at Safety Meetings	1	1	
S22	Safety Behavior Observed	1	1	
S23	Time between Reporting an Accident & Investigation	1	1	
S24	Costumers Complains	1	1	
E1	CO2 Emissions	1	9	
E2	Nox Emissions	1	5	
E3	Noise	1	4	
E4	Energy Consumption	1	3	
E5	Water Consumption	1	3	

E6	Oil Spills	1	3	
E7	Spills to Water	1	3	
E8	People/Area Influenced by Noise	2	2	E
E9	Vibration	1	2	
E10	Recycled Waste	1	2	
E11	Waste Management	1	2	
E12	Environmetal Management System	1	2	
E13	Fuel Consumption	1	2	
E14	Noise Levels out Limits	1	1	
E15	Investigations	1	1	
E16	Electricity Consumption	1	1	
E17	Renewable Energy	1	1	
HS1	First Aid Injury	2	2	S
HS2	Illnesses	1	2	
HS3	Absenteeism	1	1	
HS4	Awards	1	1	
HS5	Medical Treatment	1	1	
SEC1	Damage equipment	1	2	
SEC2	Time between shut-down and reopening security breach	1	2	
SEC3	Hijacking	1	1	
SEC4	Lost Baggage	1	1	
SEC5	Incidents at security checkpoints	1	1	
SEC6	Time needed after emergency fire, bomb threat, acts of terrorism	1	1	
SEC7	Attack on airport facilities	1	1	
SEC8	Criminal behavior at cargo on board aircraft	1	1	

Matrix 3. KPIs in AVIATION : Number of Categories & Number of Papers

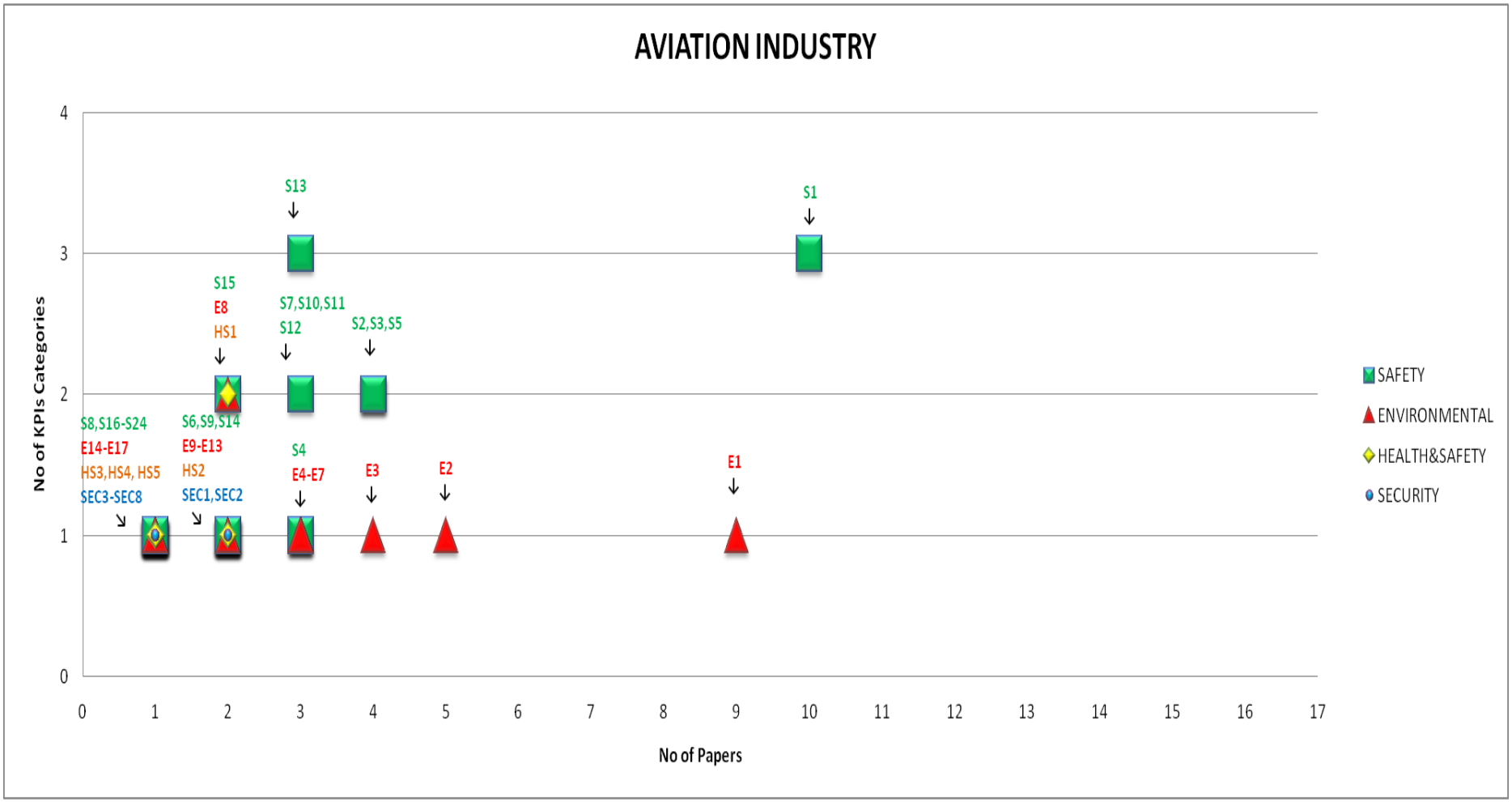


Diagram 21. All KPIs at Aviation Industry

2.4. CHEMISTRY INDUSTRY

Next industry we take into consideration is the chemical one. It has got many differences from the previous discussed ones as it is the first that doesn't participate at transport. Chemical industry is constituted by the companies that produce industrial chemicals such as raw materials (oil, natural gas, air, water, metals and minerals) [2]. Industry's output worldwide is comprised in a great volume by polymers and plastics, mainly polyethylene, polypropylene, polyvinylchloride, polyethylene, polystyrene and polycarbonate. It is obvious, that such an Industry must pay great attention to the ramifications its products could have to the environment and public's health and safety. For that reason, as the previous industries also did, the chemistry industry uses Key Performance Indicators to estimate its performance. We are going to examine which are the most effective and well used KPIs at this industry as far as safety, security, health and safety and finally environment.

For this industry we have collected data from 18 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.4.1 SAFETY Key Performance Indicators at CHEMISTRY Industry

In order to achieve the safety level which is needed, one of the major KPIs in use is trials. Chemicals must be under specified limits of temperature and pressure so they need regular control [67]. In order to make this control better it is necessary to monitor both the equipment, the control and safety system [67], [68], [69]. Inspection is a common indicators used by many industries in order to estimate every's safety performance and for that reason can be measured by many ways. Common KPIs, concerning investigations are the number of investigations completed on time or those resulted to 0 observations. After monitoring them it is necessary to record the number of failures and estimate the rate of the compliance with the safety procedure and the time needed between the accident and the investigation. Apart from inspections, internal and external audits are also done. As for the inspections, the KPIs used concerning the audits are the number of audits, the percentage of them completed on time, and the percentage of them resulted to 0 detects. Goose [70] use the previous KPIs specific for the electrical equipment. Inspections and audits are followed by maintenance. Useful KPIs are the time delay of the appropriate maintenance [67], and the percentage of maintance without defect.

Other Key Performance Indicators that are equaled important to the previous have relation with training. Employees and officers have to be prepared and trained by the company. For that reason, the majority of companies use as KPIs the hours of training courses and the percentage of completed drills. Furthermore, they have to be prepared for emergency situations, so it is need to be known the Emergency Preparedness Program and the number of false alarms. Last but not least, is the number of measures taken by a chemical company in order to prevent fire, as the most chemicals are toxic and flammable and fore is one of the most possible hazards it has to deal with.

Even though having completed all the appropriate energies for prevention an accident we cannot consider our company as safe. Estimating safety performance for a chemical company can be influenced at a great level from the incidents and accidents happen on it.

As OGP group [71] mention well known KPIs are the number of fatalities and injuries, named total recordable injury rate, the number of accidents (minor or significant).Apart from their rate we are also interested in knowing their frequency, for that reason we have adopted total recordable injury frequency rate which divides the number of injuries per the total exposed hours of the employees. This indicator we have seen before also in the previous industries so we can conclude that is a generally used one. The same stands for the following indicators, the number of lost time injuries and the number of lost time injuries frequency. To continue with other KPIs relevant to the injuries and accidents, we deal with the number of days away from work and the number of reported near misses [69], [71], [72], [73].

Expect from the generally used safety indicators, are some more that used specific to this industry. These are associating with the chemical operations and are number of leakages. As we have already said human factor is considered as KPI and more specifically human culture, the behavior of the employees, their training levels and safety process (fire fighting training or Hazard/Risk Assessment training) and their emergency preparedness [67], [74], [75]. In case an accident occurs very useful KPIs according to Fanelli [68] are the number of errors in executing operational procedures, the percentage of downtime caused by unplanned shut-downs, the mean time needed to repair the safety systems and the mean time needed between alarm activation and operator response. Some more safety KPIs are the percentage of weaknesses in technical safety barrier performance, the number of reported racking beam overloads, the percentage of correctly segregation of incompatible materials and the percentage of loss of primary containment [70], [74]. Finally, our last KPIs have been mentioned by Argawal [76] which are safety signs and notices, access, stacking, storage, ventilation, heating and lighting.

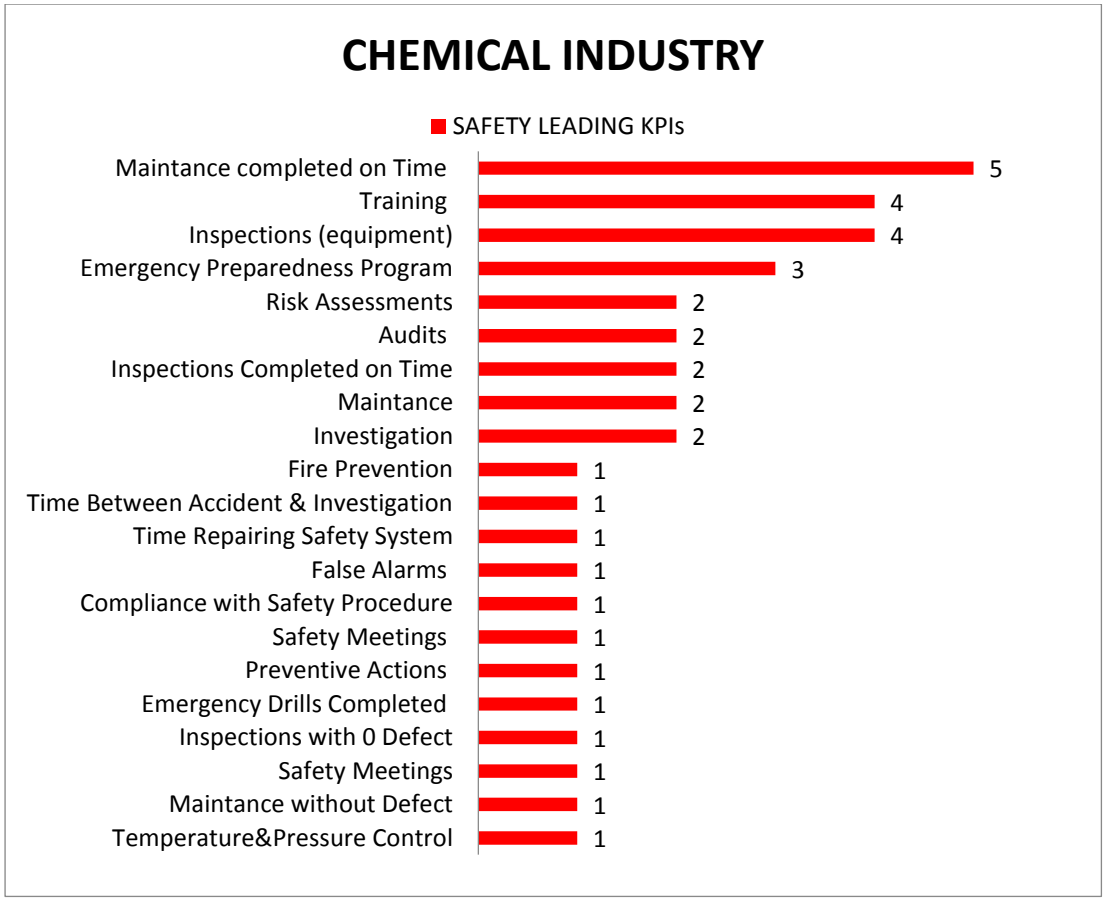


Diagram 22. Safety Leading Key Performance Indicators- Chemical Industry

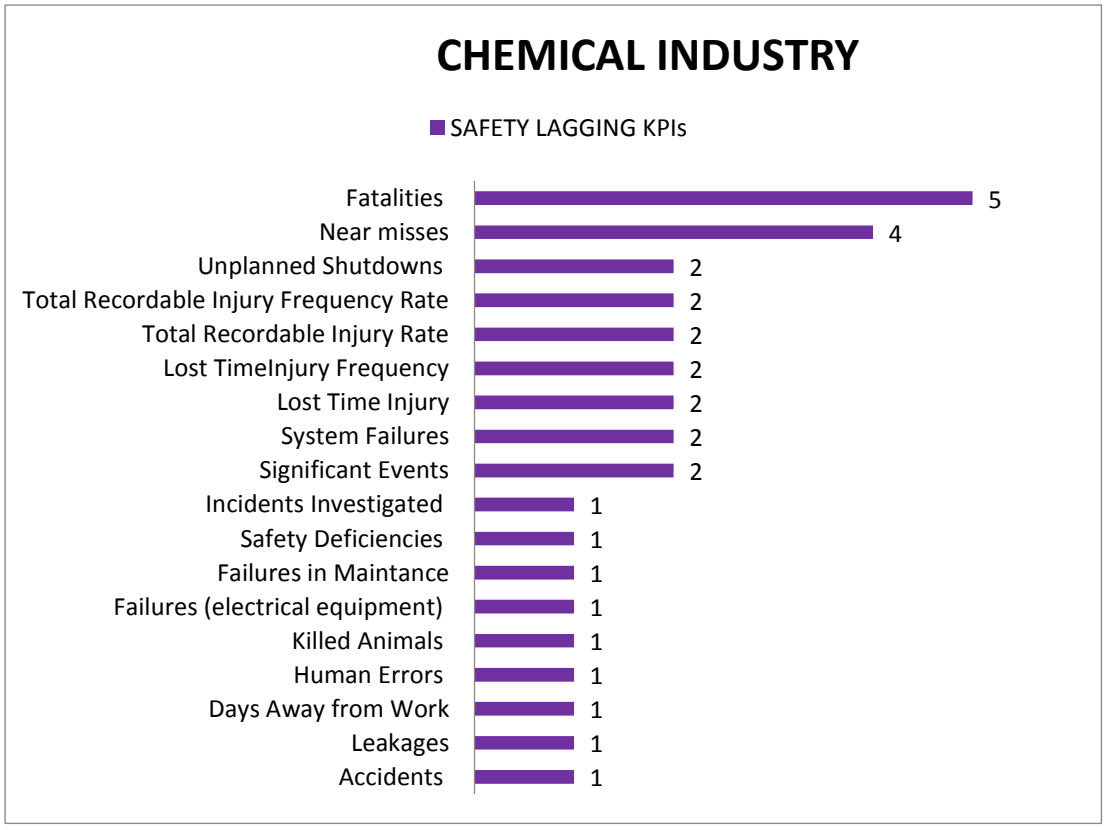


Diagram 23. Safety Lagging Key Performance Indicators- Chemical Industry

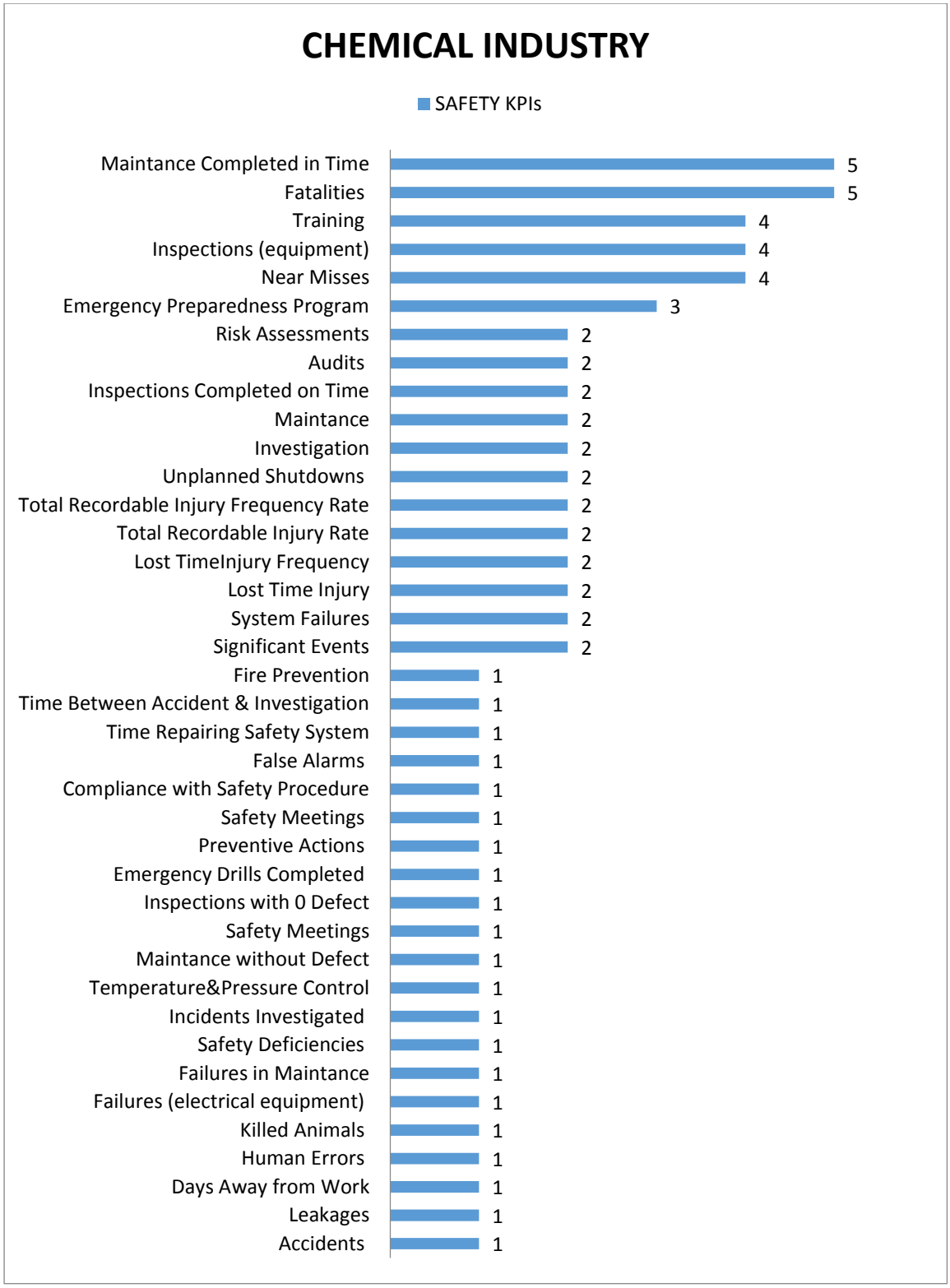


Diagram 24. Safety Key Performance Indicators- Chemical Industry

2.4.2 SECURITY Key Performance Indicators at CHEMISTRY Industry

Security category is not of main interest for a company in the chemistry industry. As we can see from the number of indicators used in it, which are only three we understand that chemical industry focuses more on safety and environmental management that on security.

However, according to Argawal [76] at its research has mentioned that in Chemical industry the most efficient and reliable Key Performance Indicators used in order to estimate security performance is the number of cyber attacks. In addition, security management and the rate of legal compliance can be used also as well.

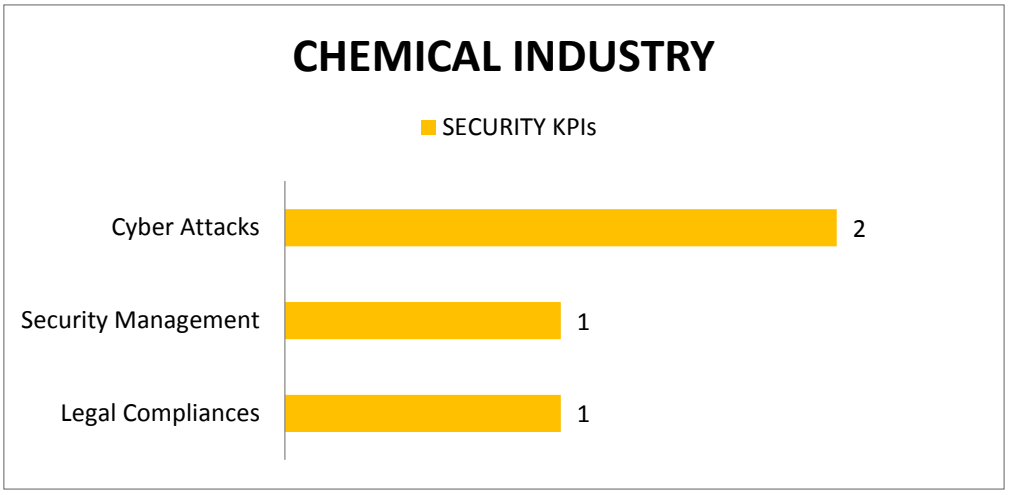


Diagram 25. Security Key Performance Indicators- Chemical Industry

2.4.3 HEALTH & SAFETY Key Performance Indicators at CHEMISTRY Industry

Once again, issues that refer to health and safety are the same that deals with safety. For example fatalities and injuries are accident's results that have been already mentioned at safety. However, regarding to Singapore Chemical Industry Council [77], the number of fatalities and the number of lost time injuries in chemical industry can be assumed as Health and Safety Key Performance Indicators. Moreover, some health and safety KPIs that have been used also in previous industries can be implemented to chemical industry as well. These are no other but the number of injuries that lead to hospitalization and the number of injuries that need meditational treatment so as to be cured. The last one can be measured per total number of employees exposed hours, per country or per employee. Each one of the company at chemistry industry can implement its one KPIs and measure them for a specific time that itself define. This time period usually is quarterly or annually.

As for the health and safety other important KPIs have been presented by Dawson [78], in order to prevent overfilling and overpressure of tanks and pipelines. For the first scope we use the percentage of_completion of inspections and test of tank gauging system and the number of times tank filled above defined safe fill level and for the second we use the number of times pressure is >10bar during transfer and ship unloaded without ship to shore checks correctly completed. Apart from Dawson, also Fanelli [68] refers to the number of physical damages in consequences to health and safety as KPIs and finally the same did Statoil group [73] who mention as KPIs the frequency of serious accidents.

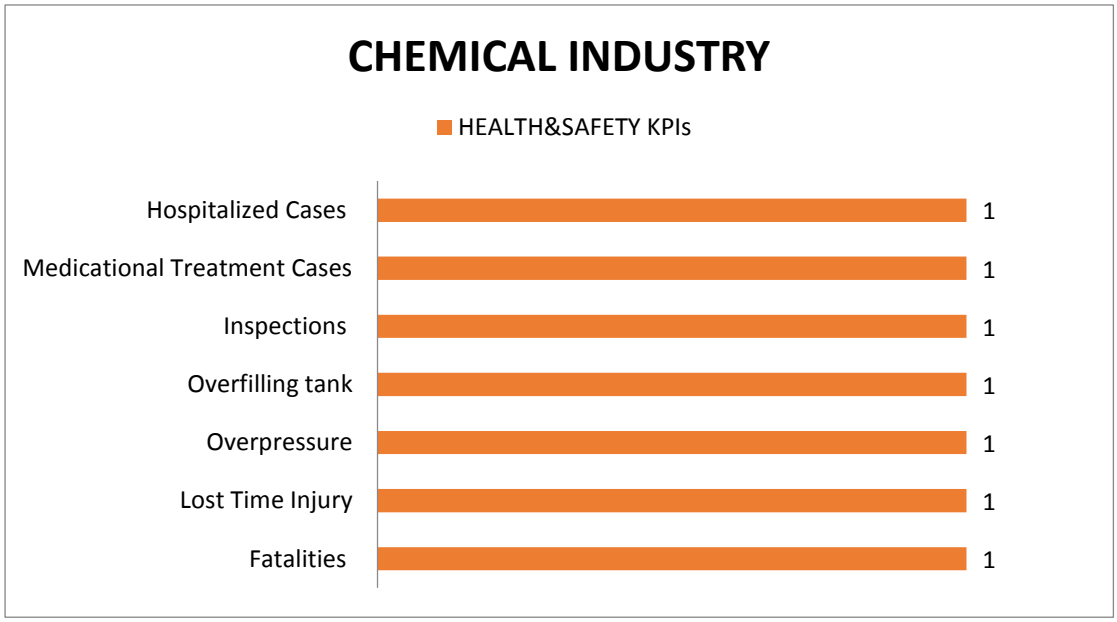


Diagram 26. Health and Safety Key Performance Indicators- Chemical Industry

2.4.4 ENVIRONMENTAL Key Performance Indicators at CHEMICAL Industry

Concerning the environment, chemicals have a great impinge on it, as they influence it by many ways, such as air and water pollution. Regarding to air pollution, the larger amounts of pollutants to the air come from the CO2 and less from NOx, Sox and VOx. So, as Ramona [72] recommends, efficiency Key Performance Indicators for measuring environmental performance can be the amount of CO2, NOx , Sox and VOx emissions at million tones. Moreover, air quality can be influenced by effects such as light, heat and noise. The levels of these phenomena are also used as KPIs in this industry. Maybe the most important, is the amount of releases to the air produced by the chemical's operation. There many kinds of chemicals that are released into the air and the amount of them are measured from the companies. Useful KPIs are the amount of toxic, explosive, corrosive ad inflamed chemicals [79],[80]

Regarding the water pollution, it is necessary to estimate the percentage of polluted water. The number of spills created by company's operation exacts a toll at water's quality. As environmental KPIs are used the volume of chemical and oil spills [81], [82]

Two more subjects needed to be considered are the strategy that every company follows as far as the handling of waste and the recycling rate. Every company that has an environmental philosophy has the obligation to estimates its recycling rate. Possible KPIs are the rate of hazard materials recycling and the rate of non hazard materials recycling. Furthermore it has to separate its waste in order to management in the proper way. KPIs are finally the amount of toxic, hazardous and non hazardous waste [83]

Last environmental KPIs , according to Tugnoli [84] are the extreme weather conditions (wind, waves), low temperature and floods. The first one leads to a possible release of high pressure gas, the uncontrolled sinking can lead to grounding, low temperature can lead to reduction of workability and finally ice formation in components increases the weight and pressure fittings. Other KPIs are the amount of stocks and the location because contact with water, for example, promotes the diffusion and evaporation rate, yields higher losses for off-shore releases in comparison with land pool facilities [85]

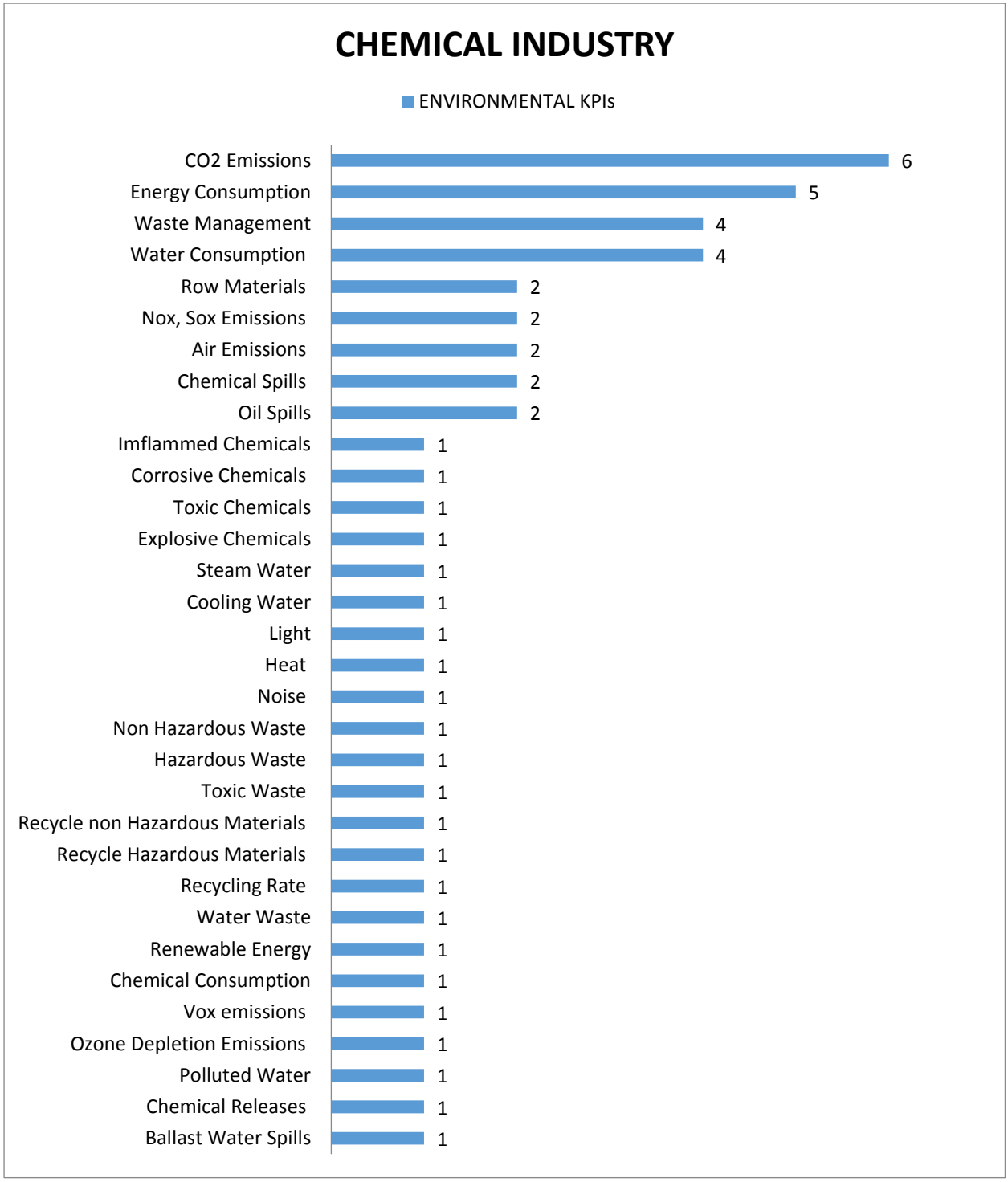


Diagram 27. Environmental Key Performance Indicators- Chemical Industry

2.4.5 KPIs BUBLE DIAGRAM at CHEMICAL Industry

Having collected all the using Key Performance Indicators at the CHEMICAL Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 18) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- CHEMICAL	CATEGORIES	PAPERS	OTHER
S1	Fatalities	2	6	HS
S2	Lost Time Injury	2	2	HS
S3	Inspections Completed on Time	2	3	HS
S4	Maintance completed on Time	1	5	
S5	Inspections (equipment)	1	4	
S6	Training	1	4	
S7	Near misses	1	4	
S8	Emergency Preparedness Program	1	3	
S9	Significant Events	1	2	
S10	System Failures	1	2	
S11	Lost TimeInjury Frequency	1	2	
S12	Total Recordable Injury Rate	1	2	
S13	Total Recordable Injury Frequency Rate	1	2	
S14	Unplanned Shutdowns	1	2	
S15	Investigation	1	2	
S16	Maintance	1	2	
S17	Audits	1	2	
S18	Risk Assessments	1	2	
S19	Accidents	1	1	
S20	Leakages	1	1	
S21	Days Away from Work	1	1	
S22	Human Errors	1	1	
S23	Killed Animals	1	1	
S24	Failures (electrical equipment)	1	1	
S25	Failures in Maintance	1	1	
S26	Safety Deficiencies	1	1	
S27	Incidents Investigated	1	1	
S28	Temperature&Pressure Control	1	1	
S29	Maintance without Defect	1	1	
S30	Safety Meetings	1	1	
S31	Inspections with 0 Defect	1	1	
S32	Emergency Drills Completed	1	1	
S33	Preventive Actions	1	1	

S34	Safety Meetings	1	1	
S35	Compliance with Safety Procedure	1	1	
S36	False Alarms	1	1	
S37	Time Repairing Safety System	1	1	
S38	Time Between Accident & Investigation	1	1	
S39	Fire Prevention	1	1	
E1	CO2 emissions	1	6	
E2	Energy consumption	1	5	
E3	Water consumption	1	4	
E4	Waste management	1	4	
E5	Oil spills	1	2	
E6	Chemical spills	1	2	
E7	Air emissions	1	2	
E8	Nox, Sox emissions	1	2	
E9	Row materials	1	2	
E10	Ballast Water Spills	1	1	
E11	Chemical Releases	1	1	
E12	Polluted Water	1	1	
E13	Ozone Depletion Emissions	1	1	
E14	Vox emissions	1	1	
E15	Chemical Consumption	1	1	
E16	Renewable Energy	1	1	
E17	Water Waste	1	1	
E18	Recycling Rate	1	1	
E19	Recycle Hazardous Materials	1	1	
E20	Recycle non Hazardous Materials	1	1	
E21	Toxic Waste	1	1	
E22	Hazardous Waste	1	1	
E23	Non Hazardous Waste	1	1	
E24	Noise	1	1	
E25	Heat	1	1	
E26	Light	1	1	
E27	Cooling Water	1	1	
E28	Steam Water	1	1	
E29	Explosive Chemicals	1	1	
E30	Toxic Chemicals	1	1	
E31	Corrosive Chemicals	1	1	
E32	Imflammed Chemicals	1	1	
HS1	Medicational Treatment Cases	1	1	
HS2	Hospitalized Cases	1	1	
HS3	Overpressure	1	1	
HS4	Overfilling tank	1	1	
SEC1	Cyber Attacks	1	2	
SEC2	Legal Compliances	1	1	
SEC3	Security Management	1	1	

Matrix 4. KPIs in CHEMISTRY : Number of Categories & Number of Papers

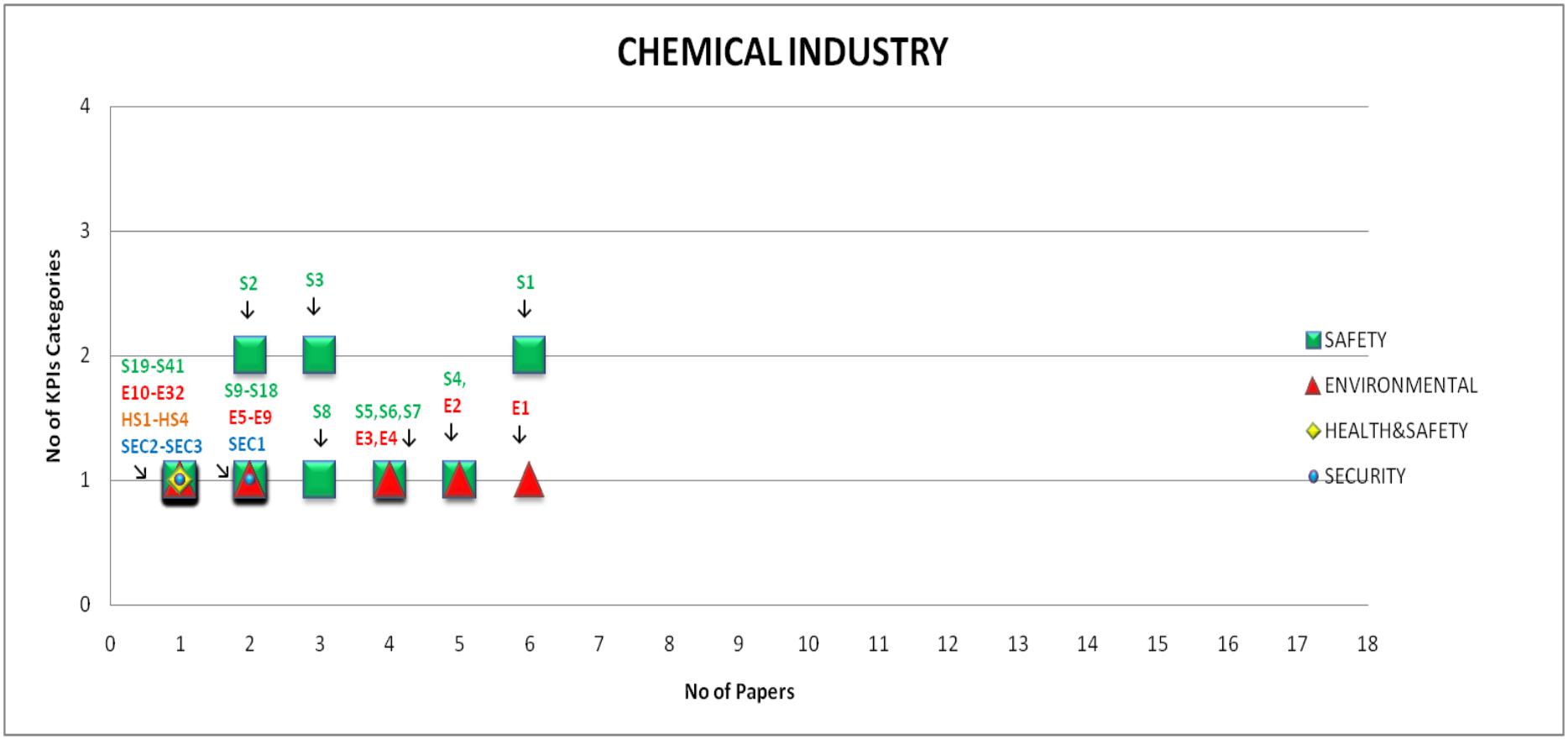


Diagram 28. All KPIs at Chemical Industry

2.5. NUCLEAR POWER PLANT INDUSTRY

One of the most dangerous industries as concerns the safety of the public and the environment is the nuclear power plant industry. Its value for safety, health, and security is enormous due to the tremendous consequences that follow an accident in that field. This industry is a thermal power station in which the heat source is a nuclear reactor. As is typical in all conventional thermal power stations the heat is used to generate steam which drives a steam turbine connected to an electric generator which produces electricity. Indirectly takes place the conversion to electrical energy. Usually the coolant is water, gas or liquid metal according on the type of reactor, which goes to a steam generator and heats water to produce steam. The pressurized steam is then usually fed to a multi-stage steam turbine. After the steam turbine has expanded and partially condensed the steam, the remaining vapor is condensed in a condenser. The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the steam generator and the cycle begins again. Finally, the water-steam cycle corresponds to the Rankine cycle [2].

For this industry we have collected data from 20 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.5.1 SAFETY Key Performance Indicators at NUCLEAR POWER PLANT Industry

To continue with the safety key performance indicators, as Jones [86] refers we use the collective radiation exposure (CRE) and WANO [87] highlights its importance especially for boiling water reactors (BWRs), pressurized water reactors (PWRs), pressurized heavy water reactors (PHWRs) and gas-cooled reactors (AGRs and GCRs) [88]. Another really important KPI used by Jones [86] is the number of the unplanned dose events. Those can be the number of unplanned power changes >20% max power per 7000 worked hours [89], number of safety system failures or unavailability and the most important one is the number of unplanned scrams. The last indicator can be calculated per year or per 7000 worked hours with or without complications given from the user with or without loss of normal heat removal [87], [89], [90]. But any result can't be made if we don't have an appropriate data. To create this we need KPIs as the number of the significant and less significant safety industrial events (and during a plant shut down). We also need το know their causes, so other KPIs are the percentage of events due to procedure deficiencies, training deficiencies, modification process deficiencies and the forced outage hours per year [90], [91]. All the above give us the information to estimate KPIs as the Industrial Safety Accident Rate (ISA) per 200.000 or 1.000.000 worked hours [87]. Another really helpful indicator is the Forced Loss Rate (FLR) which refers to unexpectedly events so we have to take into account the safety system functional failures, the equipment outages per year and the capability loss [87], [89], [91]. Finally the last indicator in that industry we have to pay attention is the fuel and how it affects us. We are interest in the number of leaking fuel assemblies, fuel failure index, fuel reliability index, coolant chemistry index (primary / secondary) both in operation and in maintenance [87],[90], [92]. The importance of maintenance we have already

understood it from the previous industries but also in this we deal with it through inspection procedures such as maintenance effectiveness, risk assessments and emergent work control, post maintenance testing, component design bases inspection, and surveillance testing. [93]

Diagram 29. Safety Key Performance Indicators- Nuclear Power Plant Industry

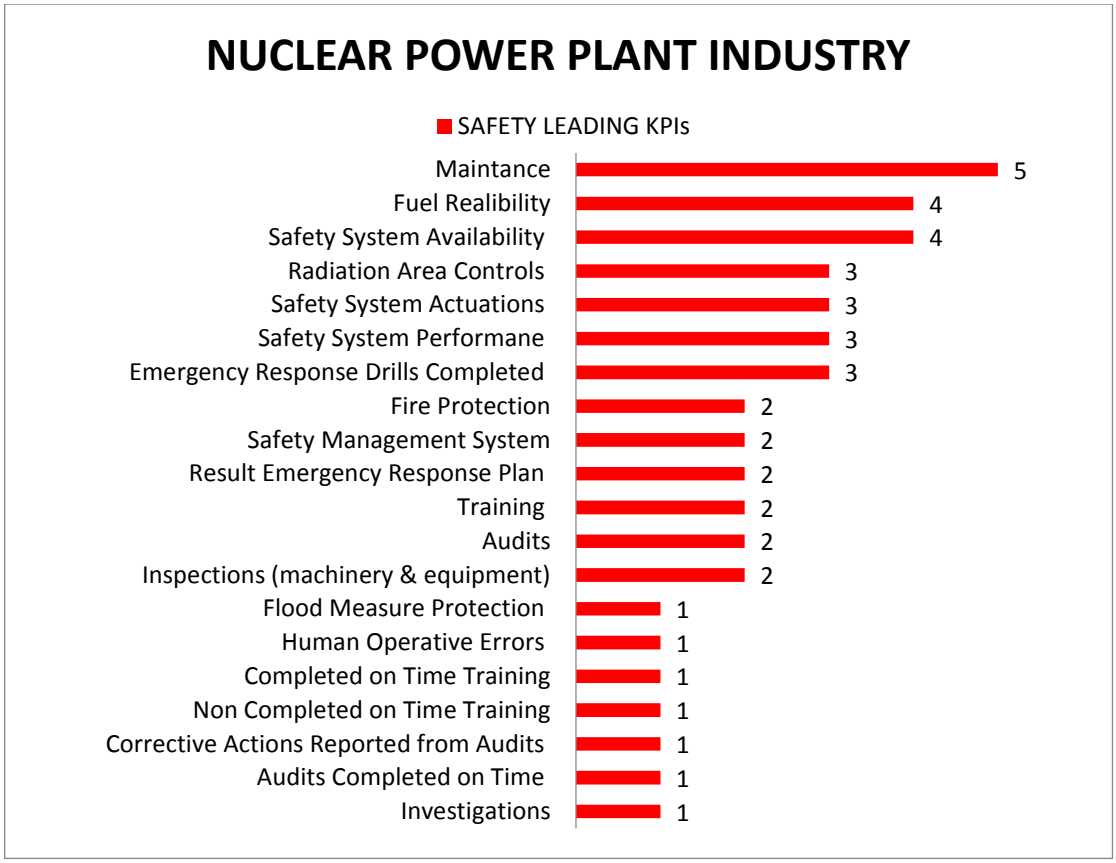


Diagram 30. Safety Leading Key Performance Indicators- Nuclear Power Plant Industry

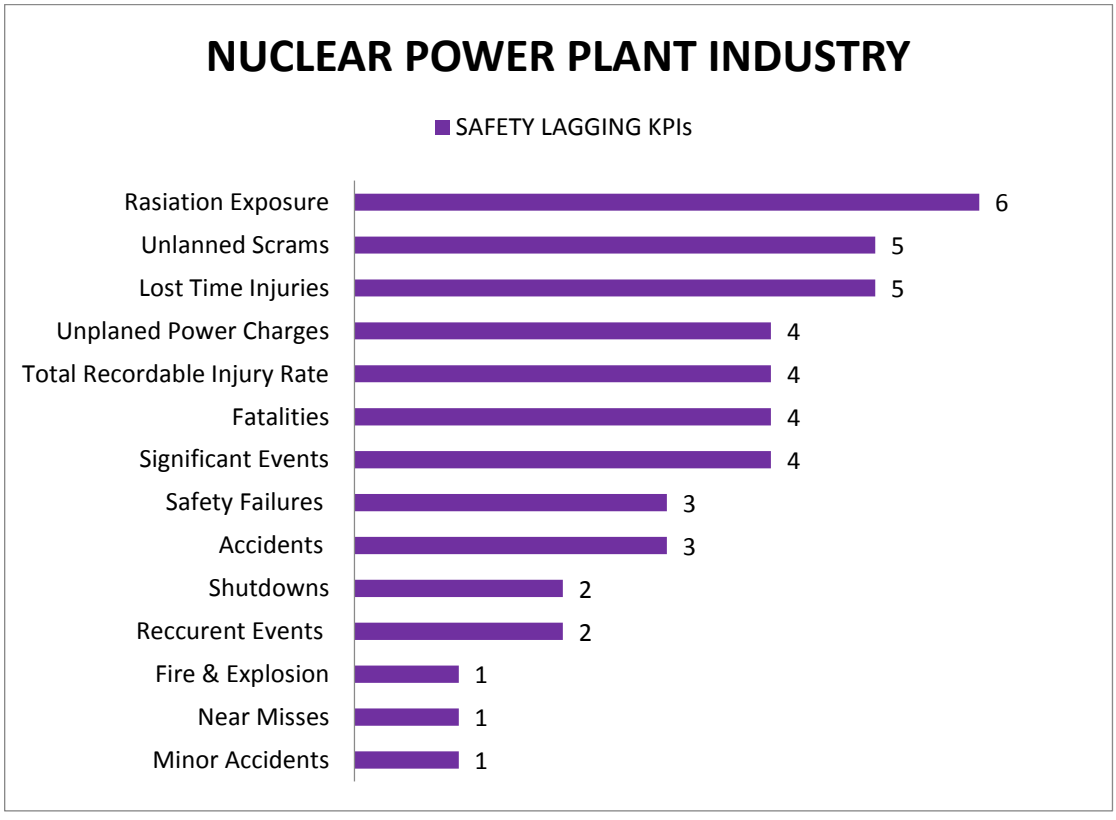


Diagram 31. Safety Lagging Key Performance Indicators- Nuclear Power Plant Industry

2.5.2 SECURITY Key Performance Indicators at NUCLEAR POWER PLANT Industry

Following, to the next category of Key Performance Indicators, those which are associating with security, we have collected the most usually used ones. The first one has been used by companies in nuclear power plant industry, in order to protect it from acts of terrorism. So as to be more specific, the first indicator measures the number of terrorism violation within a specific period for the company. Moreover, in accordance to Buriticá [94] the next KPIs are the number of cases that are related to property damage and also the necessary energies for protecting against vandalism. The last KPI can be the number of measures for protection from vandalism or generally if exist such measures or not. Finally Tomic [90] has also referred to security and measures to estimate company's security performance by propose the proper KPIs. One example of the proposed indicators is the existence or not of a Security Performance System established by the company [95].

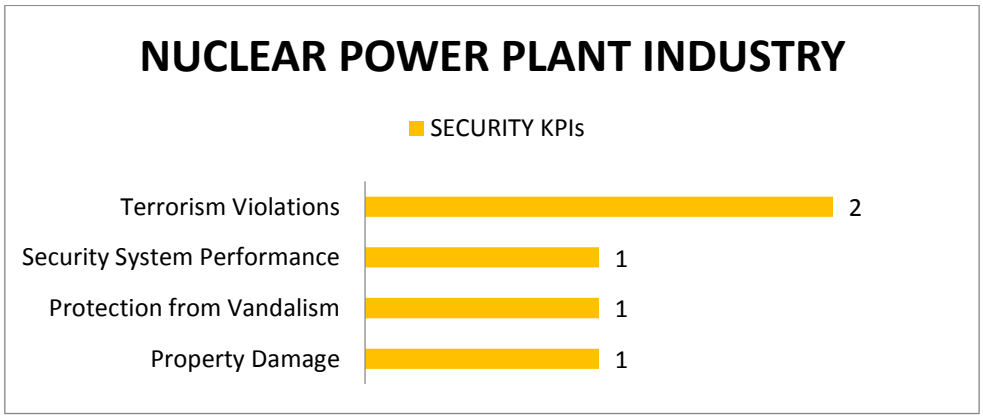


Diagram 32. Security Key Performance Indicators- Nuclear Power Plant Industry

2.5.3 HEALTH & SAFETY Key Performance Indicators at NUCLEAR POWER PLANT Industry

At nuclear power plant industry many of the health and safety indicators are also safety ones, as happens also to the most previous industries.

As concerns health and safety of the public, many efforts have been made in order to protect public from radiation exposure, through limiting worker's exposure to it. [90],[96],[97] One other common used KPI in accordance to Jones [86], is the number of personnel contaminations. If an accident occurs, in order to protect public health from the radionuclide emission, as NRC [89] refers we use KPIs as Reactor Coolant System (RCS) Activity per gram and Reactor Coolant System (RCS) Leakage per minute for every month. Moreover, to protect public health against solid and liquid amount of waste we use radiological effluent technical specifications or offsite dose calculation manual and finally in order to protect it against radiation from nuclear reactor, we can use occupational exposure control effectiveness.

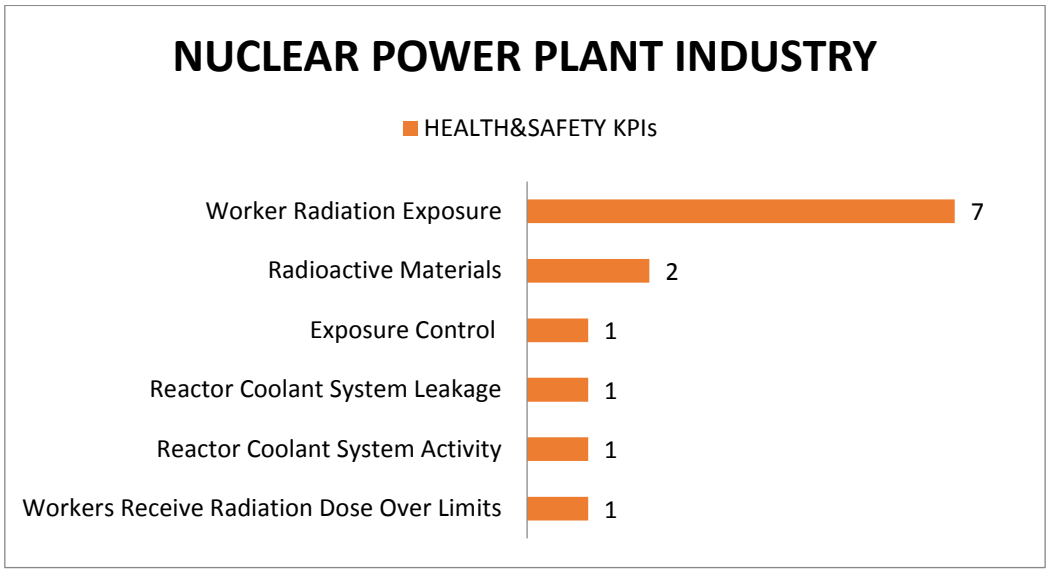


Diagram 33. Health and Safety Key Performance Indicators- Nuclear Power Plant Industry

2.5.4 ENVIRONMENTAL Key Performance Indicators at NUCLEAR POWER PLANT Industry

Last but not least is the environmental performance. After our research about the used Key Performance Indicators we realize that this industry has the most common indicators for between health and safety and environment. This can be easily understood if we take into account the major hazards that are ambushed from Nuclear Power Plant industry and can lead to harmful consequences both for health and safety and for environment as well. These are relevant to radiation exposure. As KPIs can be used the amount of radioactive materials, radioactive waste and non radioactive waste which are released into the environment. As IAEA team [98] suggests other separate KPIs can be assumed the amount of radioactive materials which is released in a protected area and the number of radiation controls holding in this area. [99],[100]

Radiation exposure can be harmful mainly to the air quality. Apart from radiation, there are also other substances that affect negatively air quality such as air emissions. As happens to the previous industries the most significant emission is the Greenhouse Gases Emissions which for this reason is one of the proposed KPIs to industry. In addition, water quality is also affected by a nuclear power plant operation by many means. Fuel leakages and chemical spills are the most common used indicators. [101],[102], [103]

Finally, concerning the company's environmental attitude is necessary to have the right strategy as concerns the recycling rate and the waste management. These are two topic with high level of importance for nowadays companies at all fields and for that reason at nuclear power plant industry there are KPIs estimating company's performance according to the above issues. Moreover, other parameters that have to be under consideration are the electricity, energy, fuel and geochemical fluid consumption. [104], [105]

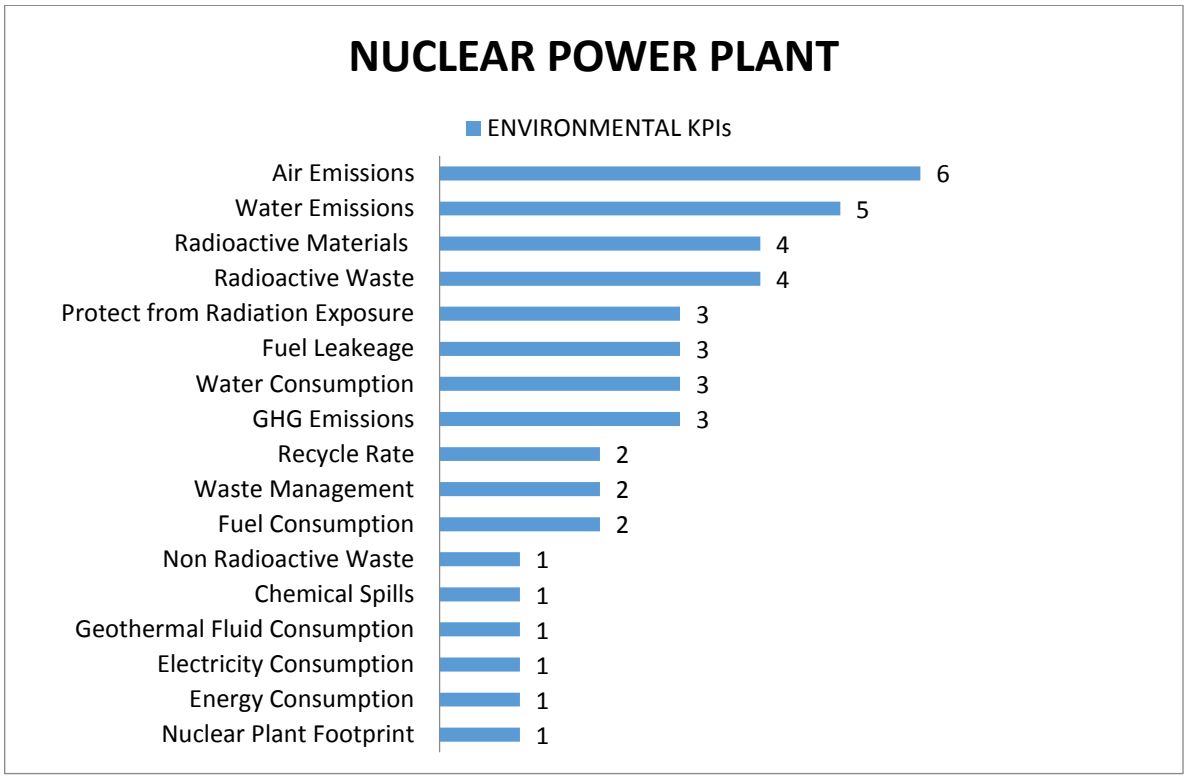


Diagram 34. Environmental Key Performance Indicators- Nuclear Power Plant Industry

2.5.5 KPIs BUBLE DIAGRAM at NUCLEAR POWER PLANT Industry

Having collected all the using Key Performance Indicators at the NUCLEAR POWER PLANT Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 20) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- NUCLEAR POWER PLANT	CATEGORIES	PAPERS	OTHER
S1	Significant Events	2	6	
S2	Radiation Area Controls	2	4	E
S3	Rasiation Exposure	1	6	
S4	Unlanned Scrams	1	5	
S5	Lost Time Injuries	1	5	
S6	Fatalities	1	4	
S7	Total Recordable Injury Rate	1	4	
S8	Unplaned Power Charges	1	4	
S9	Fuel Realibility	1	4	
S10	Safety System Availability	1	4	
S11	Accidents	1	3	
S12	Maintance	1	3	
S13	Safety System Actuations	1	3	
S14	Safety Failures	1	3	
S15	Emergency Response Drills Completed	1	3	
S16	Safety System Performane	1	3	
S17	Reccurent Events	1	2	
S18	Shutdowns	1	2	
S19	Human Operative Errors	1	2	
S20	Training	1	2	
S21	Fire & Explosion	1	2	
S22	Audits	1	2	
S23	Inspections (machinery & equipment)	1	2	
S24	Result Emergency Response Plan	1	2	
S25	Fire Protection	1	2	
S26	Completed on Time Training	1	1	
S26	Minor Accidents	1	1	
S27	Near Misses	1	1	
S28	Non Completed on Time Training	1	1	
S29	Corrective Actions Reported from Audits	1	1	
S30	Audits Completed on Time	1	1	

S31	Investigations	1	1	
S32	Safety Management System	1	1	
E1	Radioactive Materials	2	4	H&S
E2	Protect from Radiation Exposure	2	3	H&S
E3	Air Emissions	1	6	
E4	Water Emissions	1	5	
E5	Radioactive Waste	1	4	
E6	Fuel Leakeage	1	3	
E7	GHG Emissions	1	3	
E8	Water Consumption	1	3	
E9	Fuel Consumption	1	2	
E10	Waste Management	1	2	
E11	Recycle Rate	1	2	
E12	Geothermal Fluid Consumption	1	1	
E13	Electricity Consumption	1	1	
E14	Non Radioactive Waste	1	1	
E15	Nuclear Plant Footprint	1	1	
E16	Energy Consumption	1	1	
E17	Chemical Spills	1	1	
HS1	Worker Radiation Exposure	1	7	
HS2	Workers Receive Radiation Dose Over Limits	1	1	
HS3	Reactor Coolant System Activity	1	1	
HS4	Exposure Control	1	1	
SEC1	Terrorism Violations	1	2	
SEC2	Property Damage	1	1	
SEC3	Protection from Vandalism	1	1	
SEC4	Security System Performance	1	1	

Matrix 5. KPIs in NUCLEAR POWER PLANT : Number of Categories & Number of Papers

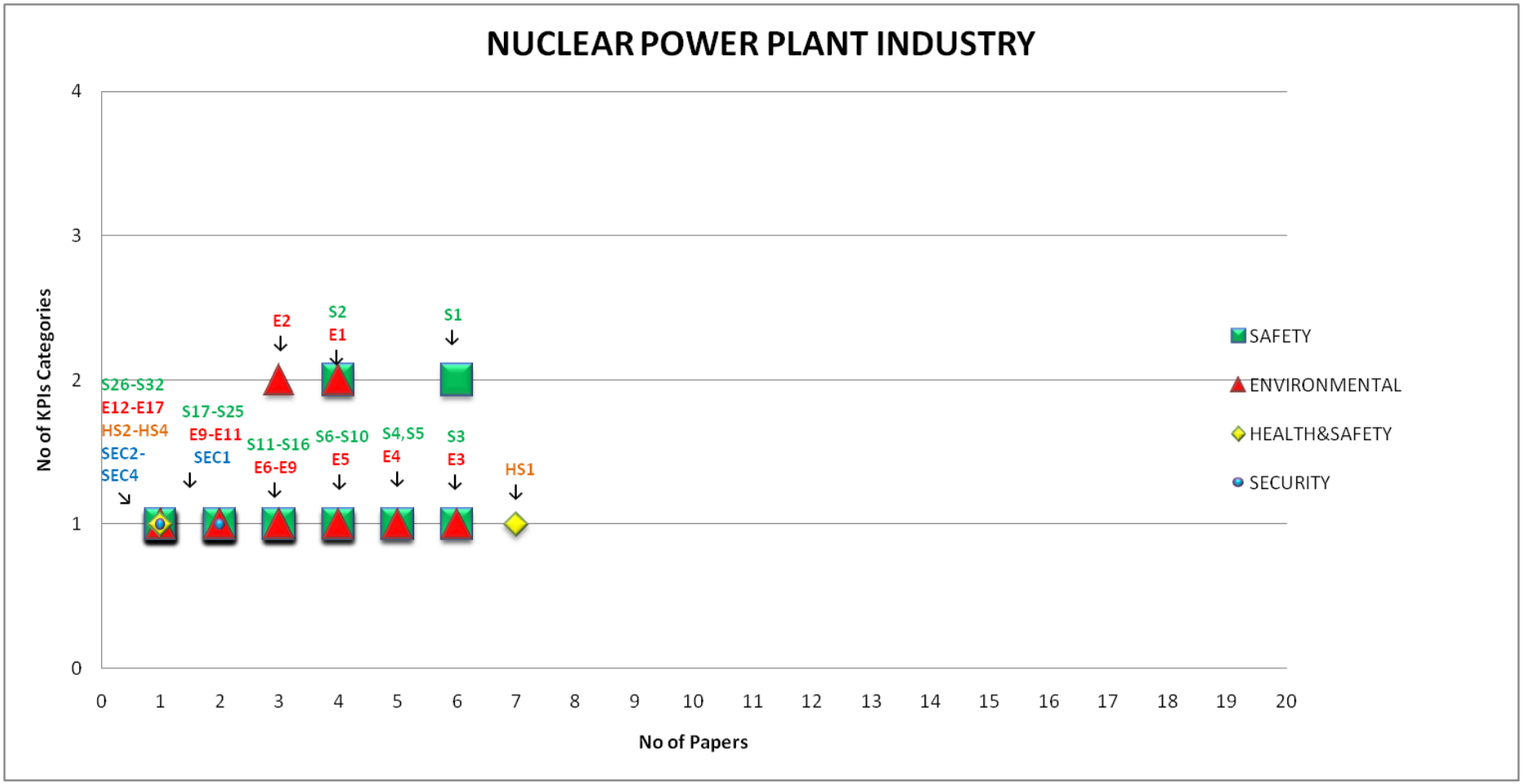


Diagram 35. All KPIs at Nuclear Power Plant Industry

2.6. OFFSHORE INDUSTRY

Beginning our occupation with sea, the first industry we are going to delve into is the Offshore Industry. In a marine environment in order to product and transmit electricity, oil gas and other resources, proper facilities and constructions are installed. These contribute to create the offshore construction. Due to the cost of the offshore structures are preferred to be done onshore by the following way. One strategy is to fully construct the offshore facility onshore, and tow the installation to site floating on its own buoyancy. Bottom founded structure are lowered to the seabed by de-ballasting whilst floating structures are held in position with substantial mooring systems. [2]

Part of the offshore industry can be assumed all the construction energies including foundations engineering, structural design, construction, and/or repair of offshore structures. Example of offshore industry's operation is the following: Some example of the offshore industry is the following:

- Subsea oil and gas developments
- Offshore platforms – fixed platforms,
- Floating oil and gas platforms
- Offshore wind power
- Submarine pipelines

For this industry we have collected data from 20 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.6.1 SAFETY Key Performance Indicators at OFFSHORE Industry

In the Offshore industry the most critical indicators are the safety ones. A lot of effort has already been made by a lot of experts who have concluded to the following safety key performance indicators (KPIs) divided them into leading and lagging.

The leading ones are those which provide information that helps the user respond to changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes. The most well known leading safety KPI is the number of inspections both for the equipment and the machinery and also the number of them which are outside limits or scheduled on time [106],[107],[108],[109],[110],[111]. Apart from the number of inspections in order to find out the safety level's we use as leading KPIs the number of audits (periodic, surprised, event drilling) investigations, and personal surveys and visits [106],[107],[108],[109],[110],[111]. As Carson [110] estimates it is also essential to use as a KPI the number of incidents investigated by the number of inspections and audits and the time between investigations. Continue with the next KPI which deals with the number of training courses [112], [113]. As concerns training, both Songa Offshore [109] and Carson [110] use as KPI the percentage of the trained employees and as Sutton [106] and the National Academes [108] suggest the number of completed on time training courses and emergency drills. The number of safety meetings and the percentage of the employee's attendance in them are also considered by Carson [110] part of the training process and so

possible KPIs. Another very useful indicator is maintance [114]. Concerning maintance, Whewel [112] and Toma [115] refer as KPIs the number of deferred or non completed on time or backlogged maintance. Finally, the last indicators deals with performance and the most common ones KPIs are those estimating compliance and non compliance with the safety rules [107],[111],[115]. For that reason Sutton [106] and SSE Company [108] announce as KPIs the index of Safety Behavior Observed (SBO) and the number of the positive SBO. They also suggest in order to monitor the progress as KPIs the number of positive rewards and recognition given [106] and the number of tool-box talks completed [107], [110], [124]. Last but not least follow up reports and recommendations about the safety progress can be considered as one more leading KPI.

Lagging indicators are not so indispensable for the company as the leading ones as they follow an unwanted event. As we have already seen in more other industries the most frequent lagging safety KPIs are the number of accidents [111], [116] and their consequences. Consequences are considered the number of fatalities [110],[114], near misses [106],[109],[116], non-injury [116], first aid events [110] and injuries . As for the injuries, a lot of work has been made and nowadays are commonly used two indexes the Total Recordable Injury Rate (TRIR) and the Lost Time Injury Rate (LTIR) [107],[110],[116],[124]. Also, as SBII Offshore Company [118] presents the above indexes can be measured according to their frequency and the suggested KPIs are Total Recordable Injury Frequency Rate (TRIFR) and Lost Time Injury Frequency Rate (LTIFR). Another category of KPIs are related to releases and as many writers suggest hydrocarbon releases from plant and equipment are a common one and it can be categorized into minor, significant and major [112],[115],[119],[120]. Moreover, according to Tugnoli [121] the stored inventory releases are also a possible KPI. Accidents apart from injuries can also lead to dangerous occurrences, so as KPIs are considered the number of collisions, fires and explosions and groudings [106], [119], [121],[120],[124]. In an offshore industry lurks the possibility of an unwanted kick. Knowing that, NOPSEMA [119] and Jackobs [114] suggest as KPIs the number of well kicks, their frequency and response time.

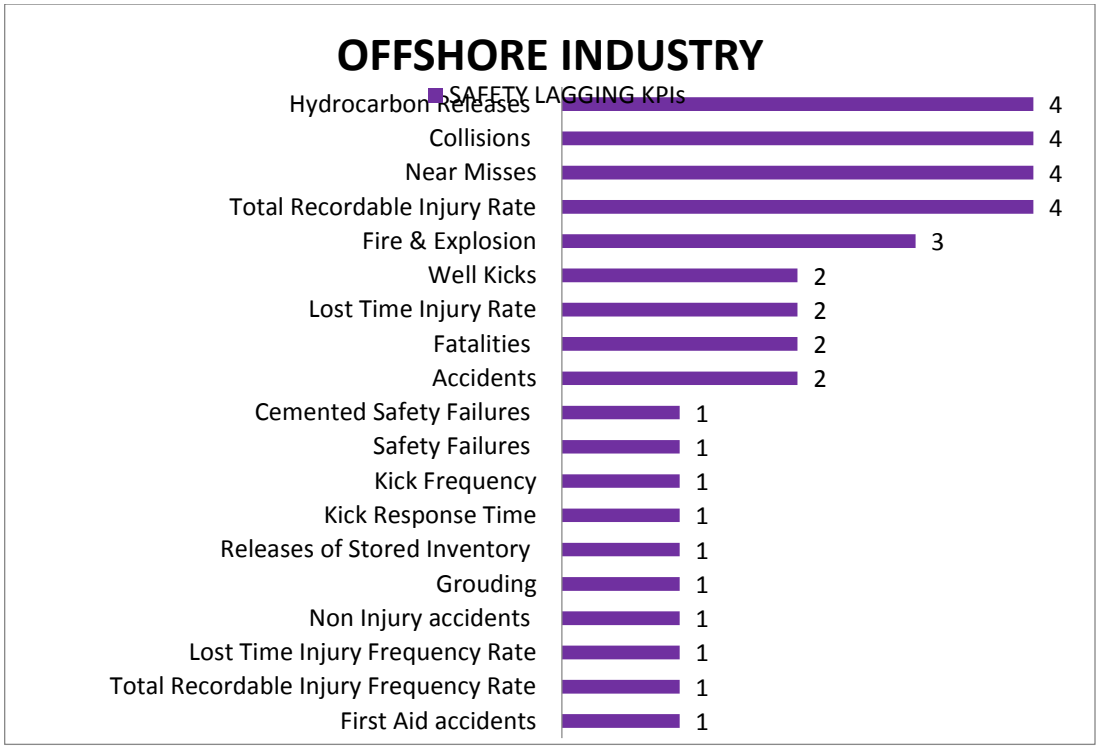


Diagram 36. Safety Lagging Key Performance Indicators- Offshore Industry

Diagram 37. Safety Leading Key Performance Indicators- Offshore Industry

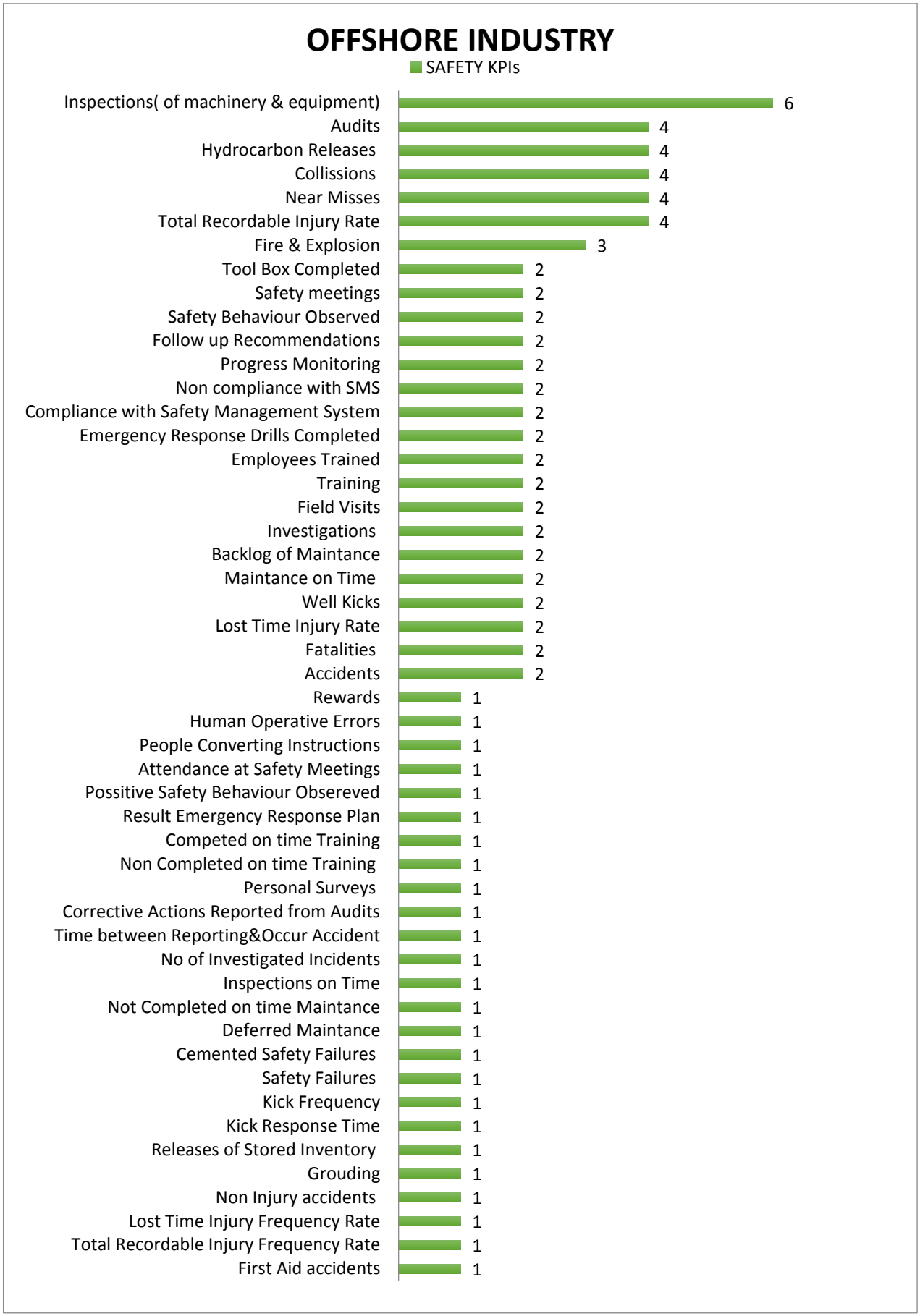


Diagram 38. Safety Key Performance Indicators- Offshore Industry

2.6.2 SECURITY Key Performance Indicators at OFFSHORE Industry

Security is one of the first priorities that an offshore company needs to ensure. In order to estimate its security levels, the company uses a set of key performance indicators (KPIs). It is well known how dangerous can be an unwanted release of the stored inventory and according to Tugnoli [121] events that can lead to an instantaneous or continually release considered security KPIs. The first one that he suggested is the existence and use of exposure devices on the deck that apart from release can lead to an ignition and even more to ship's hull failure. Another important KPI is the number of attacks. The most common are attacks with weapons which can lead to a possible perforation of the hull and tanks and also explosion. Tugnoli also pays attention to the number of direct attacks when hijackers take control of the ship as they can damage the equipment in order to release liquid gas (LNG) to the environment or attack with explosive small ships. Finally, one last security KPI is suggested by Wendy [114], the number of civil and administration violations, minor, significant or major per million produced barrels .

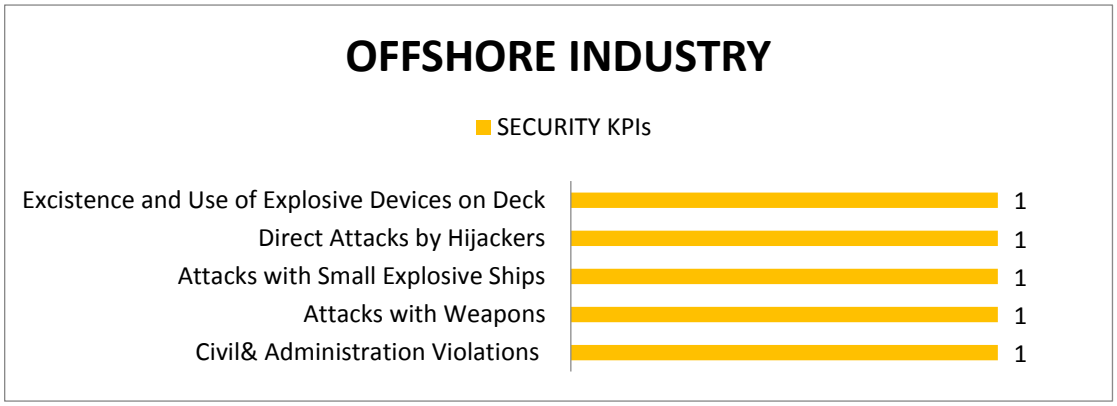


Diagram 39. Security Key Performance Indicators- Offshore Industry

2.6.3 HEALTH & SAFETY Key Performance Indicators at OFFSHORE Industry

The number of the worker's accidents and their consequences can be regarded also as health and safety KPIs, so Ziff Energy Company [116] proposes we take consideration the number of fatalities [106], [110],[112], [114],[119],[122] near misses [112], medical treatment cases [108], non Injuries , Illnesses and Injuries. A large amount of work estimates the number of injuries one of the most crucial indicators for a company [106], [110],[112], [114],[119]. For that reason, as we have already said in the previous paragraph, it is common used an index considering them known as Total Recordable Injuries Rate (TRIR) which estimates the number of injuries per the offshore population. Due to injuries importance Health & Safety Executive [123] categozised them as for their results, causes and place in which happen. So we have injuries lead to hospital admissions, fractures, amputations [7], [10]. Also injuries caused due to moving or flying objects, falls from height and slips and trips. Finally, we have injuries in maintance/ constraction, deck operations, drilling, management, production, diving part of the company. Another useful KPI concerning injuries is the Lost Time Injuries which measures the number of days absence from work due to an injury .Finally the number of illnesses is suggested as a possible KPI and also the Lost Time Illnesses like the previous one [112], [119]. SSE company suggests also as KPIs the number of dangerous occurrences and the number of incidents with potential to be worse. As for the dangerous occurrences, again we estimate the number of fires [114], [123]. Finally, hydrocarbon releases are considered also as an health and safety KPI [112],[114] and the same stands for the unwanted pollutants releases [123].

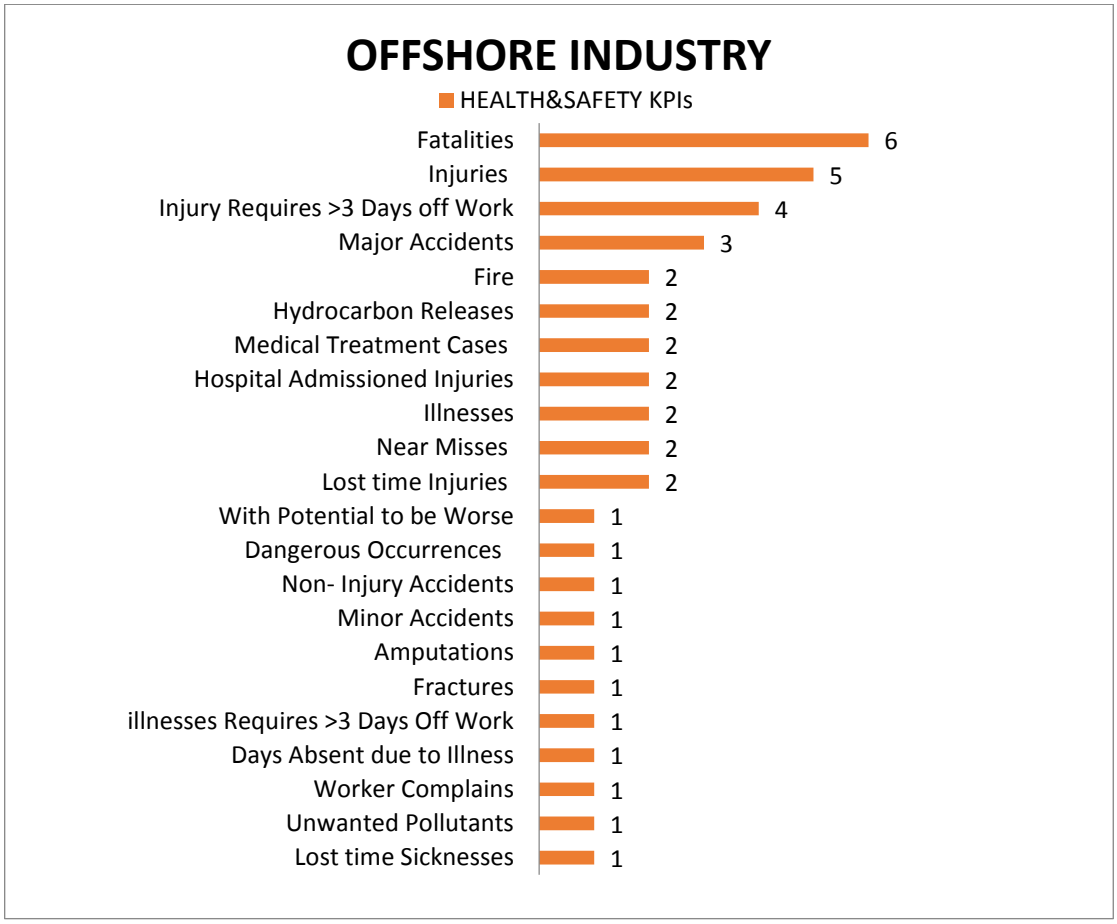


Diagram 40. Health and Safety Key Performance Indicators- Offshore Industry

2.6.4 ENVIRONMENTAL Key Performance Indicators at OFFSHORE Industry

The effects that an offshore company has to the environment can be disastrous so each company control its environmental safety performance through some KPIs. According to Australian Nation Audit Office work [111] environmental investigations, inspections, assessments and enforcements operate as KPIs. Also Carson [110] adds to these the number of environmental awards and the biological data outside action limits. Also, Tugnoli [121] underlines the meaning of weather conditions and uses as KPIs the following: extreme weather, low temperature, ice formation of the equipment, loss of mooring, flooding. The meaning of releases and emissions of pollutants has already been mentioned in the previous paragraphs but as an environmental KPI it is the most common used [118],[124]. More attention is given to Greenhaus Gase's (GHG) emissions {CO2, N2H, CH4, SF6, HFCs, PFCs.} and especially to CO2 emissions per hydrocarbon production annually [118],[123]. NOPSEMA [119] includes to environmental KPIs the hydrocarbon gases and petroleum liquid emissions. Finally environmental KPIs include the gas flared and stored inventory releases and also SO2, NOx and VOCs emissions [114], [118], [121]. Next category of KPIs pertains to the number of reported spills to air, water, land. More dangerous are the oil-petroleum spills which can be divided into categories concerning their number and volume (major, significant, minor) and according to Nistov [120] hydrocarbon spills are also interesting. Furthermore Carson [110] mention two more well known KPIs energy consumption and quantity of waste [124]. As regards the energy one more KPI is the number of energy generated from renewable sources [108] and as for the quantity of waste as a KPI supposed to be the mass of recycling waste and restavfall forbernings [123].

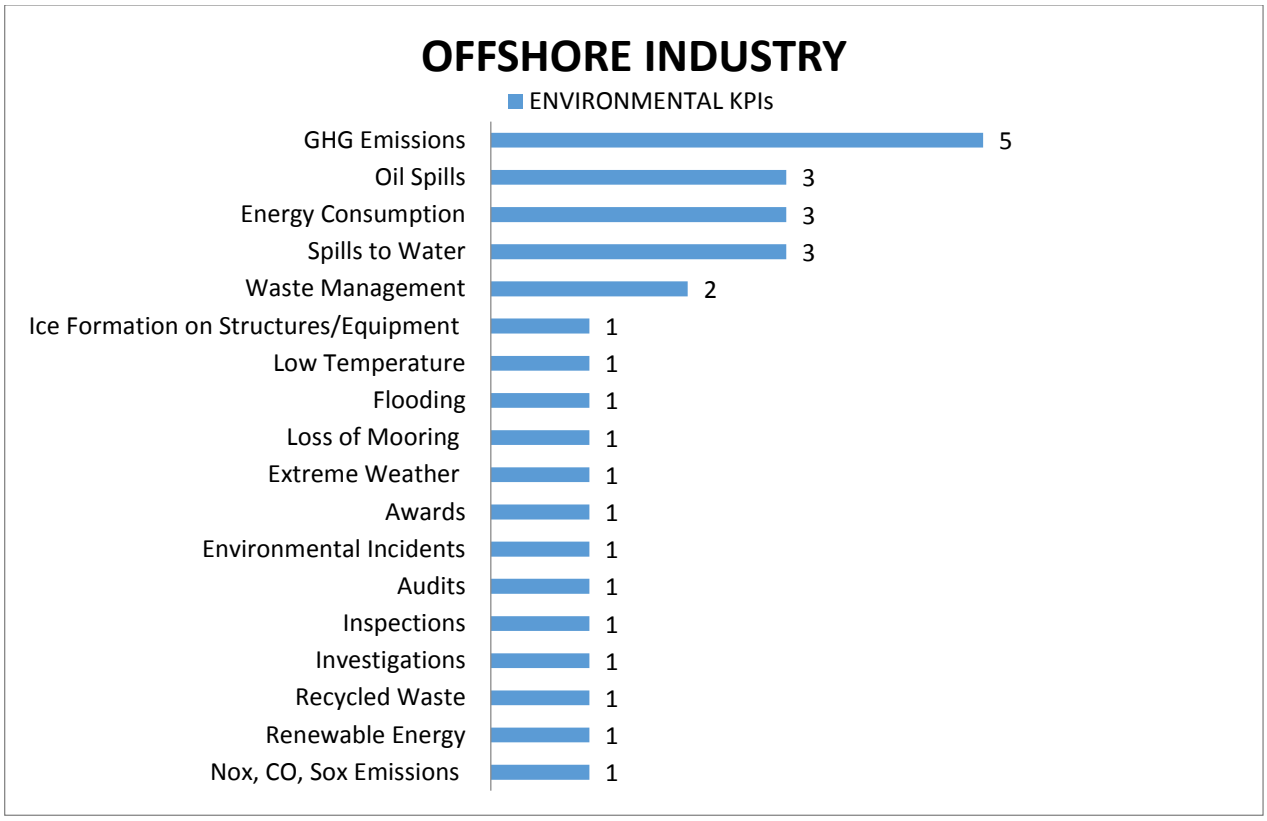


Diagram 41. Environmental Key Performance Indicators- Offshore Industry

2.6.5 KPIs BUBLE DIAGRAM at OFFSHORE Industry

Having collected all the using Key Performance Indicators at the Aviation Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 20) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- OFFSHORE	CATEGORIES	PAPERS	OTHER
S1	Hydrocarbon Releases	3	5	E, HS
S2	Inspections(of machinery & equipment)	2	6	E
S3	Near Misses	2	5	HS
S4	Collissions	2	5	HS
S5	Fire & Explosion	2	5	HS
S6	Audits	2	4	E
S7	No of Investigated Incidents	2	3	E
S8	Rewards	2	2	E
S9	Investigations	2	1	E
S10	Accidents	1	2	
S11	Field Visits	1	2	
S12	Backlog of Maintance	1	2	
S13	Maintance on Time	1	2	
S14	Training	1	2	
S15	Employees Trained	1	2	
S16	Emergency Response Drills Completed	1	2	
S17	Compliance with Safety Management System	1	2	
S18	Non compliance with SMS	1	2	
S19	Progress Monitoring	1	2	
S20	Safety Behaviour Observed	1	2	
S21	Tool Box Completed	1	2	
S22	Follow up Recommendations	1	2	
S23	Well Kicks	1	2	
S24	Safety meetings	1	2	
S25	Total Recordable Injury Frequency Rate	1	1	
S26	Lost Time Injury Frequency Rate	1	1	
S27	First Aid accidents	1	1	
S28	Inspections on Time	1	1	
S29	Personal Surveys	1	1	
S30	Time between Reporting& Occur Accident	1	1	
S31	Corrective Actions Reported from Audits	1	1	
S32	Deferred Maintance	1	1	
S33	Not Completed on time Maintance	1	1	
S34	Non Completed on time Training	1	1	
S35	Competed on time Training	1	1	
S36	Possitive Safety Behaviour Obsereved	1	1	
S37	Grouding	1	1	
S38	Result Emergency Response Plan	1	1	
S39	Kick Response Time	1	1	
S40	Kick Frequency	1	1	
S41	Safety Failures	1	1	
S42	Cemented Safety Failures	1	1	
S43	Attendance at Safety Meetings	1	1	
S44	People Converting Instructions	1	1	
S45	Releases of Stored Inventory	1	1	
S46	Human Operative Errors	1	1	

E1	Unwanted Pollutant Releases	2	4	HS
E2	Hydrocarbon Releases	2	2	HS
E3	GHG Emissions	1	5	
E4	Oil Spills	1	3	
E5	Spills to Water	1	3	
E6	Energy Consumption	1	3	
E7	Waste Management	1	2	
E8	Nox, CO, Sox Emissions	1	1	
E9	Environmnetal incidents	1	1	
E10	Renewable Energy	1	1	
E11	Recycled Waste	1	1	
E12	Extreme Weather	1	1	
E13	Loss of Mooring	1	1	
E14	Flooding	1	1	
E15	Low Temperature	1	1	
E16	Ice Formation on Structures/Equipment	1	1	
E17	Assesments	1	1	
HS1	Total Recordable Injury Rate	2	7	S
HS2	Lost time Injuries	2	7	S
HS3	Fatalities	2	6	S
HS4	Non Injury accidents	2	1	S
HS5	Major Accidents	1	3	
HS6	Injury Requires >3 Days off Work	1	3	
HS7	Illnesses	1	2	
HS8	Hospital Admissioned Injuries	1	2	
HS9	Medical Treatment Cases	1	2	
SH10	Lost time Sickness	1	1	
HS11	Fractures	1	1	
HS12	Amputations	1	1	
HS13	Minor Accidents	1	1	
HS14	Dangerous Occurrences	1	1	
HS15	With Potential to be Worse	1	1	
HS16	Worker Complains	1	1	
HS17	Days Absent due to Illness	1	1	
HS18	illnesses Requires >3 Days Off Work	1	1	
HS19	Non Injury accidents	1	1	
SEC1	Civil& Administration Violations	1	1	
SEC2	Direct Attacks by Hijackers	1	1	
SEC3	Attacks with Weapons	1	1	
SEC4	Attacks with Small Explosive Ships	1	1	
SEC5	Existence and Use of Explosive Devices on Deck	1	1	

Matrix 6. KPIs in OFFSHORE : Number of Categories & Number of Papers

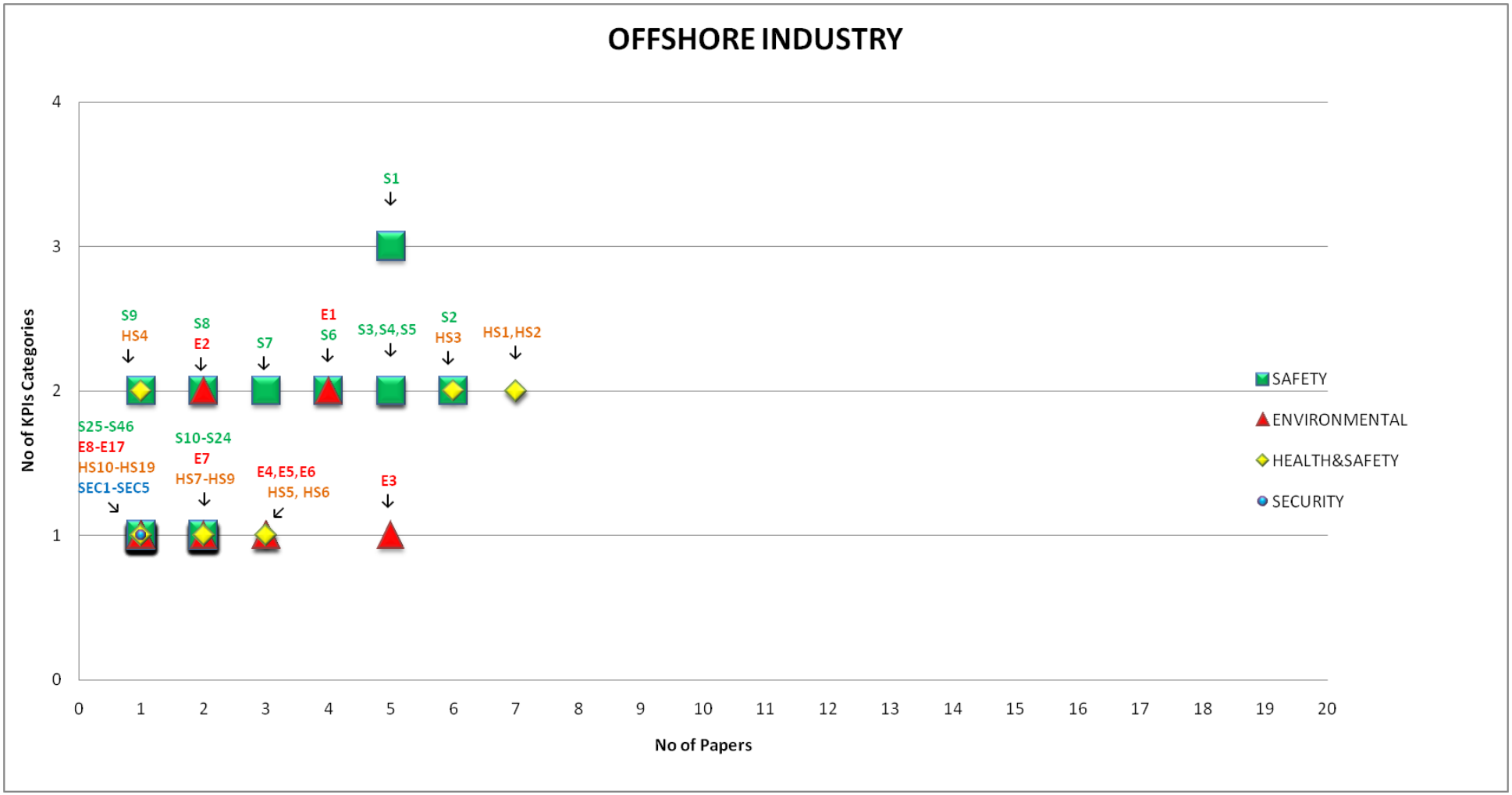


Diagram 42. All KPIs at Offshore Industry

2.7. PORT INDUSTRY

Port industry since last decade focuses on measuring and estimating its performance in four major categories. These categories include environment, safety, health and safety and last but not least the security. According to literature a well organized way to estimate the efficiency and performance is to use a list of Key Performance Indicators (KPI's). In order to conclude in the final common used KPI's a decent literature review has been made and this chapter aims to summarize the results.

For this industry we have collected data from 21 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.7.1 SAFETY Key Performance Indicators at PORT Industry

The second more important category of KPIs is the safety one. There is again the segregation between leading and lagging indicators and because of their importance we begin our analysis with the first ones. To begin with, Gligorea [125] who inserts two complex indexes the Nautical Safety Index and the Nautical Safety Efficiency Index. Continuing with Sumatra paper [126] in which is mentioned the number of ship calls and is has been also categorized by type of cargo (General/liquid/Ro-RO) , by draft (<9.5 / 9.6-10.5 / >10.5) and by length (<200 / >200). Finally, as we are used to, the number of inspection is one of the most common leading safety KPIs. In ports, inspections pertain to the hazard materials and as ICL company [127] mention KPIs that are in use are the number of occurrences in which there is improper costumer placarding or documentation per month.

Lagging safety KPIs, as usual, concerns accidents and their consequences. In ports, the number of accidents is considered by Gligorea [125] as an important KPI and they have been torn in categories which also are considered by Almi Tankers [128]. They present in their work two categories, Total incidents which include all accidents apart from near misses and minor illnesses and Critical Incidents such as pollution, serious illnesses or injuries. Both of them calculated per total number of vessels. Also as usual the number of injuries and the number of lost time injuries are considered as KPIs [128],[129],[130]. Furthermore as important as the previous ones are the KPIs which involve dangerous occurrences in ports such as the number of fires and explosions, collisions and falls [131] and finally Tugnoli [132] says that attention has to been paid to leaks and continuous releases.

Diagram 43. Safety Leading Key Performance Indicators- Port Industry

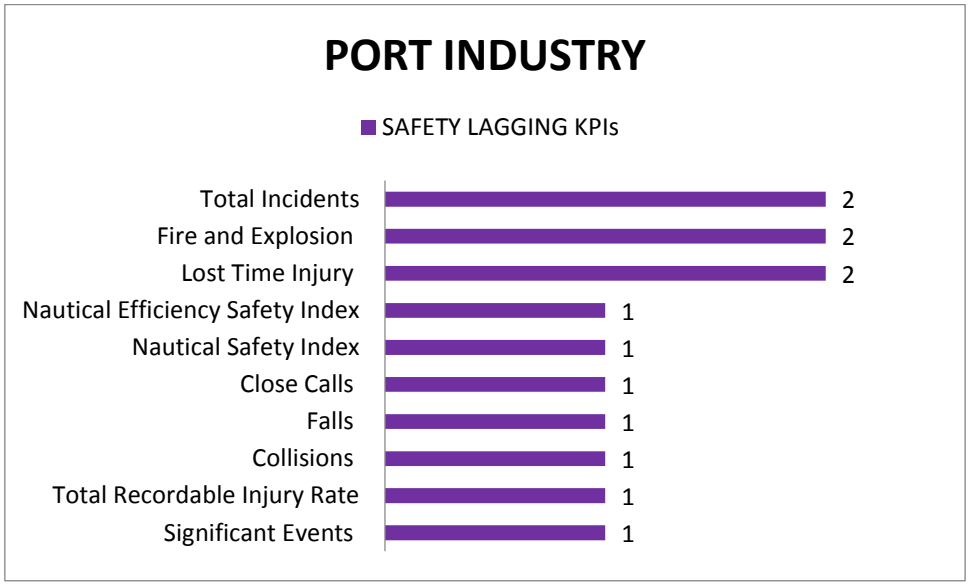


Diagram 44. Safety Lagging Key Performance Indicators- Port Industry

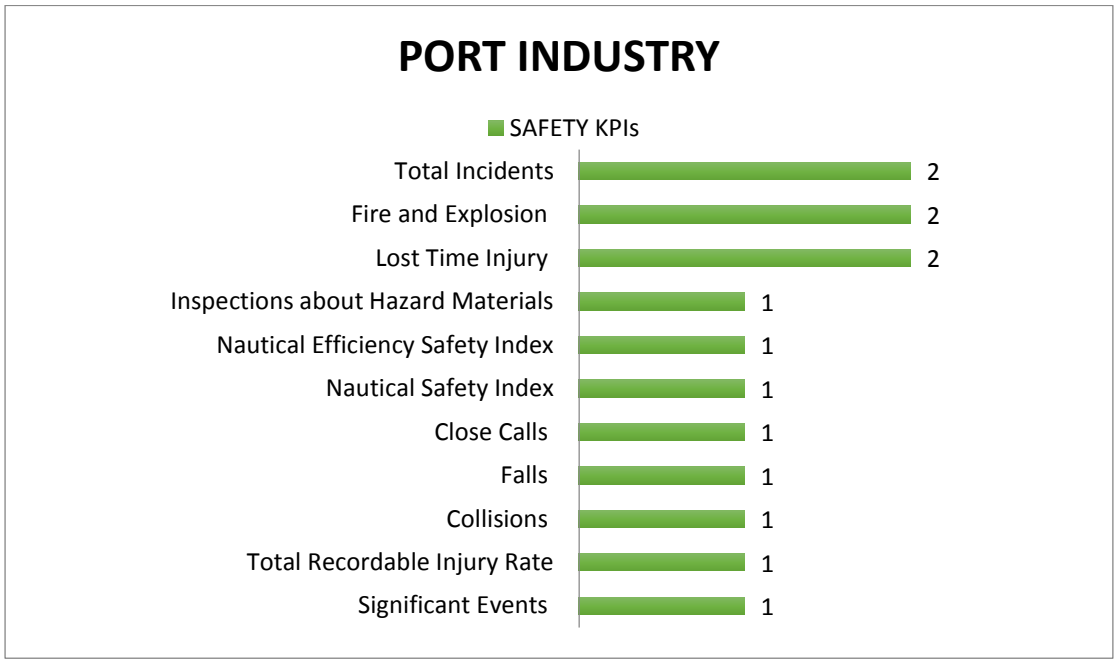


Diagram 45. Safety Key Performance Indicators- Port Industry

2.7.2 SECURITY Key Performance Indicators at PORT Industry

Security in ports is a matter of limited extend as the variety of indicators used to observe and measure the security performance is not big enough. The first category of them appertain to cargo and in accordance to Mano [133] the first security KPIs are the number of stolen, broken and damaged cargo. In order to control the security levels one KPI introduced by Sumatra [126] is the (non) compliance with the International Ship and Port Security Code (ISPS) measured by annually audits. Finally we meet the most significant security indicator in the end of this paragraph and there is no else but the number of investigations. According to Yang [134] inspections of cargoes, unaccompanied bagaggies, stored areas, and within restricted areas are common used as security KPIs as also the number of costumer's placarding and documents about hazard materials.

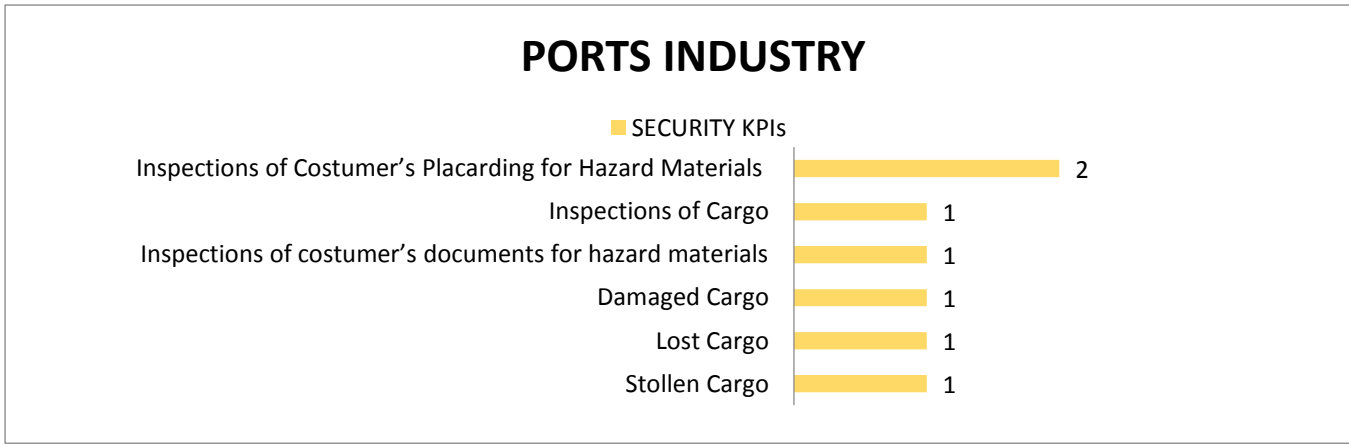


Diagram 46. Security Key Performance Indicators- Port Industry

2.7.3 HEALTH&SAFETY Key Performance Indicators at PORT Industry

As for the health and safety KPIs we have observed that have a lot in common with the safety ones. As health and safety KPIs considered the total number of accidents and the number of critical accidents [128]. Unfortunately, as we have already said these two factors don't take into consideration the illnesse's levels. Both injuries and illnesses are basic health and safety KPIs and they are measured through two other indexes: Office health factor and Vessel health factor [128]. As is explained the first one displays the illness and injuries leave days per total work days and the second the illness repatriation per total repatriation. Finally employee's health also influenced by air's quality and specially by noise levels [132]. Last health and safety indicators are given by Sumatra [126] related with compliance with occupational health and safety and are the number of investigation services and the number of measures and penalties.

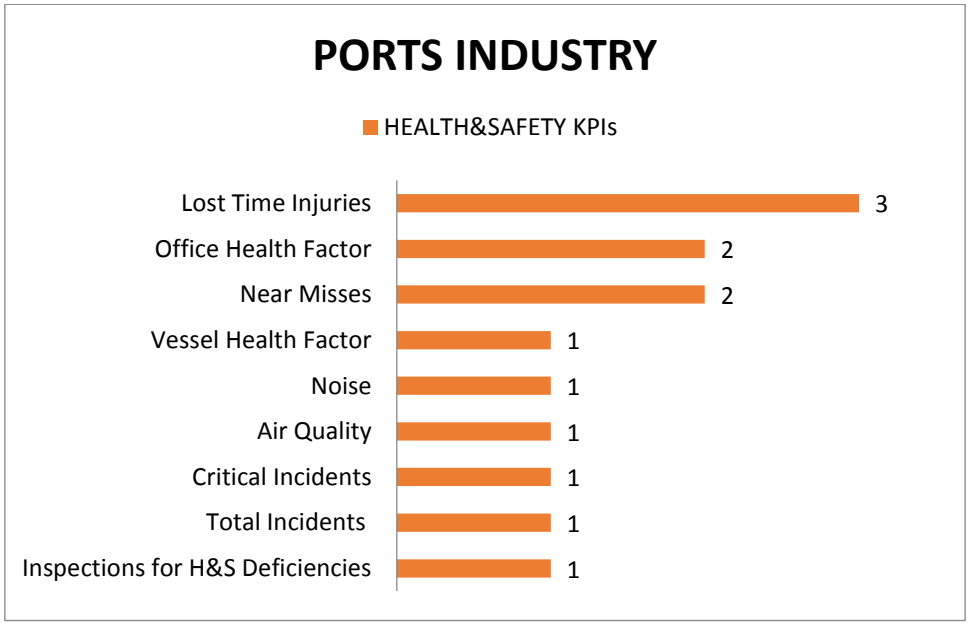


Diagram 47.Health and Safety Key Performance Indicators- Port Industry

2.7.4 ENVIRONMENTAL Key Performance Indicators at PORT Industry

In port's industry among the KPI's categories we have to investigate (safety, health and safety, security, environmental) the most significant one is the environmental. The environmental indicators give information on the quality and state of the environment and more specifically, they analyze the quality of air, water, sediment and soid [135],[136]. As regards the quality of the air, the major factor that influences it, is the number and the weight of emissions which can be direct, indirect, energy indirect and it is estimated that the most familiar KPI is the carbon footprint (tons of CO2 and CH4) [135], [136], [137], [125], [128]. ESPO [138] and Mano [133] add to the previous KPIs other substances emissions such as NOx, SOx, PM10, VOCs CO, O and finally at Hourneaux's work [139] Ozone-depleting substances (ODS) are mentioned. Concerning the water quality, essential KPIs are the water consumption [135],[136],[137],[140],[141],[142],[143] and the percentage of recycled and reused water [139]. Next, KPIs for both water and soil conditions are related to spills and waste. According to Fremantle Ports [129] the number and weight of chemical, oil and waste spills are suggested as KPIs and respectively the amount of waste and recycled waste.One other common KPI is the amount of energy consumption per year, costumer or service by primary energy sources and annual cargo handled. Other KPIs relevant to energy are the saved amount of energy [140] and the percentage of renewable energy [138],[142]. Futhermore, both Puig [136] and ESPO [138] refer to KPIs relevant to environmental conditions such as levels of noise and dust per day and night, levels of salinity and also thermal, nutrient and oxygenation conditions. Apart from the environmental conditions, Puig [136] also suggestes as KPIs environmental areas like terrestrial habitats, marine ecosystems and conservation areas (estuaries). Finally the last category of KPIs deal with the materials and their use. In Almi Tankers [128] we see the amount of paper and chemical per number of vessels as KPIs and also the total amount of used materials [139] and the recycling rate [142].

Proceed in analyzing the environmental KPIs, we meet those ones which are relevant to the company's environmental performance. The most significant is the Environmental Management System (EMS). Follow the existence of aspects inventory and monitoring program [137], [141]. Moreover, according to Dublin Port Company [142] other KPIs can be considered the number of environmental audits, recommendations, awards and finally the number of the training courses per total number of employees. Last but not least we have to bring up Hourneaux [139] additional KPIs which are the environmental investment and the percentage of (non) compliance with limits at day and night.

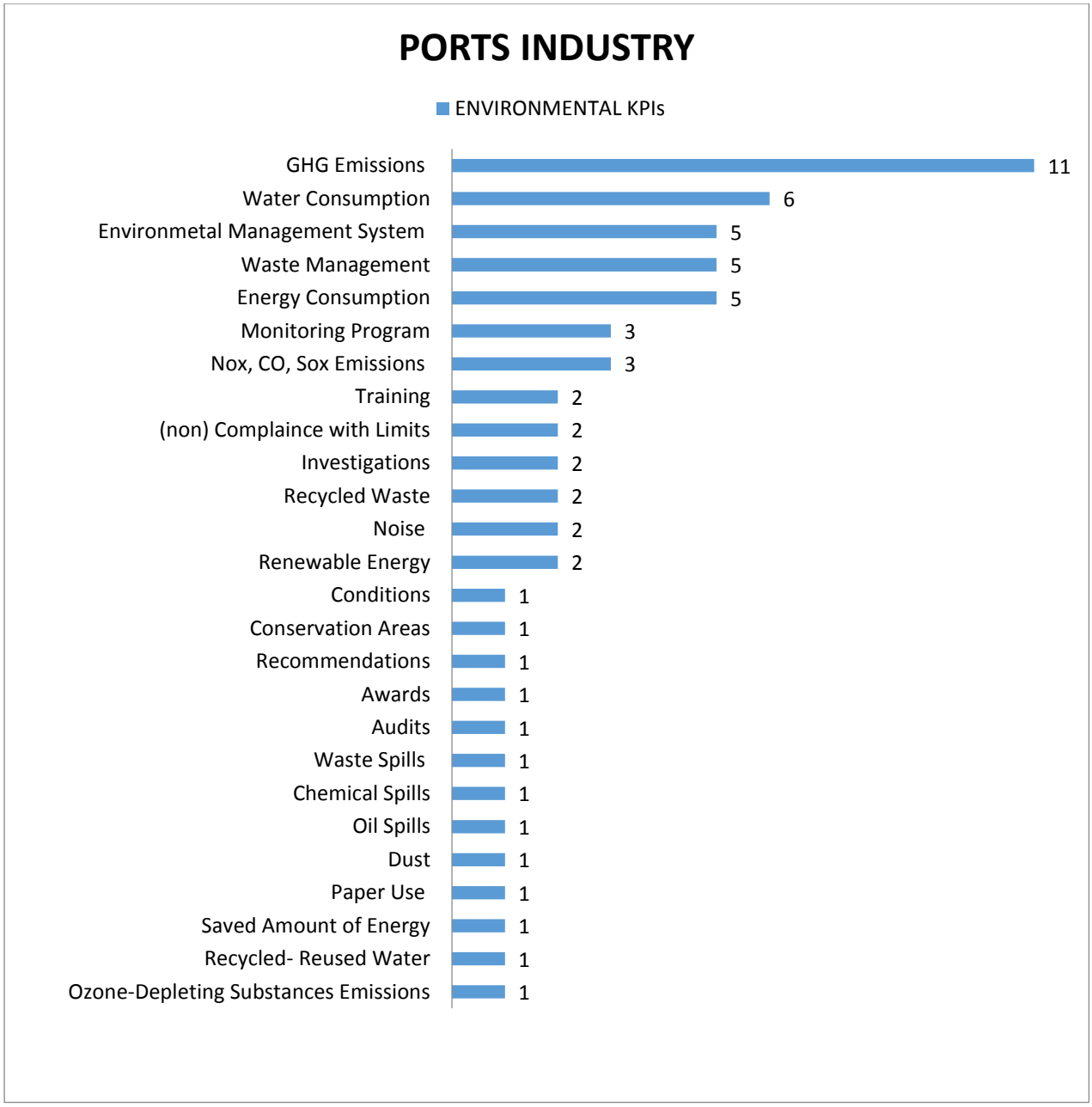


Diagram 48. Environmental Key Performance Indicators- Port Industry

2.7.5 KPIs BUBLE DIAGRAM at PORT Industry

Having collected all the using Key Performance Indicators at the Port Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 21) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- PORTS	CATEGORIES	PAPERS	OTHER
E1	GHG Emissions	2	12	HS
E2	Investigations	2	6	S
E3	(non) Complaince with Limits	2	3	SEC
E4	Oil Spills	2	2	S
E5	Noise	2	2	HS
E6	Audits	2	2	SEC
E7	Water Consumption	1	8	
E8	Waste Management	1	5	
E9	Energy Consumption	1	5	
E10	Environmetal Management System	1	5	
E11	Monitoring Program	1	3	
E12	Nox, CO, Sox Emissions	1	2	
E13	Recycled Waste	1	2	
E14	Renewable Energy	1	2	
E15	Training	1	2	
E16	Ozone-Depleting Substances Emissions	1	1	
E17	Chemical Spills	1	1	
E18	Waste Spills	1	1	
E19	Recycled- Reused Water	1	1	
E20	Recycled Waste	1	1	
E21	Saved Amount of Energy	1	1	
E22	Dust	1	1	
E23	Paper Use	1	1	
E24	Conservation Areas	1	1	
E25	Conditions	1	1	
E26	Awards	1	1	
E27	Recommendations	1	1	
S1	Total Incidents	2	2	HS
S2	Inspections about Hazard Materials	2	2	
S3	Total Recordable Injury Rate	2	1	
S4	Significant Events	2	1	
S5	Fire and Explosion	1	2	
S6	Lost Time Injury	1	2	
S7	Close Calls	1	1	
S8	Nautical Safety Index	1	1	
S9	Nautical Efficiency Safety Index	1	1	
S10	Collisions	1	1	
S11	Falls	1	1	
HS1	Office Health Factor	1	2	
HS2	Vessel Health Factor	1	1	
SEC1	Inspections of costumer’s documents for hazard materials	2	2	
SEC2	Inspections of Costumer’s Placarding for Hazard Materials	2	2	
SEC3	Stollen Cargo	1	1	
SEC4	Damaged Cargo	1	1	
SEC5	Lost Cargo	1	1	
SEC6	Inspections of Cargo	1	1	

Matrix 7. KPIs in PORTS : Number of Categories & Number of Papers

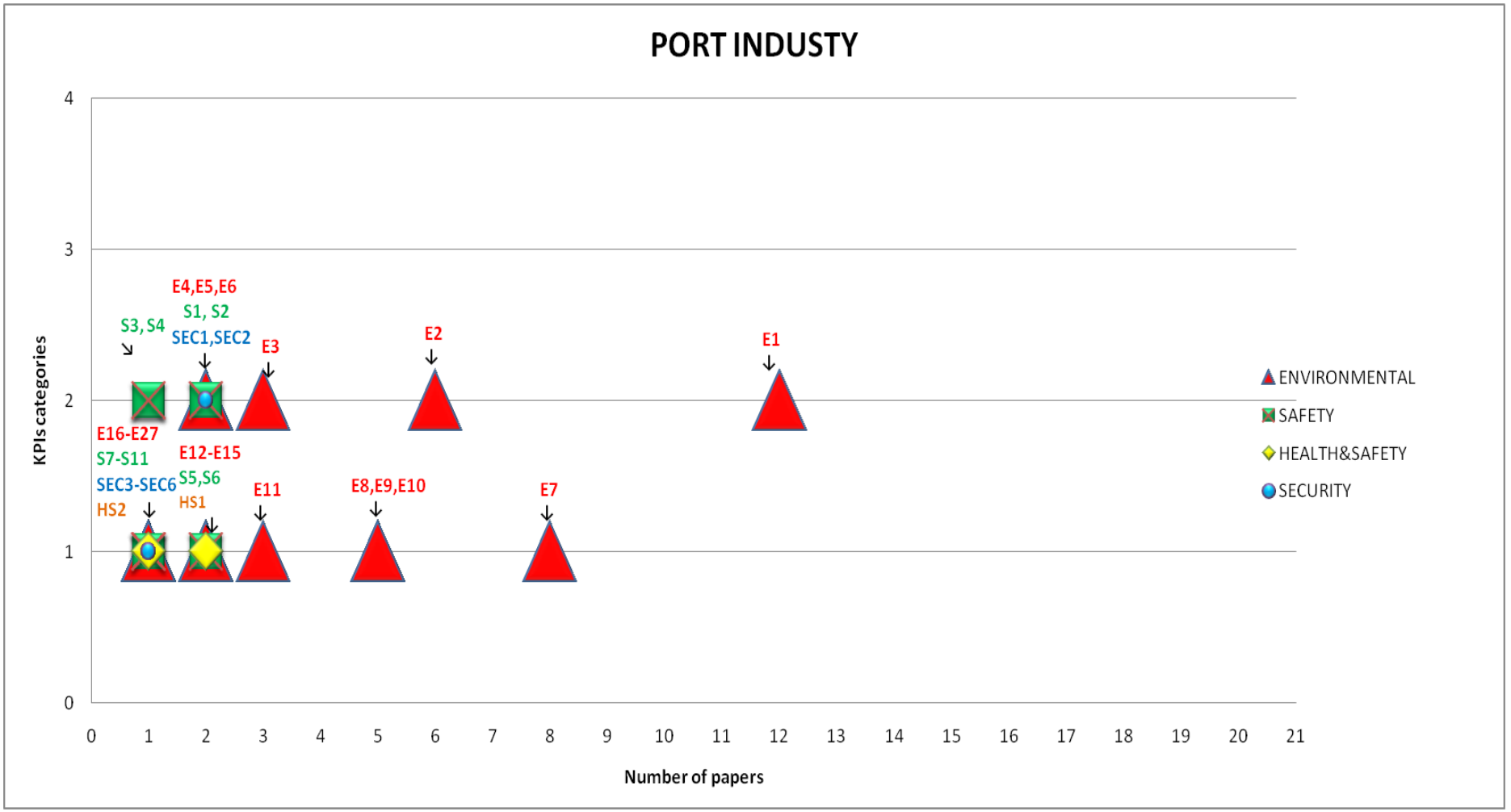


Diagram 49. All KPIs at Ports Industry

2.8. SHIPPING INDUSTRY

Shipping industry is the last industry we are going to examine in our search. Shipping is one of the most popular ways of transport and communication and is without doubt that is of the most (or even the most) safety one and Nowadays, more and more actions have been made in order to make that industry more environmental friendly.

For this industry we have collected data from 18 scientific papers in order to conclude to the most common used Key Performance Indicators for every category. The final ones are presented to the following matrixes, (separately for every category), with hierarchy order according to the number of papers they have been presented.

2.8.1 SAFETY Key Performance Indicators at SHIPPING Industry

Every industry concerns about safety, so the same worries has to deal the shipping industry. There is again a division of safety KPIs into two categories, leading and lagging. Due to it's importance we begin with the first category in which again we encounter an unique indicator the number and nature of navigational deficiencies according to the Port Safety Control which include the number of deficiencies per total number of external inspections [145],[146],[147],[148],[149]. The number of inspections is also a possible KPI as the number of audits [146],[150],[151]. In accordance to Qshipping [150] as leading KPIs have to be considered the number of procedures, campaigns briefings and safety meetings. Last leading indicator is the number of crew and officer's training days in courses that are hold every three years [148],[150],[151],[152],[153]. In order to make training a more easy process we follow Dag's [148] recommendation and encounter both officer's experience rate and crew discipline rate as KPIs.

On the one hand there are the leading indicators we have just analyzed in the previous paragraph. On the other hand there are the lagging which measure how many navigational incidents happen in shipping industry. Initial indicator as Saipem [151] points out is the number of accidents and the number of them lead to fatalities, injuries, lost time injuries or have minor consequences. Due to their importance in order to measure injuries there is a widerly used index, Total Recordable Injuries Rate (TRIR) and the same for measuring the lost hours through Lost Time Injuries Rate (LTIR) and Lost Time Injuries Frequency Rate (LTIFR) [148],[154],[155]. Apart from the number of accidents KPIs also measure the number of dangerous navigational occurrences. In that industry possible examples of these occurrences can be the number of collisions, allissions, grounding, fire& explosions which compound together through a mathematical equation one index, the navigational index= 2*collisions+ allissions+ 2*grounding, which is calculated annually, in ports, seas, rivers and restricted waters [146],[147],[148],[152]. GL Lloyd [152], refers as additionally KPIs the number of lost, wrecked, foundered ships, hull damaged ships and ships with equipment failure.

Diagram 50. Safety Leading Key Performance Indicators- Shipping Industry

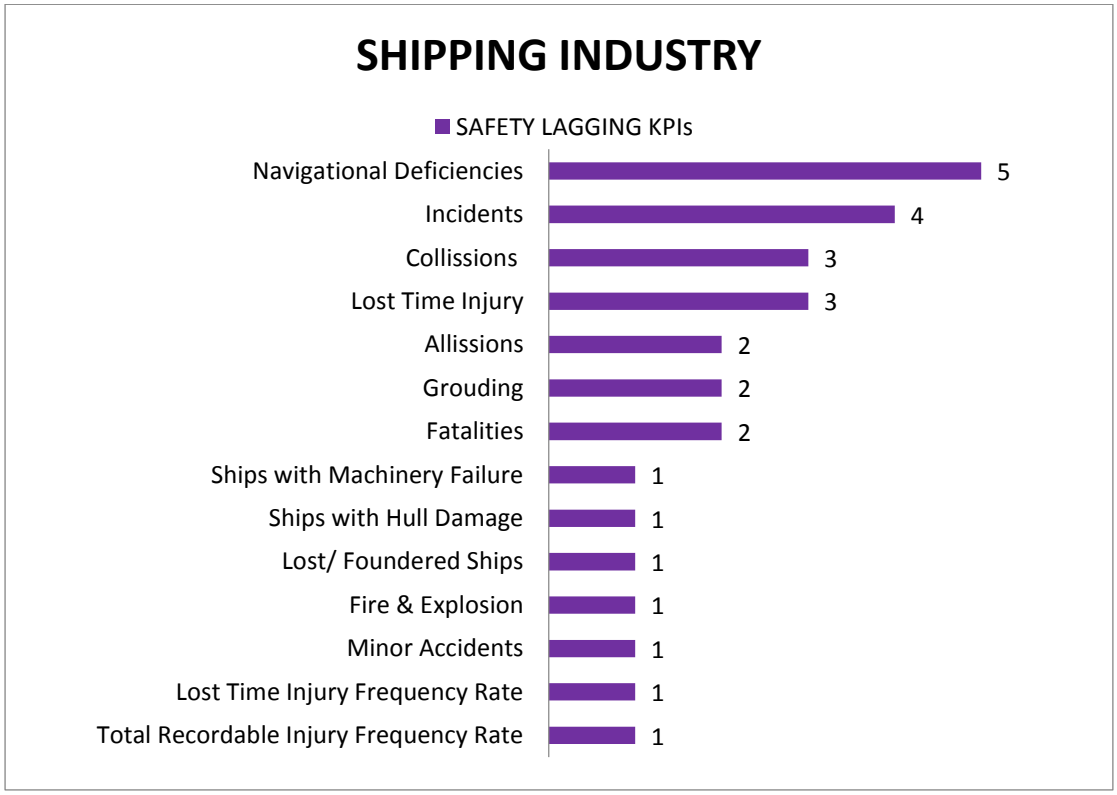


Diagram 51. Safety Lagging Key Performance Indicators- Shipping Industry

Diagram 52. Safety Key Performance Indicators- Shipping Industry

2.8.2 SECURITY Key Performance Indicators at SHIPPING Industry

Another category of KPIs regards security issues. The first KPI we meet in the international literature is the number of security deficiencies [146], [147], [148], [149]. Next frequent indicator is Port State Control Performance which involves the number of inspections with 0 deficiencies per total number of inspections [146], [147], [148]. In accordance to Mano [149] some more indicators are International Ship Port Security (ISPS) violations and the number of damaged, lost and theft cargo per total number of cargo. In order to control the above violations we use the number of anti-piracy measures such as military action, preventive measures and increased armed guards on board, and also the vessel's availability as KPIs. Last indicator is given by Okan [146] and it concerns the number of failures of critical equipment.

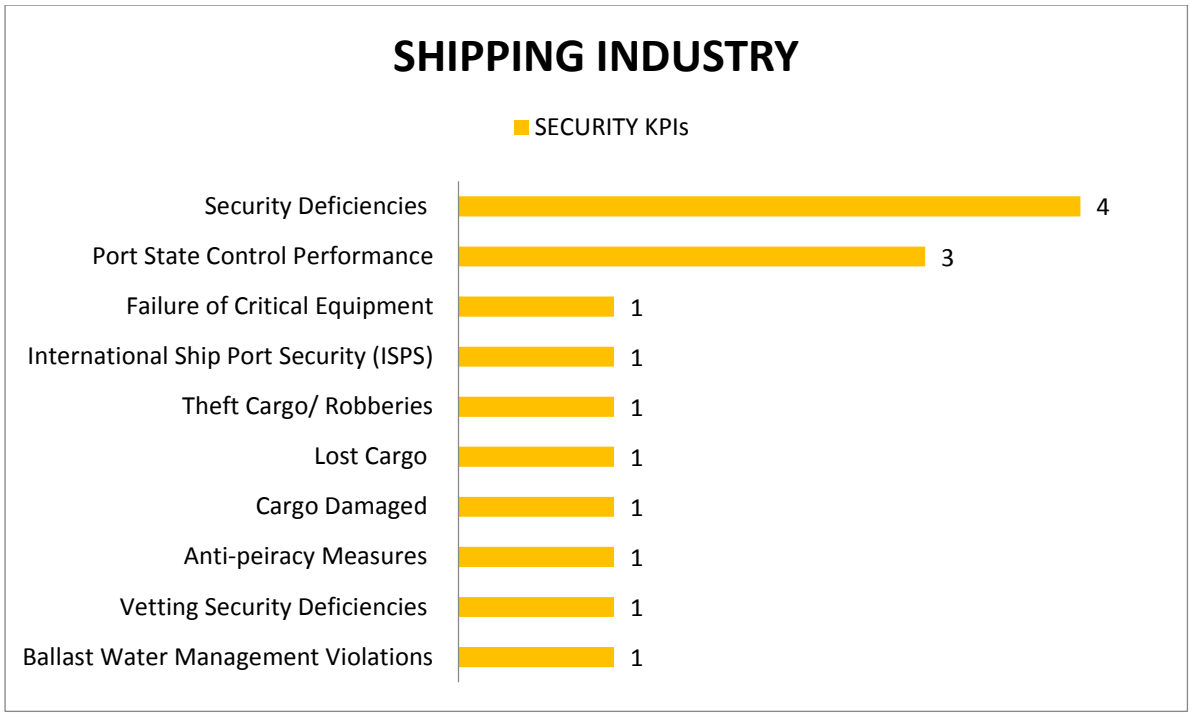


Diagram 53. Security Key Performance Indicators- Shipping Industry

2.8.3 HEALTH & SAFETY Key Performance Indicators at SHIPPING Industry

A lot in common with safety indicators we are going to find in this paragraph of health and safety KPIs. The number of deficiencies is also a part of this category as many papers suggest [145],[146],[148],[156] but the most important category is still associated with health and safety accidents. KPIs that are essential for a company to measure are the LTIFR per one million man hours, LTSFR (Lost Time Sickness Frequent Rate) and the number of injuries [145],[146],[156],[157]. Other useful KPIs are the number of near misses, medical treatment needed and TRIR [153]. In order to test company's health and safety levels we use KPIs such as the number of classification surveys between one or five years and vetting inspections about vessel's condition [145]. Also important indicator is Port State Control Performance (PSP) [145],[146],[147],[156] which measures the number of PSP with zero deficiencies per number of total PSP.

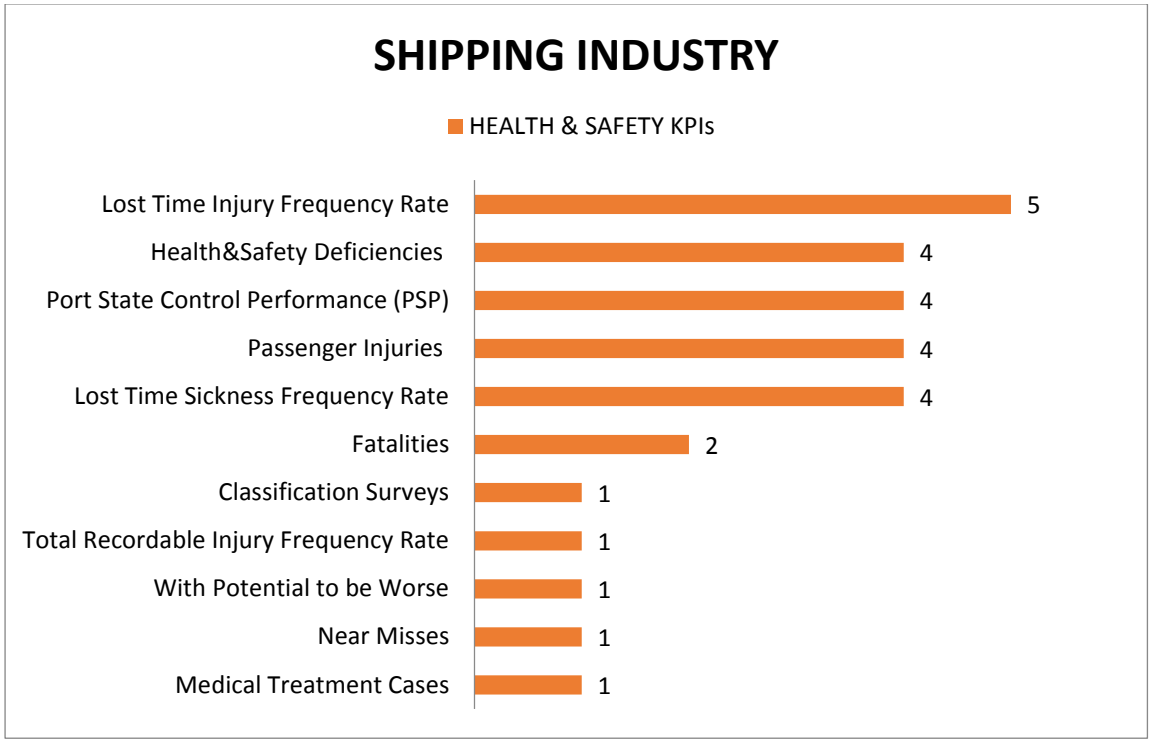


Diagram 54. Health & Safety Key Performance Indicators- Shipping Industry

2.8.4 ENVIRONMENT Key Performance Indicators at SHIPPING Industry

In shipping industry main accent is given to environmental issues, so it is obvious that the majority of the more used KPIs would be the environmental ones. Initially, this is the only industry in which is in use an indicator named environmental deficiencies. Okan [146], Shipping KPIs [147] and Dag [148] agreed in introducing the previous KPI and two more, the number of severe or contained bulked liquid spills and the number of substance's emissions covered by MARPOL. General, the number and weight of the emissions is a crucial factor for the shipping industry and for that reason a lot of work has already been made in examine which of the emissions are more frequent and operate like shipping environmental KPIs. The two wide categories we are interested in are air and water emissions [157], [158]. Accordance to [157] Greenhaus Gas's emissions and Sulphur Emission Control Areas form some of the main indicators. Finally one more generally admitted indicator in that field is the weight of SO2, Nox,CO2 emissions produced by vessels, cranes, ship auxiliaries and tracks [148],[156]. In addition, other factors that influence a company is the level's of consumption. Energy consumption is one of the most significant KPIs and follow fuel and CFC consumption . As we can imagine, water plays an important role in this industry so it has to be included in KPIs list and as Okan [146]and Shipping KPIs [147] suggest as the number of water ballast management violations. The last indicators, as we already used to are relevant to upgrade and examine the performance. Firstly, in order to improve environmental safety, number of the crew training courses are essential to be measured [145],[147],[150] as secondly, in order to monitor progress, we use KPIs such as the number of labeling, management systems, performance evaluation and life cycle assessment [152],[159].

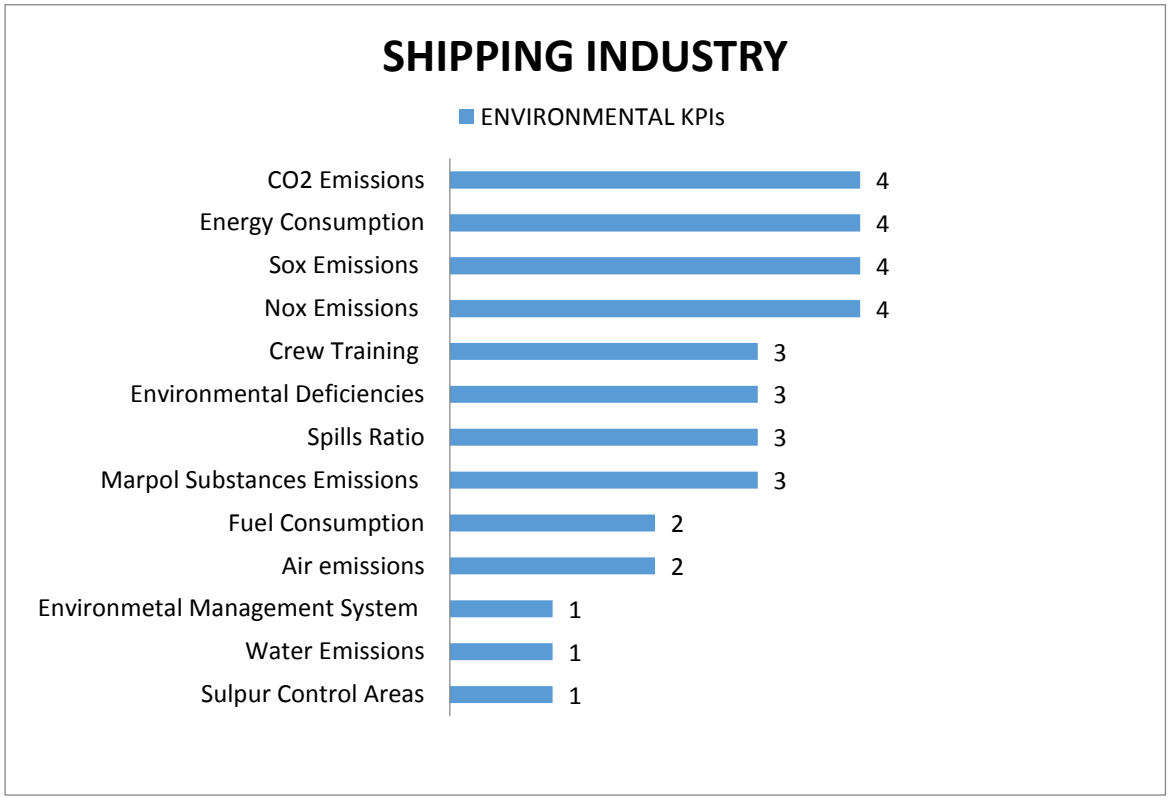


Diagram 55. Environmental Key Performance Indicators- Shipping Industry

2.8.5 KPIs BUBLE DIAGRAM at SHIPPING Industry

Having collected all the using Key Performance Indicators at the SHIPPING Industry regarding Safety, Security, Health and Safety and Environmental Performance comes to our attention that many of them are using to more than one industry. The following diagram shows for every indicator the number of categories (1-4) that is using and for these categories the total number of papers (1- 18) it has been referred. With green color appear the safety indicators, with red the environmental, with orange the health and safety and finally with blue the security one.

Scope of below diagram is to understand in this industry if the KPIs using in every category are unique and specific for its category or if they can be used also in other.

Parallel to the diagram there is the follow matrix, showing the KPIs that appear to the diagram:

	Key Performance Indicators (KPIs)- SHIPPING	CATEGORIES	PAPERS	OTHER
E1	Nox Emissions	1	4	
E2	Sox Emissions	1	4	
E3	CO2 Emissions	1	4	
E4	Energy Consumption	1	4	
E5	Marpol Substances Emissions	1	3	
E6	Environmental Deficiencies	1	3	
E7	Spills Ratio	1	3	
E8	Air emissions	1	2	
E9	Fuel Consumption	1	2	
E10	Water Emissions	1	1	
E11	Sulpur Control Areas	1	1	
E12	Environmetal Management System	1	1	
S1	External Inspections (machinery & equipment)	2	3	HS
S2	Ships with Machinery Failure	2	2	SEC
S3	Crew Training	1	7	
S4	Navigational Deficiencies	1	5	
S5	Lost Time Injury	1	3	
S6	Collissions	1	3	
S7	Allissions	1	2	
S8	Grouding	1	2	
S9	Procedures	1	2	
S10	Crew Discipline Rate	1	1	
S11	Officer Experience Rate	1	1	
S12	Audits	1	1	
S13	Campaigns	1	1	
S14	Safety Communications & Meetings	1	1	
S15	Fatalities	1	1	
S16	Minor Accidents	1	1	
S17	Fire & Explosion	1	1	
S18	Lost/ Foundered Ships	1	1	
S19	Ships with Hull Damage	1	1	
HS1	Lost Time Injury Frequency Rate	2	7	S
HS2	Total Recordable Injury Rate	2	5	S
HS3	Port State Control Performance (PSP)	2	5	SEC
HS4	Total Recordable Injury Frequency Rate	2	2	S
HS5	Lost Time Sickness Frequency Rate	1	4	
HS6	Health & Safety Defiencies	1	4	
HS7	Near Misses	1	2	
HS8	Medical Treatment Cases	1	1	
HS9	Cases with Potential to be Worse	1	1	
HS10	Classification Surveys	1	1	
SEC1	Security Deficiencies	1	4	
SEC2	Anti-peiracy Measures	1	1	
SEC3	Cargo Damaged	1	1	
SEC4	Lost Cargo	1	1	
SEC5	Theft Cargo/ Robberies	1	1	
SEC6	International Ship Port Security (ISPS)	1	1	
SEC7	Ballast Water Management Violations	1	1	

Matrix 8. KPIs in SHIPPING : Number of Categories & Number of Paper

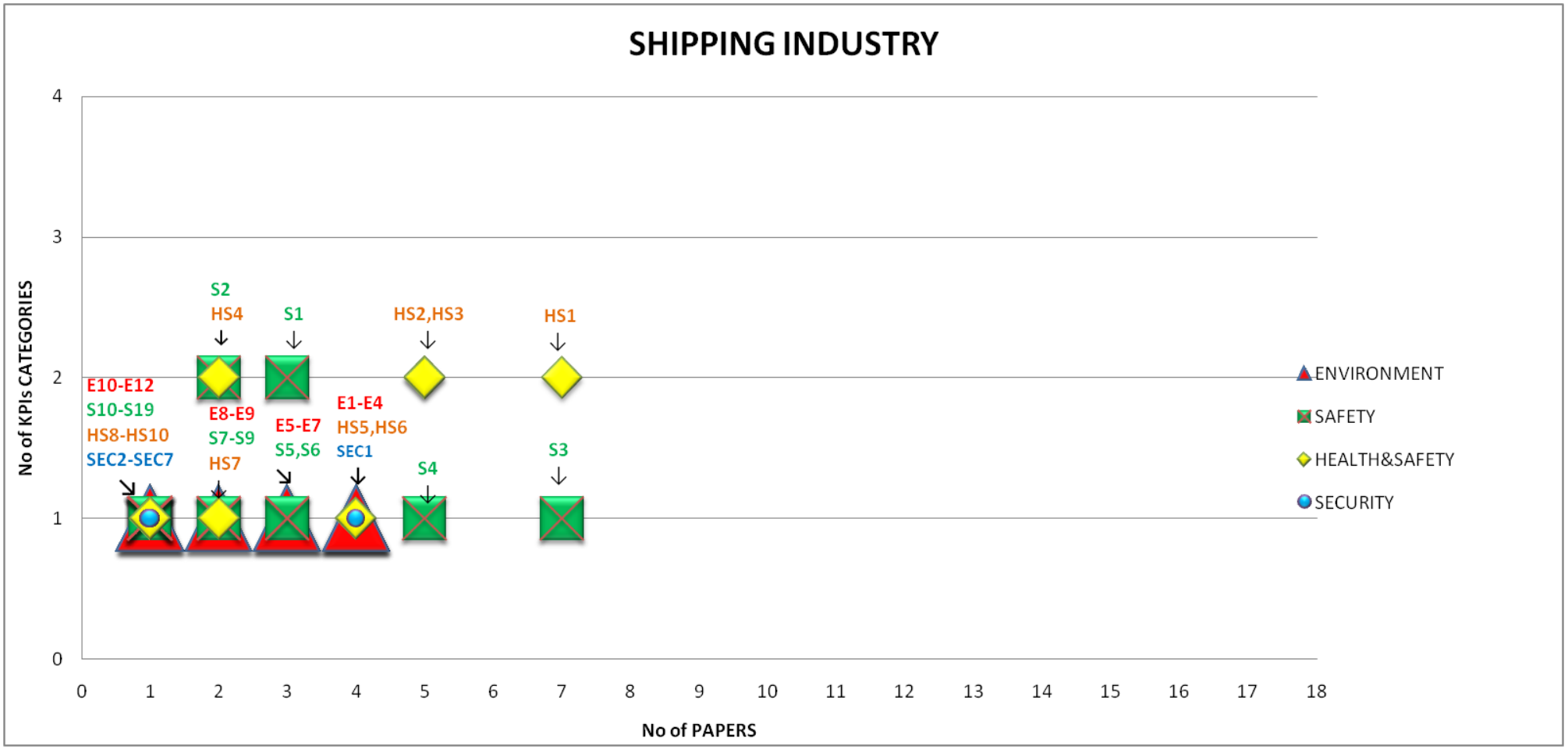


Diagram 56. All KPIs at Shipping Industry

CHAPTER 3: " SET OF SHIPPING KPIs".

Scope of this chapter is the selection of the most popular, proper and useful Key Performance Indicators that can be used for a shipping industry in order to estimate its performance regarding safety, health and safety, security and environment.

In order to achieve this goal, in the previous chapter we have mentioned and analyzed all the already used shipping Key Performance Indicators concerning the above fields. One solution would be to create a set of the most popular KPIs based on the previous chapter. However, due to the analysis made in the previous chapter for also other seven (7) industries,(road, rail, aviation, nuclear power plant, chemical, offshore, ports) we proceeded the process of KPIs selection based on the other industries as well.

For that reason, in this chapter we are going to find out the most popular KPIs from all industries as some of them are used not only to one but also to other industries, comparing them with those indicators that are already in used from a real shipping compary and from other organizations for shipping. At the end of this process we will be able to choose the most appropriate indicators for our proposed set of KPIs. The last paragraph of this chapter is the evaluation of each indicator weight as are not all the indicators equall. In order to complete that evaluation we examine the tend of industries concerning safety, health and safety, security and environment through spider diagram.

3.1. COMPARISON OF KPIs AMONG ALL INDUSTRIES

For each one of the interested fields that we are going to examine company's performance (safety, health and safety, security and environment) we have gathered all the information from the previous chapter two, so as to conclude which are the most usually used Key Performance Indicators based on all the eight (8) examined industries. That goal is achieved by creating the following four (4) diagrams, (one for each category) which shows for every one of the indicators mentioned on all industries, in how many categories has been used (1-4) and in how many papers has been mentioned. Further to each diagram is provided also one matrix that shows for every indicator exactly at which industries has been used.

3.1.1 SAFETY Key Performance Indicators –ALL INDUSTRIES

SAFETY KPIs at ALL INDUSTRIES											
N	SUM PAPER	SAFETY KPIs	RAIL	PORTS	SHIPPING	OFFSHORE	ROAD	AVIATION	CHEMICAL	NUCLEAR	SUM INDUSTRY
1	27	Fatalities	7		2	2	6	1	5	4	7
2	26	Total Recordable Injury Rate	7	1		4	5	3	2	4	7
3	19	Lost Time Injury		2	3	2	2	3	2	5	7
4	19	Training (crew & officers)	1		5	2	4	1	4	2	7
5	12	Audits	1		1	4		2	2	2	6
6	16	Maintance on Time				2	2	2	5	5	5
7	16	External Inspections	1	1	2	6			4	2	6
8	14	Collissions	3	1	3	4	3				5
9	14	Incidents	1	2	4		1	6			5
10	12	Near Misses				4	1	2	4	1	5
11	9	Fire & Explosion	2	2	1	3				1	5
12	7	Safety Communications & Meetings	1		1	2		2	1		5
13	10	Accidents				2	4		1	3	4
14	7	Safety Management System Compliance				2		2	1	2	4
15	5	Lost Time Injury Frequency Rate			1	1		1	2		4
16	7	Significant Events		1					2	4	3
17	6	Safety Failures				1			2	3	3
18	6	Emergency Response Drills Completed				2			1	3	3
19	6	Result Emergency Response Plan				1			3	2	3
20	5	Investigations				2			2	1	3
21	4	Total Recordable Injury Frequency Rate			1	1			2		3
22	4	Inpections on Time	1			1			2		3
23	3	Time between Reporting&Occur Accident				1		1	1		3
24	3	Human Operative Errors				1			1	1	3
25	7	Signals Passed in Danger	4				3				2
26	5	Accidents due to Vehicle Condition	3					2			2
27	4	Shutdowns							2	2	2
28	3	Grouding			2	1					2
29	3	Safety Tours	1					2			2
30	3	Safety Behaviour Observed				2		1			2
31	3	Tool Box Completed				2	1				2
32	3	Fire Protection							1	2	2
33	2	Risk Assessment							1	1	2
34	2	First Aid accidents				1		1			2
35	2	Minor Accidents			1					1	2
36	2	Deferred Maintance				1	1				2
37	2	No of Investigated Incidents				1			1		2
38	2	Audits Completed on Time	1							1	2
39	2	Corrective Actions Reported from Audits				1				1	2
40	2	Non Completed on time Training				1				1	2
41	2	Competed on time Training				1				1	2
42	2	Attendance at Safety Meetings				1		1			2
43	2	Driver Management & Discipline	1				1				2
44	2	Driver Selectively & Tenture	1				1				2
45	6	Drink Driving					6				1
46	6	Radiation Exposure								6	1

47	5	Level Crossing Accidents	5								1
48	5	Unlanned Scrams								5	1
49	5	Navigational Deficiencies			5						1
50	4	Serious Injuries					4				1
51	4	Use of Seat Belts					4				1
52	4	Exceeding Speed Limits					4				1
53	4	Unplaned Power Charges								4	1
54	4	Safety System Availability								4	1
55	4	Fuel Realibility								4	1
56	4	Hydrocarbon Releases				4					1
57	3	Accidents due to Traffic	3								1
58	3	Levels of Traffic Speed					3				1
59	3	Derailments	3								1
60	3	Birds Strikes						3			1
61	3	Safety System Performane								3	1
62	3	Safety System Actuations								3	1
63	3	Radiation Area Controls								3	1
64	2	Reccurent Events								2	1
65	2	Fatality Weighted Injury	2								1
66	2	Allissions			2						1
67	2	Use of Helmets					2				1
68	2	Vehicle Crashes					2				1
69	2	Well Kicks				2					1
70	2	Backlog of Maintance				2					1
71	2	Time to Resolve Issues						2			1
72	2	Field Visits				2					1
73	2	Employees Trained				2					1
74	2	Non compliance with SMS				2					1
75	2	Progress Monitoring				2					1
76	2	Follow up Recommendations				2					1
77	1	Dangerous Occurences						1			1
78	1	Days Away from Work							1		1
79	1	Drugs Driving					1				1
80	1	Distance Aircrafts Fly						1			1
81	1	Flghts Delay						1			1
82	1	Delay> 15 min						1			1
83	1	Delay due to Technical Reasons						1			1
84	1	Releases of Stored Inventory				1					1
85	1	Leakages							1		1
86	1	Lost/ Foundered Ships			1						1
87	1	Ships with Hull Damage			1						1
88	1	Ships with Machinery Failure			1						1
89	1	Kick Response Time				1					1
90	1	Kick Frequency				1					1
91	1	Nautical Safety Index		1							1
92	1	Nautical Efficiency Safety Index		1							1
93	1	Cemented Safety Failures				1					1
94	1	Failures in Maintance							1		1
95	1	Failures (electrical equipment)							1		1
96	1	Safety Deficiencies							1		1
97	1	Killed Animals							1		1
98	1	Not Completed on time Maintance				1					1
99	1	Maintance without Defect							1		1
100	1	Inspections about Hazard Materials		1							1
101	1	Inspections with 0 Defect							1		1
102	1	Safety Tous on Time	1								1
103	1	Personal Surveys				1					1

104	1	Compliance with Speed Limits					1				1
105	1	Possitive Safety Behaviour Obsereved				1					1
106	1	People Converting Instructions				1					1
107	1	Costumers Complains						1			1
108	1	Rewards				1					1
109	1	Procedures			1						1
110	1	Campaigns			1						1
111	1	Officer Experience Rate			1						1
112	1	Crew Discipline Rate			1						1
113	1	Flood Measure Protection								1	1
114	1	High Risk Drivers					1				1
115	1	Driver Participation in OHS					1				1
116	1	Drivers Age					1				1
117	1	Preventive Actions							1		1
118	1	Time Repairing Safety System							1		1
119	1	Medical Treatment Cases					1				1
120	1	Close Calls		1							1
121	1	Berrier Performance				1					1
122	1	False Alarms							1		1
123	1	Temperature&Pressure Control							1		1

Matrix 9. Safety Key Performance Indicators- No of Industries and papers of all industries

In the following diagram you can see for every indicator the number o industries that using it and the number of papers that have mentioned it. It is obvious that the most useful and popular indicators are those which presented at top right of the diagram. As you can see below, these are the indicators 1-13 from which we are going to choose some of them to ceate our shipping KPIs set. These 13 indicators are the following:

N	SAFETY KPIs	SUM PAPER	SUM INDUSTRY	SCORE= PAPER*INDUSTRY
1	Fatalities	27	7	189
2	Total Recordable Injury Rate	26	7	182
3	Lost Time Injury	19	7	133
4	Training (crew & officers)	19	7	133
5	Audits	12	6	72
6	Maintance on Time	16	5	80
7	External Inspections	16	6	96
8	Collissions	14	5	70
9	Incidents	14	5	70
10	Near Misses	12	5	60
11	Fire & Explosion	9	5	45
12	Safety Communications & Meetings	7	5	35
13	Accidents	10	4	40

Matrix 10. Most common used safety KPIs at all Industries

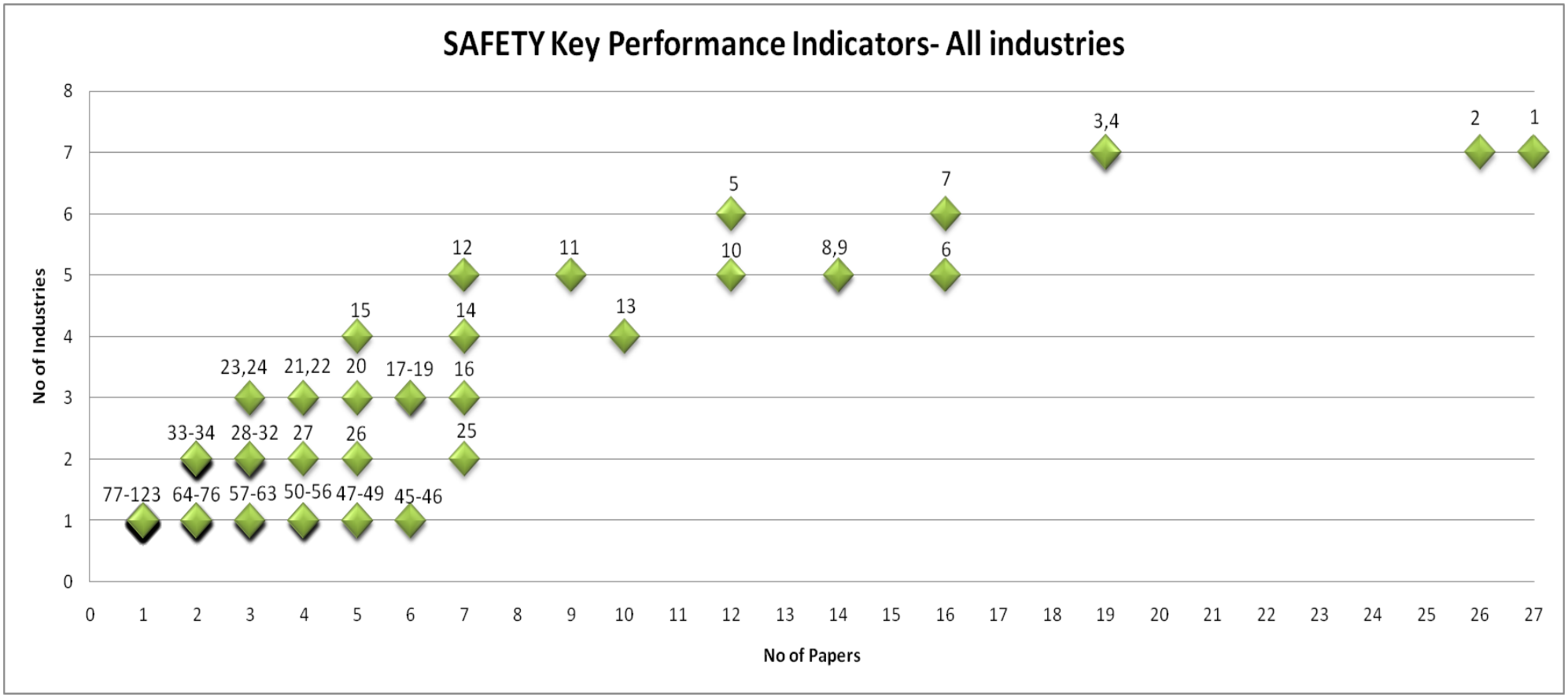


Diagram 57. Safety key Performance Indicators- all indusrties

3.1.2 SECURITY Key Performance Indicators –ALL INDUSTRIES

SECURITY KPIs at ALL INDUSTRIES											
N	SUM PAPER	SECURITY KPIs	RAIL	PORTS	SHIPPING	OFFSHORE	ROAD	AVIATION	CHEMICAL	NUCLEAR	SUM INDUSTRY
1	3	Stollen cargo		1	1			1			3
2	3	Damaged cargo		1	1			1			3
3	3	Lost cargo		1	1			1			3
4	4	Property Damages					3			1	2
5	3	Failure of Critical Equipment			1			2			2
6	2	Violence rape	1			1					2
7	2	Direct Attacks by Hijackers				1		1			2
8	4	Security Deficiencies			4						1
9	3	Port State Control Performance			3						1
10	2	Suicides	2								1
11	2	Terrorism Violations								2	1
12	2	Inspections of Costumer's Placarding for Hazard Materials		2							1
13	2	Time between shut-down and reopening security breach						2			1
14	2	Cyber attacks							2		1
15	1	Anti-piracy measures			1						1
16	1	Malicious Acts	1								1
17	1	Attacks with small explosive ships				1					1
18	1	Attacks on airports facilities						1			1
19	1	Attacks with Weapons				1					1
20	1	Homicide	1								1
21	1	Protection from Vandalism								1	1
22	1	Excistence and Use of Explosive Devices on Deck				1					1
23	1	Electromagnetic attacks	1								1
24	1	Inspections of Cargo		1							1
25	1	Inspections of Unaccompanied Baggages		1							1
26	1	Lost baggages						1			1
27	1	Inspections of Storage Areas		1							1
28	1	Inspections within Restriced Areas		1							1
29	1	Inspections of costumer's documents for hazard materials		1							1
30	1	Vetting Security Deficiencies			1						1
31	1	Community Satisfaction with Police Services					1				1
32	1	Effective Police Patrol Teams					1				1
33	1	Illegal Taxicab Operations					1				1
34	1	Incidents at security checkpoints						1			1
35	1	Time needed after emergency fire, bomb threat, acts of terrorism						1			1
36	1	Legal Compliances							1		1
37	1	Security Management							1		1
38	1	Ballast Water Management Violations			1						1
39	1	Security System Performance								1	1

Matrix 11. Security Key Performance Indicators- No of Industries and papers of all industries

Regarding security performance, it is obvious that almost every industry uses its own Key Performance Indicators and it is difficult to conclude to some more common used indicators.

However, looking at the below diagram we can observe that at top right are the first 14 indicators some of which we are going to choose later, having in mind that these have to be acceptable of the shipping industry. The 14 indicators are:

N	SECURITY KPIs	SUM PAPER	SUM INDUSTRY	SCORE= PAPER*INDUSTRY
1	Stollen cargo	3	3	9
2	Damaged cargo	3	3	9
3	Lost cargo	3	3	9
4	Property Damages	4	2	8
5	Failure of Critical Equipment	3	2	6
6	Violence rape	2	2	4
7	Direct Attacks by Hijackers	2	2	4
8	Security Deficiencies	4	1	4
9	Port State Control Performance	3	1	3
10	Suicides	2	1	2
11	Terrorism Violations	2	1	2
12	Inspections of Costumer's Placarding for Hazard Materials	2	1	2
13	Time between shut-down and reopening security breach	2	1	2
14	Cyber attacks	2	1	2

Matrix 12. Most common used security KPIs at all Industries

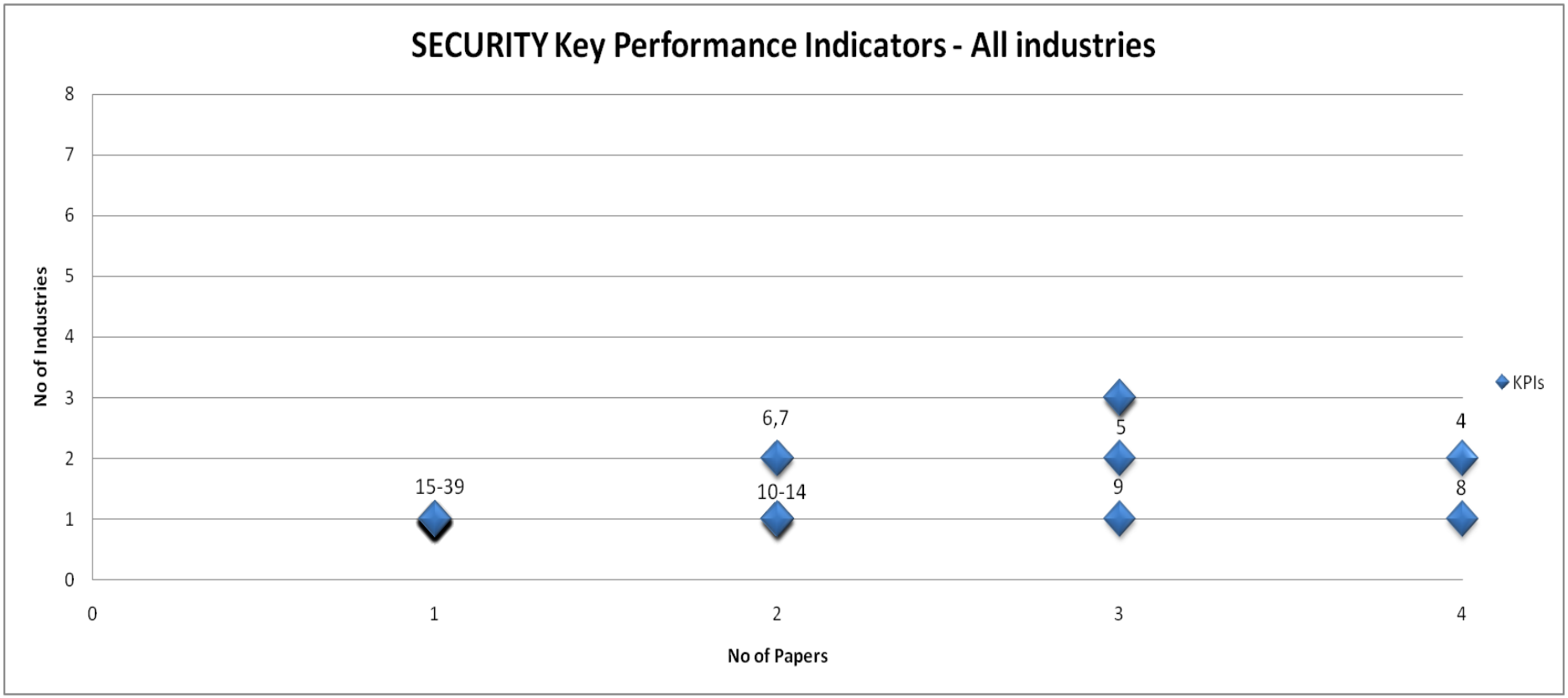


Diagram 58. Security key Performance Indicators- all indusrties

3.1.3 HEALTH & SAFETY Key Performance Indicators –ALL INDUSTRIES

HEALTH&SAFETY KPIs at ALL INDUSTRIES											
N	**SUM PAPER**	**SAFETY KPIs**	**RAIL**	**PORTS**	**SHIPPING**	**OFFSHORE**	**ROAD**	**AVIATION**	**CHEMICAL**	**NUCLEAR**	**SUM INDUSTRY**
1	18	Fatalities	3	2	2	6	2	2	1		7
2	16	Lost time Injuries		3	5	2	3	2	1		6
3	11	Near Misses	2	2	1	2	2	2			6
4	6	Medical Treatment Cases			1	2	1	1	1		5
5	14	Injuries	3		4	5		2			4
6	8	Lost Time Sickness		2	4	2		0			3
7	5	Illnesses				2	1	2			3
8	3	Days Absent due to Illness				1	1	1			3
9	5	Total incidents		1				4			2
10	3	First aid injury					1	2			2
11	3	Hospital Admissioned Injuries				2			1		2
12	2	Inspection		1					1		2
13	2	Accidental Frequency Rate	1				1				2
14	2	Critical Incidents		1			1				2
15	2	With potential to be worse			1	1					2
16	2	Air quality		1				1			2
17	2	Noise		1				1			2
18	7	Worker radiation exposure								7	1
19	4	Health and Safety Deficiencies			4						1
20	3	Major Injuries				3					1
21	2	(non) Lost Time Injury Rate	2								1
22	2	Hydrocarbon Releases				2					1
23	2	Fire				2					1
24	2	Fire Prevention					2				1
25	2	Training					2				1
26	2	Control Risk					2				1
27	2	Radioactive materials								2	1
28	1	Lost Time Injury Frequency Rate					1				1
29	1	Non occupetional illnesses					1				1
30	1	illnesses requires >=3 days off work				1					1
31	1	Injuries resulted in fractures				1					1
32	1	Injuries resulted in amputations				1					1
33	1	Permanet Medical Services					1				1
34	1	Injuries lead to Emergency Medical					1				1
35	1	Minor Accidents				1					1
36	1	Non- Injury Accidents				1					1
37	1	Dangerous Occurrences				1					1
38	1	Unwanted pollutants releases				1					1
39	1	People exposued in noise						1			1
40	1	Worker complains				1					1
41	4	Port State Control Performance			4						1
42	1	Awards						1			1
43	1	Audits						1			1
44	1	Total Recordable Injury Frequency Rate			1						1
45	1	Crowding & Density of passengers	1								1
46	1	Personel contaminations								1	1
47	1	No of workers receive dose over limits								1	1
48	1	Reactor Coolant System Activity								1	1
49	1	Reactor Coolant System Leakage								1	1
50	1	Exposure Control								1	1
51	1	Overpressure							1		1

52	1	Classification Surveys			1						1
53	1	Overfilling tank							1		1

Matrix 13. Health & Safety Key Performance Indicators- No of Industries and papers of all industries

As in the previous fields, noticing the below diagram we can easily observe that the most common used indicators are those at the top right side of the diagram and more specific the following 1-7 (from these we will select the one to put in our set of shipping KPIs concerning health and safety).

N	HEALTH& SAFETY KPIs	SUM PAPER	SUM INDUSTRY	SCORE= PAPER*INDUSTRY
1	Fatalities	18	7	126
2	Lost time Injuries	16	6	96
3	Near Misses	11	6	66
4	Medical Treatment Cases	6	5	30
5	Injuries	14	4	56
6	Lost Time Sickness	8	3	24
7	Illnesses	5	3	15

Matrix 14. Most common used health and safety KPIs at all Industries

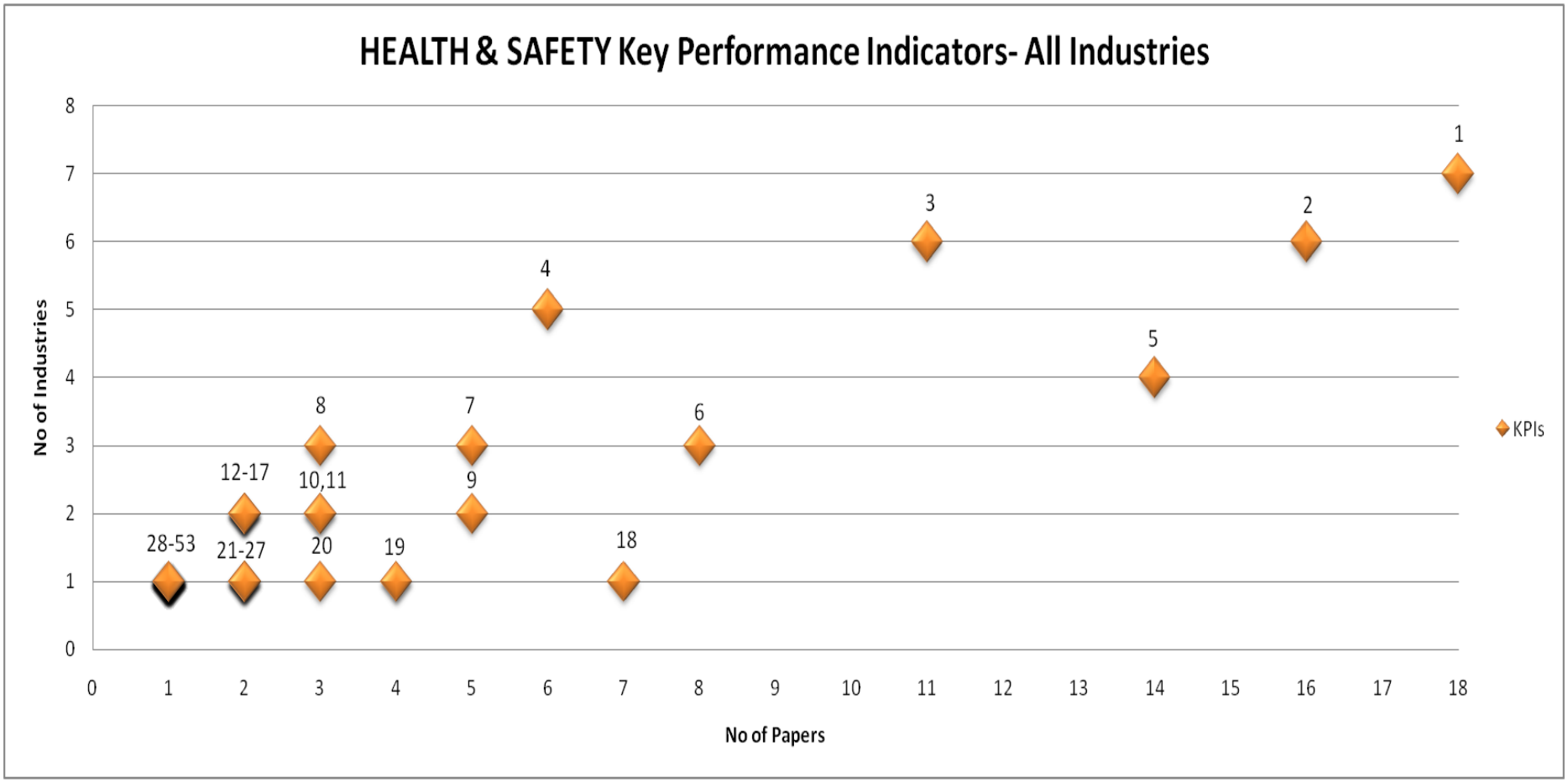


Diagram 59. Health and Safety key Performance Indicators- all indusrties

3.1.4 ENVIRONMENTAL Key Performance Indicators –ALL INDUSTRIES

ENVIRONMENTAL KPIs at ALL INDUSTRIES											
N	SUM PAPER	SECURITY KPIs	RAIL	PORTS	SHIPPING	OFFSHORE	ROAD	AVIATION	CHEMICAL	NUCLEAR	SUM INDUSTRY
1	50	CO2 emissions	9	11	4	5	3	9	6	3	8
2	30	Energy Consumption	8	5	4	3	1	3	5	1	8
3	19	Waste Management	3	5		2	1	2	4	2	7
4	18	Nox Emissions	3	3	4	1		5	2		6
5	20	Water Consumption	4	6				3	4	3	5
6	13	Sox Emissions	3	3	4	1			2		5
7	13	Noise	5	2			1	4	1		5
8	9	Recycled Waste	3	2		1	1	2			5
9	6	Renewable Energy	1	2		1		1	1		5
10	11	Air Emissions			2		1		2	6	4
11	11	Environmetal Management System	3	5	1			2			4
12	9	Oil Spills		1		3		3	2		4
13	7	Training		2	3		1	1			4
14	5	Investigations		2		1	1	1			4
15	7	Water Emissions			1		1			5	3
16	6	Fuel Consumption			2			2		2	3
17	4	Chemical Spills		1					2	1	3
18	3	Audits		1		1		1			3
19	3	Environmental Incidents	1			1		1			3
20	6	Spills to Water				3		3			2
21	5	Vibration	3					2			2
22	3	Dust	2	1							2
23	3	Recycle Rate							1	2	2
24	3	Raw Materials					1		2		2
25	2	VOC Emissions					1		1		2
26	2	Ozone-Depleting Substances Emissions		1					1		2
27	2	Electricity Consumption						1		1	2
28	2	Paper use	1	1							2
29	2	Awards		1		1					2
30	2	Extreme Weather				1	1				2
31	4	Radioactive Waste								4	1
32	4	Radioactive Materials								4	1
33	3	Marpol Substances Emissions			3						1
34	3	Fuel Leakeage								3	1
35	3	Spills Ratio			3						1
36	3	Environmental Deficiencies			3						1
37	3	Monitoring Programm		3							1
38	3	Protect from Radiation Exposure								3	1
39	2	People/Area Influenced by Noise						2			1
40	2	(non) Complaince with limits		2							1
41	1	Emissions from Automobile					1				1
42	1	Nuclear Plant Footprint								1	1
43	1	Emissions of smoke	1								1
44	1	Sulpur Control Areas			1						1
45	1	Recycled- Reused Water		1							1
46	1	Water Waste							1		1
47	1	Cool Water							1		1
48	1	Steam Water							1		1
49	1	Saved Amount of Energy		1							1
50	1	Chemical consumption							1		1
51	1	Geothermal Fluid Consumption								1	1
52	1	Paper consumption	1								1

53	1	Noise Levels out Limits						1			1
54	1	Smog					1				1
55	1	Odours	1								1
56	1	Heat							1		1
57	1	Light							1		1
58	1	Chemical Releases							1		1
59	1	Waste spills		1							1
60	1	Toxic Waste							1		1
61	1	Hazardous Waste							1		1
62	1	Non Hazardous Waste							1		1
63	1	Non Radioactive Waste								1	1
64	1	Recycle Hazardous Materials							1		1
65	1	Recycle non Hazardous Materials							1		1
66	1	Inspections				1					1
67	1	Recommendations		1							1
68	1	Conservation Areas		1							1
69	1	Loss of Mooring				1					1
70	1	Flooding				1					1
71	1	Low Temperature				1					1
72	1	Ice Formation on Structures/Equipment				1					1
73	1	Explosive chemicals							1		1
74	1	Toxic chemicals							1		1
75	1	Corrosive chemicals							1		1
76	1	Imflammed chemicals							1		1

Matrix 15. Environmental Key Performance Indicators- No of Industries and papers of all industries

Noticing the above matrix and the below diagram the most common used Key Performance Indicators regarding environmental performance we conclude to the following twelve (12) indicators:

N	ENVIRONMENTAL KPIs	SUM PAPER	SUM INDUSTRY	SCORE= PAPER*INDUSTRY
1	CO2 emissions	50	8	400
2	Energy Consumption	30	8	240
3	Waste Management	19	7	133
4	Nox Emissions	18	6	108
5	Water Consumption	20	5	100
6	Sox Emissions	13	5	65
7	Noise	13	5	65
8	Recycled Waste	9	5	45
9	Renewable Energy	6	5	30
10	Air Emissions	11	4	44
11	Environmetal Management System	11	4	44
12	Oil Spills	9	4	36

Matrix 16. Most common used environmental KPIs at all Industries

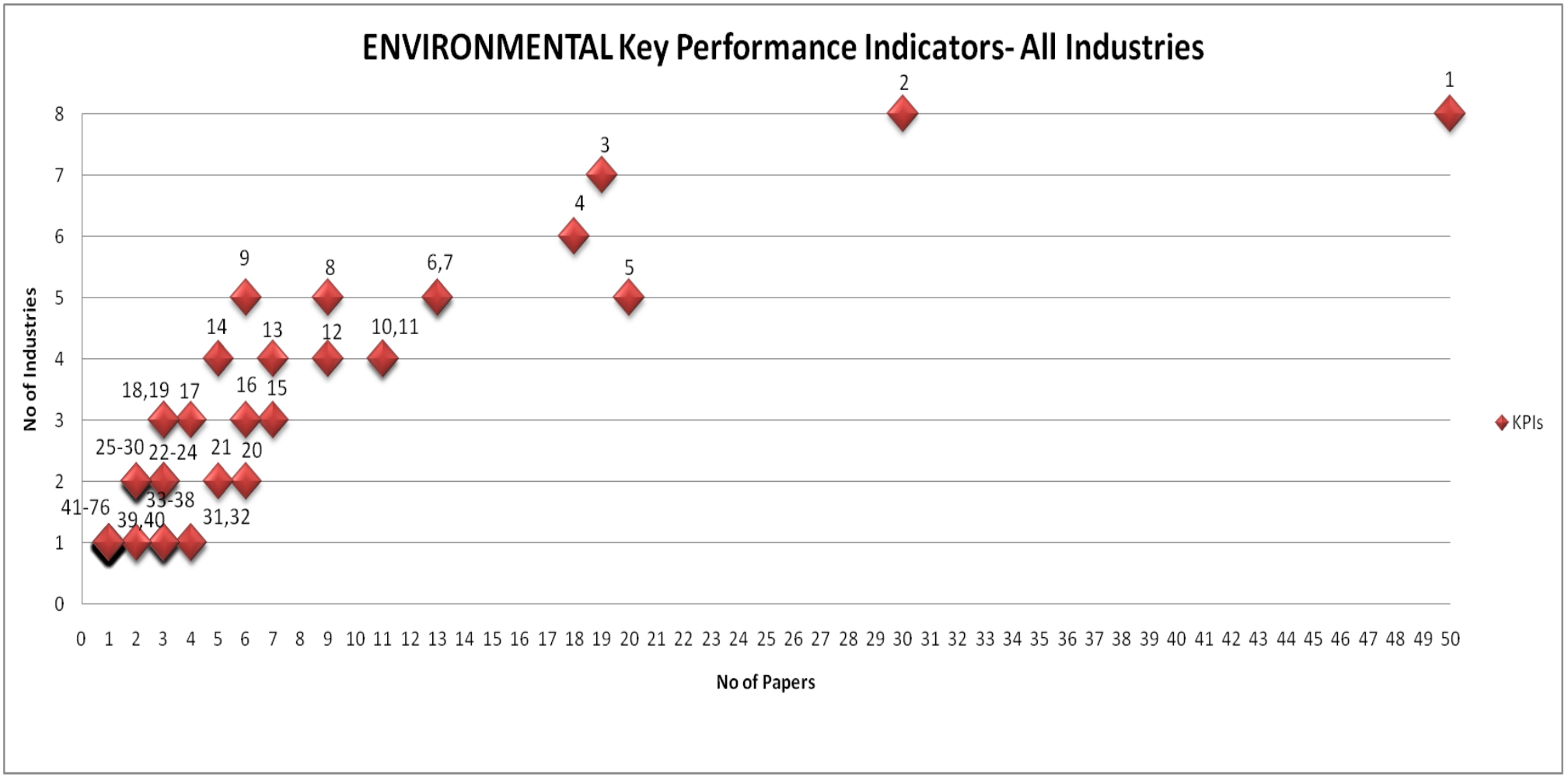


Diagram 60. Environmental key Performance Indicators- all indusrties

3.2. PROPOSED SET OF KPIs BY BIMCO

Continuing our efford to find the appropriate indicators as inputs to our system, in the previous paragraph we examined the most common used Key Performance Indicators at all the previous industries. Now, at this paragraph we compare them with a set of KPIs which BIMCO organization proposed.

BIMCO organization is an international shipping association providing services to its members such as information, advice and education about topics concerning all shipping related activities. As BIMCO's members can be considered ship owners, operators, managers, brokers and agents. So, it is obvious that such an organization, in order to be reliable and up to date, has to provide its members with a wide range of topics that reflect the current ongoing international agenda and to be flexible enough to change its topics depending on whether they continue to be of concern to its members.

In order to achieve its previous goal and answers to its members need for estimating progress BIMCO, is in charge of a Shipping Key Performance Indicators System, showing once again Key Performance Indicators value in shipping industry.

This tool uses a set of 64 indicators divided into seven (7) groups, each of which represents one of the seven (7) areas of interest in shipping industry: environment performance, health and safety management and performance, human resources performance, navigational safety performance, security performance and last but not least technical performance.

Due to the fact that in our paper we focus only in four (4) out of seven (7) areas of shipping industry's interest, Environmental performance, Health and Safety Performance, Navigational Performance and Security Performance, we will focus on these KPIs which are relevant to the above categories. In the following matrix, we have sum up BIMCO's Shipping Key Performance Indicators, as far as these categories. [164]

Categories	Key Performance Indicators	
Health and Safety Performance	Port State Control Performance	percentage
	Lost Time Injury Frequency	number
	Health and Safety Defiencies	number
	Lost Time Sickness Frequency	number
	Passenger Injury Ratio	percentage
Navigational Safety Performance	Navigational Deficiencies	number
	Navigational Incidents	number
Environmental Performance	Releases of Substances as def by Marpol Annex 1-6	number
	Ballast Water management violations	number
	Contained Spills	number
	Environmental Deficiencies	number
Security Performance	Port State Control Performance	number
	Security Deficiencies	number

Matrix 17. Key Performance Indicators proposed by BIMCO

Apart from these indicators, BIMCO also uses some other Key Performance Indicators that interest us and can be found either in a different category or in no category. These KPIs are collected in the following matrix.

Categories	Key Performance Indicators	
Without Category	Sox efficiency	(g/cargounit)mile
	Nox efficiency	(g/cargounit)mile
	CO2 efiiciency	(g/tonmile)
	Fire & Explosion	number
Operational Performance	Vetting Deficiencies	number
Human Resources Performance	Training Days per Officer	number

Matrix 18. Added Key Performance Indicators proposed by BIMCO

These indicators can be assumed as part of one of the categories that interest us. For example Sox efficiency, Nox Efficiency and CO2 efficiency play a big role in environmental performance of a company, so we estimate that they can be used in order to help in measuring environmental performance. In addition, incidents as fire and explosion affect the safety level of a vessel, so it can be used as a safety key performance indicator. Finally, vetting deficiencies and training also affects the safety levels of a vessel, and they can be assumed as leading indicators for safety.

In order to understand better what every indicator represents, BIMCO also provide a throughout definition of every Key Performance Indicator. Each of the previous ones is explaining bellow.

**** Definition of SECURITY KEY PERFORMANCE INDICATORS (BIMCO)*

- **Security Deficiencies:**

This KPI expresses the ship manager's security performance measured by the number of deficiencies recorded during external inspections and audits. The KPI counts the number of security related deficiencies including any sub standard act, practice or condition (such as lack of compliance to the ISPS code) recorded during external inspections and audits. The number of deficiencies is then made relative to the total number of external inspections and audits.

- **Port State Control Performance:**

The KPI counts the number of times where Port State Control Inspections are conducted without any deficiency being reported and divides this number by the total number of Port State Control Inspections conducted during the same period.

**** Definition of HEALTH AND SAFETY KEY PERFORMANCE INDICATORS (BIMCO)*

- **Port State Control Performance:**

As already mentioned.

- **Lost Time injury Frequency :**

This KPI expresses the company's ability to safeguard crew against injuries and fatalities. The KPI counts the number of Lost Time Injuries (LTI) among the crew per million exposure hours. Exposure hours are 24 hours per day while serving onboard. Note that injuries during spare-time on board are also included. LTI is the sum of Fatalities, Permanent Total Disabilities, Permanent Partial Disabilities and Lost Workday Cases. The term 'crew' refers to any person being part of the vessel's complement. (e.g. officers, ratings, cadets, superintendents).

- **Health and Safety Deficiencies:**

This KPI expresses the company's ability to avoid health and safety related deficiencies recorded during external inspections and audits. The KPI counts the number of health and safety related deficiencies including any sub standard act, practice or condition (such as misplaced life buoys or fire hoses) recorded during external inspections and audits. The number of deficiencies is then made relative to the total number of external inspections.

- **Lost Time Sickness Frequency :**

This KPI expresses the company's ability to safeguard crew sickness and fatalities while serving onboard. The KPI counts the cases of sick crew and any fatality due to sickness. Exposure hours are 24 hours per day while serving onboard. The term 'crew' refers to any person being part of the vessel's complement. (e.g. officers, ratings, cadets, superintendents).

- **Passenger Injury Ratio:**

This KPI expresses the company's ability to safeguard all passengers while onboard. The KPI represents a ratio between the number of injured (including fatalities) passengers reported during embarkation, disembarkation and voyage relative to the passenger exposure hours in the reporting period. By defining the KPI as a ratio, benchmarking is feasible even between different vessel size. Only vessels certified to carry passengers should use this KPI. Note that supernumeraries (family members, riding crew, superintendents and stowaways) are not considered as passengers.

**** Definition of ENVIRONMENTAL KEY PERFORMANCE INDICATORS (BIMCO)*

- **NOx Efficiency:**

This KPI expresses the amount of NOx emitted relative to the transport work performed. As the PI Value 'Emitted Mass NOx' is to be given in tons, the figure is multiplied by 1 million to get the KPI value in g/transport work (tonmile, passengermile, TEUmile, etc).

- **Releases of substances as defined by Marpol Annex 1-6:**

This KPI expresses the company's ability to avoid releases of substances as defined by MARPOL (Annex 1-6). This is done by counting (and aggregating) the number of (severe) spills of liquid and releases of substances. A severe spill is a spill above one barrel (42 US gallons or 159 litres).

- **Sox Efficiency :**

This KPI expresses the mass of SOx emitted relative to the transport work performed. As the PI Value 'Emitted Mass SOx is to be given in kg, the figure is multiplied by 1 thousand to get the KPI value in g/transport work (tonmile, passengermile, TEUmile, etc).

- **CO2 Efficiency:**

This KPI expresses the energy efficiency of the vessel by comparing emitted mass of CO2 to the vessel's total transport work. The expression gives the emitted mass of CO2 per ton cargo transported one mile. As the PI Value 'Emitted Mass CO2' is to be given in tons, the figure is multiplied by 1 million to get the KPI value in g/transport work (tonmile, passengermile, TEUmile, etc).

- **Contained Spills:**

This KPI expresses the company's ability to avoid spills, not the ability to contain them. The KPI counts the total number of contained spills. Contained spills should cover liquid spills including (but not limited to) cargo and bunkers contained on the vessel. Contained spills in secure areas as engine rooms are not counted, only spills that could have a potential environmental impact if not contained. Total number of spills on deck where nothing goes overboard of bulk liquids which could have had an environmental impact.

- **Environmental Deficiencies:**

This KPI expresses the company's environmental performance by measuring environmental related deficiencies recorded during external inspections and audits. The KPI counts the number of environment related deficiencies including any sub standard act, practice or condition of an environmental consequence (local regulations and MARPOL) such as failure in the Oily Water Separator, recorded during external inspections and audits. The number of deficiencies is expressed relative to the total number of external inspections and audits.

**** Definition of SAFETY KEY PERFORMANCE INDICATORS (BIMCO)*

- **Navigational Deficiencies:**

This KPI expresses the company's ability to avoid navigational related deficiencies recorded during external inspections and audits. The KPI counts the number of navigational related deficiencies including any sub standard act, practice or condition (such as a mal functioning radar), recorded during external inspections and audits. The number of deficiencies is then made relative to the total number of external inspections.

- **Navigational Incidents:**

This KPI expresses the company's navigational performance. The KPI counts any navigational incident resulting in a collision, allision or grounding. All incidents are counted regardless of the cause of the incident. Value parameters are used to weight collisions and groundings twice that of allisions.

- **Training Days per Officer**

This KPI expresses the company's commitment to maintain and enhance the officers' competence. The KPI represents the ratio between the ship manager's efforts in training over the total number of officer working days. Basically the average number of training days per officer day at sea.

- **Vetting Inspections**

This KPI expresses the ship manager's ability to avoid deficiencies and negative observations from vetting inspections. The KPI counts the number of deficiencies (including any sub standard act, practice or condition) and negative observations, recorded during vetting inspections. The number of deficiencies and negative observations is then made relative to the total number of vetting inspections.

- **Fires and Explosion**

This KPI expresses the company's ability to avoid fire and explosions onboard the vessel. The KPI counts the number of fire and explosion incidents as reported in the company's internal incident reports.

3.3. USED SET OF KPIs BY AN EXISTING EXISTING SHIPPING COMPANY

We decided to examine the indicators that BIMCO apporves and uses, beacuase it is an international approved organization and also because its Shipping Key Performance Indicators System is organized in collaboration with more than 20 shipping related companies and interest organizations, so we consider BIMCO and its system as trustworthy.

However, apart from those indicators that BIMCO proposes, it would be very useful and helpful, in order to be more sure that our set of KPIs can be used in a shipping company, to examine also with those that an existing shipping company already uses, in order to estimates its performance as far as the same fields as BIMCO, security, health and safety, safety and environment. This is a way to combine and compare the results from bibliography and the real market.

In order to achieve our goal we have communicated with an existing shipping company and we have bored its KPIs. As we did about BIMCO, we are going to focus only on those associating with security, health and safety, safety and environment, which are representing in the below matrix:

Categories	Key Performance Indicators	
Health and Safety Performance	Fatalities	number
	Lost Time Injury	number
	Lost Time Injury Frequency	number
	Total Recordable Cases	number
	Total Recordable Cases Frequency	number
Navigational Safety Performance	Incidents	number
	Collisions/Contacts	number
	Fire&Explosion	number
	Grouding	number
	Allissions	number
	Technical	number
	Flooding	number
	Crew Training Achievement	percentage
	Vetting observations/inspections	number
Environmental Performance	Spills to water<1 barrel	number
	Spills to water > 1 barrel	number
	Contained spills	number
	Spill Ratio	number
	Violation of Marpol	number
	Garbage disposed to shore	m3/ shipxday
	Garbage disposed to sea	m3/ shipxday
	Garbage incinerated	m3/ shipxday
	CO2 emissions	MT
	SO2 emissions	gr/Tn Nm
	NOx emissions	YES/NO
	EEOI	gr/Tn Nm
	Aspect Impact Resister	
Security Performance	PSC observations/inpsections	number

Matrix 19. Key Performance Indicators already in used by an existing shipping company

Following there is the definition of each one indicator,that the existing shipping company gave to us.

**** Definition of HEALTH AND SAFETY KEY PERFORMANCE INDICATORS (SHIPPING COMPANY)*

- **Fatalities** :

Number of fatalities on all vessels under management divided by the number of these vessels.

- **Lost Time Injury (LTI) :**

This index expresses the total number of fatalities, permanent total disabilities, permanent portial disabilities and lost workday cases.

- **Lost Time Injury Frequency (LTIF) :**

This index expresses the number of Lost Time Injuries per one million man exposure hours.

- **Total Recordable Cases (TRC) :**

This index expresses the total number of work related fatalities, lost time injuries, restricted work injuries & medical treatment injuries.

- **Total Recordable Frequency Cases (TRFC) :**

This index expresses the number of Total Recordable Cases per one million man exposure hours.

**** Definition of ENVIRONMENT KEY PERFORMANCE INDICATORS (SHIPPING COMPANY)*

- **Spills to water < 1 barrel (abs 200 lts) :**

Total number of spills of all vessels under management < 1 barrel.

- **Spills to water >1 barrel (abs 200 lts) :**

Total number of spills of all vessels under management > 1 barrel.

- **Contained spills:**

Total number of contained spills of all vessels.

- **Spill Ratio:**

Total number of spills to water expressed as a percentage (%) of the total number of laden voyages for all vessels.

- **Violations of Marpol or BW convention:**

Record number of violation of Marpol / Ballast Water incidents.

- **Garbage disposed to shore:**

Volume of waste disposed to shore by ship per day.

- **Garbage disposed to sea:**

Volume of waste disposed to sea by ship per day.

- **Atmospheric emissions CO2 for fleet:**

Emitted mass of CO2 per ton cargo transported for all types of fuel.

- **Atmospheric emissions Sox (gr/ Ton x m):**

Emitted mass of Sox given in gr per tonxm.

- **Atmospheric emissions NOx compliance (YES/NO) :**

Express of vessel is compliant with requirement of NOx technical code 2008.

- **EEOI(gr CO2/TonxNm):**

An indicator of ship in operation as an expression of efficiency in the form of CO2 emitted per unit of transport work.

- **Aspect Impact of Register :**

To determine and list those aspects that have or can have significant impact on the environment on an annual basis.

*** *Definition of SAFETY KEY PERFORMANCE INDICATORS (SHIPPING COMPANY)*

- **Incidents :**

Total number of incidents of all vessels.

- **Collisions:**

Total number of collisions of all vessels.

- **Fire and Explosion :**

Total number of fire and explosion of all vessels.

- **Allission :**

Total number of allissions of all vessels.

- **Grouding :**

Total number of grouding of all vessels.

- **Technical :**

Total number of technical issues of all vessels.

- **Flooding :**

Total number of flooding of all vessels.

- **Observations per inspection:**

Number of vetting observations divided by the number of vetting inspections on all vessels.

- **Crew Training achievement :**

Percentage of the arranged training courses which finally completed on time on all vessels.

*** Definition of SECURITY KEY PERFORMANCE INDICATORS (SHIPPING COMPANY)*

- **Port State Control Observations per inspection :**

Number of Port State Control observations divided by the number of Port State Control inspections on all vessels.

3.4. PROPOSED SET OF SHIPPING KPIs

Gathering all the information given both from shipping industry itself, from all the examined industries, form BIMCO and from the existing company we concluded to propose the following four (4) set of Key Performance Indicators regarding Safety, Health and Safety, Environment and Security Performance of a shipping company.

SHIPPING KEY PERFORMANCE INDICATORS (KPIs)	SAFETY
Training Achievement (Crew and Officers)	(percentage)
Vetting Observations per inspection	(number)
Incidents	(number)
Fire and Explosion	(number)

SHIPPING KEY PERFORMANCE INDICATORS (KPIs)	ENVIRONMENTAL
Atmospheric emissions SOx	(number)
Atmospheric emissions NOx	(number)
Atmospheric emissions CO2	(Rightship Rate)
Spills	(number)

SHIPPING KEY PERFORMANCE INDICATORS (KPIs)	HEALTH&SAFETY
Fatalities	(number)
Lost Time injuries Frequency	(number)
Lost Time Sickness Frequency	(number)
Near Misses	(number)

SHIPPING KEY PERFORMANCE INDICATORS (KPIs)	SECURITY
Damaged Cargo	(percentage)
Lost Cargo	(percentage)
Theft Cargo	(percentage)
Anti-Piracy Measures	(percentage)

Matrix 20. Our Proposed Set of KPIs

**** Explanation of SAFETY KEY PERFORMANCE INDICATORS (OUR PROPOSED SET)*

Initially, we have to mention that concerning safety, in our proposed set of KPIs we use not only lagging but also leading indicators, in order to have a more completed idea of the safety performance. Differences between leading and lagging indicators have already been mentioned in the first chapter.

LEADING INDICATORS:

- ***Training Achievement (Crew and Officers) : (percentage)***

Total number of completed crew & officers training courses expressed as a percentage (%) of the total training courses for crew and officers on each vessel under management for the examined period.Training courses at this point concern training only regaring safety matters and not any other field.

- ***Vetting observations per inspection: (number)***

Average number of vetting observations, on each tanker vessel under management divided by the number of vetting inspections the subject vessel during the examined period.

LAGGING INDICATORS:

- ***Incidents: (number)***

Total number of incidents of each vessel under management for the examined period.

By incident means any event could cause safety disturbance. Such events, in shipping industry, considered to be, the groudings, allissions, collisions/contacs, flooding and technical problems. The first three incidents are the most important for ship's safety and for that reason we have decided to use them in order to calculate the above index. So, the number of incidents equals the sum of the number of collisions, groudings and allissions. However, the three substances are not equal . Collisions and groudings have higher priority than allissions and for that reason the final index can be calculated through the below mathematical equation:

$$Incidents[number] = 2 \times Collisions + Allissions + 2 \times Groudings$$

- ***Fire and Explosion: (number)***

Total number of fire and explosion on each vessel under management for the examined period. Apart from collisions, groudings and allissions, other events which have many possibilities to happen, especially on a tanker vessel, are also fires and explosions.

**** Explanation of ENVIRONMENTAL KEY PERFORMANCE INDICATORS (OUR PROPOSED SET)*

- ***Atmospheric Emissions of Sox (number)***

Value of Sox emitted mass in Kg per transportation unit and miles.

$$Sox[kg/T \times NM] = \frac{Sox\ emitted\ mass}{Transporated\ tonnes\ of cargo\ \times Nautical\ miles\ \times 10\text{^}(-3)}$$

As transporation unit we refer to the total number of transportation cargo, in our case Tonnes and total number of transported nautical miles.

The total mass of emitted SOx in laden and ballast condition. Calculation is based on the fuel consumption and fuel quality, so to be accurate the emitted mass should be calculated for each bunkering (or at least each change in sulphur content) and each leg and then aggregated.

Sulfur dioxides are emitted during combustion of marine fuels. The default emission calculation is the following:

$$Sox\ [tonnes] = 2 \times content\ of\ fuel\ \times tonnes\ of\ fuel$$

, where the sulfur content of fuel is to be obtained from the fuel testing reports.

Effective 01st January 2012, IMO through MARPOL Annex VI mandates reduction in sulfur oxide (Sox) emissions from ship, with the global sulfur cap reduced to 3,5%. MEPC 58/23/Add.1 in Regulation 14 issued on 1st July 2010 defines special areas called Emission Control Areas (ECA), with a special mandatory measure of Sox Emissions. Ships are required to prevent, reduce and control air pollution from Sox and its attendant adverse impacts on land and sea areas. In Emission Control Areas global sulfur cap is at the moment reduced to 0,1%.

Date	Sulfur Limit in Fuel (% m/m)	
	SOx ECA	Global
2000	1.5%	4.5%
2010.07	1.0%	
2012		3.5%
2015	0.1%	
2020[a]		0.5%

Picture 5.MARPOL Annex VI Fuel Sulfur Limits, Source : International IMO, Marine Engine Regulations , (2015).

- ***Atmospheric Emissions of Nox (number)***

Value of Nox emitted mass in Kg per transportation unit and miles.

$$Nox[kg/T \times NM] = \frac{Nox\ emitted\ mass}{Transporated\ tonnes\ of cargo\ \times Nautical\ miles\ \times 10\text{^}(-3)}$$

Emitted mass in kilos is estimated from each vessel technical file, in which the maker of the main engine mentions the value of NOx emissions regarding in accordance to rpm value. The total mass of emitted NOx in laden and ballast condition, calculated on the basis of fuel consumption and engine speed. Only the main engine should be accounted for.

As transporation unit we refer to the total number of transportation cargo, in our case Tonnes and total number of transported nautical miles.

NOx emission limits are set for diesel engines depending on the engine maximum operating speed (n, rpm), as shown in the below picture Tier I and Tier II limits are global, while the Tier III standards apply only in NOx Emission Control Areas (ECAs).

Tier	Date	NOx Limit, g/kWh		
		$n < 130$	$130 \le n < 2000$	$n \ge 2000$
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96
† In NOx Emission Control Areas (Tier II standards apply outside ECAs).				

Picture 6. MARPOL Annex VI Nox Emissions Limits Source: International IMO, Marine Engine Regulations , (2015).

- ***Atmospheric Emissions of CO2: (Rightship Rate)***

Last Rightship's Rate concerning Greenhouse gases of each vessel for the examined period.

This indicator estimates the carbon dioxide emissions that should be obtained from combustion processes from fugitive emissions resulting from firefighting equipment leakages and will reported separately as the major component of Greenhouse Gases (GHG) emissions. CO2 Emissions are measured through the EEDI or EEOI indicator, by the follow equation:

$$EEDI = \frac{CO_2\ emission}{transport\ work}$$

The CO2 emission represents total CO2 emission from combustion of fuel, including propulsion and auxiliary engines and boilers, taking into account the carbon content of the fuels in question. The transport work is calculated by multiplying the ship's capacity (dwt), as designed, with the ship's design speed measured at the maximum design load condition and at 75% of the rated installed shaft power. [165]

Due to the fact the CO2 emissions has a large impact in environment, many organization has been establishes in order to rank each vessel to categories concerning its CO2 production. One of the most significant and known of such organizations is Rightship which has won great recognition the last years from the majority of the shipping companies. More and more shipping companies participate at Rightship organization which has lead to have as members more than 76,000 vessels from all the categories.

The Greenhouse Gas (GHG) Emissions Rating is a practical measure derived from the EVDI™ that allows relative comparison of a ship's carbon dioxide emissions to vessels of a similar size and type using a simple A – G rating scale, as Rightship page mentions [166]. At the next paragraphs you will find the combination we have assumed concerning the Rightship GHG Emissions Rating and the value of KPI at our proposed Environmental KPI set.

- ***Spills : (number)***

Total number of spills to water resulted from each vessel's operation during both at sea and on port for the examined period.

**** Explanation of HEALTH & SAFETY KEY PERFORMANCE INDICATORS (OUR PROPOSED SET)*

- ***Fatalities : (number)***

Number of deaths among the crew or any person being part of the vessel, on each vessel under management resulting from a work injury (not illness or other conditions) regardless of the length of time between the injury and death.

- ***Lost Time Injuries Frequency (LTIF): (number)***

Number of Lost Time Injury incidents as per OCIMF Marine Injury Reporting guidelines publication on each vessel under management. Lost time injuries incidents sums the number of permanent total disabilities (PID), permanent portial disabilities (PPD) and lost workday cases (LWC)

This number is expressed as the total number of the above Lost Time Injuries per one million man exposure hours.

As exposed hours can be assumed as the product of the total number of crew or anyone who is part of the subject vessel , the number of days and the number of hours each day they are expossued (being on board means that you are expossued 24 hours a day). The above is measured during the examined period.

As a concequence :

$$LTIF = \frac{(PID + PPD + LWC) \times 1{,}000{,}000}{crew \times days \times 24}$$

- ***Lost Time Sickness Frequency (LTSF): (number)***

Number of sicked people among the crew or any one who is part of the subject vessel over 24 hours and the number of lost workday cases among the crew or anyone who is part of the subject vessel resulting from an illness on all vessel under management during the examined period.

This number is expressed as the total number of the above Lost Time Illnesses per one million man exposure hours.

As exposed hours can be assumed as the product of the total number of crew or anyone who is part of the subject vessel , the number of days and the number of hours each day they are expossued (being on board means that you are expossued 24 hours a day). The above is measured during the examined period.

As a concequence :

$$LTSF = \frac{(sicked\ people + LWC) \times 1{,}000{,}000}{crew \times days \times 24}$$

- ***Near Misses (number)***

Average number of near misses reported on each vessel management for the examined period.

A ‘‘Near Miss’’ is any situation onboard a vessel, such as an unsafe act or an unsafe condition, that has the potential to cause an injury, loss of containment or endangerment to the vessel and its cargo. A near miss can also be considered:

- An incident with no consequences which could have reasonably resulted in consequences under different conditions.
- An incident that had some consequences that could have reasonably resulted in more severe consequences under different conditions.

Near miss reporting is a vital component of effective safety management and companies in the shipping industry support the near miss reporting principle. This procedure is intended to provide guidance to shore based and shipboard personnel on the reporting of the near misses. Near Misses have to be reported without fear of retribution. The master is responsible for ensuring that the crew is able to make miss reports and ensuring that they are acted upon to prevent a near miss becoming an accident. When a near miss is reported then it must be reported and then the corrective and preventive actions will take place. Finally, the severity of each near miss and the potential consequences of them have also to be reported.

The near miss report includes basic information and a sufficient description so the circumstances of the near miss are clear. As a minimum, the following information should be reported:

- Which positions and/or what equipment was involved (i.e. unsafe act or unsafe condition)
- What happened, where, when and in what sequence?
- What were the potential consequences had the near miss occurred under different conditions?
- What corrective action was taken to address the near miss?
- What preventive action was or will be taken to help prevent recurrence?

For near misses with potential to cause serious injury, loss of containment or vessel damage the investigation process shall be the same as if an accident had actually occurred in order to identify the root cause and prevent recurrence.

**** Explanation of SECURITY KEY PERFORMANCE INDICATORS (OUR PROPOSED SET)*

- ***Damaged Cargo : (percentage)***

Damaged cargo on each one of the vessels under management expressed as a percentage (%) of the total cargo transported in this period. The mentioned damaged cargo concerns damages that are associated to security violations and not any other reason that could propably cause damage to the transferred cargo.

- ***Lost Cargo : (percentage)***

Lost cargo on each one of the vessels under management expressed as a percentage (%) of the total cargo transported in this period. As previously concerninf the daaged cargo, also at this indicator we take into account the amount of cargo that has been lost only due to security causes and not for any other reason could lead to a loss of cargo.

- ***Theft Cargo : (percentage)***

Lost cargo on each one of the all vessels under management expressed as a percentage (%) of the total cargo transported in this period.

- ***Anti- Piracy Measures : (percentage)***

The total number of the used anti-piracy measures on each one of all vessels under management expressed as a percentage (%) of the total proposed anti-piracy measures. Especially for tanker vessels in order to be protected against possible pirate's attacks below you can find a list of 23 anti-piracy measures according to ReCAAP ISC, [167].

1. To discourage and deter boarding and access to the ship's accommodation, ship should consider implementing strong hardening measures such as barber/razor wire barriers, spikes or other industry recognized methods as deemed appropriate.
2. All doors and hatches, not just those facing the weather deck, but including interior ones providing access to the bridges, accommodation and machinery spaces must be property secured to prevent them from being opened.
3. Hatches can be reinforced with measures such as Padlock/Angle Bar Protection Box which reinforce weather-tight doors by preventing easy cutting or knocking of padlocks and eye-pads. However, such measures will be useless if poor quality padlocks are used. A regular review on padlock quality for suitable size its security grades {EN 12320} and water-proofing is necessary.
4. In addition to the padlocking of the skyline hatch from outside, sling wire-lashing from the inside of the ship's stores onto the hatch can be made with the end secured to turn-buckle to prevent slack. Without a turn-buckle, the hatch can still be breached and the sling wire-lashing may slack through vibration or other factors.
5. A designated and limited number of access points must be used for security patrols and routine access. The use of these doors or hatches must be controlled by the Officer of the Watch.

6. Means of blocking or lifting external ladders on the accommodation block to prevent use and to restrict external access to the bridge.
7. Barbed/razor wire barriers can be emplaced in particularly vulnerable, lower-entry zones of the ship, such as the low freeboard areas. In case of time restrictions, these areas ought to be hardened fist whereas the remaining area to do so while the ship is underway. Due consideration to be accorded fog crew evacuation should the need arises.
8. Accommodation port holes and windows which could be used to gain access to the ship accommodation must be fitted with hardening arrangements such as dead lights or interior grilles. To facilitate evacuation in times of safety hazards, mechanisms such as variable bolts and butterfly latches can be used to secure the interior grilles.
9. Water sprays should be rigger-hoses and foam monitors (delivering water) in a ready state should be fixed in position to cover likely access routes particularly the vulnerable quarter decks and other blind spots on board the ship.
10. Tools and equipment that may be of use to attackers must be stored in a secure location.
11. Alarms-the alarm systems are important and useful to warn the crew on board regarding threat or intrusion. Alarm likewise serves as an alert to the perpetrators that they had been detected, thus, it has been an effective tool in compelling the perpetrators to leave after knowing that they had been spotted.
12. Ship Security Alert System (SSAS) – in compliance with ISPS Code and guidelines from IMO, operational status of the SSAS should be checked prior each voyage and the familiarization of crew should be carried out with its functionally and discreet operations periodically.
13. Tracking devices and communications equipment enable marine and naval ships to track, identify and monitor a ship's position, location and any other detail that might be important in maneuvering and stabilizing a ship's route and course. The use and installation of different types of tracking devices and communication equipment gives added advantage to the ships especially during times of distress.
14. Emergency communications equipment, such as iridium-powered phones, can be stored on board and used in case of the ship's main communications were disabled by perpetrators. A backup iridium-powered phone should also be stowed in a secure location or any safe room.
15. Search Light/Lighting-the use of search lights is useful as it can detect any approaching ships or boats at greater distance and can be used as a signaling device. Having sufficient lighting around the ship is also a source of deterrence to pirates and robbers at night whether the ship is at port or underway. Lighting can provide maximum illumination within and around the decks giving the watches and lookouts better view around the ship.
16. Close-circuit television (CCTV) – is useful to ensure that vulnerable locations of ship are monitored, and the owner is able to view these vulnerable portions in the owner's control room ashore and on board the ship manned by an operator.
17. It is advisable to install a CCTV outside the master's cabin for the ship master to monitor exterior situations.

18. Fabricated steel plating on the weather deck doors for protection against firearms.
19. Polycarbonate screens that are lightweight and damage-resistant for additional protection of the bridge area.
20. Motion sensors (infra-red or laser) especially in vulnerable areas such as the quarter decks and entrances to detect suspicious movements.
21. Commercial software that allows the ship manager or CSO to remotely monitor any attempts of oil cargo theft or disabling of AIS on board the ship.
22. Commercial software to allow the ship manager or CSO onshore to track the ship on voyage.
23. Citadel – with bulletproof doors, emergency rations lasting at least 72 hours, as well as USB plug for crew to remotely monitor the exterior via CCTV. The crew should be aware of the procedures of evacuation to the citadel and exercise regularly on swift evacuation in case of inevitable boarding by the perpetrators. The citadel which provides protection must ensure a reliable means of communication ashore to maintain certain degree of situation awareness and responses from the authorities. As it provides resistance to forced entry for a fixed period of time, due consideration is necessary to ensure the ability to control the ship to avoid collision especially in busy waters.

3.5. WEIGHT OF PROPOSED SHIPPING KPIs

In the previous paragraph we analyzed the proposed Key Performance Indicators but we didn't mention any of them as more or less important. In this paragraph we are going to find out the weights of each Key Performance indiacators as the don't appear to be equal.

For this porpose we will use again the findings of the second chapter regarding all the examined industries. For every industry we have mentioned the total number of examined papers and the number of which safety, health and safety, security and environment had been mentioned. Gathering this information lead us to conclude which is tend of each industry. In the matrixs below all the mentioned information is gathered.

	INDUSTRIES							
PAPERS	ROAD	RAIL	AVIATION	CHEMICAL	NUCLEAR	OFFSHORE	PORTS	SHIPPING
ENVIRONMENT	5	10	11	9	12	13	13	14
HEALTH & SAFETY	5	5	7	2	8	8	4	6
SECURITY	4	4	5	2	3	2	4	5
SAFETY	14	13	12	12	15	16	9	12
TOTAL	18	20	17	18	20	20	21	18

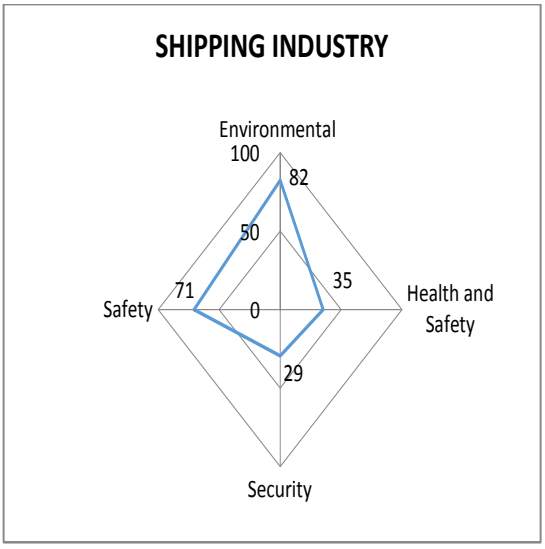
Matrix 21. Number of papers mentioning performance for every industry

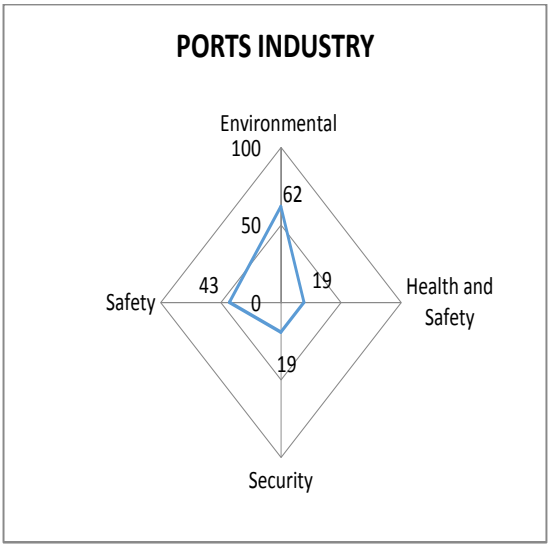
Based on the above matrix we calculated the percentage of appearance environmental, safety, health and safety and security performance for every industry. In the following matrix you can see the tend of every industry regarding the above fields of interest.

	INDUSTRIES							
PAPERS	ROAD	RAIL	AVIATION	CHEMICAL	NUCLEAR	OFFSHORE	PORTS	SHIPPING
ENVIRONMENT	28	50	65	50	60	65	62	78
HEALTH & SAFETY	28	25	41	11	40	40	19	33
SECURITY	22	20	29	11	15	10	19	28
SAFETY	78	65	71	67	75	80	43	67

Matrix 22. Percentage of mentioning performance for every industry

The last matrix can be assumed as an evidence of all industries tend regarding the interest fields. It is obivious that industries with common nature it is logical to have the same tend as it appears to the above matrix. In order to compare industries preferences and tention and to find similar ones with shipping industry we created the following spider diagrams based on the above matrix's results.



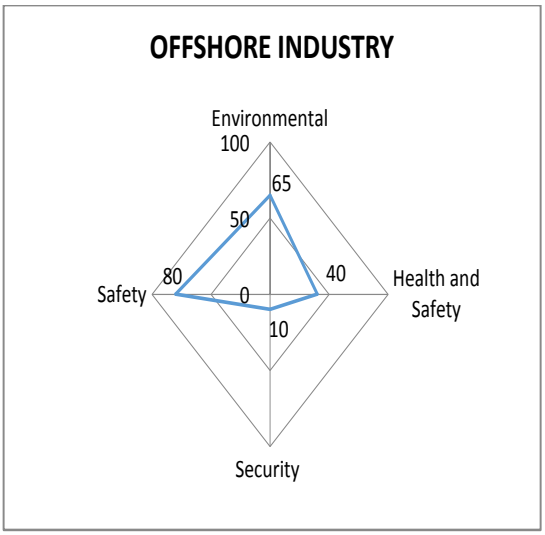


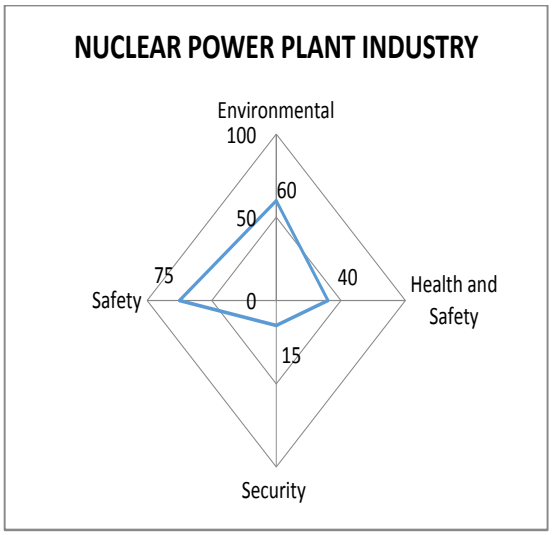
SHIPPING INDUSTRY

ENVIRONMENTAL	82
SAFETY	71
HEALTH&SAFETY	35
SECURITY	29

PORTS

ENVIRONMENTAL	62
SAFETY	43
HEALTH&SAFETY	19
SECURITY	19



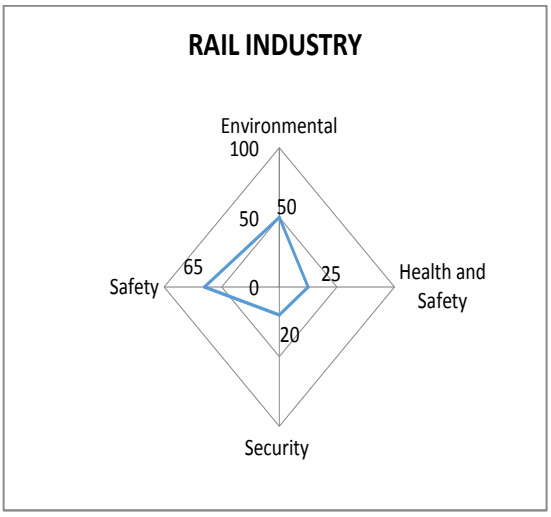


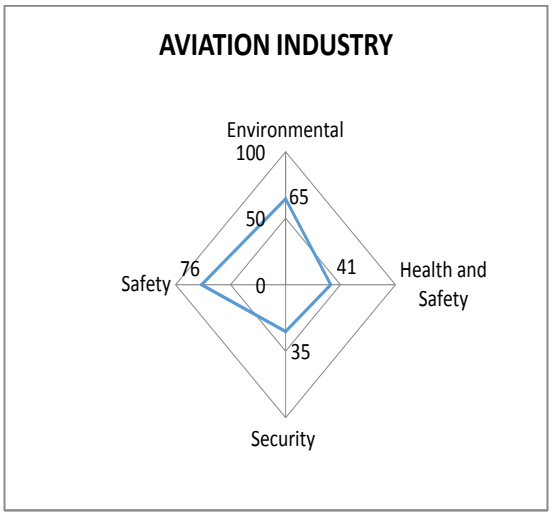
OFFSHORE INDUSTRY

SAFETY	80
ENVIRONMENTAL	65
HEALTH&SAFET	40
SECURITY	10

NUCLEAR POWER PLANT INDUSTRY

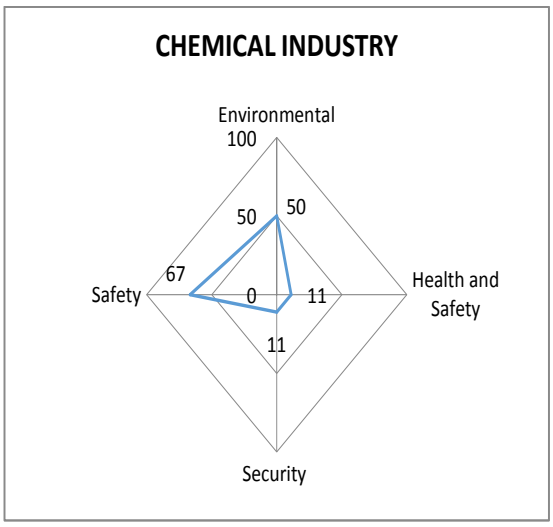
SAFETY	75
ENVIRONMENTAL	60
HEALTH&SAFETY	40
SECURITY	15

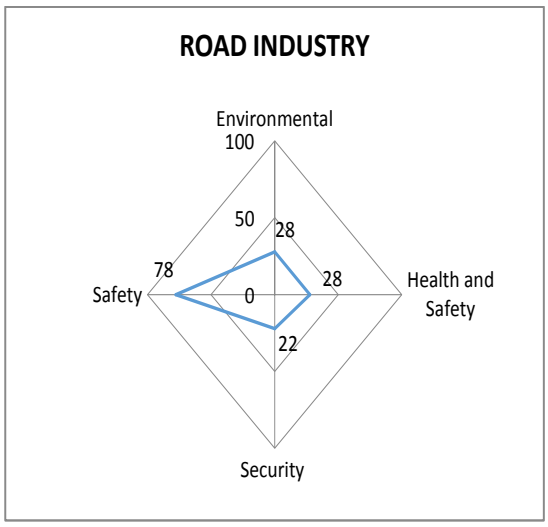




RAIL INDUSTRY	
SAFETY	65
ENVIRONMENTAL	50
HEALTH&SAEFTY	25
SECURITY	20

AVIATION INDUSTRY	
SAFETY	76
ENVIRONMENTAL	65
HEALTH&SAFETY	41
SECURITY	35





CHEMICAL INDUSTRY	
SAFETY	67
ENVIRONMENTAL	50
HEALTH&SAFETY	11
SECURITY	11

ROAD INDUSTRY	
SAFETY	78
ENVIRONMENTAL	28
HEALTH&SAFETY	28
SECURITY	22

Diagram 61. Spider Diagrams of all Industries

Comparing all industries based on the above spider diagrams we can easily conclude to the following observations:

- All the examined industries have less papers about their security performance. The reason of that is that security is one field that every company at every industry wants to keep secret and doen't give many details.
- All the examined industries give more information about their health and safety performance than their security performance but they pay less attention comparing to their safety and environmental performance.
- The majority of the industries pay the most attention at its safety performance apart from the shipping and ports industry.
- Offshore and Nuclear Power Plan industry have the same tend considering how important they assume these four mentioned field as they have also a lot common Key Performance Indicators.
- The same tention appear to have also port and shipping industry as they are simiral industries with a a lot common Key Performance Indicators, common nature and tention to pay the most of their attention to the environmental performance. For that reason they are the only two industries that pay the most of their attention examining their envronmnetal performance.
- About rail, road and aviation industries we were waiting to have the same tention as they have the same nature as transportation industries. However, road tends to have some differences with the other two, which are simiral and also the chemical industry as a surprise appears to have also the same tention as rail and aviation industries.

As a sequence of the above observations and the spider diagrams is that shipping industry has the same tention as the ports industry and as s result is the only one industry that we will take into consideration during the Key Performance Indicators weight evaluation process.

A total of two industries (shipping and ports) were consulted to give their preferences to KPIs. Their preferenced based on the number of papers mentioned the specific indicator as a percentage of the total number of papers that mentioned KPIs of the same field. Through this way each industry assignes its preference to the examined indicators and the two of them together determine the importance weights of them.

Weight's evaluation process is analyzed throughtout in the following matrixs for safety, environmental, health and safety, security selected Key Performance Indicators seperatelly.

***** Safety Performance*****

Safety Key Performace Indicators - LITERATURE REVIEW		
KPIs/ Industries	PORTS	SHIPPING
Training Achivement	0	5
Vetting Observations	0	2
Incidents	2	4
Fire & Explosion	2	1
All **SAFETY papers** per industry :	9	12

Safety Key Performace Indicators - WEIGHTS EVALUATION				
Industries/ **KPIs**	*Training Achivement*	*Vetting Observations*	*Incidents*	*Fire & Explosion*
PORTS	0	0	2,22	2,22
SHIPPING	4,17	1,67	3,33	0,83
AVERAGE	2,08	0,83	2,78	1,53
SUM	7,22			
WEIGHTS	0,29	0,12	0,38	0,21
SUM WEIGHTS	1	OK		

Matrix 23. Weight Evaluation of Safety KPIs

	SAFETY KPIs	**WEIGHT RESULTS**
1	**Incidents**	**38%**
2	**Training Achivement**	**29%**
3	**Fire & Explosion**	**21%**
4	**Vetting Observations**	**12%**

Matrix 24. Weight of Safety KPIs

***** Environmental Performance*****

Environmental Key Performace Indicators - LITERATURE REVIEW		
KPIs/ Industries	PORTS	SHIPPING
Sox Emissions	3	4
Nox Emissions	3	4
CO2 Emissions	11	4
Spills	1	3
All **ENVIRONMENTAL papers** per industry :	13	14

Environmental Key Performace Indicators - WEIGHTS EVALUATION				
Industries/ **KPIs**	*Sox Emissions*	*Nox Emissions*	*CO2 Emissions*	*Spills*
PORTS	2,31	2,31	8,46	0,77
SHIPPING	2,86	2,86	2,86	2,14
AVERAGE	2,58	2,58	5,66	1,46
SUM	12,28	0,00	0,00	0,00
WEIGHTS	**0,21**	**0,21**	**0,46**	**0,12**
SUM WEIGHTS	1	OK		

Matrix 25. Weight Evaluation of Environmental KPIs

	ENVIRONMENTAL KPIs	**WEIGHT RESULTS**
1	**CO2 Emissions**	**46%**
2	**Sox Emissions**	**21%**
3	**Nox Emissions**	**21%**
4	**Spills**	**12%**

Matrix 26. Weight of Environmental KPIs

Health & Safety Performance

Health & Safety Key Performace Indicators - LITERATURE REVIEW		
KPIs/ Industries	PORTS	SHIPPING
Fatalities	2	2
Lost Time Injury Frequency	3	5
Lost Time Sickness Frequency	2	4
Near Misses	2	1
All **HEALTH&SAFETY** papers per industry :	4	6

Health & Safety Key Performace Indicators - WEIGHTS EVALUATION				
Industries/ KPIs	*Fatalities*	*Lost Time Injury Frequency*	*Lost Time Sickness Frequency*	*Near Misses*
PORTS	5	7,5	5	5
SHIPPING	3,33	8,33	6,67	1,67
AVERAGE	4,17	7,92	5,83	3,33
SUM	21,25			
WEIGHTS	0,20	0,37	0,27	0,16
SUM WEIGHTS	1	OK		

Matrix 27. Weight Evaluation of Health & Safety KPIs

As Fatalities is without doubt the most major Key Performance Indicator, we assume that this is the first of importance. So the final weight of Health and Safety Key Performance Indicators is:

	HEALTH & SAFETY KPIs	WEIGHT RESULTS
1	**Fatalities**	**37%**
2	**Lost Time Injury Frequency**	**27%**
3	**Lost Time Sickness Frequency**	**20%**
4	**Near Misses**	**16%**

Matrix 28. Weight of Health & Safety KPIs

***** Security Performance*****

Security Key Performace Indicators - LITERATURE REVIEW		
KPIs/ Industries	PORTS	SHIPPING
Damaged Cargo	1	1
Theft Cargo	1	1
Lost Cargo	1	1
Anti-Piracy Measures	0	1
All SECURITYY papers per industry :	4	5

Security Key Performace Indicators - WEIGHTS EVALUATION				
Industries/ KPIs	*Damaged Cargo*	*Theft Cargo*	*Lost Cargo*	*Anti-Piracy Measures*
PORTS	2,5	2,5	2,5	0
SHIPPING	2	2	2	2
AVERAGE	2,25	2,25	2,25	1
SUM	7,75			
WEIGHTS	0,29	0,29	0,29	0,13
SUM WEIGHTS	1	OK		

Matrix 29. Weight Evaluation of Security KPIs

	SECURITY KPIs	WEIGHT RESULTS
1	**Damaged Cargo**	**29%**
2	**Theft Cargo**	**29%**
3	**Lost Cargo**	**29%**
4	**Anti-Piracy Measures**	**13%**

Matrix 30. Weight of Security KPIs

CHAPTER 4: " FUZZY LOGIC MODELS"

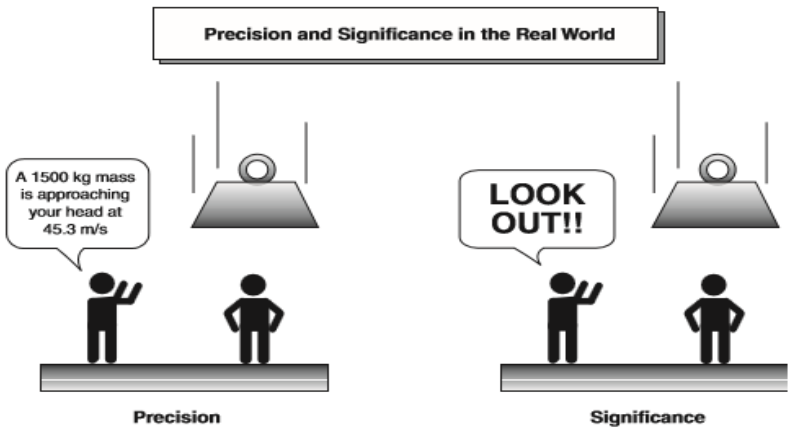
4.1. FUZZY LOGIC THEORY

4.1.1. Description of Fuzzy Logic (FL)

Fuzzy Logic (FL) is a double meaning methodology. On the one hand is a logical system, an extension of multivalued logic and on the other hand is almost synonymous with the fuzzy sets theory. The fuzzy sets theory concerns classes of objects with unsharp boundaries in which membership is a matter of degree [168].

The main characteristic of Fuzzy Logic is the fact that uses words rather than values; something that makes it simpler as words are closer to human's nature. Another basic characteristic of FL, which plays a central role in most of its applications, is that of a fuzzy rule (if-then). Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). High importance has gained the last years the combinated methodologies in soft computing such as fuzzy logic and neurocomputing, which lead to neuro-fuzzy systems and with Dr. Roger's research the ANFIS system (Adaptive Neuro-Fuzzy Inference System) has been established.

Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision— something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concepts of fuzzy logic relies on age-old skills of human reasoning. Finally one more evidence of its importance is the fact that gives to its users the ability to map an input space to an output space, something that can be the starting point of everything.



Picture 7. Example of Precision and Significance in the real world

4.1.2 Advantages of Fuzzy Logic (FL)

Nowadays, the number and variety of applications of fuzzy logic have increased significantly and this is due to the large amount of fuzzy logic advantages. Some of them are presented below:

1. Easy to be understood as it consists of simple mathematical concepts.

2. High flexibility

3. Tolerant in cases with imprecise data

4. Ability of modeling nonlinear functions of arbitrary complexity, so as to match any set of input-output. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

5. Can be built on top of the experience of experts, as let the users rely on their experience.

6. Ability to be blended with conventional control techniques and not necessarily replace them.

7. Fuzzy logic is based on natural language and as a consequence is easy to be used.

4.1.3 Cases when Fuzzy Logic (FL) is not recommended

Despite all the above advantages of Fuzzy Logic, there are cases in which the use of Fuzzy Logic is not recommended. Some of them are the following ones:

1. When big accuracy is needed.

2. When the problem can be easily solved with other methods

3. When there is an alternative solution.

4.1.4 Fuzzy Logic Methodology

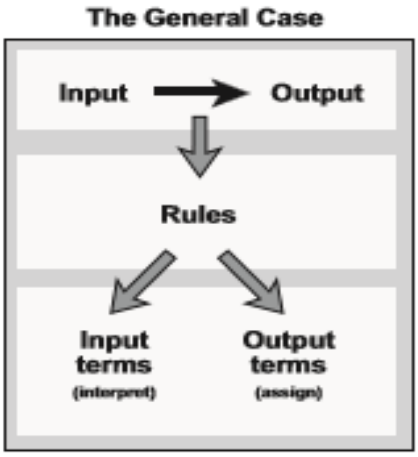
In an attempt to use fuzzy logic in any application, the user is fully in charge. That means that he has to deal with all the necessary issues that have to be fixed. The methodology of Fuzzy Logic has many parts. The basic are the following:

1. Fuzzy Sets .
2. Membership Functions.
3. Logical Operations.
4.IF-Then Rules.
5. Types of Inference System.

Before starting analyzing what each of the above means we will make a small reference to the main scope of Fuzzy Logic.

4.1.4.1 Main Concept of Fuzzy Logic (FL)

Scope of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is unimportant. The rules themselves are useful because they refer to variables and the adjectives that describe those variables. Before you can build a system that interprets rules, you must define all the terms you plan on using and the adjectives that describe them. The following diagram provides a roadmap for the fuzzy inference process as it shows the general description of a fuzzy system .



Picture 8. General case of Fuzzy Inferece process

As Fuzzy Logic Toolbox refers according to the concept of fuzzy inference, '' fuzzy inference is a method that interprets the values in the input vector and, based on some set of rules, assigns values to the output vector''.

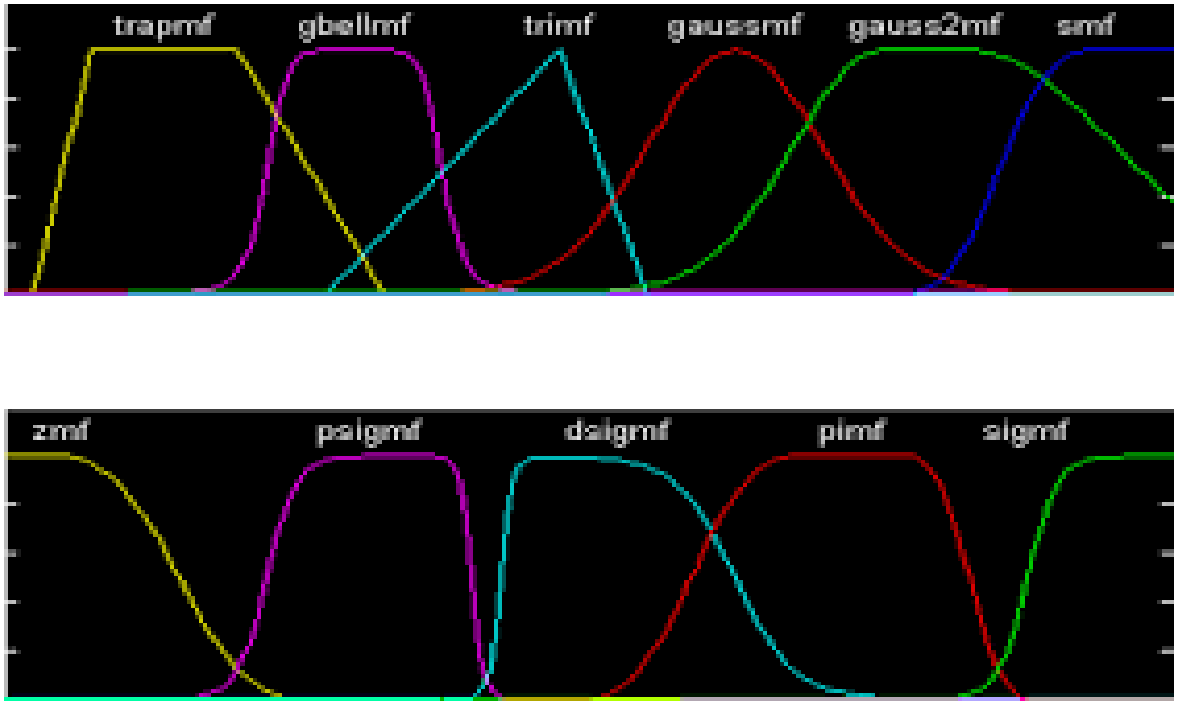
.

4.1.4.2. Fuzzy Sets of Fuzzy Logic (FL)

The beginning of any fuzzy application begins with the concept of a fuzzy set, which is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. In order to understand better what a fuzzy set is first we define ehat a classical set is. A classical set is a container that wholly includes or wholly excludes any given element and it is called like that because it has been around for a long time.

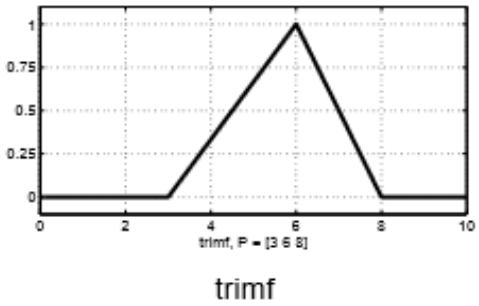
4.1.4.3. Membership Functions of Fuzzy Logic (FL)

Membership functions (MF) are curves that define how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept. The only condition a membership function must really satisfy is that it must vary between 0 and 1. The function itself can be an arbitrary curve whose shape we can define as a function that suits us from the point of view of simplicity, convenience, speed, and efficiency. The possible shapes that vary for a membership function are: *triangular, trapezoidal, Gaussian, generalized bell, sigmoidal, Z curves, S curve,* and *Pi curves.*



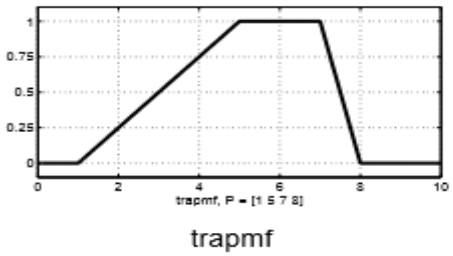
Picture 9. Types of Membership Functions

- *Triangular membership function:* Named trimf. Is the simplest membership function as is formed using straight lines.



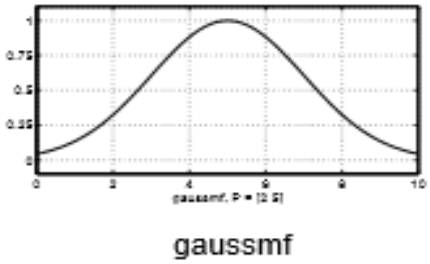
Picture 10. Trimf Membership Function

- *Trapezoidal membership function:* Named trapmf. Is has got a flat top and really is just a truncated triangle curve. It has also the advantage of simplicity.



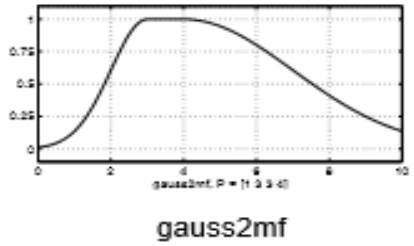
Picture 11. Trapmf Membership Function

- *Gaussian membership function*: Named gaussmf . Is build on the Gaussian distribution curve.



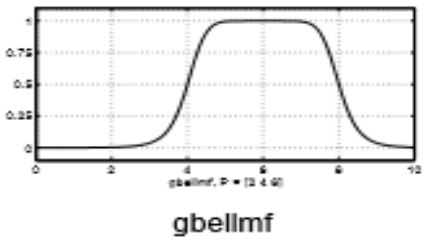
Picture 12. Gaussmf Membership Function

- *Two Gaussian membership functions:* Named gauss2mf . Is a two-sided composite of two different Gaussian curves.



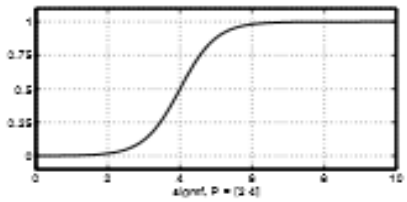
Picture 13. Gauss2mf Membership Function

- *Bell membership function*: Named gbellmf . Is specified by three parameters with one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned.



Picture 14. Gbellmf Membership Function

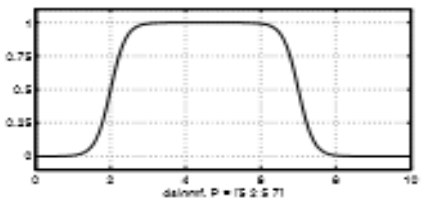
- *Sigmoidal membership function*: Named sigmf . That type of membership function specifies asymmetric membership functions which are important in centrain application, which can be either open left or right.



sigmf

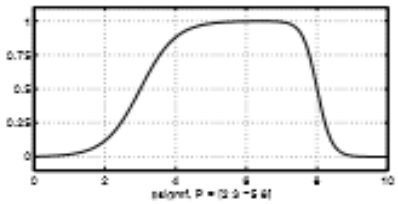
Picture 15. Sigmf Membership Function

- *DSigmoidal or PSigmoidal membership function:* Named dsigmf and psigmf as well. These membership functions are been synthesized using two sigmoidal functions.



dsigmf

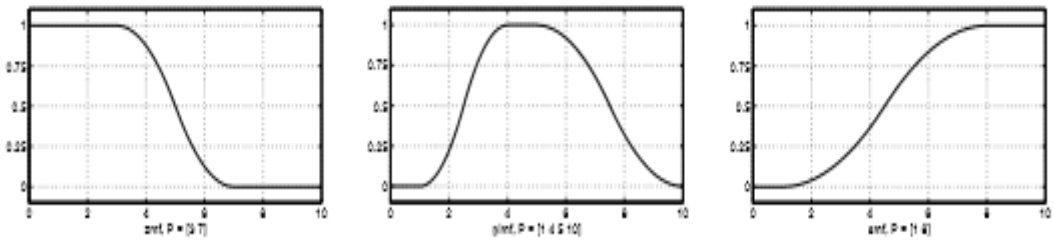
Picture 16. DSigmf Membership Function



psigmf

Picture17. PSigmf Membership Function

- *Polynomial membership functions (Z, S, Pi curves):* Named zmf, smf, pimf. The function zmf is the asymmetrical polynomial curve open to the left, smf is the mirror-image function that opens to the right, and pimf is zero on both extremes with a rise in the middle.



zmf pimf smf

Picture18. Polynomial Membership Functions

4.1.4.4. Logical Operation of Fuzzy Logic (FL)

After the previous analysis, we will focus on the application of logical operation to fuzzy logic. The basic element is that if you keep the fuzzy values at their extremes of 1 (completely true), and 0 (completely false), standard logical operations will hold.

Considering that there are two inputs, A, B and that they are limited to values between 0 and 1 there are three logical operations that can be accomplished in fuzzy logic. These logical operations are: *AND, OR, NOT.* Each one of the three logical operations can be resolved by a function. As it can be easily understood from the follow pictures, the equal functions for the logical operations are the following:

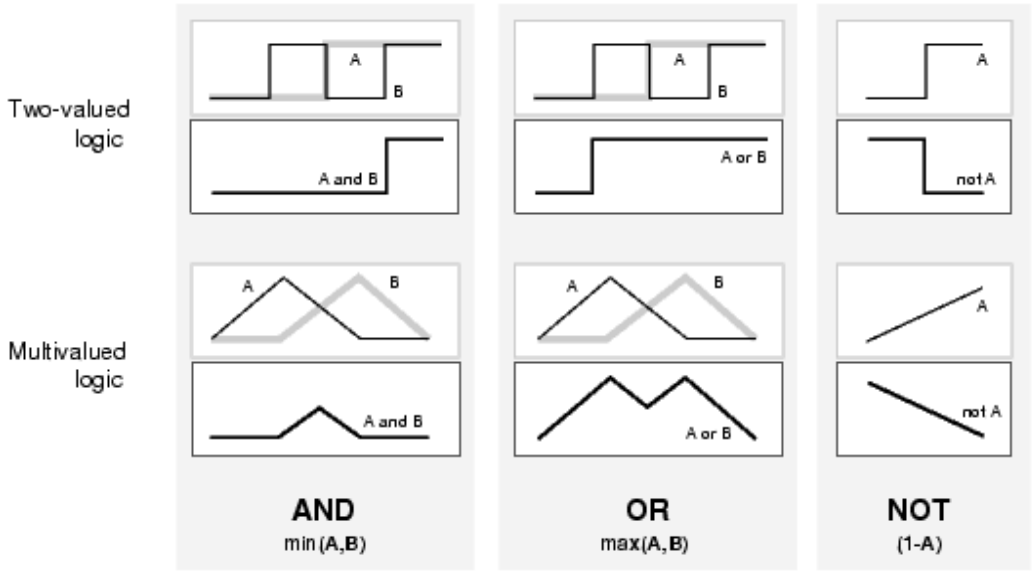
- Fuzzy Intersection or conjunction, (AND): A AND B -------- min(A,B)
- Fuzzy union or disjunction (OR): A OR B --------- max (A,B)
- Fuzzy Complement (NOT) : A NOT --------- 1-A

Fuzzy intersection (AND) of A and B is specified in general by a binary mapping T, which aggregates two membership functions as follows:

$\mu A \cap B(x) = T(\mu A(x), \mu B(x))$

Like fuzzy intersection, the fuzzy union operator (OR) is specified in general by a binary mapping S:

$\mu A \cup B(x) = S(\mu A(x), \mu B(x))$



Picture 19. Logical Operations in Fuzzy Logic

4.1.4.5. IF-Then Rules of Fuzzy Logic (FL)

A single if-then fuzzy rule assumes the form:

if x is A then y is B,

where A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion. Inputs to the if-then rules are the current values for the input variables and the output is the entire fuzzy set, which is going to be defuzzified, assigning one value to the output (this section will be analyzing in the next paragraphs).

The process of **If-then rules** is presented below:

1 Fuzzify inputs: Resolve all fuzzy statements in the antecedent to a degree of membership between 0 and 1. If there is only one part to the antecedent, then this is the degree of support for the rule.

2 Apply fuzzy operator to multiple part antecedents: If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1. This is the degree of support for the rule.

3 Apply implication method: Use the degree of support for the entire rule to shape the output fuzzy set. The consequent of a fuzzy rule assigns an entire fuzzy set to the output. This fuzzy set is represented by a membership function that is chosen to indicate the qualities of the consequent. If the antecedent is only partially true, (i.e., is assigned a value less than 1), then the output fuzzy set is truncated according to the implication method.

The number of rules is steed every time by the user by we have to notice that one rule alone is not effective in general. Two or more rules that can play off one another are needed. The output of each rule is a fuzzy set. The output fuzzy sets for each rule are then aggregated into a single output fuzzy set. Finally the resulting set is defuzzified, to a single number.

4.1.4.6. Types of Fuzzy Inference System

There are two known systems of Fuzzy Inference.

1. Madmani System

2. Sugeno System

The first one is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani-type inference, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification.

Below examples are based on two fuzzy control rules in the form of

R_1: if x is A_1 and y is B_1 then z is C_1
R_2: if x is A_2 and y is B_2 then z is C_2

Result: z is C, where x equals x_0 and y equals y_0.

The firing levels of the rules, denoted by α_i, i = 1, 2 are calculated by

$$\alpha_1 = A_1(x_0) \wedge B_1(y_0)$$

$$\alpha_2 = A_2(x_0) \wedge B_2(y_0)$$

The individual rule outputs are derived by

$$C_1^{'}(\omega) = (\alpha_1 \wedge C_1(\omega))$$

$$C_2^{'}(\omega) = (\alpha_2 \wedge C_2(\omega))$$

Then the overall system output is calculated by oring the individual rule outputs

$$C(\omega) = C_1^{'}(\omega) \vee C_2^{'}(\omega) = (\alpha_1 \wedge C_1(\omega)) \vee (\alpha_2 \wedge C_2(\omega))$$

Finally, to obtain a deterministic control action, chosen defuzzification mechanism must be implemented.

The second system, Sugeno, or Takagi-Sugeno-Kang, method of fuzzy inference was introduced in 1985 and is similar to the previous method in many respects. The common characteristics between the two methods are related to the inputs and the rules. Their main difference concerns the output membership functions, which are either linear or constant.

Below examples are based on two fuzzy control rules in the form of

R_1: if x is A_1 and y is B_1 then z is $z_1 = a_1x_1+b_1y_1$
R_2: if x is A_2 and y is B_2 then z is $z_2 = a_2x_2+b_2y_2$

Result: z_0, where x equals x_0 and y equals y_0.

The individual rule outputs are calculated from the below relationships

$$z_1 = a_1 \cdot x_0 + b_1 \cdot y_0$$

$$z_2 = a_2 \cdot x_0 + b_2 \cdot y_0$$

If there is *n* rules in the rule matrix, the crisp control result derived from the following equations

$$z_o = \frac{\sum_{i=1}^{n} \alpha_i z_i}{\sum_{i=1}^{n} \alpha_i}$$

where α_i is a firing level of the *i* rule, and *i* = 1, …., *n*.

The Sugeno method works well with linear techniques, as it is computationally efficient. It is suitable to apply optimisation and adaptive techniques. Furthermore, it guarantees continuity of the output surface and it is well suited to mathematical analysis. An advantage of the Mamdani method is that is it intuitive and has widespread of acceptance. It can be well suited to human input.

Sugeno system is commonly used of adaptive techniques for constructing fuzzy models as it is more compact Mamdani. These adaptive techniques can be used to customize the membership functions so that the fuzzy system best models the data. In order to have a more complete impression about the two systems, in the next paragraphs are presented the advantages of each system:

To begin with the Madmani method, its advantages are the following:

• Intuitive.

• Widespread acceptance.

• Well suited to human input.

In contrast to Madmani, the Sugeno method, has the following advantages:

• Computationally efficient.

• Working well with linear and adaptive techniques and optimization

• Guaranteed continuity of the output surface.

• Well suited to mathematical analysis.

4.1.5. Fuzzy Inference Process

Fuzzy inference process comprises of five parts:

• *Fuzzification of the input variables :*

The real world input to the fuzzy system is applied to fuzzifier. The fuzzifier converts precise quantity to the form of imprecise quantity like 'low', 'medium', 'high' etc. with a degree of belongingness to it.

• Application of the fuzzy operator (AND or OR) in the antecedent :

After the inputs are fuzzified, you know the degree to which each part of the antecedent is satisfied for each rule. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number is then applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth value. Any number of well-defined methods can fill in for the AND operation or the OR operation. In the toolbox, two built- in AND methods are supported: min (minimum) and prod (product). Two built-in OR methods are also supported: max (maximum), and the probabilistic OR method probor. In addition to these built-in methods, you can create your own methods for AND and OR by writing any function and setting that to be your method of choice.

• Implication from the antecedent to the consequent :

It is needed to determine the rule's weight. Every rule has a weight (a number between 0 and 1), which is applied to the number given by the antecedent. Generally, this weight is 1 and thus has no effect at all on the implication process. From time to time you may want to weight one rule relative to the others by changing its weight value to something other than 1.

• Aggregation of the consequents across the rules :

Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the fifth and final step, defuzzification. The input of the aggregation process is the list of truncated output functions returned by the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable. As long as the aggregation method is commutative (which it always should be), then the order in which the rules are executed is unimportant.

• *Defuzzification:*

The output generated by the inference block is always fuzzy in nature. A real world system will always require the output of the fuzzy system to the crisp or in the form of real world input. The job of defuzzifier is to receive the fuzzy input and provide real world output. In operation, it works opposite to the input block.

As a conclusion, the fuzzy expert system works as follows:

1) Determine the fuzzy membership values activated by the inputs.

2) Determine which rules are fired in the rule set.

3) Combine the membership values for each activated rule using the AND operator.

4) Trace rule activation membership values back through the appropriate output fuzzy membership functions.

5) Utilize defuzzification to determine the value for each output variable.

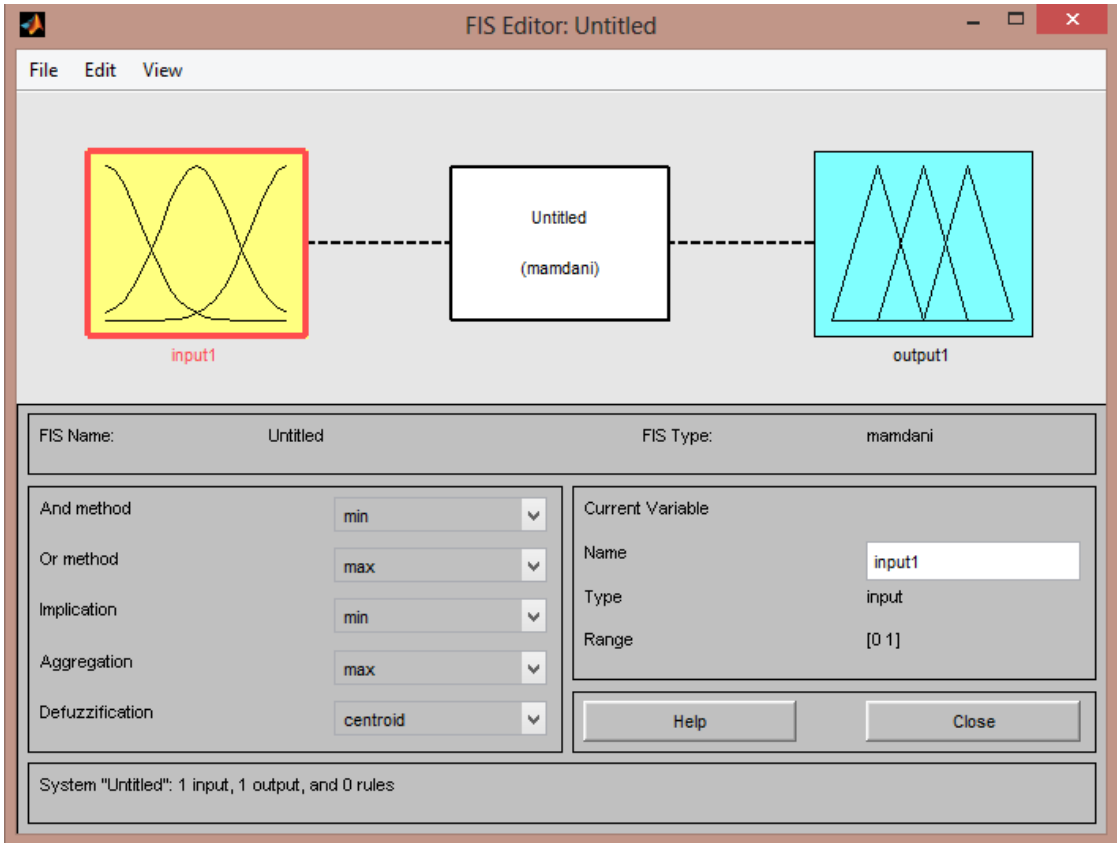
6) Make decision according to the output values.

4.2. FUZZY LOGIC MATLAB TOOLBOX

Matlab gives the opportunity to its users to build a fuzzy system and take advantage from all fuzzy's benefits. That becomes real through its fuzzy logic matlab toolbox [168]. It is easy to use and gives the user many abilities in order to establish his own system, as he is the creator of the system throughout. That means has he is responsible for establishing all the parameters of the system, which are the following:

- The system
- The inputs
- The outputs
- The membership functions
- The rules

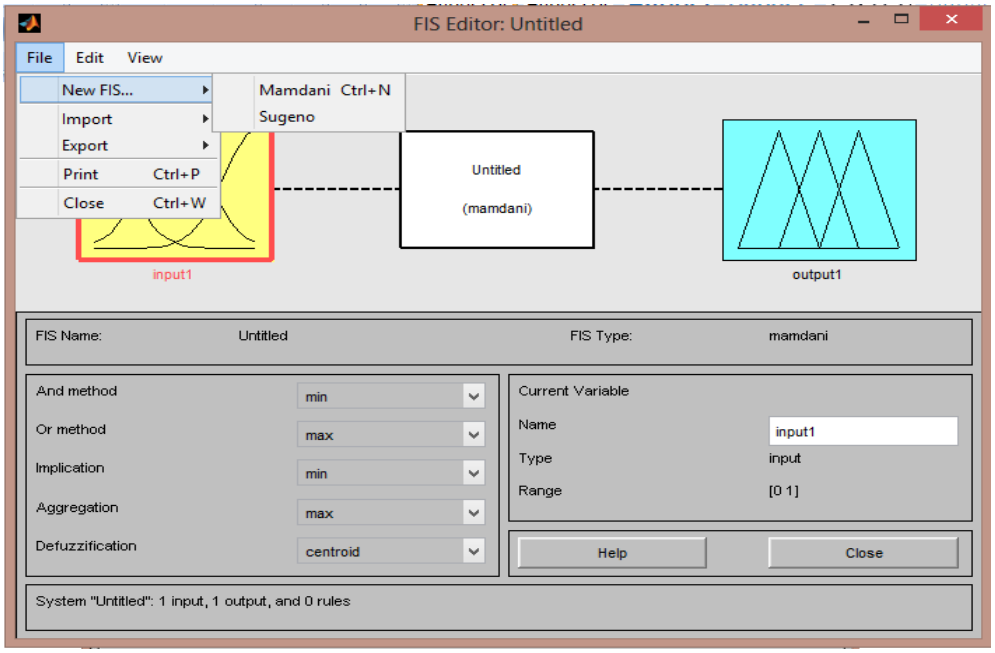
Beginning the creation of a fuzzy system, the first action is to open the Matlab program and calculate ***fuzzy*** in the command window. Then the fuzzy window appears as it looks in the next picture.



Picture 20. Fuzzy Logic Toolbox window

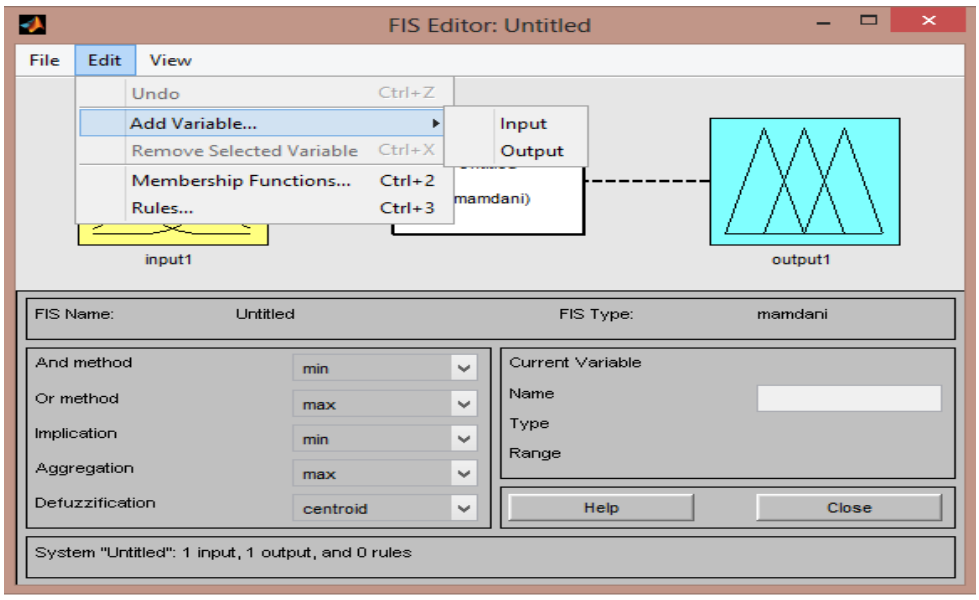
According to fuzzy logic methodology, as it was analyzing in the previous paragraphs, logical operation is succeded through the AND and OR and their equal relations min and max as it shows the above picture. Apart from the logical operations, and defuzzication which have already been established by the system there are all the above parameters that have to be chosen.

To begin with, ***System*** is the first parameter the user is called to choose. From Fuzzy Logic theory, is already known that the choices are two the Mamdani and the Sugeno and the choice can easily be done through the File, as it is shown in the following picture.



Picture 21. Fuzzy Logic System choice

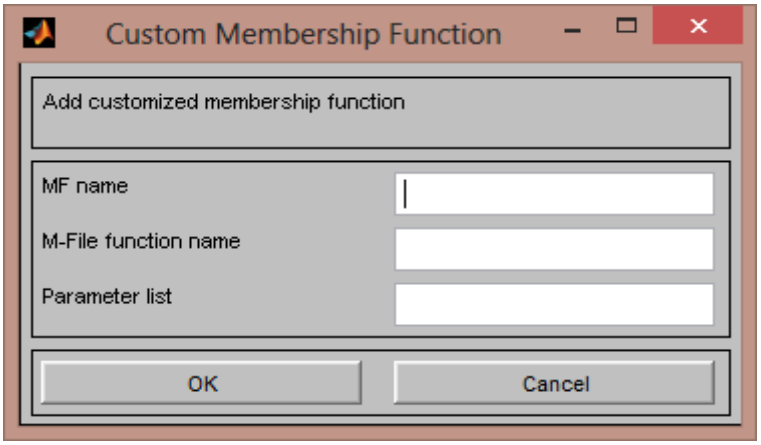
In addition, according to systems needs, the number of ***inputs*** and ***outputs*** has also to be decided. In order to add or remove one or more inputs and outputs to the system , you can press edit and as the following picture shows you can choose as desired. There is no limit in the choiced number but as it is obvious the more inputs and outputs the system has, the more complicated is becoming.



Picture 22. Fuzzy Logic Inputs and Outputs choice

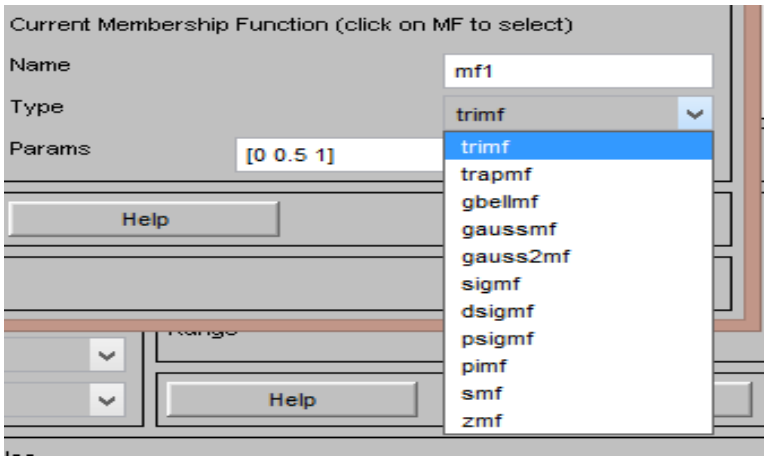
Moreover, for every input and output that we have selected we have to identify its ***Membership Function***. The choice of the Membership Function is also accepted through Edit as it shows the above picture.

As we already said there is a variety of membership functions our fuzzy system can has and according to its nature we select the one that is more appropriate and simple. The program let us choose which function we want to use through the following matrix:



Picture 23. Fuzzy Logic Membership Functions

As is shows in the previous picture, for every Membership Function, the user choices the MF name = the name, the M-File function name= the shape and the parameter list= the range the function extends. Concerning the shape, we have already mentioned the possible ones, *triangular, trapezoidal, Gaussian, generalized bell, sigmoidal, Z curves, S curve,* and *Pi curve* and their codec names for toolbox*: trimp, trampf, gaussmf, gauss2mf, gbellmf, sigmf, dsigmf, psigmf, pimf, and smf* as shows the following picture:

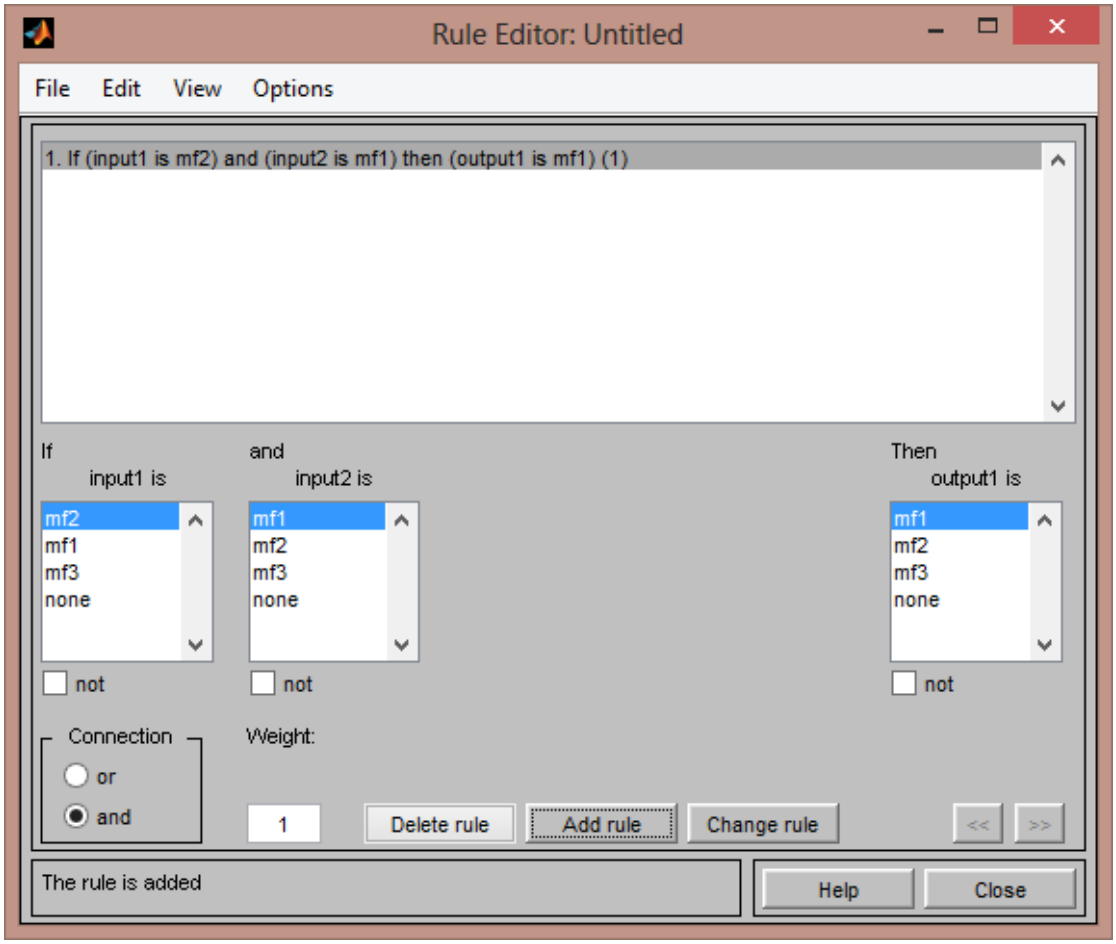


Picture 24. Fuzzy Logic Shapes of Membership Function

Finally as regards Membership Functions we have to notice each input or output can have one or more membership functions, with different name, shape and obvious range. Also the inputs and the outputs can have different number of membership functions, shapes and range.

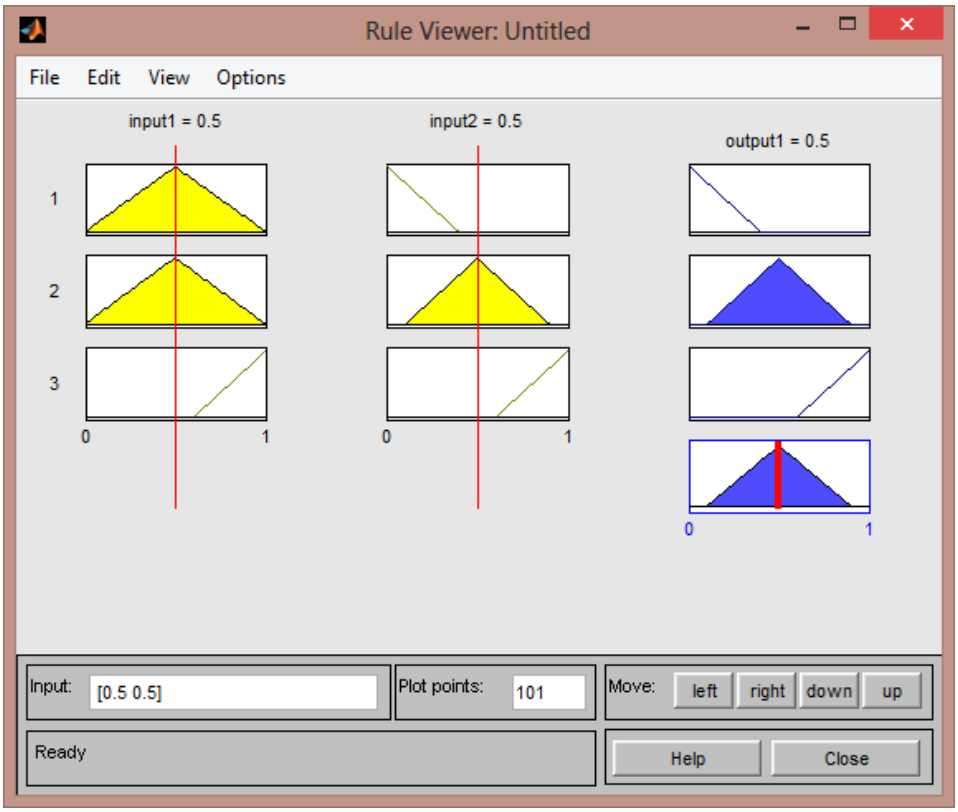
Last but not least is the definition of the **rules**. There is no specific way to match the rules between the inputs and the outputs and no specific number of needed rules. As we have already said the more input and outputs and membership functions we have the more complicated the system will become and that occurs from the fact that rules need to fix all the possible combinations among the membership functions of all the inputs and outputs. The combination of the rules is one of the system maker's responsibility and deals with the logical meaning of the inputs and outputs.

The combination among the Membership Function can be progressed through the logical operations that we have already mentioned and that are: AND/ OR/ NOT. The maker is again in charge of choosing which logical equation will have every rule and if will be used all the three of them or only one. Finally each rule can have each own weight, according the severity it has got. You can add, delete or change a rule. All the previous steps made pressing Edit as shows picture and continues in the following matrix:



Picture 25. Fuzzy Logic Rules

At that point, having completing the definition of the system's parameters, **defyzzification** progress will follows by giving values to the inputs. The output result will be estimated either as a number or as a graphic. For example, lets assume that we have a fuzzy system with two inputs and one output and have defined both their membership functions and the rules among them. Then the output after the defyzzification progress assuming input1 and input2 values as 0,5 is showing in the following picture equal to 0,5 :



Picture 26. Defyzzification of Fuzzy Logic-Example

4.3. FUZZY LOGIC MODELS

In the previous paragraphs have been analyzed not only the theory of Fuzzy Logic but also the Matlab Toolbox we can use in order to create a Fuzzy System. At that point, we are going to present and analyze the fuzzy system we have created in order to estimate the performance of a shipping company as regards the fields of: safety, security, health and safety and environment.

In real, we have created not one but four fuzzy systems, separately for every one of the above fields as every field (safety, security, health and safety, and environment) differs from the other and needs separately operation. However, the four different fuzzy systems we created have common basic principles. The main of these are that use as inputs the four Key Performance Indicators (KPIs) which mentioned in our proposed set in the previous section and as output the shipping's performance in the examined field.

At each one of the created Fuzzy Logic Systems, we as makers, had to clarify the following parameters, which will be analyzed separately for every system:

- The system
- The inputs
- The outputs
- The membership functions.
- The rules

To sum up, we have created, Four (4) Fuzzy Logic Systems, the following ones:

- **Safety Fuzzy Logic System**, in order to estimate the safety performance of a shipping company.
- **Security Fuzzy Logic System**, in order to estimate the security performance of a shipping company.
- **Health & Safety Fuzzy Logic System**, in order to estimate the health and safety performance of a shipping company.
- **Environmental Fuzzy Logic System**, in order to estimate the environmental performance of a shipping company.

4.3.3 SAFETY FUZZY LOGIC SYSTEM

The Safety Fuzzy Logic System has been created by us in order to estimate a shipping company's performance regarding its safety levels. In order to achieve that goal we used the information given from the Safety Key Performance Indicators we have selected in the previous paragraph as the Safety KPIs set. Each one of these indicators can be measured and finally takes a mathematical value. Scope of this Fuzzy Logic System is to combine these four different values to one value-the output value which will estimate the shipping company's safety performance.

In order to make our system understood we are going to present its main particulars concerning the inputs, outputs, membership functions and finally some of the established rules.

♠ SYSTEM

As in all the following Fuzzy Logic Systems, the chosen system is the Mamdani System due to the advantages as described in the previous sections.

♠ INPUTS

As inputs we have assumed the FOUR (4) mentioned Safety Key Performance Indicators, which are:

	INPUTS	Unit	Weight	Period
1	**Incidents**	number	38%	annually
2	**Training Achievement**	percentage	29%	annually
3	**Fire&Explosion**	number	21%	annually
4	**Vetting Observations**	number	12%	annually

Matrix 31. Safety Fuzzy Logic System- Inputs

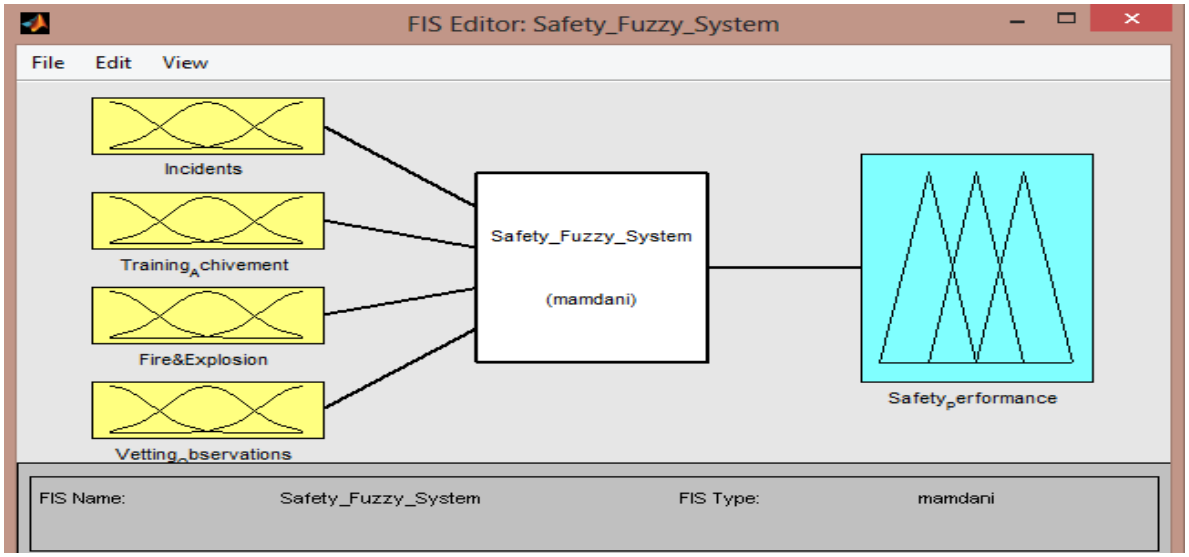
♠ OUTPUT

As ONE output we have chosen the safety performance

	OUTPUT	Unit	Period
1	**Safety Performance**	Index [0,1]	annually

Matrix 32. Safety Fuzzy Logic System- Output

The above parameters have been established to the system as shows the following picture:

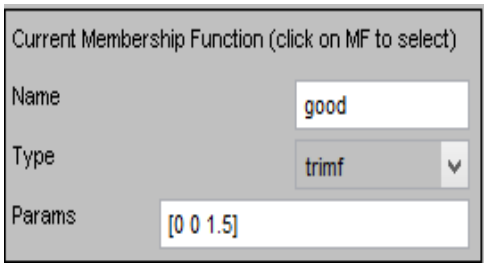


Picture 27. Safety Fuzzy Logic System

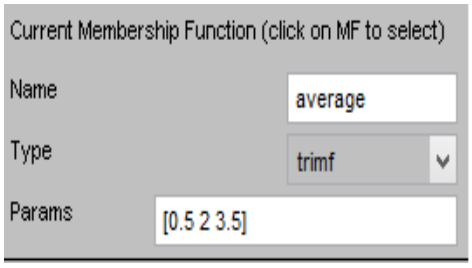
♠ MEMBERSHIP FUNCTION

*** Incidents***

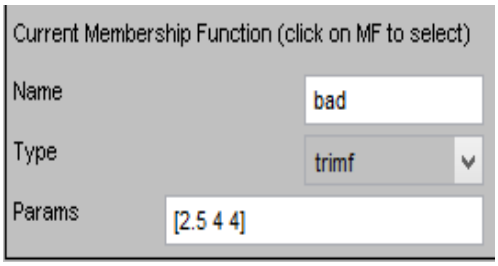
The number of incidents is the first safety input. It consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of safety concerning incidents. Incidents are measured as numbers and their characteristics are shown at their Membership Function below:



Picture 28. Incidents- MF1: GOOD

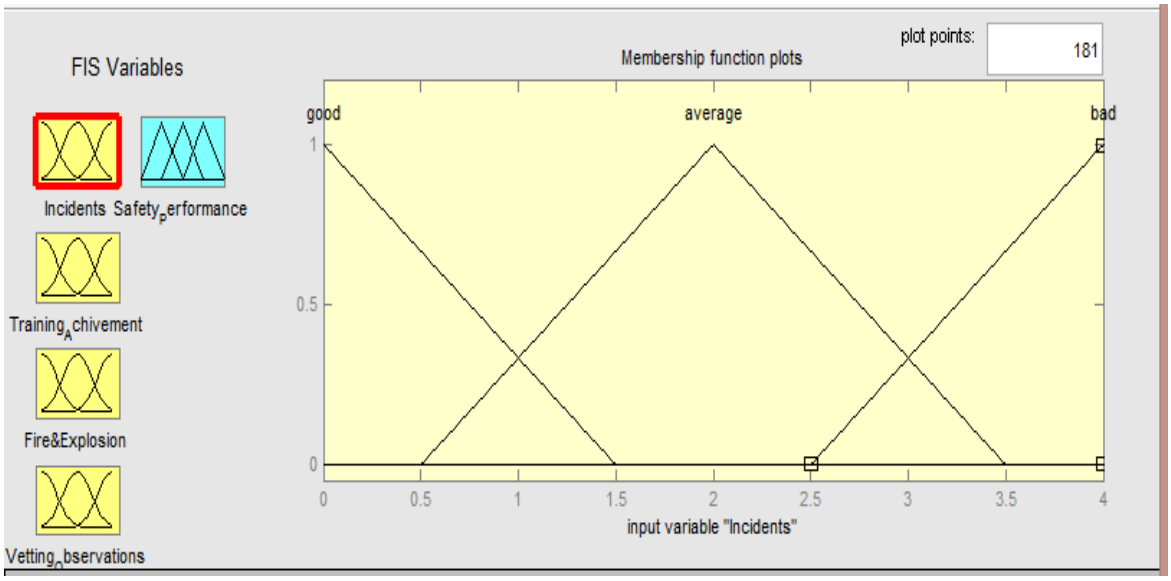


Picture 29. Incidents- MF2: AVERAGE



Picture 30. Incidents- MF3: BAD

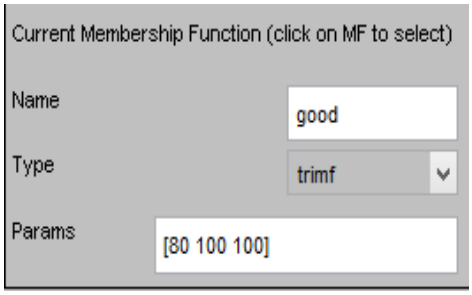
The following graphic shows the total Membership Function of ‘‘Incidents’’:



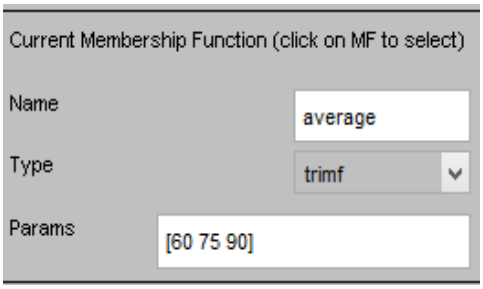
Picture 31. Membership Function of ‘‘Incidents’’

*** Training Achievement***

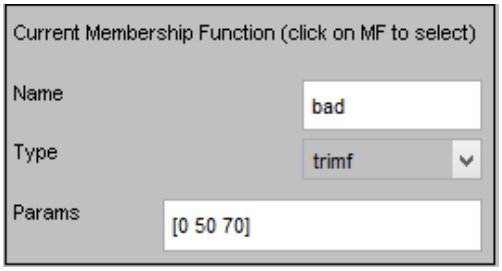
Next input is the percentage of the scheduled training courses that finally completed and called ''Training Achievement''. As the previous input, It consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of safety regarding training. We continue with its Membership Function's parameters.



Picture 32. Training Achievement- MF1: GOOD

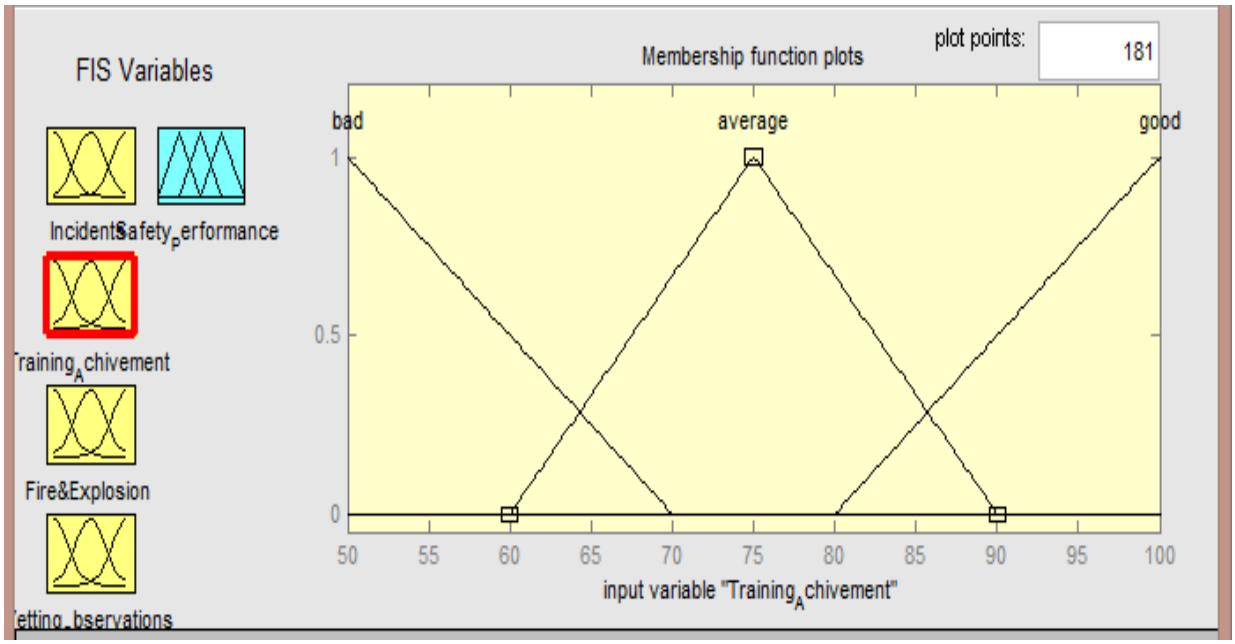


Picture 33. Training Achievement- MF2: AVERAGE



Picture 34. Training Achievement- MF3: BAD

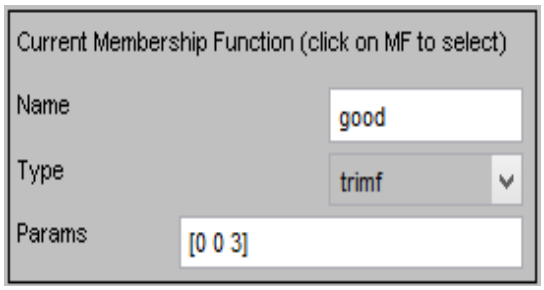
The following graphic shows the total Membership Function of ''Training Achievement'':



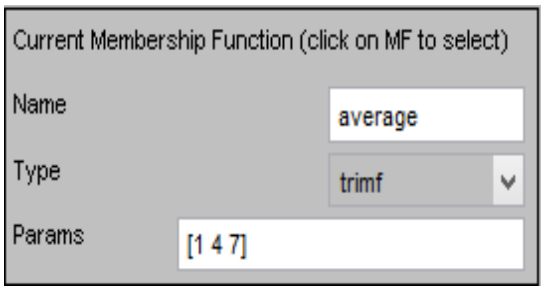
Picture 35. Membership Function of ''Training Achievement''

*** Fire and Explosion***

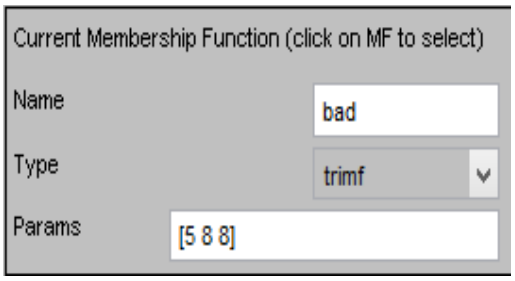
Next input is the number of fires and explosions that happened to the vessel and called ''Fire and Explosion''. As the previous inputs, it consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of safety regarding fire and explosion issues. Inputs Membership Functions are the following:



Picture 36 Fire and Explosion- MF1: GOOD

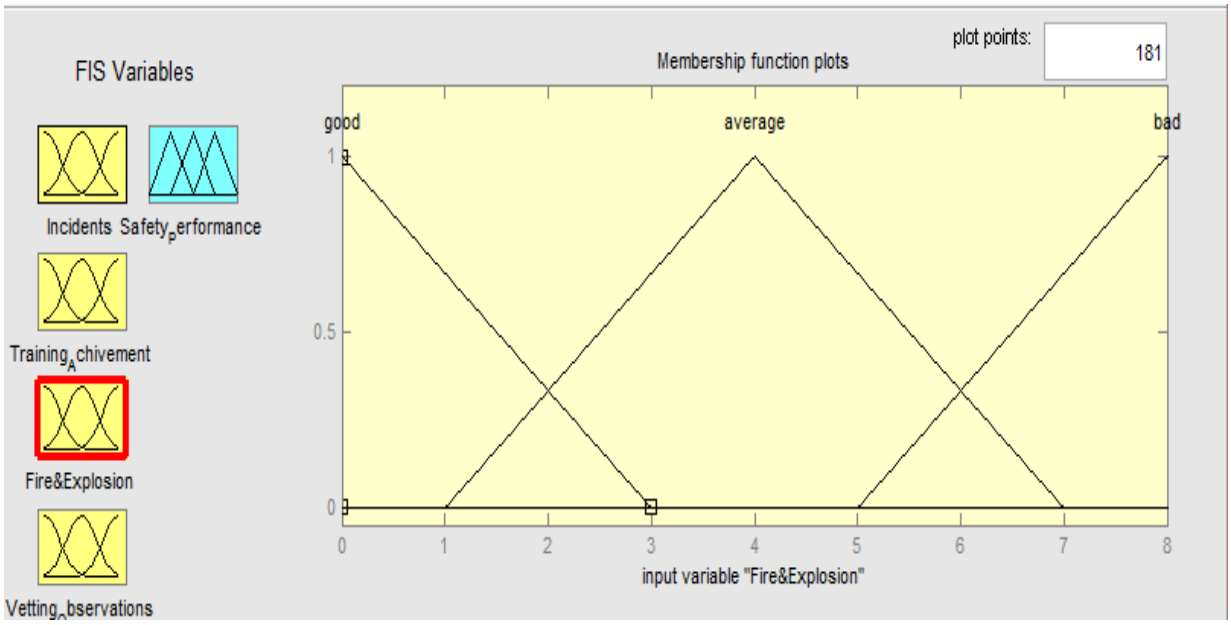


Picture 37. Fire and Explosion- MF2: AVERAGE



Picture 38. Fire and Explosion- MF3: BAD

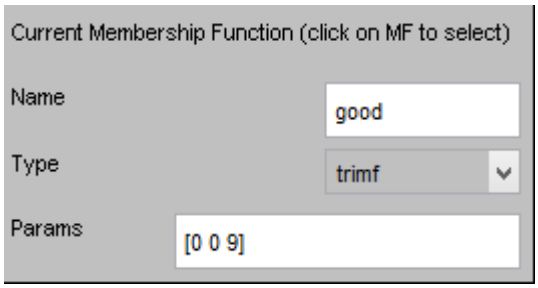
The following graphic shows the total Membership Function of ''Fire and Explosion'':



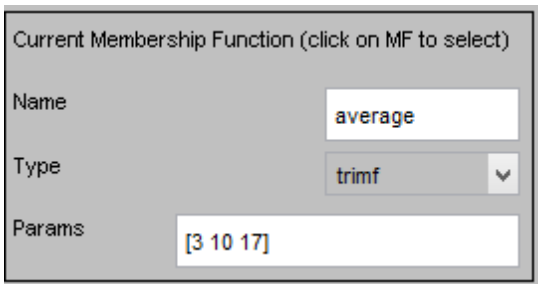
Picture 39. Membership Function of ''Fire and Explosion''

*** Vetting Observations per Inspection***

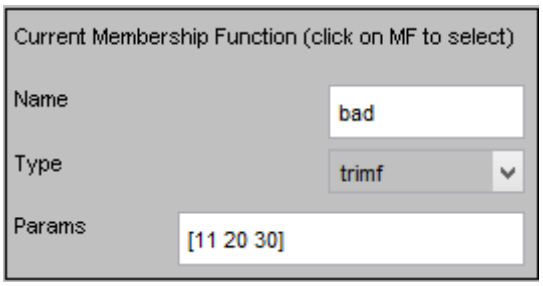
Last input is the number of vetting observations per inspection. As the previous inputs, it consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of safety regarding vetting observations. Inputs Membership Functions are the following:



Picture 40. Vetting Observations- MF1: GOOD

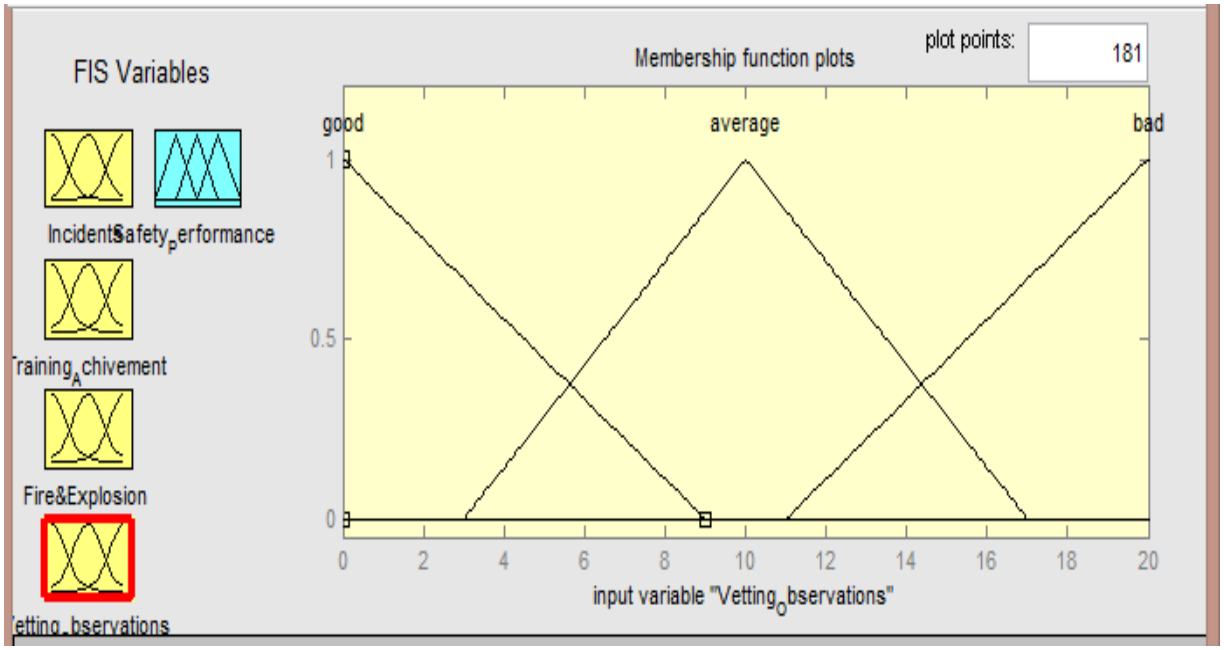


Picture 41. Vetting Observations- MF2: AVERAGE



Picture 42. Vetting Observations- MF3: BAD

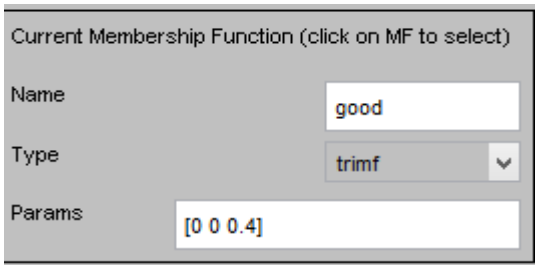
The following graphic shows the total Membership Function of ''Vetting Observations'':



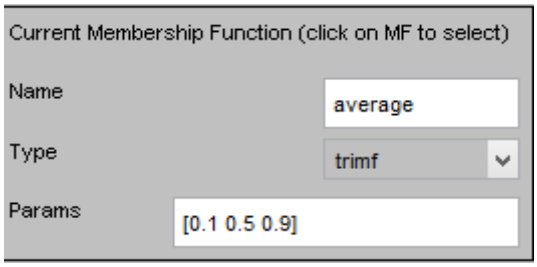
Picture 41. Membership Function of ''Vetting Observations''

*** Safety Performance***

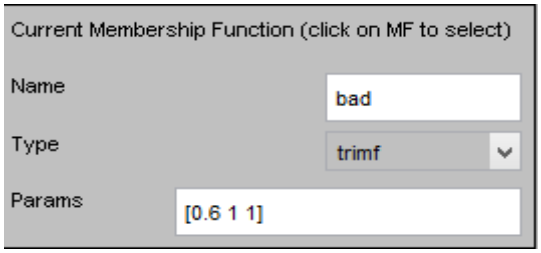
Having completing our analysis about the Membership Functions of the inputs values, we continue with the one output, which is the ''Safety Performance''. The value of the output is a number and according to the Membership Functions that we have defined for it, shows the level of safety performance, GOOD, AVERAGE, BAD. As the inputs, it consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD. Output Membership Functions are the following:



Picture 42. Safety Performance- MF1: GOOD

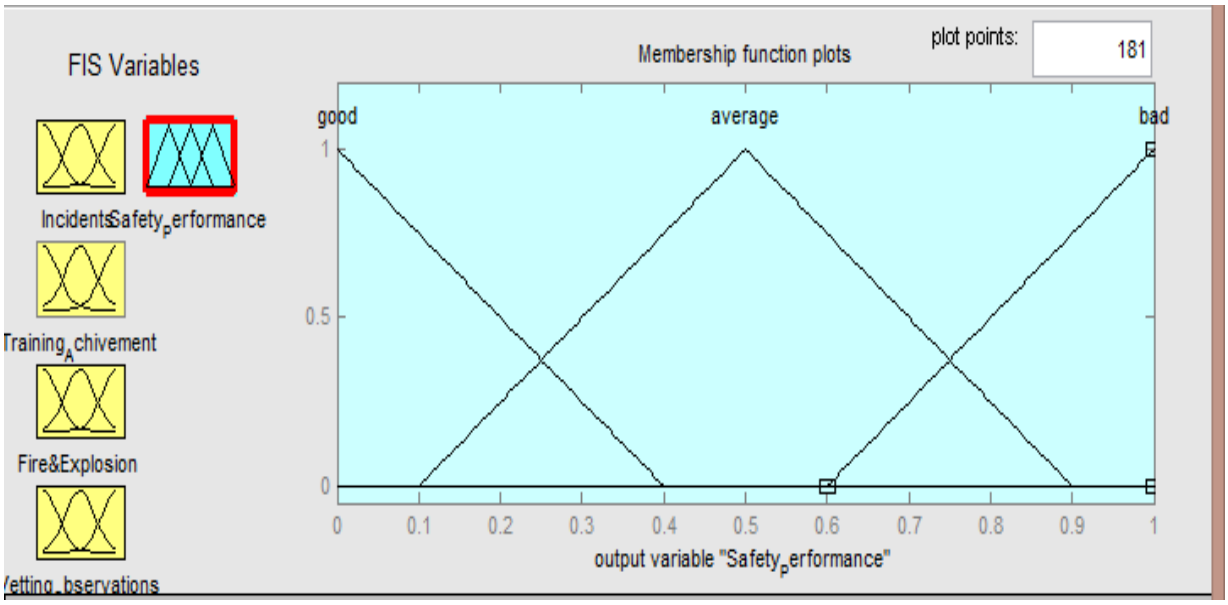


Picture 43. Safety Performance- MF2: AVERAGE



Picture 44. Safety Performance- MF3: BAD

The following graphic shows the total Membership Function of ''Safety Performance'':



Picture 45. Membership Function of ''Safety Performance''

♠ RULES

In order to present the connection rules, we have to define the number of them, their weights and their logical connection. The number of Rules is not specific. In our case we want to take into consideration all the possible combinations and for that reason we have created 81 Rules (4 inputs, 3 MF each of them). Finally, concerning their weight are all equal to 1 and are connected through AND connection. Some of the established rules are presented below:

1. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is good) and (Vetting_Observations is good) then (Safety_Performance is good) (1)
2. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is good) and (Vetting_Observations is average) then (Safety_Performance is good) (1)
3. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is good) and (Vetting_Observations is bad) then (Safety_Performance is good) (1)
4. If (Incidents is average) and (Training_Achivement is average) and (Fire&Explosion is average) and (Vetting_Observations is bad) then (Safety_Performance is average) (1)
5. If (Incidents is average) and (Training_Achivement is average) and (Fire&Explosion is average) and (Vetting_Observations is average) then (Safety_Performance is average) (1)
6. If (Incidents is average) and (Training_Achivement is average) and (Fire&Explosion is average) and (Vetting_Observations is good) then (Safety_Performance is average) (1)
7. If (Incidents is bad) and (Training_Achivement is bad) and (Fire&Explosion is bad) and (Vetting_Observations is bad) then (Safety_Performance is bad) (1)
8. If (Incidents is bad) and (Training_Achivement is bad) and (Fire&Explosion is bad) and (Vetting_Observations is average) then (Safety_Performance is bad) (1)
9. If (Incidents is bad) and (Training_Achivement is bad) and (Fire&Explosion is bad) and (Vetting_Observations is good) then (Safety_Performance is bad) (1)
10. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is average) and (Vetting_Observations is good) then (Safety_Performance is good) (1)
11. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is average) and (Vetting_Observations is average) then (Safety_Performance is good) (1)
12. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is average) and (Vetting_Observations is bad) then (Safety_Performance is average) (1)
13. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is bad) and (Vetting_Observations is good) then (Safety_Performance is good) (1)
14. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is bad) and (Vetting_Observations is average) then (Safety_Performance is good) (1)
15. If (Incidents is good) and (Training_Achivement is good) and (Fire&Explosion is bad) and (Vetting_Observations is bad) then (Safety_Performance is average) (1)
16. If (Incidents is good) and (Training_Achivement is average) and (Fire&Explosion is good) and (Vetting_Observations is good) then (Safety_Performance is good) (1)
17. If (Incidents is good) and (Training_Achivement is average) and (Fire&Explosion is good) and (Vetting_Observations is average) then (Safety_Performance is good) (1)

Matrix 33: Sample of Rules at Safety Fuzzy Model

4.3.2 SECURITY FUZZY LOGIC SYSTEM

The Security Fuzzy Logic System has been created by us in order to estimate a shipping company's security performance. It has got the same principles as the Safety Fuzzy System and it's parameters are explained below:

♠ SYSTEM

As previous, the chosen system is the Mamdani System.

♠ INPUTS

As inputs we have assumed the FOUR (4) Security Key Performance Indicators:

	INPUTS	Unit	Weight	Period
1	**Damaged Cargo**	percentage	29%	annually
2	**Theft Cargo**	percentage	29%	annually
3	**Lost Cargo**	percentage	29%	annually
4	**Anti-piracy Measures**	percentage	13%	annually

Matrix 34. Security Fuzzy Logic System- Inputs

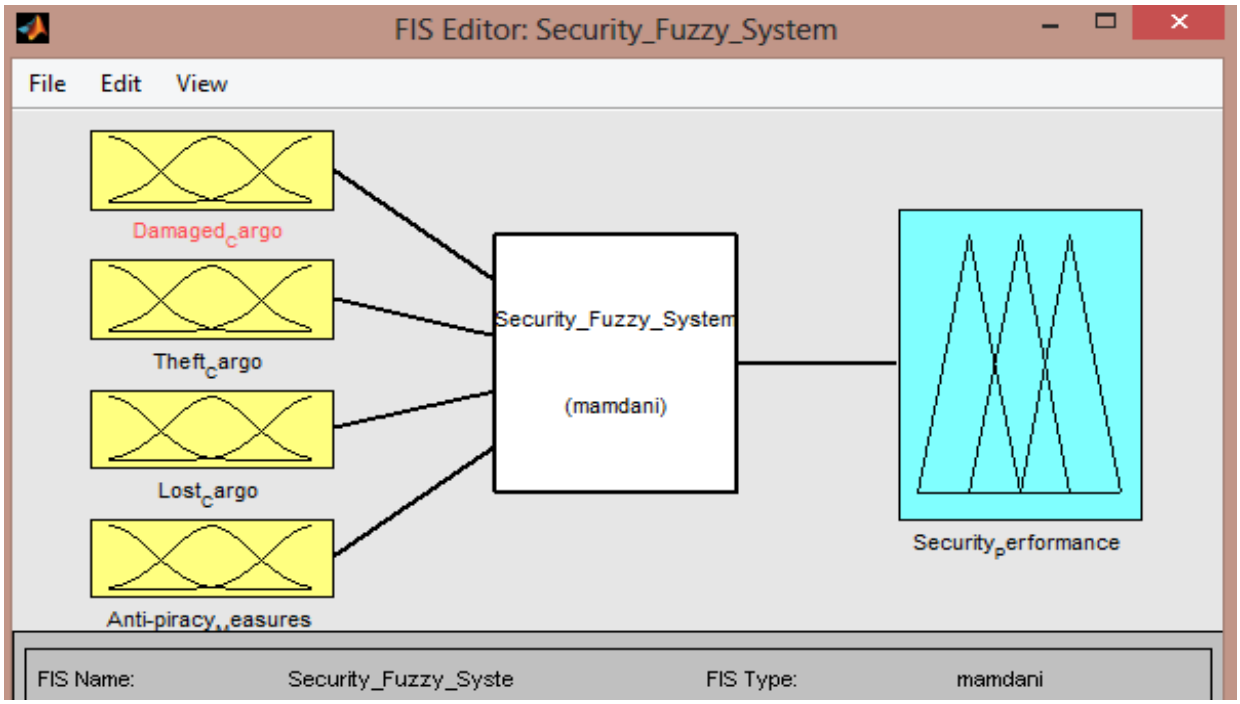
♠ OUTPUT

As ONE output we have chosen the Security performance:

	OUTPUT	Unit	Period
1	**Security Performance**	Index [0,1]	annually

Matrix 35. Security Fuzzy Logic System- Output

The above parameters have been established to the system as shows below:

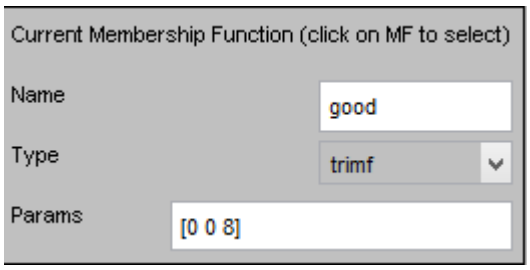


Picture 46. Security Fuzzy Logic System

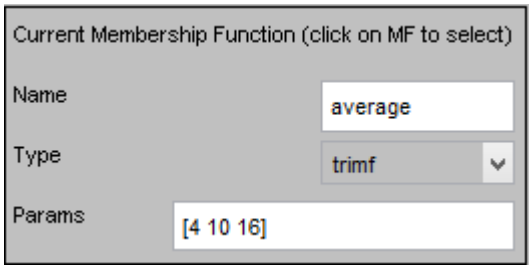
♠ MEMBERSHIP FUNCTION

*** Damaged Cargo***

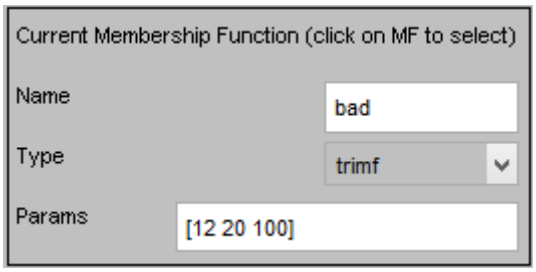
The percentage of the total cargo that ended damaged due to a security threat is the first security input and called, ''Damaged Cargo'' It consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of security concerning cargo which was damaged. This indicator is estimated as percentage and its characteristics are shown at Membership Function below:



Picture 47. Damaged Cargo- MF1: GOOD

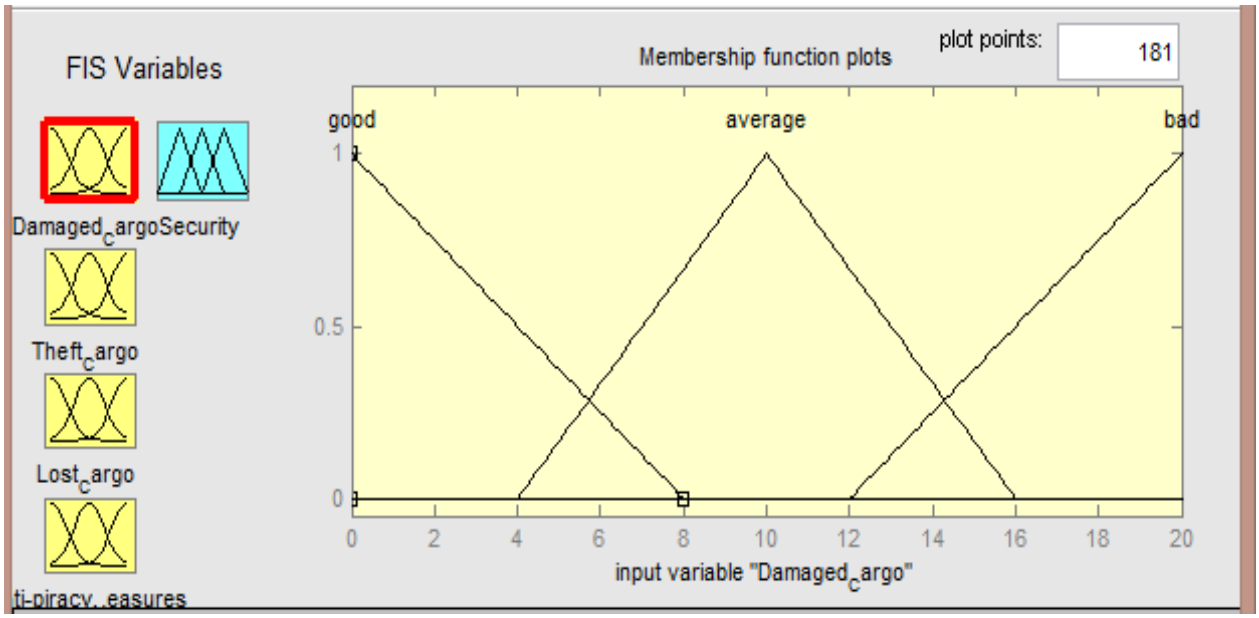


Picture 48. Damaged Cargo- MF2: AVERAGE



Picture 49. Damaged Cargo- MF3: BAD

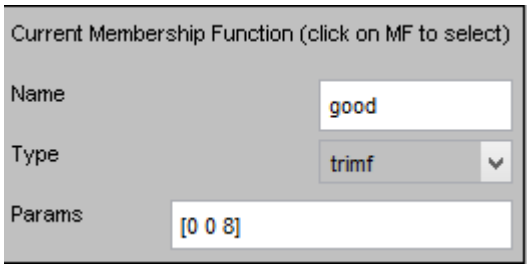
The following graphic shows the total Membership Function of ''Damaged Cargo'':



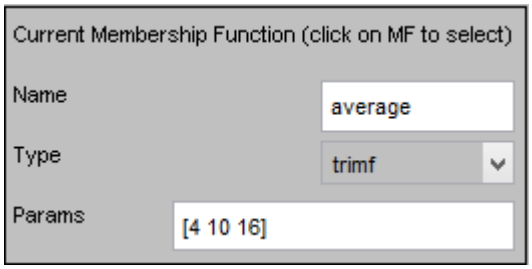
Picture 50. Membership Function of ''Damaged Cargo''

*** Theft Cargo***

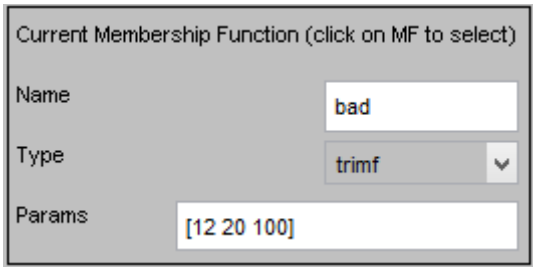
The percentage of the total cargo that ended theft due to a security threat is the next security input and called, ''Theft Cargo''. It consists of the three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of security concerning cargo which was theft, which are same with the Damaged Cargo MFs. This indicator is estimated as percentage and its characteristics are shown at Membership Function below:



Picture 51. Theft Cargo- MF1: GOOD

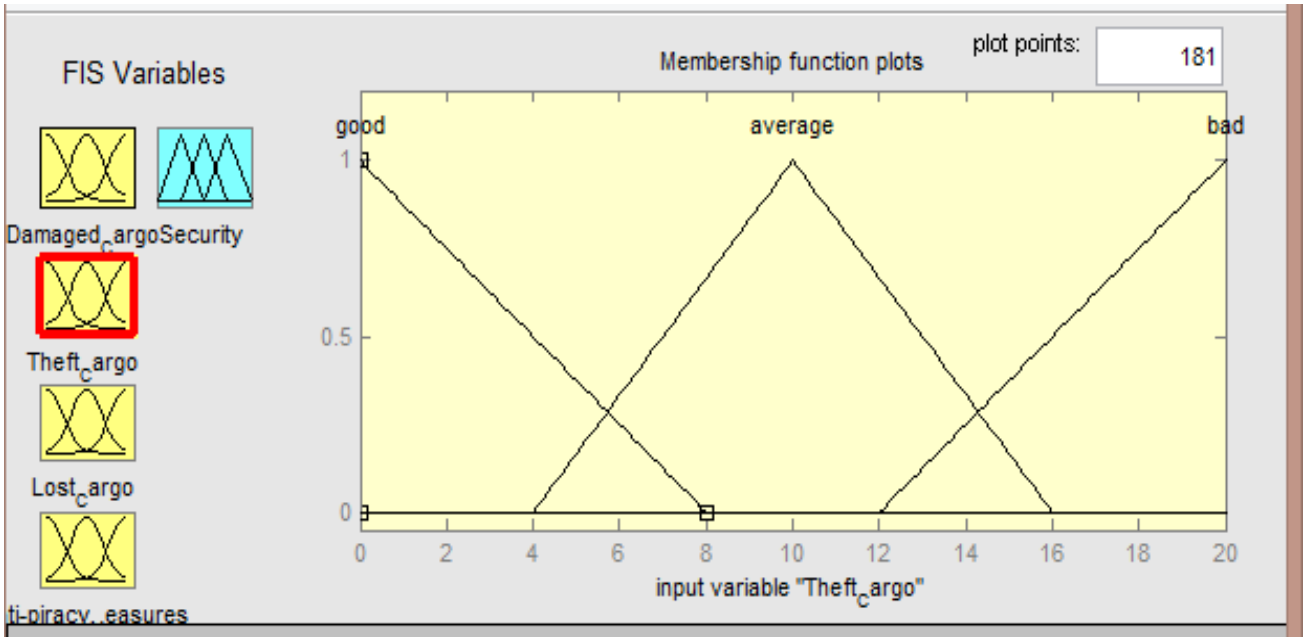


Picture 52. Theft Cargo- MF2: AVERAGE



Picture 53. Theft Cargo- MF3: BAD

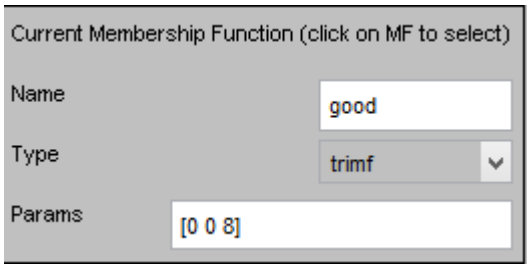
The following graphic shows the total Membership Function of ''Theft Cargo'':



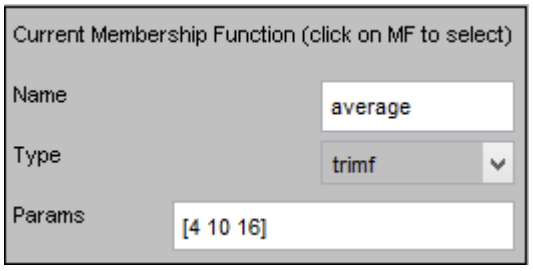
Picture 54. Membership Function of ''Theft Cargo''

*** Lost Cargo***

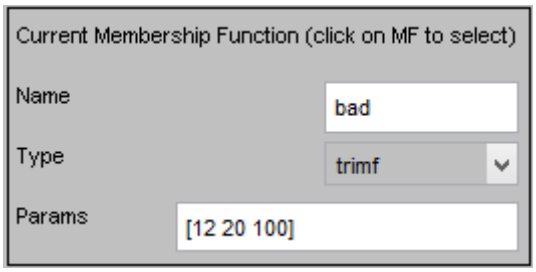
The percentage of the total cargo that was lost due to a security incident is also a security input and called, ''Lost Cargo''. Same as the previous two inputs it consists of the same three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of security concerning cargo which was lost. This indicator is estimated as percentage and its characteristics are shown at Membership Function below:



Picture 55. Lost Cargo- MF1: GOOD

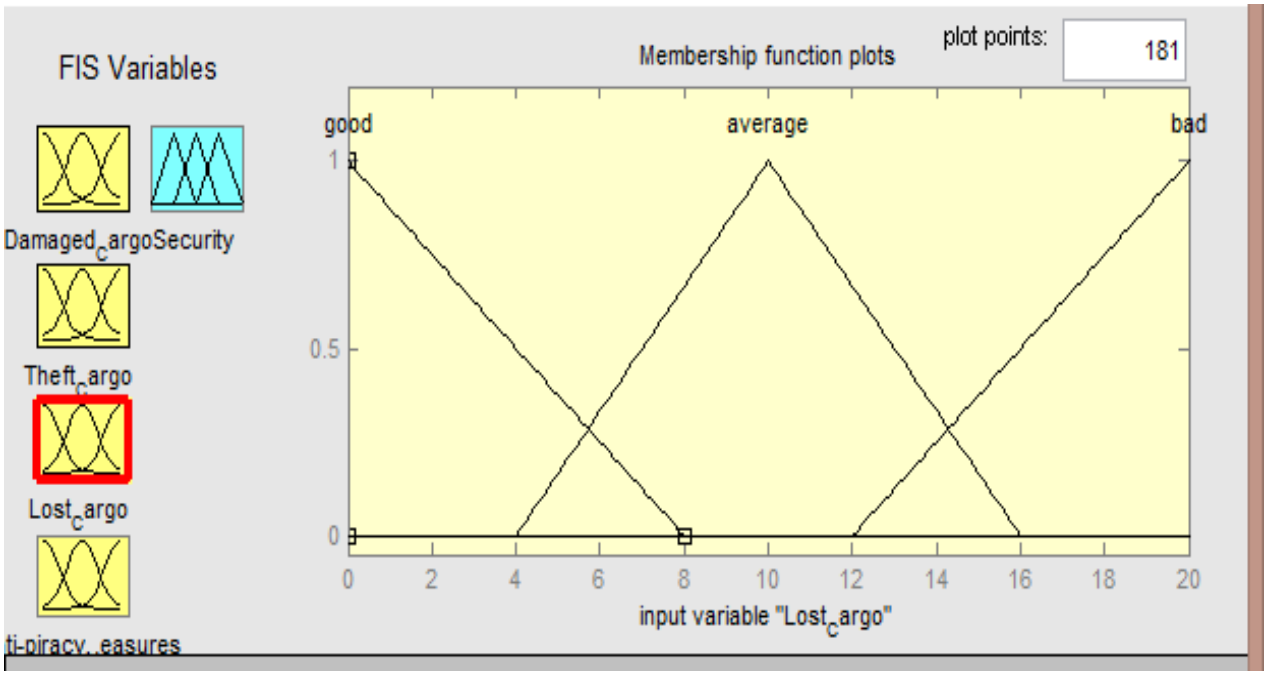


Picture 56. Lost Cargo- MF2: AVERAGE



Picture 57. Lost Cargo- MF3: BAD

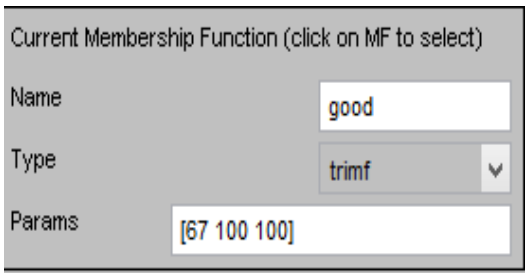
The following graphic shows the total Membership Function of ''Lost Cargo'':



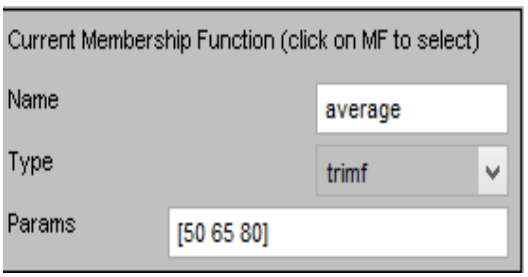
Picture 58. Membership Function of ''Lost Cargo''

*** Anti-piracy Measures***

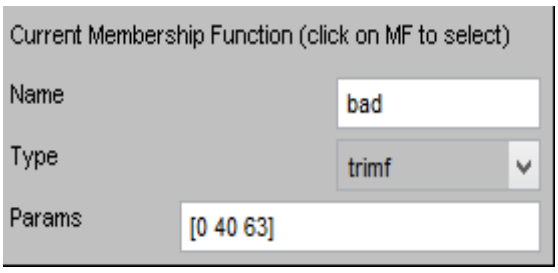
The percentage of the total proposed measures that a vessel use in order to be protected against the piracy attacks is the last input and called ''Anti-piracy Measures''. It consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD level of security concerning the used anti-piracy measures. This indicator is estimated as percentage and its characteristics are shown at Membership Function below:



Picture 59. Anti-Piracy Measures – MF1: GOOD

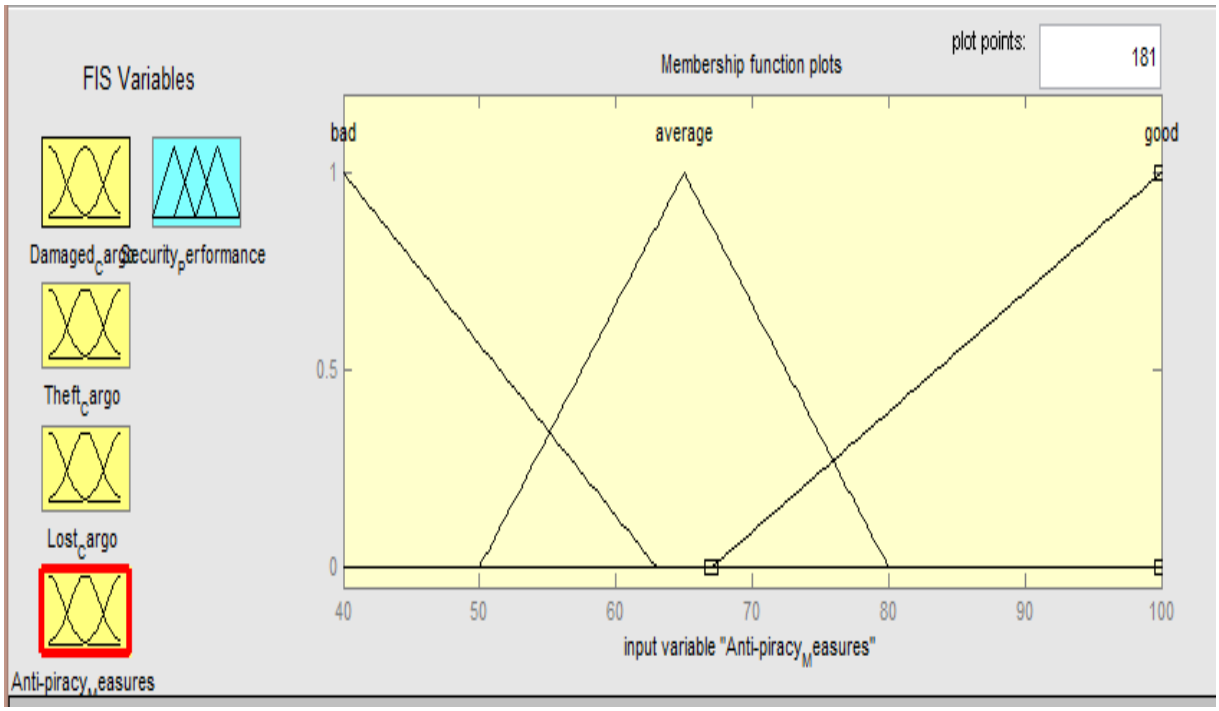


Picture 60. Anti-Piracy Measures – MF2: AVERAGE



Picture 61. Anti-Piracy Measures – MF3: BAD

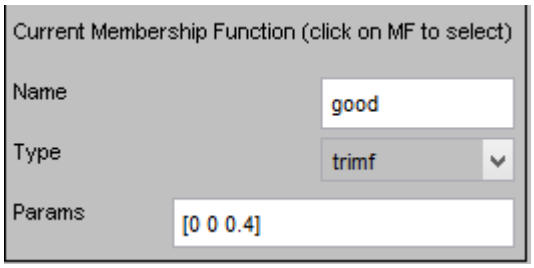
The following graphic shows the total Membership Function of ''Anti-Piracy Measures:



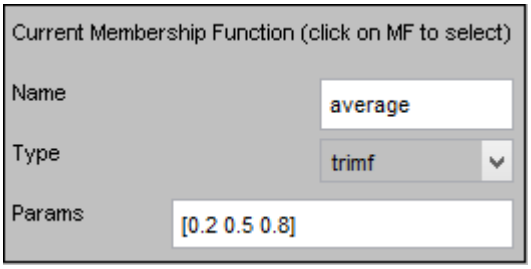
Picture 62. Membership Function of ''Anti-Piracy Measures''

*** Security Performance***

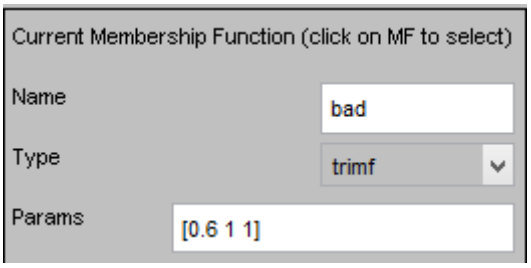
Having completing our analysis about the Membership Functions of the inputs values, we continue with the one output, which is the ''Security Performance''. The value of the output is a number and according to the Membership Functions that we have defined for it, shows the level of safety performance, GOOD, AVERAGE, BAD. As the inputs, it consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD. Output Membership Functions are the following:



Picture 63. Security Performance- MF1: GOOD

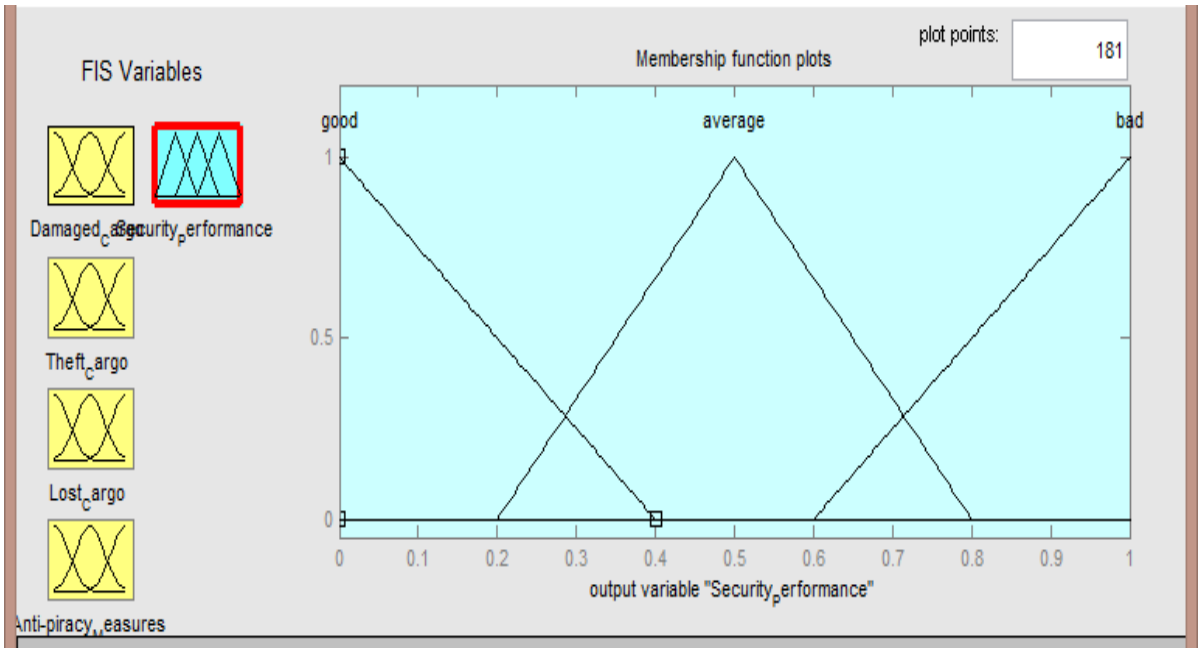


Picture 64. Security Performance- MF2: AVERAGE



Picture 65. Security Performance- MF3: BAD

The following graphic shows the total Membership Function of ''Security Performance'':



Picture 66. Membership Function of ''Security Performance''

♠ RULES

Following the same process as above and taken into account the severity of each input, we created the following set of rules. The total sum of rules is, as above, 81 in order to include all the possible combinations and all have the same weight equal to 1. Finally concerning the logical operation inputs and outputs are combined through the AND connection. Some of the established rules are presented below:

1. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is good) then (Security_Performance is good) (1)
2. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is average) then (Security_Performance is good) (1)
3. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is bad) then (Security_Performance is average) (1)
4. If (Damaged_Cargo is average) and (Theft_Cargo is average) and (Lost_Cargo is average) and (Anti-piracy_Measures is bad) then (Security_Performance is average) (1)
5. If (Damaged_Cargo is average) and (Theft_Cargo is average) and (Lost_Cargo is average) and (Anti-piracy_Measures is good) then (Security_Performance is average) (1)
6. If (Damaged_Cargo is average) and (Theft_Cargo is average) and (Lost_Cargo is average) and (Anti-piracy_Measures is average) then (Security_Performance is average) (1)
7. If (Damaged_Cargo is bad) and (Theft_Cargo is bad) and (Lost_Cargo is bad) and (Anti-piracy_Measures is good) then (Security_Performance is average) (1)
8. If (Damaged_Cargo is bad) and (Theft_Cargo is bad) and (Lost_Cargo is bad) and (Anti-piracy_Measures is bad) then (Security_Performance is bad) (1)
9. If (Damaged_Cargo is bad) and (Theft_Cargo is bad) and (Lost_Cargo is bad) and (Anti-piracy_Measures is average) then (Security_Performance is bad) (1)
10. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is average) and (Anti-piracy_Measures is good) then (Security_Performance is good) (1)
11. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is average) and (Anti-piracy_Measures is average) then (Security_Performance is good) (1)
12. If (Damaged_Cargo is good) and (Theft_Cargo is good) and (Lost_Cargo is average) and (Anti-piracy_Measures is bad) then (Security_Performance is average) (1)
13. If (Damaged_Cargo is average) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is good) then (Security_Performance is good) (1)
14. If (Damaged_Cargo is average) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is average) then (Security_Performance is good) (1)
15. If (Damaged_Cargo is average) and (Theft_Cargo is good) and (Lost_Cargo is good) and (Anti-piracy_Measures is bad) then (Security_Performance is average) (1)
16. If (Damaged_Cargo is good) and (Theft_Cargo is average) and (Lost_Cargo is good) and (Anti-piracy_Measures is good) then (Security_Performance is good) (1)
17. If (Damaged_Cargo is good) and (Theft_Cargo is average) and (Lost_Cargo is good) and (Anti-piracy_Measures is average) then (Security_Performance is good) (1)

Matrix 36: Sample of Rules at Security Fuzzy Model

4.3.3 HEALTH&SAFETY FUZZY LOGIC SYSTEM

In addition, Health & Safety Fuzzy System has been created so as to estimate a shipping company's health and safety performance. Its principles are analyzed below:

♠ SYSTEM

Once again, the chosen system is the Mamdani System.

♠ INPUTS

As inputs we have assumed the FOUR (4)Heath and Safety Key Performance Indicators:

	INPUTS	Unit	Weight	Period
1	**Fatalities**	number	37%	annually
2	**Lost Time Injuries Frequency**	number	27%	annually
3	**Lost Time Sicknesses Frequency**	number	20%	annually
4	**Near Misses**	number	16%	annually

Matrix 37. Heath and Safety Fuzzy Logic System- Inputs

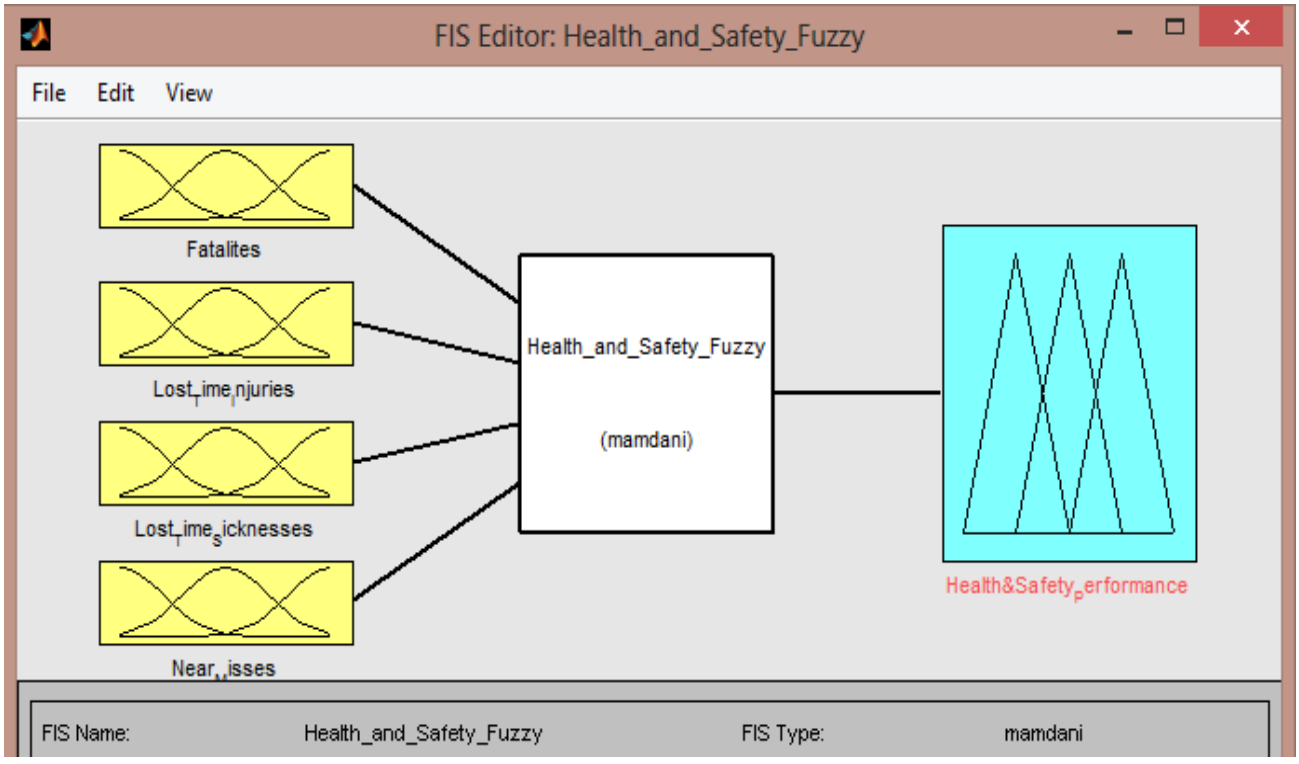
♠ OUTPUT

As ONE output we have chosen the Health and Safety performance:

	OUTPUT	Unit	Period
1	**Environmental Performance**	Index [0,1]	annually

Matrix 38. Health and Safety Fuzzy Logic System- Output

The above parameters have been established to the system as shows below:

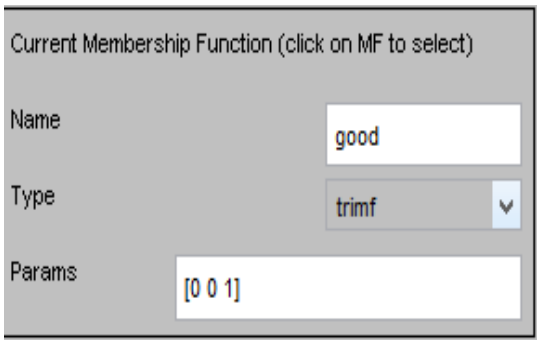


Picture 67. Health & Safety Fuzzy Logic System

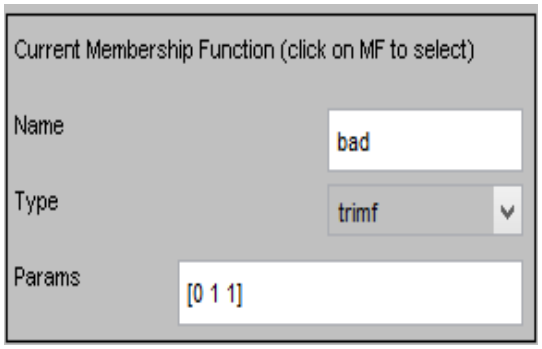
♠ MEMBERSHIP FUNCTION

*** Fatalities***

This is the input that cannot be avoided. The number of fatalities is the first and more important parameter of that system. Due to its nature and severity it has got only two (2) Membership Functions, GOOD or BAD which characteristics shown below:

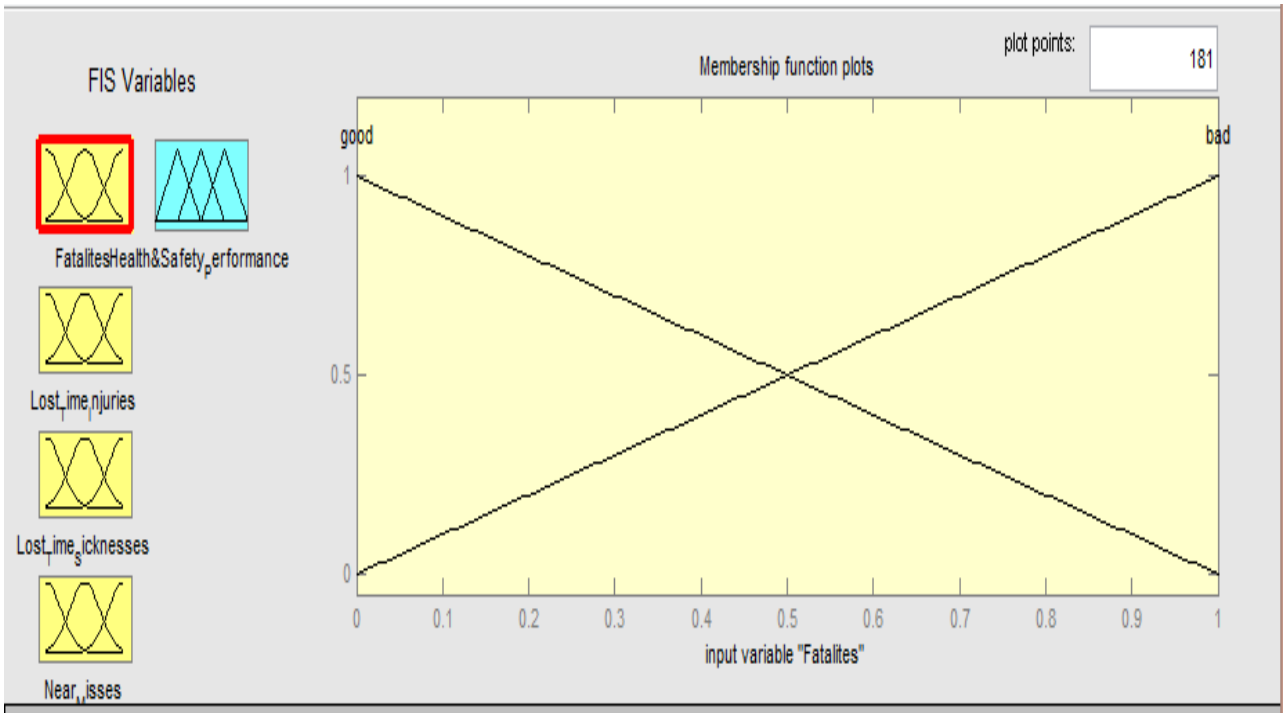


Picture 68. Fatalities– MF1: GOOD



Picture 69. Fatalities– MF2: BAD

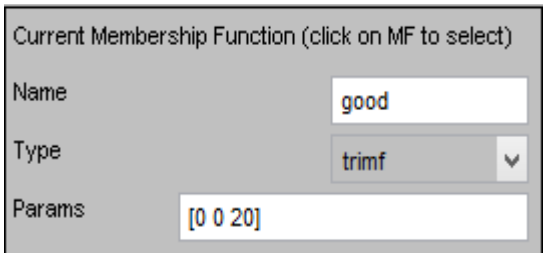
The following graphic shows the total Membership Function of ''Fatalities''.



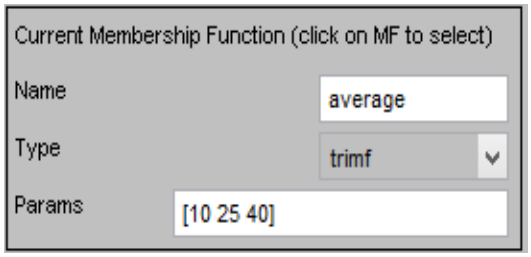
Picture 70. Membership Function of ''Fatalities''

*** Lost Time Injuries***

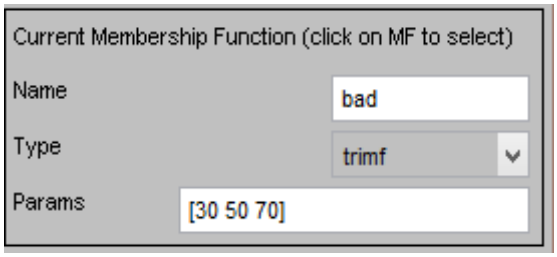
The second input of the system deals with the number of injuries, permanent and total disabilities. More specific, the input value is the frequency rate that injuries occur, the number of them per million total exposed hours (number of employees* number of days travelling during the year* 24hours). It has got three (3) Membership Functions, GOOD , AVERAGE, BAD which characteristics shown below:



Picture 71. Lost Time Injuries– MF1: GOOD

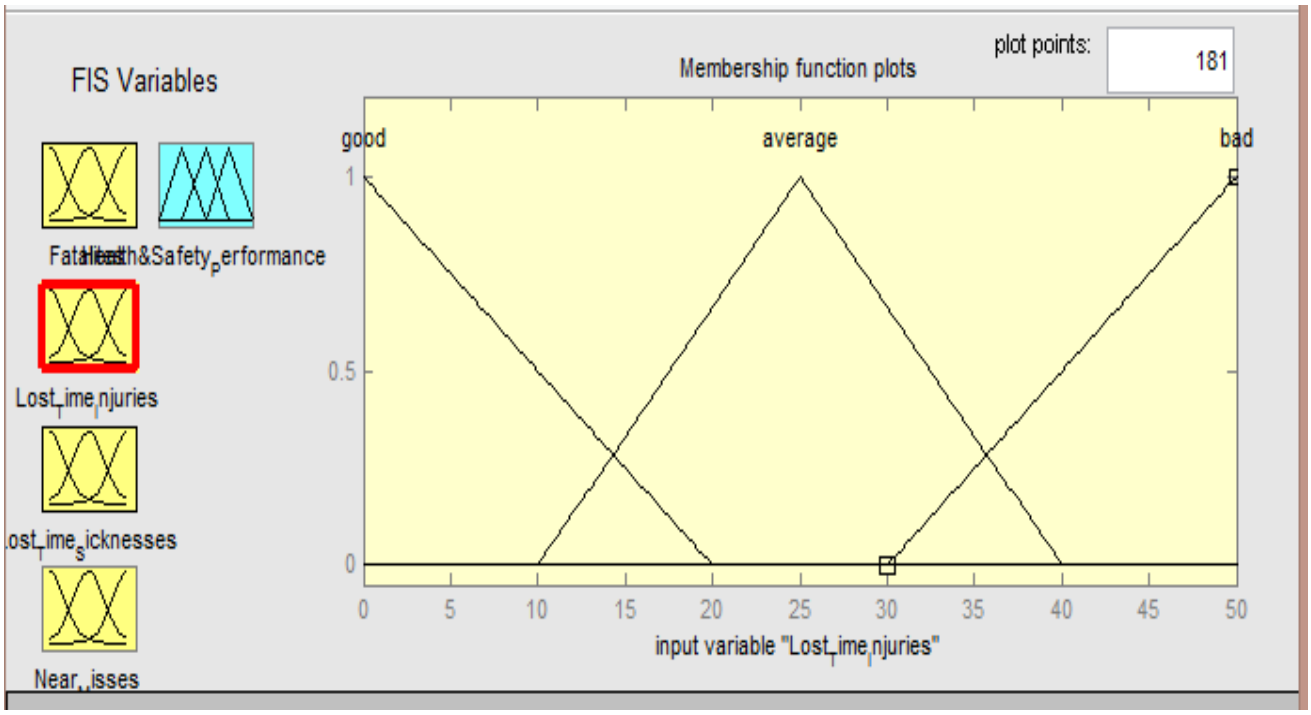


Picture72. Lost Time Injuries– MF2: AVERAGE



Picture 73. Lost Time Injuries– MF3: BAD

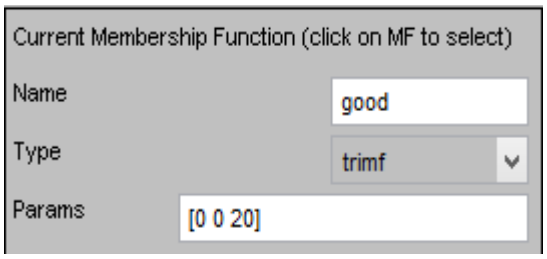
The following graphic shows the total Membership Function of ''Lost Time Injuries''.



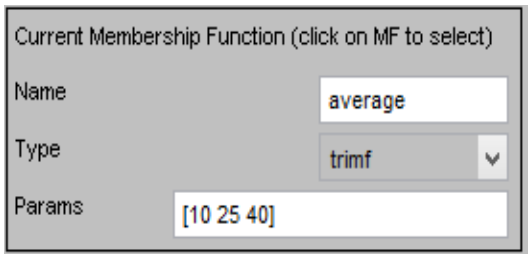
Picture 74. Membership Function of ''Lost Time Injuries''

*** Lost Time Sicknesses***

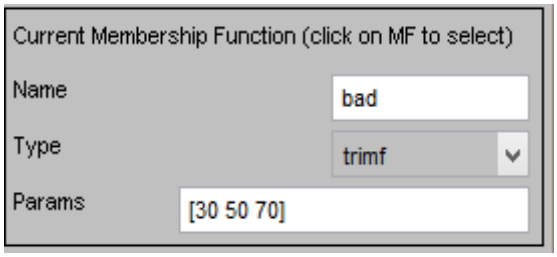
Third input in our system is the number of sicked employees per the total number per one million exposure hours. Its Membership Functions, GOOD, AVERAGE, BAD have the below characteristics, the same as the Membership Functions of the previous input, Lost Time Injuries:



Picture 75. Lost Time Injuries– MF1: GOOD

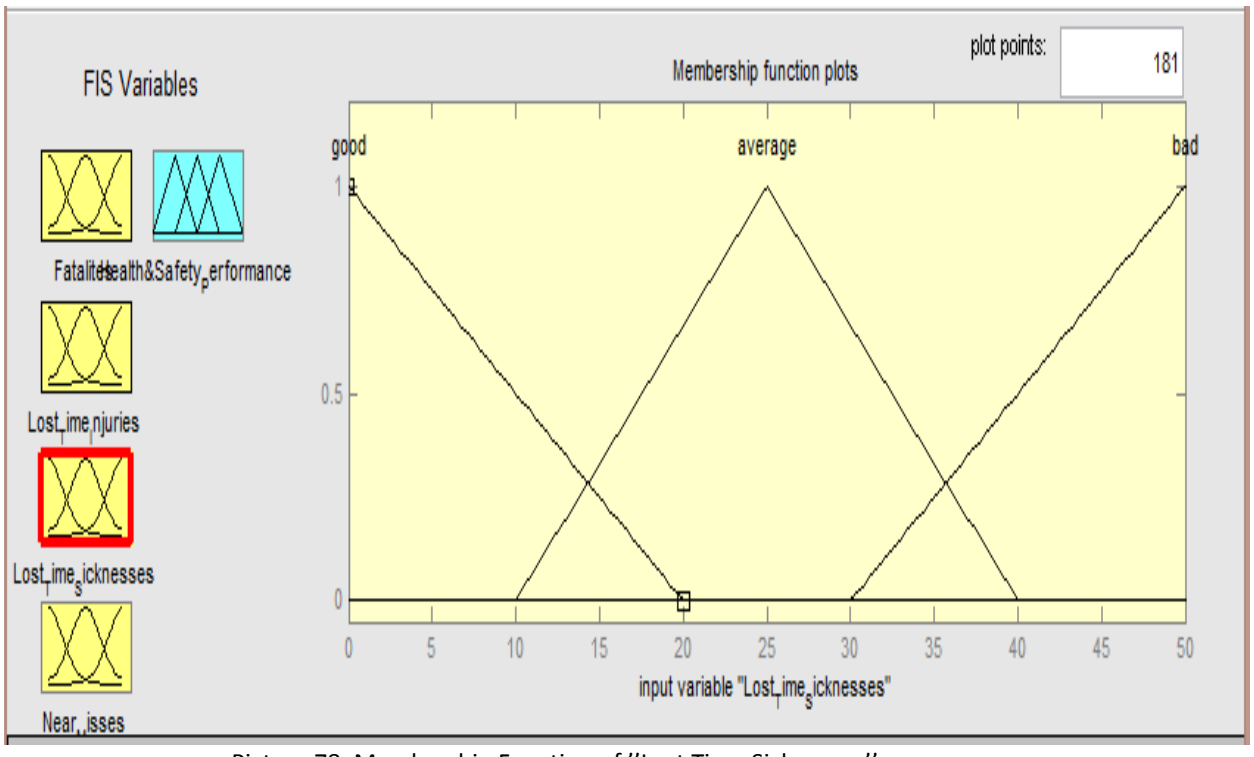


Picture 76. Lost Time Injuries– MF2: AVERAGE



Picture 77. Lost Time Injuries– MF3: BAD

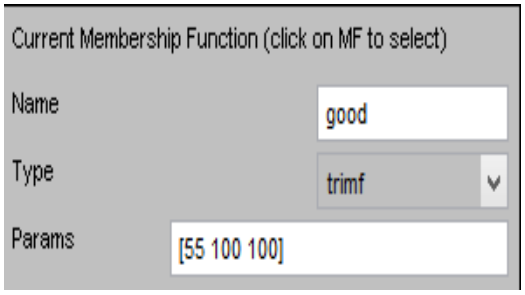
The following graphic shows the total Membership Function of ''Lost Time Sicknesses''.



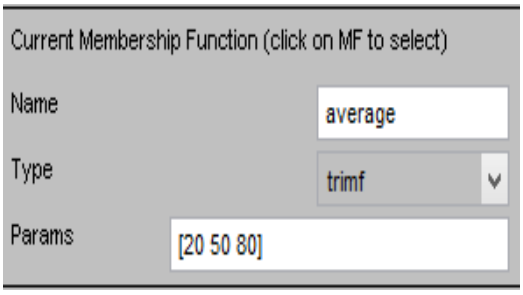
Picture 78. Membership Function of ''Lost Time Sicknesses''

*** Near Misses***

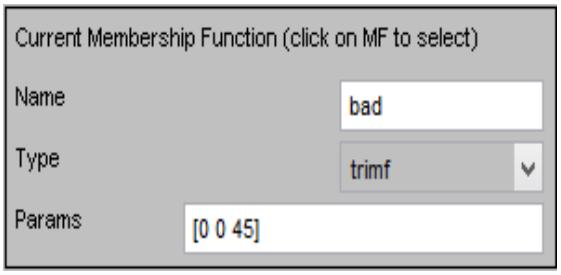
The last input concerns the number of recorder near misses, called as a consequence ''Near Misses''. It consists of three (3) Membership Functions: GOOD, AVERAGE, BAD for which parameters have been assumed as follow:



Picture 79. Near Misses– MF1: GOOD

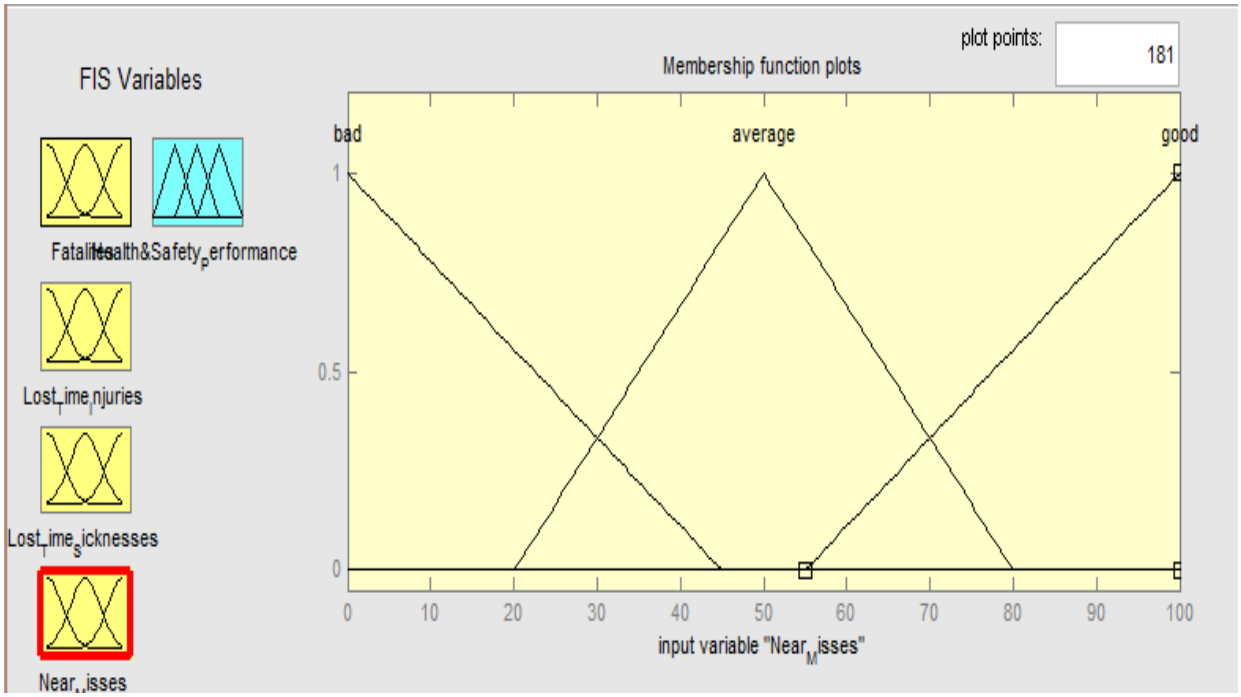


Picture 80. Near Misses– MF2: AVERAGE



Picture 81. Near Misses– MF3: BAD

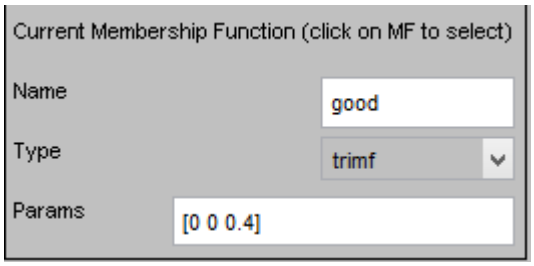
The following graphic shows the total Membership Function of ''Near Misses''.



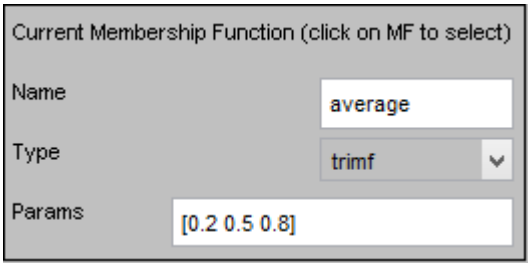
Picture 82. Membership Function of ''Near Misses''

Health and Safety Performance

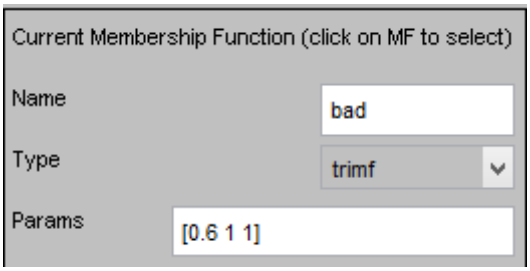
Having completing our analysis about the Membership Functions of the inputs values, we continue with the one output, which is the ''Health and Safety Performance''. The value of the output is a number and according to the Membership Functions that we have defined for it, shows the level of safety performance, GOOD, AVERAGE, BAD. It consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD. Output Membership Functions are the following:



Picture 83. Environmental Performance- MF1: GOOD

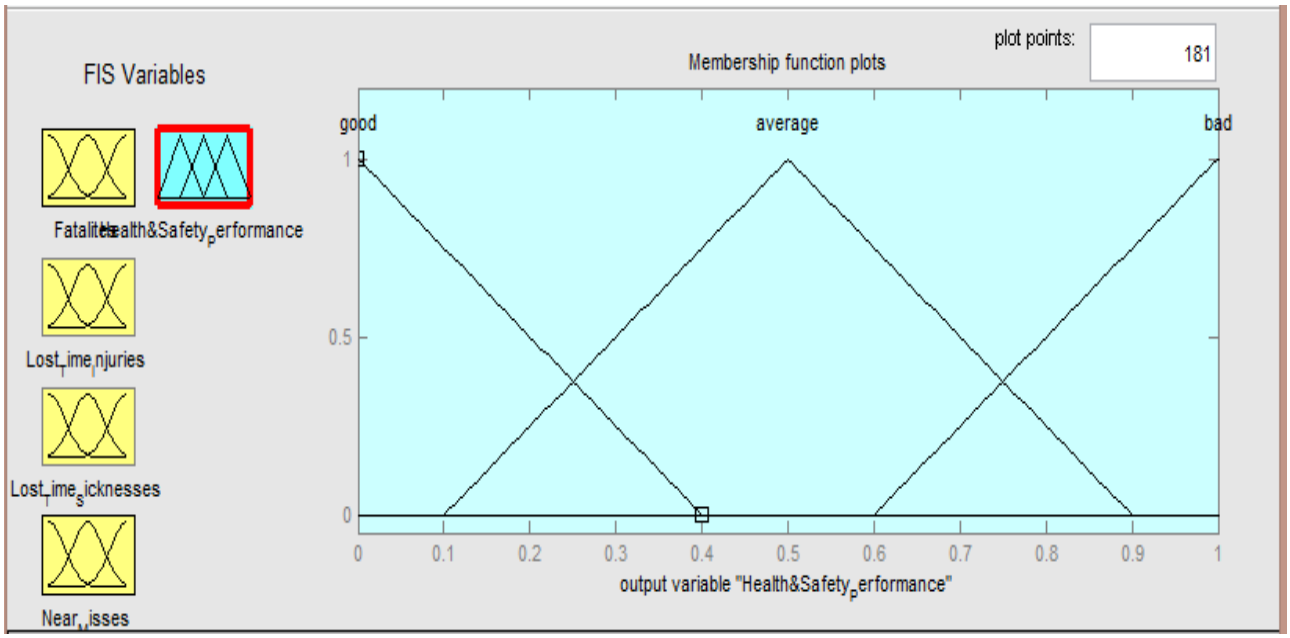


Picture 84. Environmental Performance- MF2: AVERAGE



Picture 85.Environmental Performance- MF3: BAD

The following graphic shows the total Membership Function of ''Health & Safety Performance'':



Picture 86. Membership Function of ''Health and Safety Performance''

♠ RULES

In that case, the number of the Rules is smaller than the previous ones, as the first input, Fatalities, have only two membership functions. For that reason the total number of Rules needed is 54, all with the same weight (1) and with the same logical combination as AND. Some of the established rules are presented below:

1. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is good) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
2. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is good) and (Near_Misses is average) then (Health&Safety_Performance is good) (1)
3. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is good) and (Near_Misses is bad) then (Health&Safety_Performance is good) (1)
4. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is average) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
5. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is average) and (Near_Misses is average) then (Health&Safety_Performance is good) (1)
6. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is average) and (Near_Misses is bad) then (Health&Safety_Performance is average) (1)
7. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is bad) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
8. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is bad) and (Near_Misses is average) then (Health&Safety_Performance is good) (1)
9. If (Fatalites is good) and (Lost_Time_Injuries is good) and (Lost_Time_Sicknesses is bad) and (Near_Misses is bad) then (Health&Safety_Performance is average) (1)
10. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is good) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
11. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is good) and (Near_Misses is average) then (Health&Safety_Performance is good) (1)
12. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is good) and (Near_Misses is bad) then (Health&Safety_Performance is average) (1)
13. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is average) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
14. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is average) and (Near_Misses is average) then (Health&Safety_Performance is average) (1)
15. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is average) and (Near_Misses is bad) then (Health&Safety_Performance is average) (1)
16. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is bad) and (Near_Misses is good) then (Health&Safety_Performance is good) (1)
17. If (Fatalites is good) and (Lost_Time_Injuries is average) and (Lost_Time_Sicknesses is bad) and (Near_Misses is average) then (Health&Safety_Performance is average) (1)

Matrix 39: Sample of Rules at Health and Safety Fuzzy Model

4.3.4 ENVIRONMNETAL FUZZY LOGIC SYSTEM

Last but not least is the Environmental Fuzzy Logic System, created in order to estimate a shipping company's environmental performance. Its principles are analyzed below:

♠ SYSTEM

As always, the chosen system is the Mamdani System.

♠ INPUTS

As inputs we have assumed the FOUR (4) Environmental Key Performance Indicators:

	INPUTS	Unit	Weight	Period
1	**CO2 Emissions**	Rightship Rate	46%	annually
2	**Sox Emissions**	number	21%	annually
3	**Nox Emissions**	number	21%	annually
4	**Spills**	number	12%	annually

Matrix 40. Environmental Fuzzy Logic System- Inputs

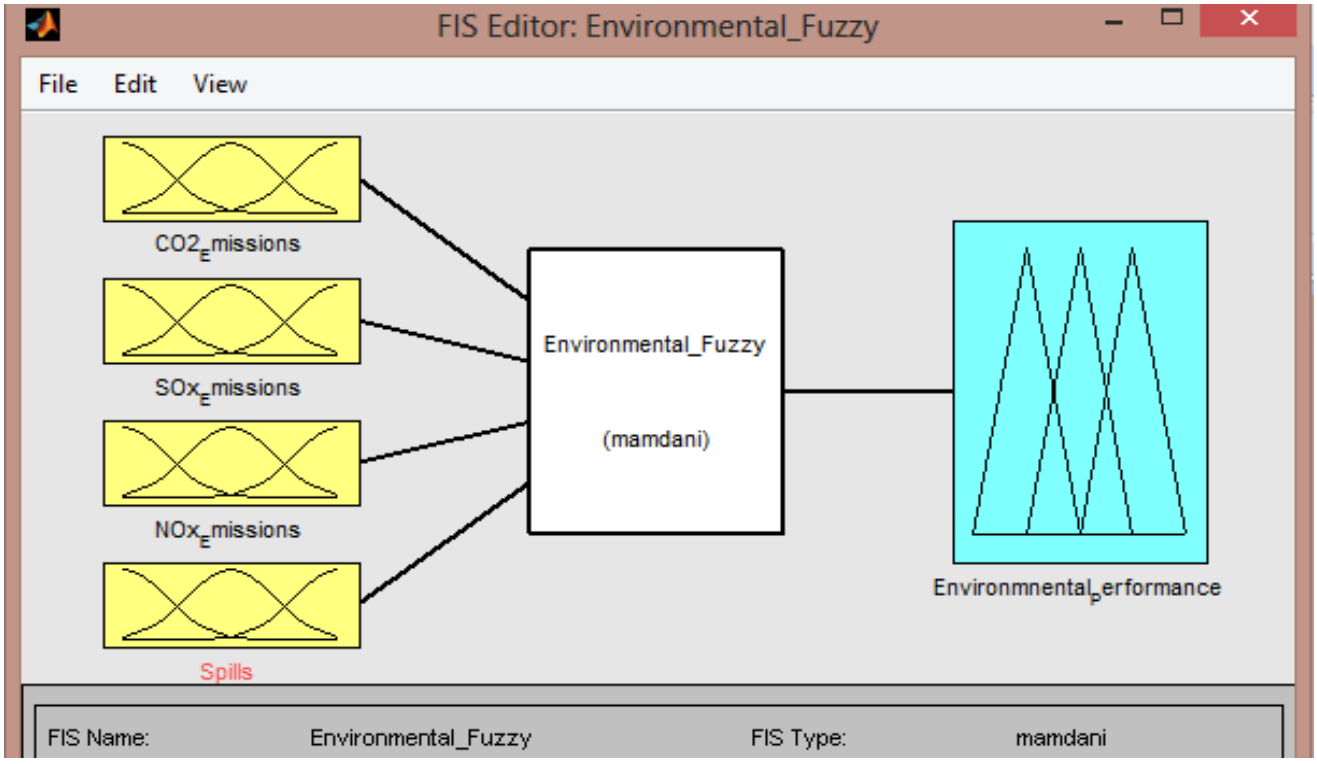
♠ OUTPUT

As ONE output we have chosen the Environmental performance:

	OUTPUT	Unit	Period
1	**Environmental Performance**	Index [0,1]	annually

Matrix 41. Environmental Fuzzy Logic System- Output

The above parameters have been established to the system as shows below:



Picture 87. Environmental Fuzzy Logic System

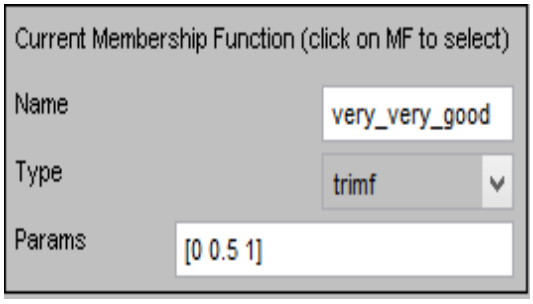
♠ MEMBERSHIP FUNCTION

*** CO2 Emissions***

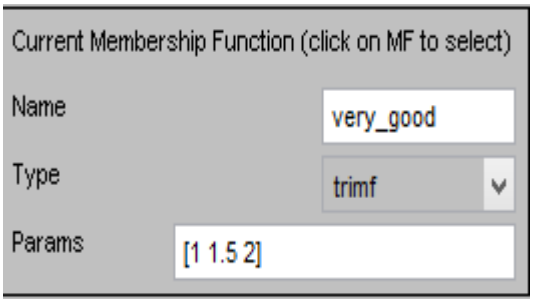
To begin with, ‘’CO2 Emissions’’ is the first input to the Environmental Fuzzy Logic System. As input we have assumed that rate that Rightship organization has gave to the vessel under examination. The membership functions for that input are not three (3) as we were used from the previous inputs but seven (7) as the categories of the Environmnetal Rating according to Rightship. These are the VERY VERY GOOG, VERY GOOD, GOOD, AVERAGE, BAD, VERY BAD and VERY VERY BAD, and all triangular shaped. This input differs from the other in the system concerning its Membership Function. Although its Membership Function are triangular and it is part of a Fuzzy Logic System, its values as an input are not fuzzy but crisp. More specific the Environmental Rating giving by Rightship, is matched to the following crisp values:

Rightship Environmental Rating	Co2 Emissions Input's Values
A	0.5
B	1.5
C	2.5
D	3.5
E	4.5
F	5.5
G	6.5

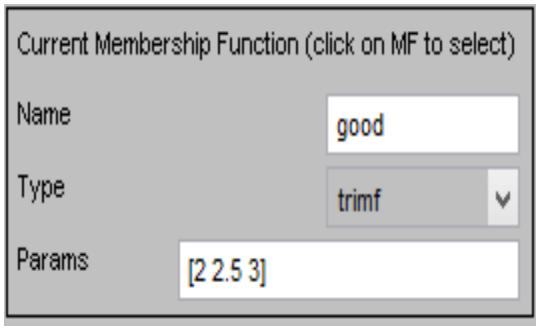
The parameters of the Membership Functions are presented below:



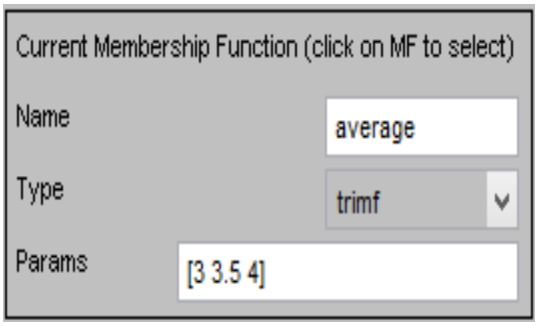
Picture 88. CO2 Emissions– MF1: VERY VERY GOOD



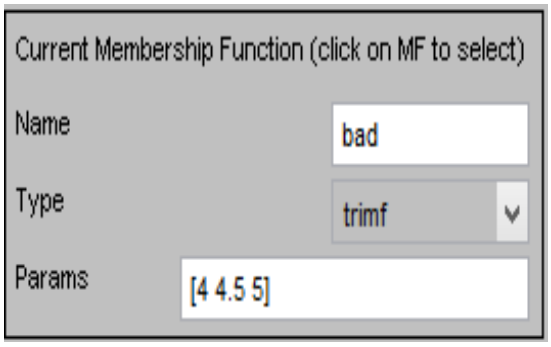
Picture 89. CO2 Emissions– MF2: VERY GOOD



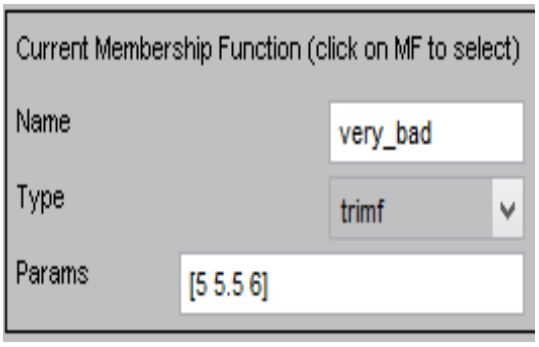
Picture 90. CO2 Emissions– MF3: GOOD



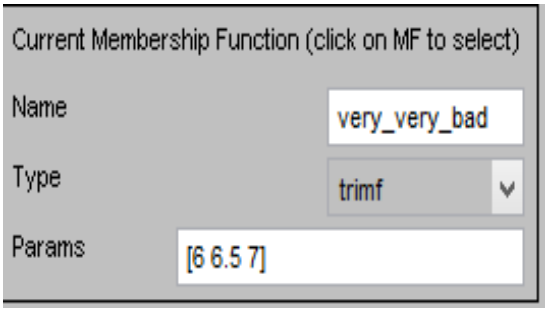
Picture 91. CO2 Emissions– MF4: AVERAGE



Picture 92. CO2 Emissions– MF5: BAD

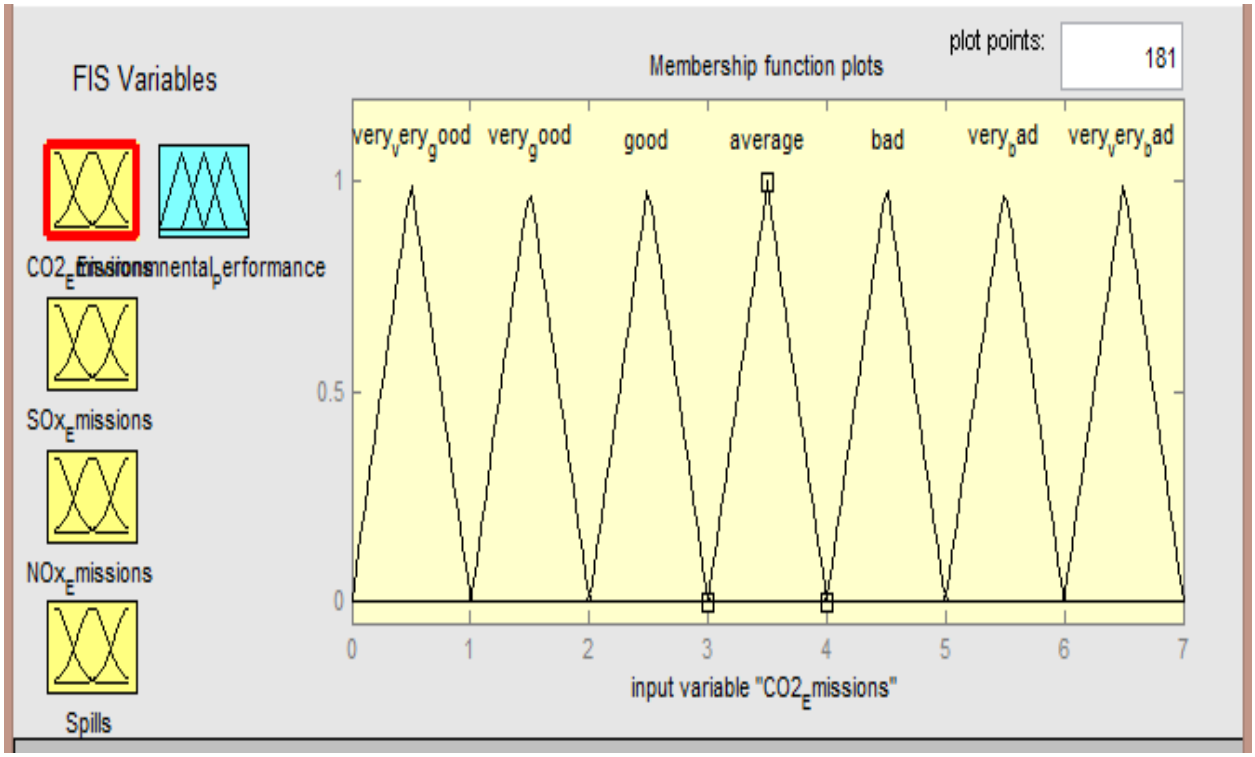


Picture 93. CO2 Emissions– MF6: VERY BAD



Picture 94. CO2 Emissions– MF7: VERY VERY BAD

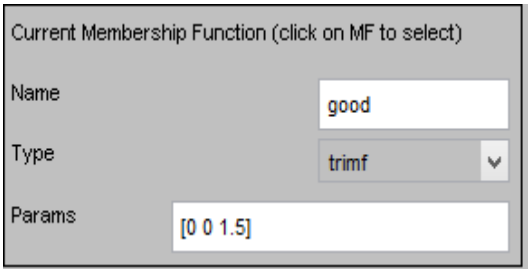
The following graphic shows the total Membership Function of ''CO2 Emissions'':



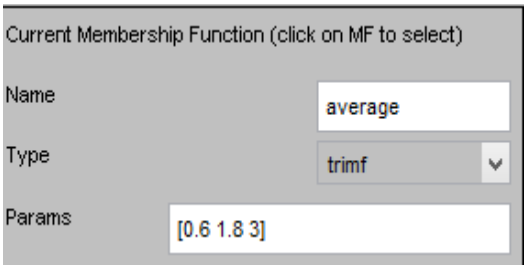
Picture 95. Membership Function of ''CO2 Emissions''

*** SOx Emissions***

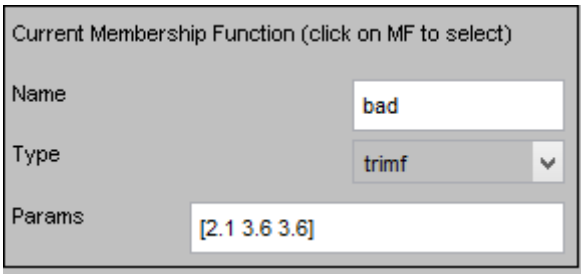
To continue with, ‘’SOx Emissions’’ is the next input in our system. As an input value is the mass of Nox emission per transport work. By transport work we mean the number of nautical miles that the subject tanker distant annually and the total transpored cargo annually. It has got three Membership Functions GOOD, AVERAGE, BAD with the follow characteristics:



Picture 96. SOx Emissions– MF1: GOOD

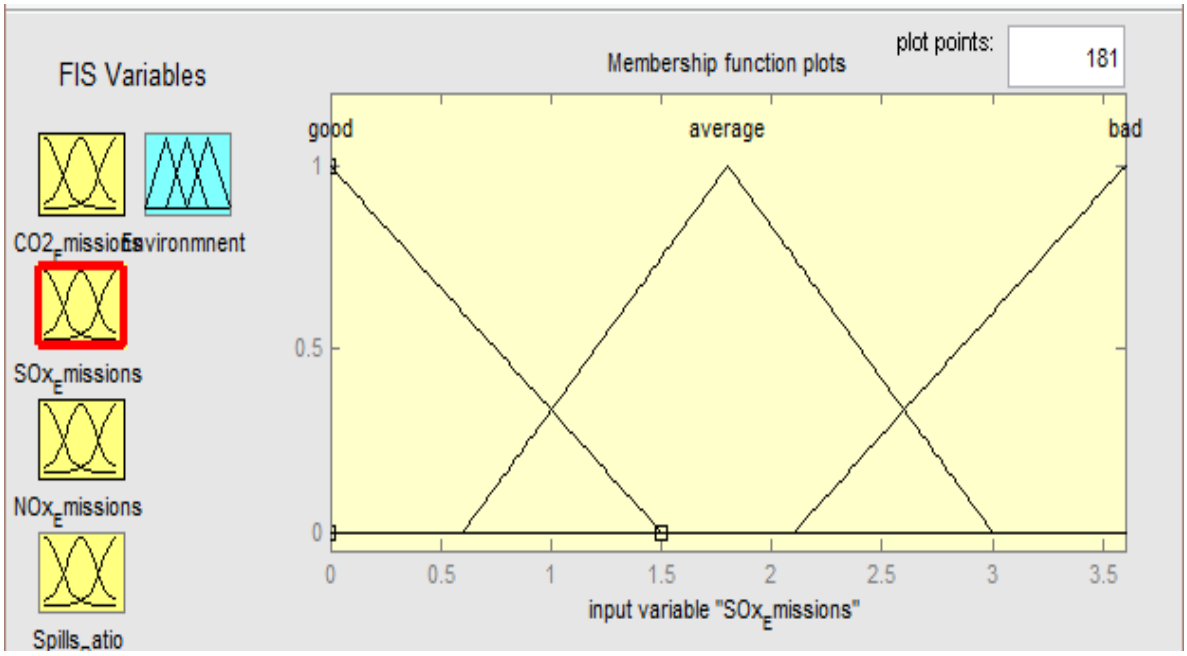


Picture 97. SOx Emissions– MF2: AVERAGE



Picture 98. SOx Emissions– MF3: BAD

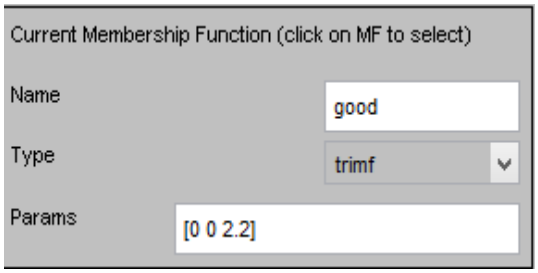
The following graphic shows the total Membership Function of ‘’SOx Emissions’’:



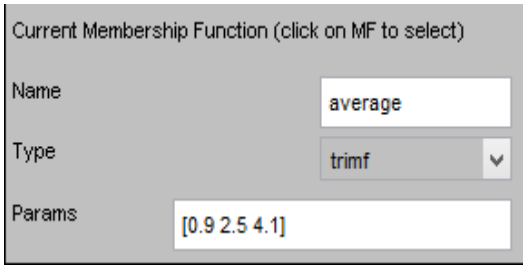
Picture 99. Membership Function of ’’SOx Emissions’’

*** NOx Emissions***

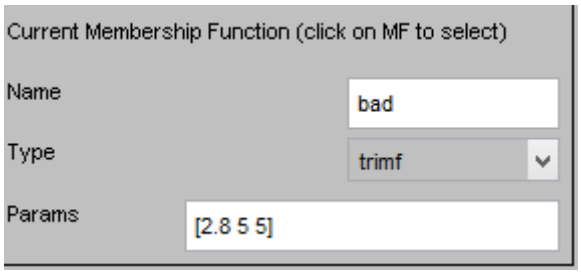
In the same situation as Sox Emissions leads the next input, named '' NOx Emissions''. As an input value is the mass of Nox emission per transport work. By transport work we mean the number of nautical miles that the subject tanker distant annually and the total transpored cargo annually. It has got the same three Membership Functions GOOD, AVERAGE, BAD as the Sox Emissions input, as appear below:



Picture 100. NOx Emissions– MF1: GOOD

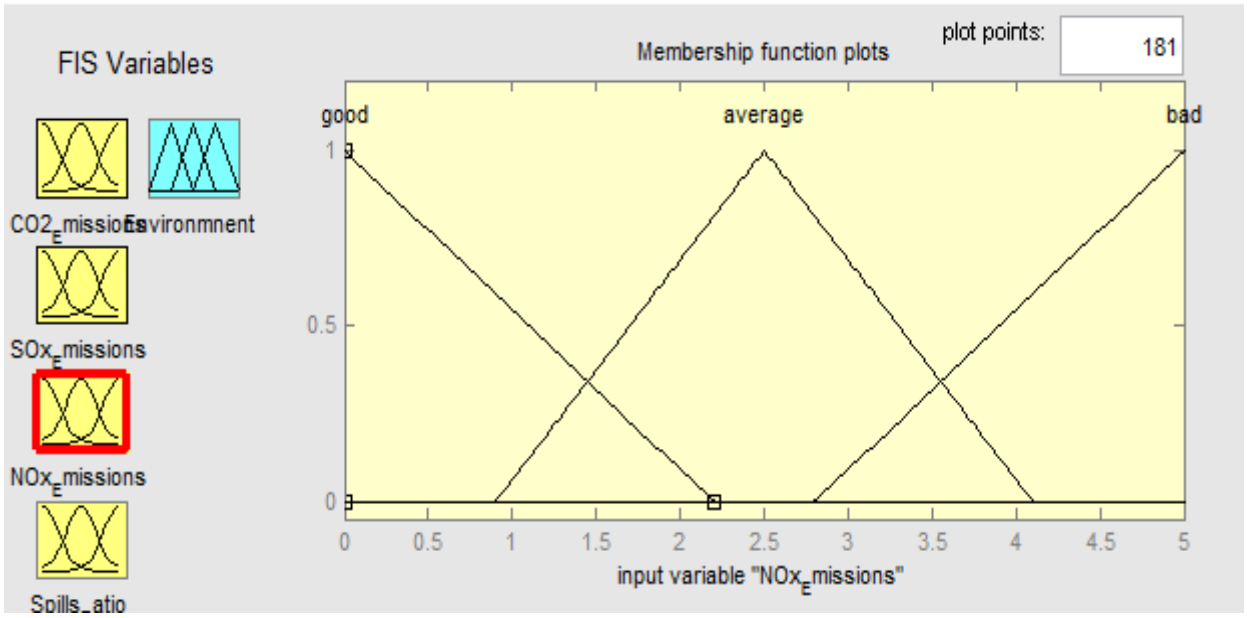


Picture 101. NOx Emissions– MF2: AVERAGE



Picture 102. NOx Emissions– MF3: BAD

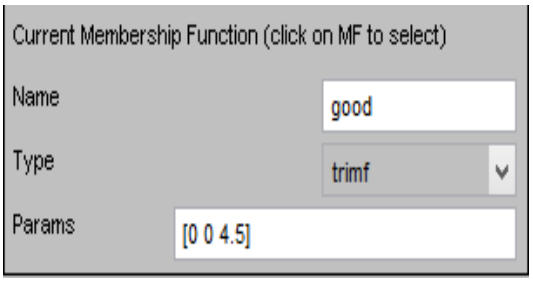
The following graphic shows the total Membership Function of ''NOx Emissions'':



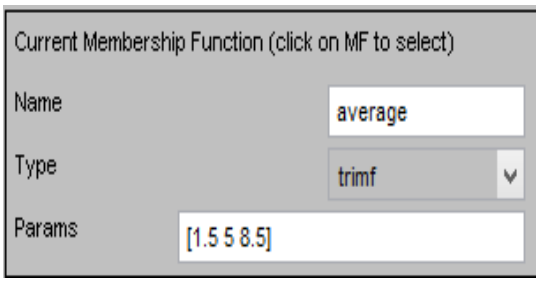
Picture 103. Membership Function of ''NOx Emissions''

*** Spills***

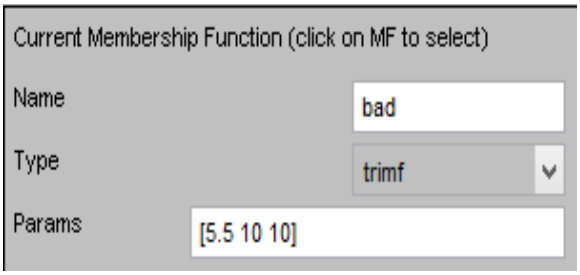
Our last input Key Performance Indicator is the total number of spills that the vessel has created in its operation during one year. Obviously this input called, ''Spills''. It has got the same three Membership Functions GOOD, AVERAGE, BAD as the Sox Emissions input, as appear below:



Picture 104. Spills– MF1: GOOD

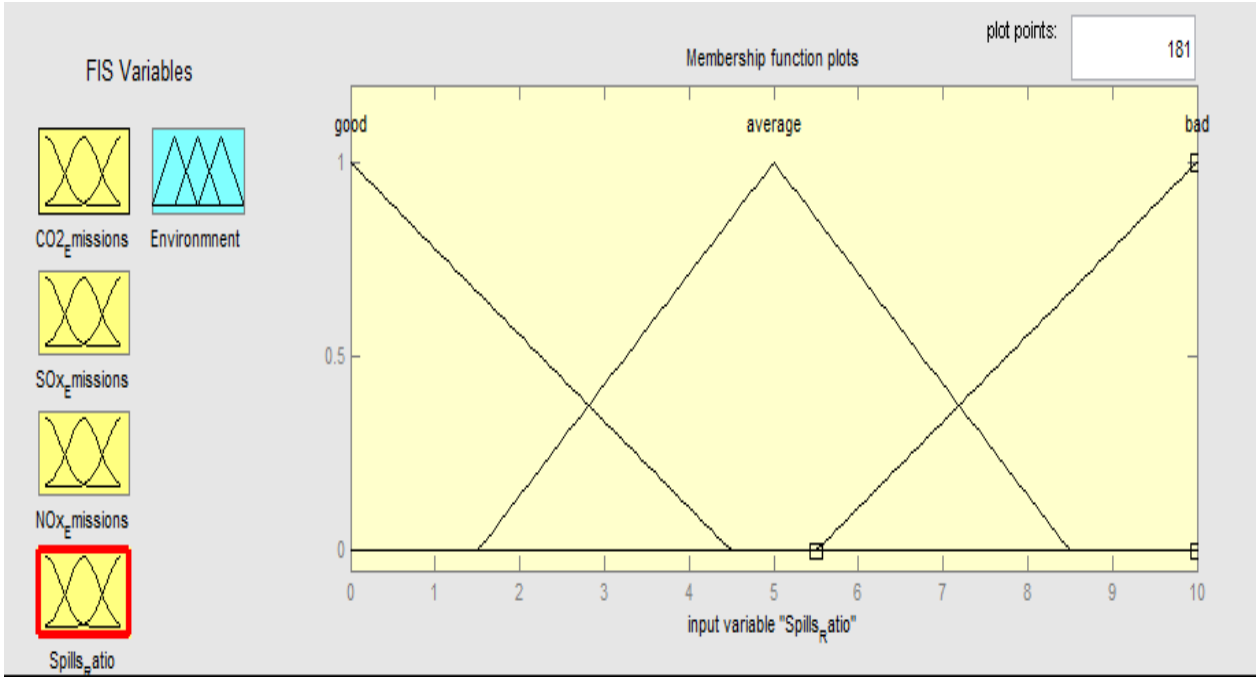


Picture 105. Spills– MF2: AVERAGE



Picture106. Spills– MF3: BAD

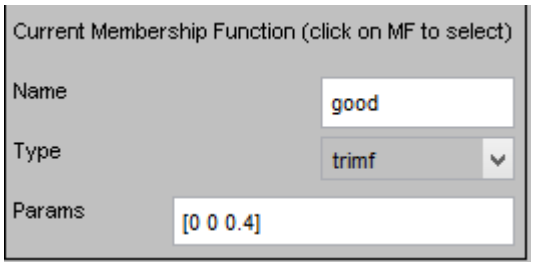
The following graphic shows the total Membership Function of ''Spills'':



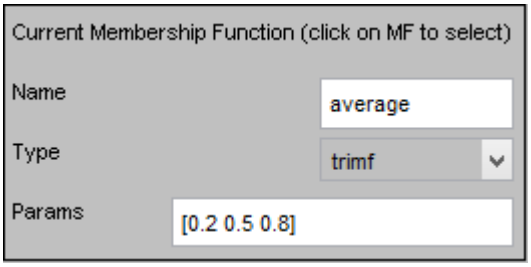
Picture107. Membership Function of ''Spills''

*** Environmental Performance***

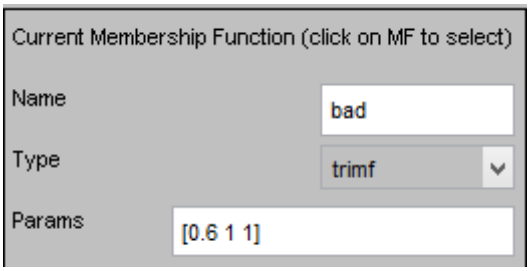
Having completing our analysis about the Membership Functions of the inputs values, we continue with the one output, which is the ''Environmental Performance''. The value of the output is a number and according to the Membership Functions that we have defined for it, shows the level of safety performance, GOOD, AVERAGE, BAD. As the inputs, it consists of three (3) Membership Functions (MF), all triangular shaped, shown the GOOD, AVERAGE and BAD. Output Membership Functions are the following:



Picture 108. Environmental Performance- MF1: GOOD

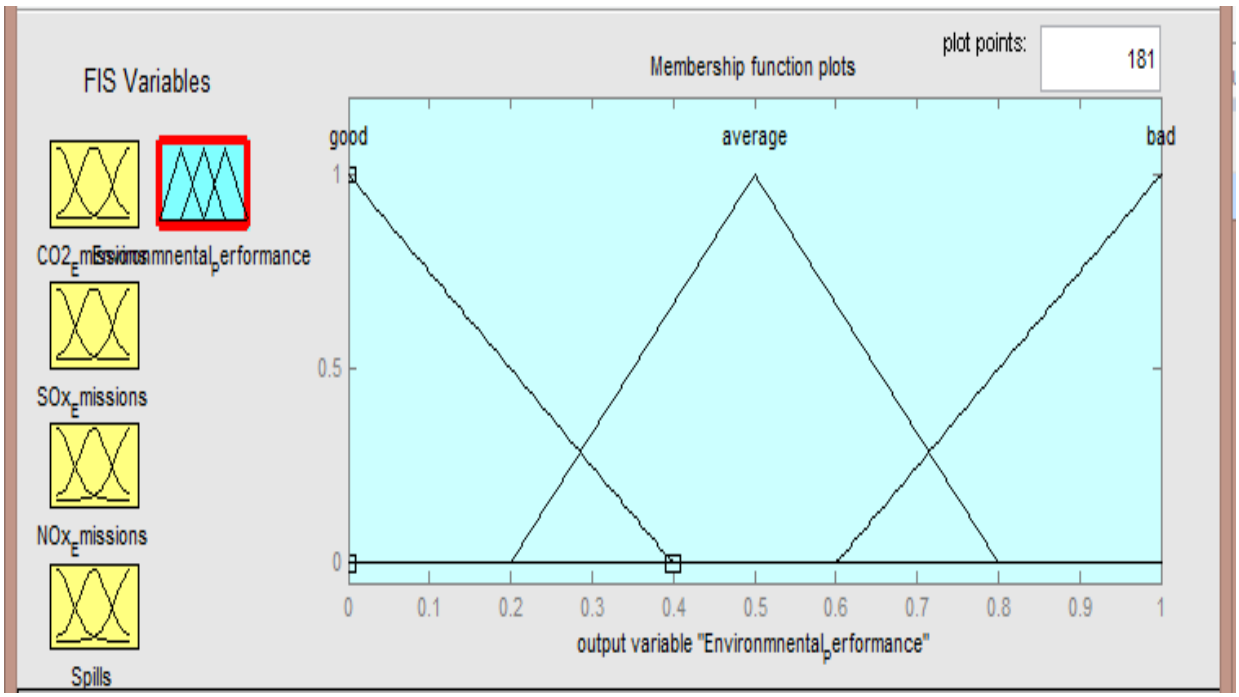


Picture 109. Environmental Performance- MF2: AVERAGE



Picture 110. Environmental Performance- MF3: BAD

The following graphic shows the total Membership Function of ''Environmental Performance'':



Picture 111. Membership Function of ''Environmental Performance''

♠ RULES

Identifying the set of Rules is more difficult in that system, as due to the more Membership Functions of the first input, CO2 Emissions, the total number of rules is getting too high equal to 189, in order to cover all the possible combination. As in the previous systems, rules are of the same weight equal to 1 and are combined through AND combination. Some of the established rules are presented below:

1. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is good) and (Spills is good) then (Environmnental_Performance is good) (1)
2. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is good) and (Spills is average) then (Environmnental_Performance is good) (1)
3. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is good) and (Spills is bad) then (Environmnental_Performance is good) (1)
4. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is average) and (Spills is good) then (Environmnental_Performance is good) (1)
5. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is average) and (Spills is average) then (Environmnental_Performance is good) (1)
6. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is average) and (Spills is bad) then (Environmnental_Performance is average) (1)
7. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is bad) and (Spills is good) then (Environmnental_Performance is good) (1)
8. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is bad) and (Spills is average) then (Environmnental_Performance is average) (1)
9. If (CO2_Emissions is good) and (SOx_Emissions is good) and (NOx_Emissions is bad) and (Spills is bad) then (Environmnental_Performance is average) (1)
10. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is good) and (Spills is good) then (Environmnental_Performance is good) (1)
11. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is good) and (Spills is average) then (Environmnental_Performance is good) (1)
12. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is good) and (Spills is bad) then (Environmnental_Performance is bad) (1)
13. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is average) and (Spills is good) then (Environmnental_Performance is good) (1)
14. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is average) and (Spills is average) then (Environmnental_Performance is average) (1)
15. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is average) and (Spills is bad) then (Environmnental_Performance is average) (1)
16. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is bad) and (Spills is good) then (Environmnental_Performance is good) (1)
17. If (CO2_Emissions is good) and (SOx_Emissions is average) and (NOx_Emissions is bad) and (Spills is average) then (Environmnental_Performance is average) (1)

Matrix 42: Sample of Rules at Environmental Fuzzy Model

CHAPTER 5: "PERFORMANCE EVALUATION"

To continue with the previous chapter, having completing the creation each one of our fuzzy system models (safety, health and safety, security and environmental) we are able now to use them in order to estimate the safety, health and safety, security and environmental performance. The previous models have been created in order to be applicable to tanker vessels of all types and for that reason the vessels we are going to examine are tankers as well.

Scope of this chapter is first of all the application of the previous models to a number of tanker vessels with different Key Performance Indicators values with a view to conclude to an average performance for each one of the fields of safety, health and safety, security and environment. For that reason we examine 30 tanker vessels. Having creating the average performance, in the last paragraph we compare the average performance with the examined tanker vessel performance.

The first step for estimating the average performance is the performance estimation of each one of the 30 tanker vessels. This procedure will be successfully completed when the user put the inputs(Key Performance Indicators values) and then the fuzzy system lead the user to the output (vessel performance) using the membership function and the rules that we have already mentioned in the previous chapter.

In order to make the more easy the above progress both for us as users and for the shipping company which desires to find out the performance of the vessels which has got under its management we have created the following questionnaire with the necessary information needed for evaluating the values of Key Performance Indicators, in the form which is needed for the fuzzy logic system. The questionnaire concerns only one vessel, the one which in the next step we are going to evaluate its performance. The mentioned questionnaire as well the way we use the information of it and calculate the Key Performance Indicators values can be seen as below:

QUESTIONNAIRE PER VESSEL	1	Number of all tanker vessels under management	B1
SAFETY PERFORMANCE	2	Number of allissions of the subject tanker vessel annually	B2
	3	Number of collisions of the subject tanker vessel annually	B3
	4	Number of groudings of the subject tanker vessel annually	B4
	5	Number of fires and explosions of the subject tanker vessel annually	B5
	6	Number of scheduled training courses for crew and officers of the subject tanker vessel annually	B6
	7	Number of training courses done on time for crew and officers of the subject tanker vessel annually	B7
	8	Number of vetting inspections on the subject tanker vessel annually	B8
	9	Number of observations on all vetting inspections of the subject tanker vessel annually	B9
HEALTH & SAFETY PERFORMANCE	10	Number of deaths among the crew or anyone who is part of the vessel, of the subject tanker vessel, resulting from a work injury or illnesses annually	B10
	11	Number of permanent total disabilities among the crew or anyone who is part of the subject tanker vessel, resulting from a work injury (not illness or other conditions) annually	B11
	12	Number of permanent portial disabilities among the crew or anyone who is part of the subject tanker vessel, resulting from a work injury (not illness or other conditions) annually	B12
	13	Number of lost workday cases among the crew or anyone who is part of the subject tanker vessel, resulting from a work injury (not illness or other conditions) annually	B13
	14	Total number of crew or anyone who is part of the subject tanker vessel annually	B14
	15	Total number of days crew or anyone who is part of the subject tanker vessel is exposued annually	B15
	16	Number of sicked among the crew or anyone who is part of the subject taker vessel over 24 hours annually	B16
	17	Number of lost workday cases among the crew or anyone who is part of the subject tanker vessel, resulting from an illness annually	B17
	18	Number of near misses on the subject tanker vessel annually	B18
SECURITY PERFORMANCE	19	Total number of used anti-piracy measures on the subject tanker vessel annually	B19
	20	Total amount of transferred cargo on the subject tanker vessel annually	B20
	21	Total amount of damaged cargo on the subject tanker vessel annually	B21
	22	Total amount of lost cargo on the subject tanker vessel annually	B22
	23	Total amount of stolen cargo on the subject tanker vessel annually	B23
ENVIRONMENTAL PERFORMANCE	24	Total number of created spills to water of the subject tanker vessel annually	B24
	25	Number of Kilograms of Emmited mass of Sox in laden and ballast condition based on fuel consumption &fuel quality.	B25
	26	Number of Kilograms of Emmited mass of Nox in laden and ballast condition based on fuel consumption & engine speed.	B26
	27	Number of distance sailed the subject tanker annually in nautical miles	B27
	28	Rightship GHG rating for the vessel(A/B/C/D/E/F/G) annually	B28

Matrix 43. Questionnaire per Tanker Vessel

Key Performance Indicators (KPIs)- EVALUATION METHOD				
SAFETY PERFORMANCE	1	INCIDENTS	(2*B3+B2+2*B4)	number
	2	FIRE AND EXPLOSION	B5	number
	3	TRAINING ACHIEVEMENT	B7/B6*100	%
	4	VETTING OBSERVATIONS per INSPECTION	B9/B8	number
HEALTH & SAFETY PERFORMANCE	1	FATALITIES	B10	number
	2	LTIF	(B11+B12+B13)*1,000,000/B14*B15*24	number
	3	LTSF	(B16+B17)*1,000,000/B14*B15*24	number
	4	NEAR MISSES	B18	number
SECURITY PERFORMANCE	1	DAMAGED CARGO	B21/B20*100	%
	2	LOST CARGO	B22/B20*100	%
	3	STOLEN CARGO	B23/B20*100	%
	4	ANTI-PIRACY MEASURES	B19/B23*100	%
ENVIRONMNETAL PERFORMANCE	1	CO2 EMISSIONS	B28	letter
	2	Sox EMISSIONS	B25/B20*B27*10^(-3)	Kg/tmn
	3	Nox EMISSIONS	B26/B20*B27*10^(-3)	Kg/tmn
	4	SPILLS	B24	number

Matrix 44. Evaluation Method of Key Performance Indicators

5.1. AVERAGE PERFORMANCE (30 Tanker vessels)

VESSEL No.1

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	95
3. Fire&Explosion	0
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,137**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	30
HEALTH&SAFETY PERFORMANCE	**0,166**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	100
SECURITY PERFORMANCE	**0,13**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,11
3. Nox Emissions	0,12
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,131**

There are other 29 senarios for different Tankers whose performance can be found in Appendix.

To sum up, in the following matrix, you can find the values of the average performance concerning the safety, health and safety, security, and environmental levels.

As we have already mentioned the environment is the most sensitive field for shipping industry nowadays, and for that reason we can understand why environmental performance has got the lowest value in contract with the security which in all previous industries has been paid the less attention, and it has got the highest performance value as expected.

VESSELS	*SAFETY PERFORMANCE*	*HEALTH & SAFETY PERFORMANCE*	*SECURITY PERFORMANCE*	*ENVIRONMENTAL PERFORMANCE*
V.No 1	0,137	0,166	0,13	0,131
V.No 2	0,149	0,161	0,153	0,134
V.No 3	0,41	0,158	0,132	0,133
V.No 4	0,142	0,153	0,44	0,138
V.No 5	0,143	0,153	0,13	0,155
V.No 6	0,377	0,151	0,132	0,151
V.No 7	0,165	0,144	0,403	0,142
V.No 8	0,142	0,142	0,132	0,141
V.No 9	0,427	0,14	0,395	0,152
V.No 10	0,13	0,138	0,155	0,161
V.No 11	0,336	0,135	0,138	0,164
V.No 12	0,149	0,164	0,351	0,159
V.No 13	0,132	0,135	0,132	0,166
V.No 14	0,161	0,133	0,146	0,211
V.No 15	0,149	0,132	0,166	0,183
V.No 16	0,157	0,13	0,138	0,269
V.No 17	0,405	0,166	0,132	0,159
V.No 18	0,35	0,318	0,212	0,308
V.No 19	0,158	0,384	0,448	0,133
V.No 20	0,132	0,388	0,5	0,219
V.No 21	0,149	0,415	0,319	0,149
V.No 22	0,157	0,46	0,138	0,135
V.No 23	0,142	0,37	0,337	0,389
V.No 24	0,136	0,164	0,138	0,158
V.No 25	0,166	0,865	0,146	0,144
V.No 26	0,149	0,138	0,398	0,161
V.No 27	0,136	0,135	0,725	0,154
V.No 28	0,343	0,136	0,138	0,165
V.No 29	0,153	0,144	0,13	0,161
V.No 30	0,274	0,135	0,132	0,261
AVERAGE PERFORMANCE	**0,2052**	**0,2184**	**0,2389**	**0,1762**

Matrix 45. Values of Average Performance

5.2. PERFORMANCE EVALUATION OF TANKER VESSEL "GATE"

In this paragraph we use the created fuzzy models n order to estimate the value of the performance of one tanker vessel and then to compare its value at one of the mentioned four fields in order to conclude in which level is grater or lower that the average performance.

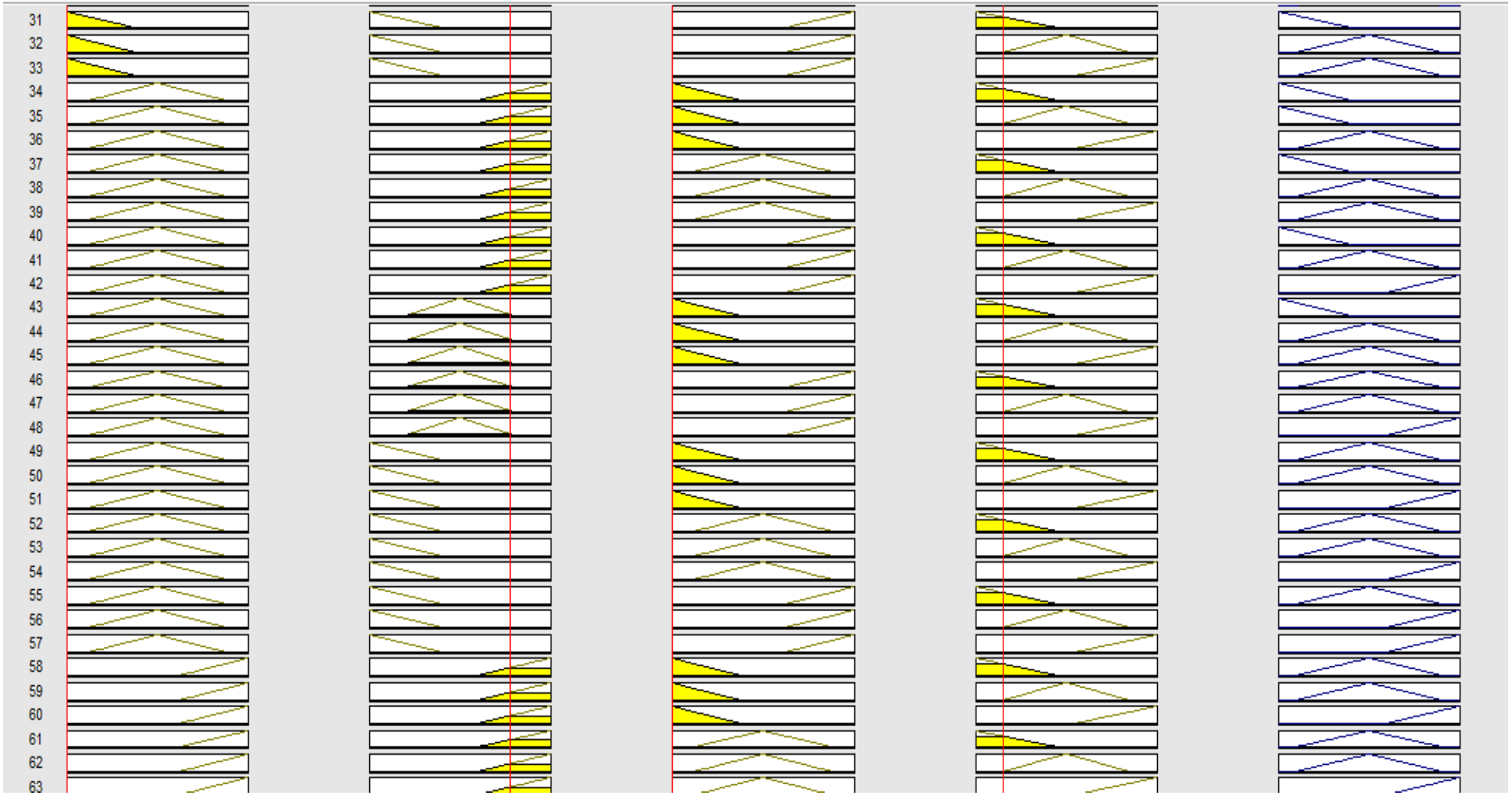
For the examined tanker vessel, named '' GATE'', the shipping company which has got it under its management has completed the questionnaire we send them and as has previous mentioned the results of the Key Performance Indicators are shown in the following matrix:

Key Performance Indicators (KPIs)- EVALUATION METHOD				
SAFETY PERFORMANCE	1	INCIDENTS	0	number
	2	FIRE AND EXPLOSION	0	number
	3	TRAINING ACHIEVEMENT	89	%
	4	VETTING OBSERVATIONS per INSPECTION	3	number
HEALTH & SAFETY PERFORMANCE	1	FATALITIES	0	number
	2	LTIFR	0	number
	3	LTSFR	0	number
	4	NEAR MISSES	43	number
SECURITY PERFORMANCE	1	DAMAGED CARGO	0	%
	2	LOST CARGO	0	%
	3	STOLEN CARGO	0	%
	4	ANTI-PIRACY MEASURES	87	%
ENVIRONMNETAL PERFORMANCE	1	CO2 EMISSIONS	A	letter
	2	Sox EMISSIONS	0,48	Kg/TNM
	3	Nox EMISSIONS	0,75	Kg/TNM
	4	SPILLS	0	number

Matrix 46. Evaluation Method of Key Performance Indicators of examined tanker vessel ''GATE''

As previous, each one of the interested performance will be analyzed separately and the results are presented below:

***** Safety Performance- Examined vessel ''GATE''*****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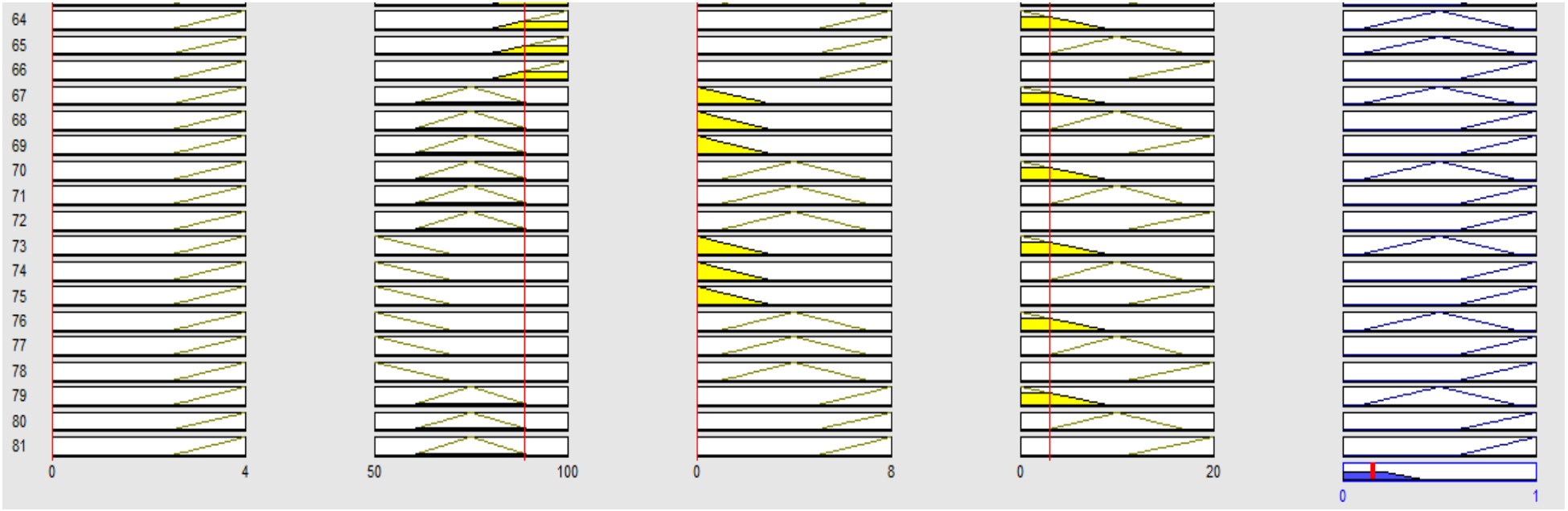
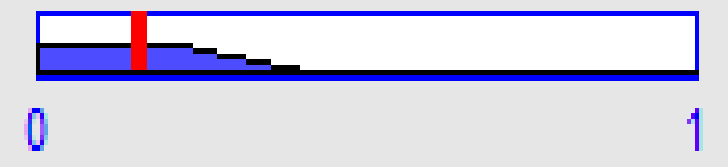
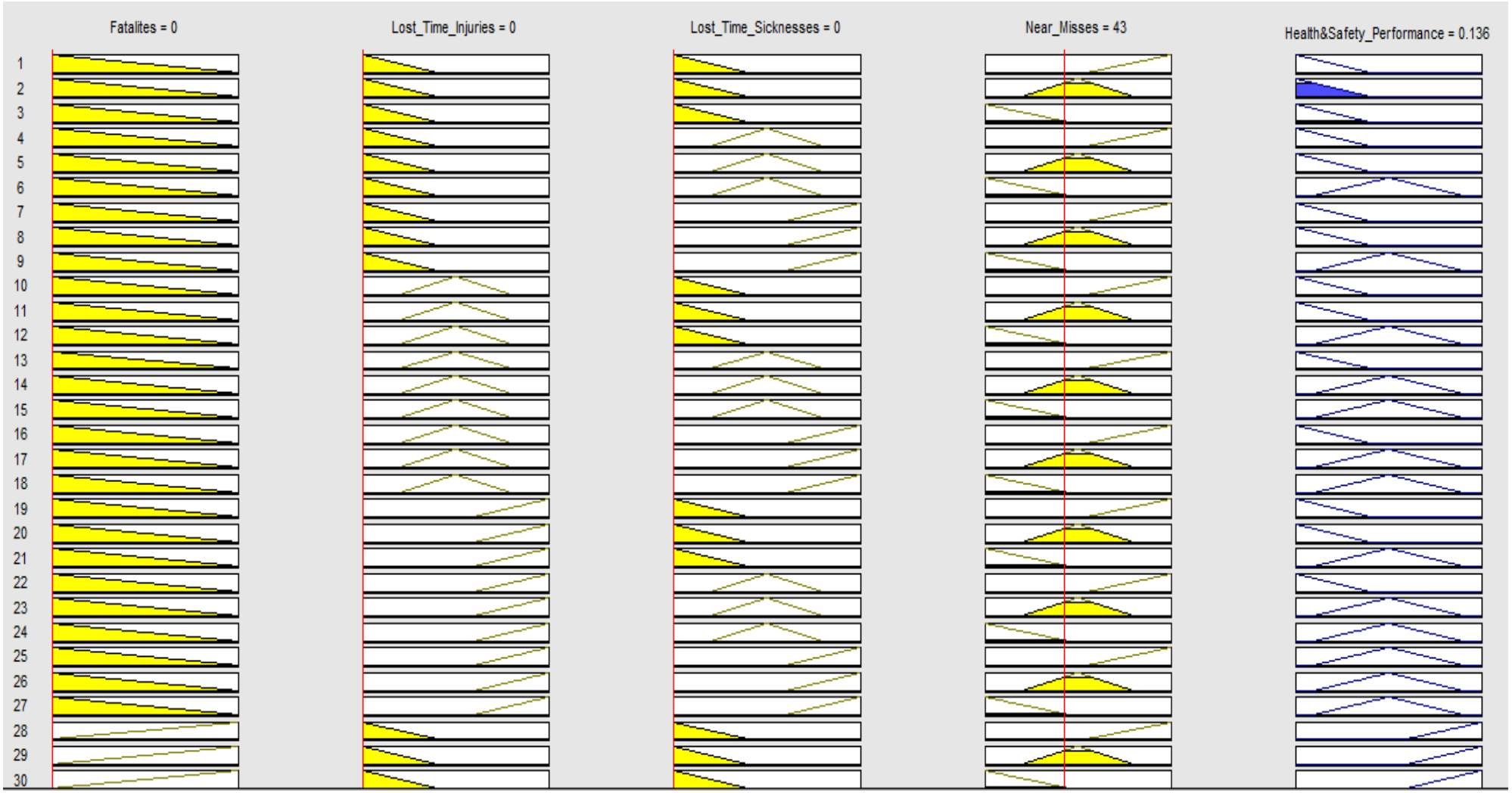
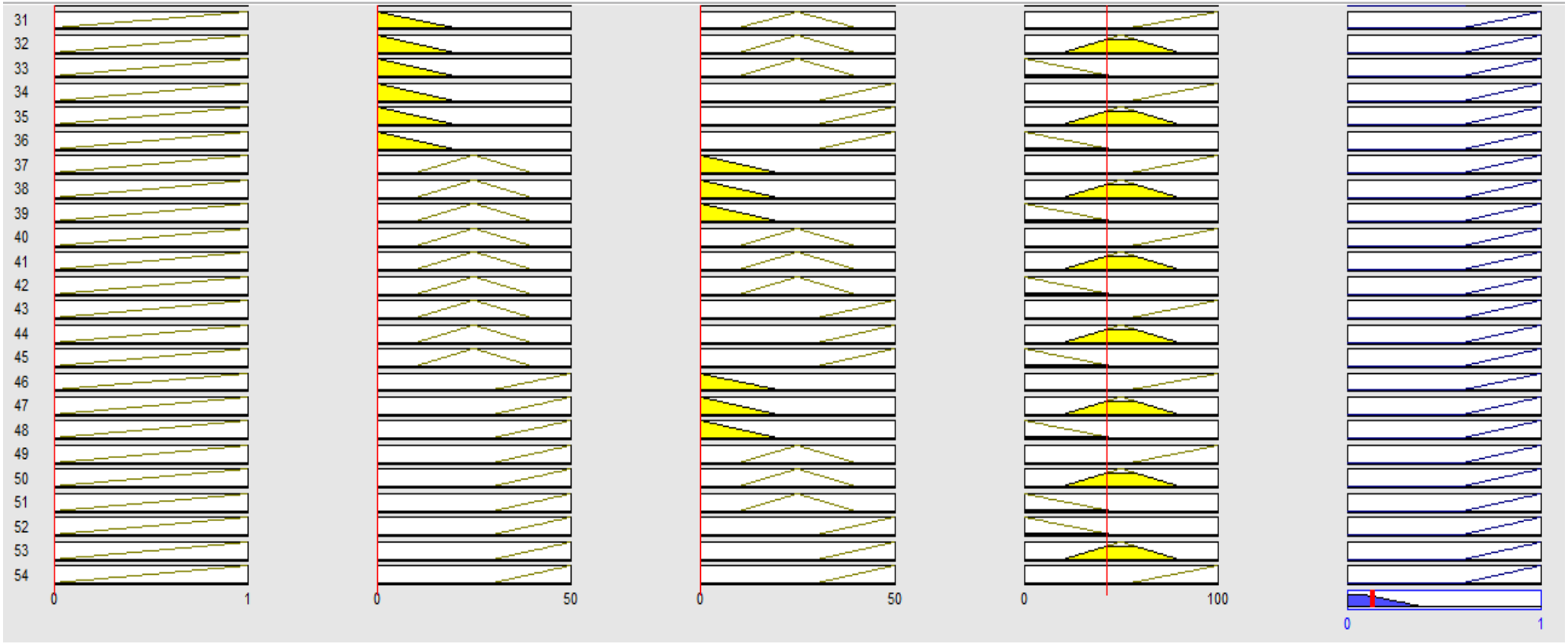


To sum up**, SAFETY PERFORMANCE** for tanker vessel **'' GATE''** is equal to:

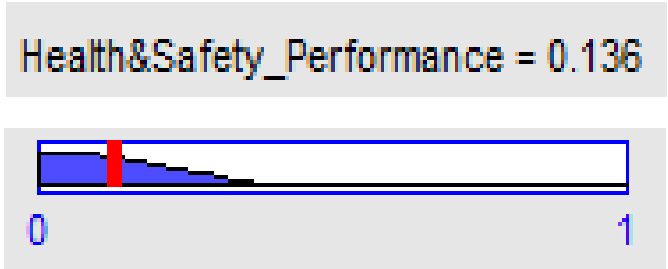


***** Health & Safety Performance- Examined vessel ''GATE''*****

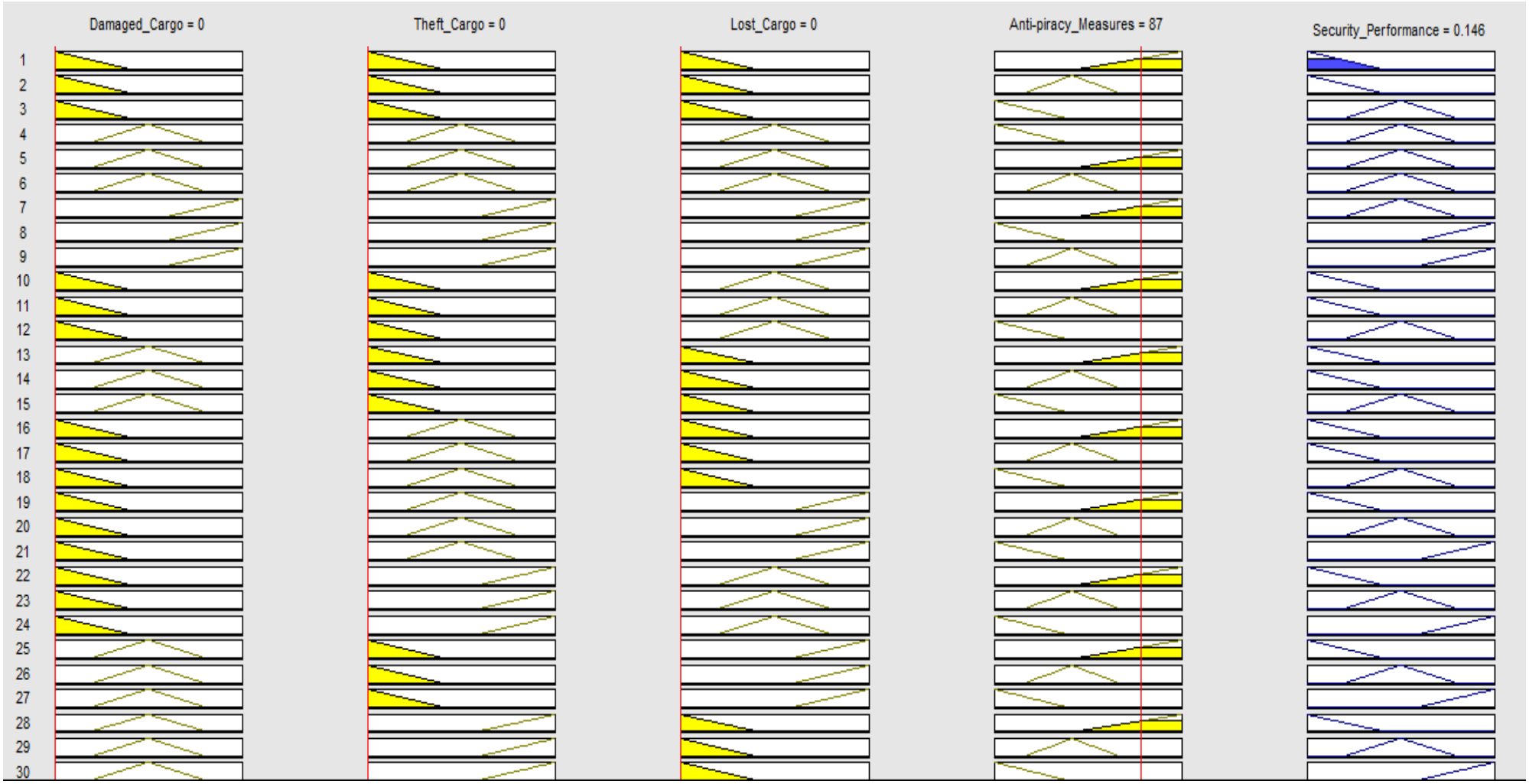


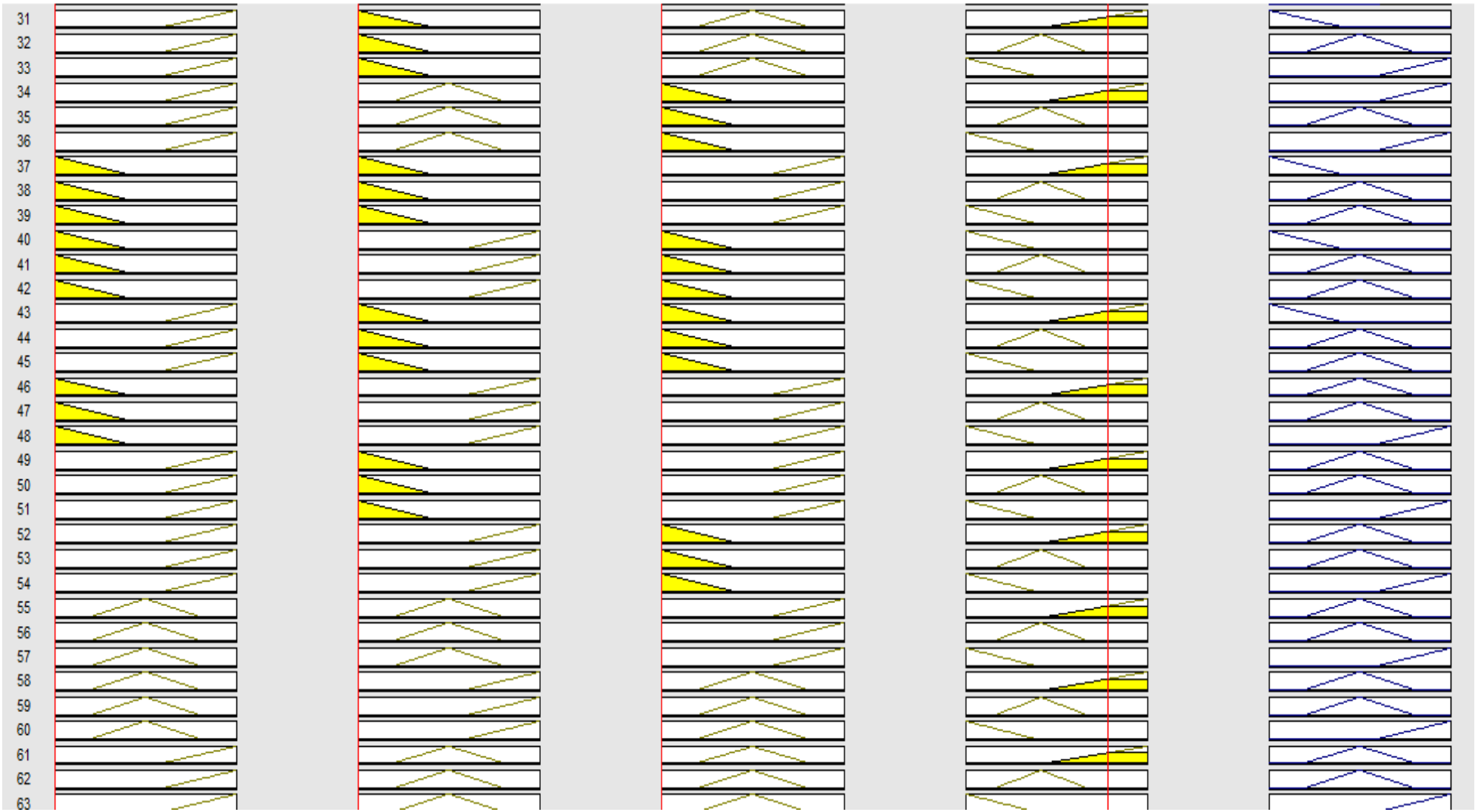


To sum up**, HEALTH & SAFETY PERFORMANCE** for tanker vessel **" GATE"** is equal to:



***** Security Performance- Examined vessel ''GATE''*****

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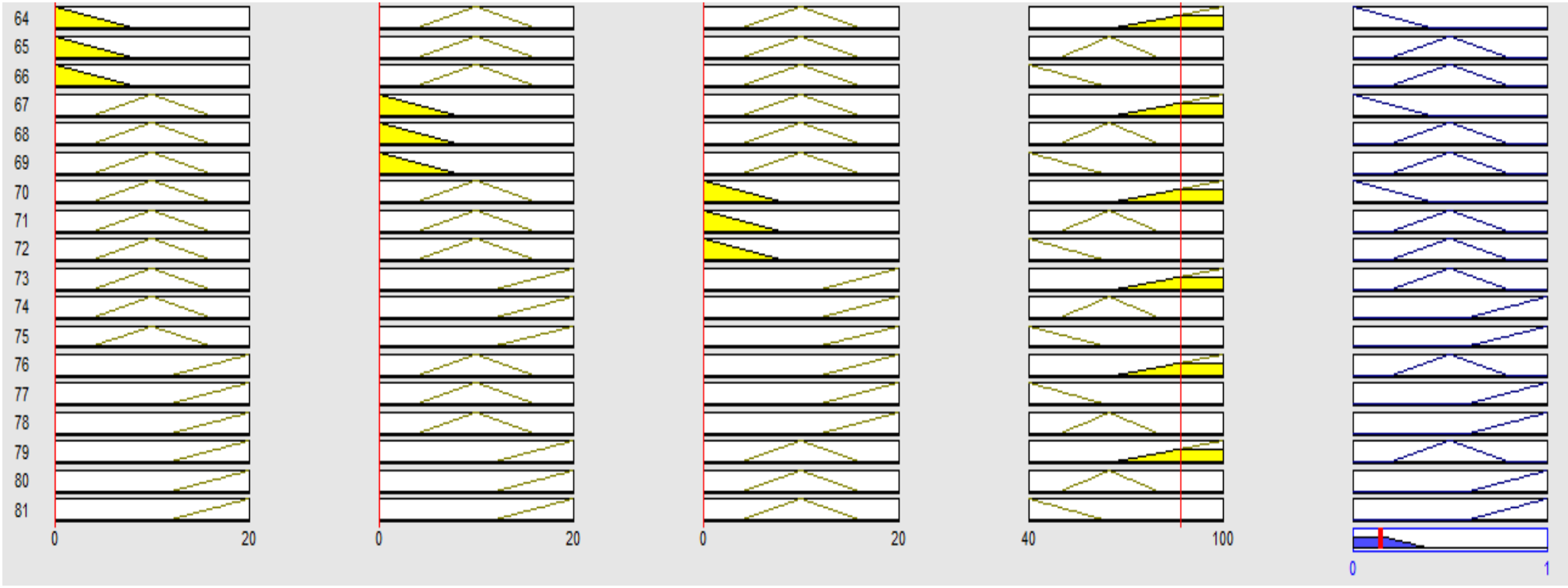
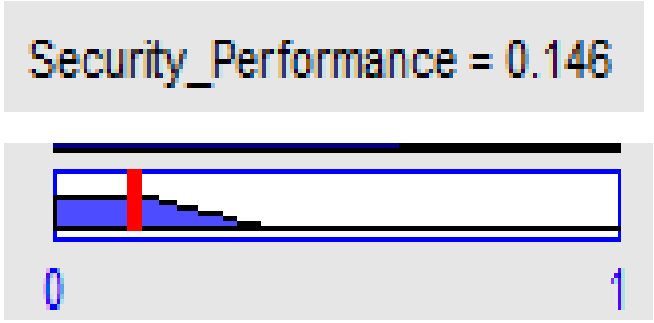
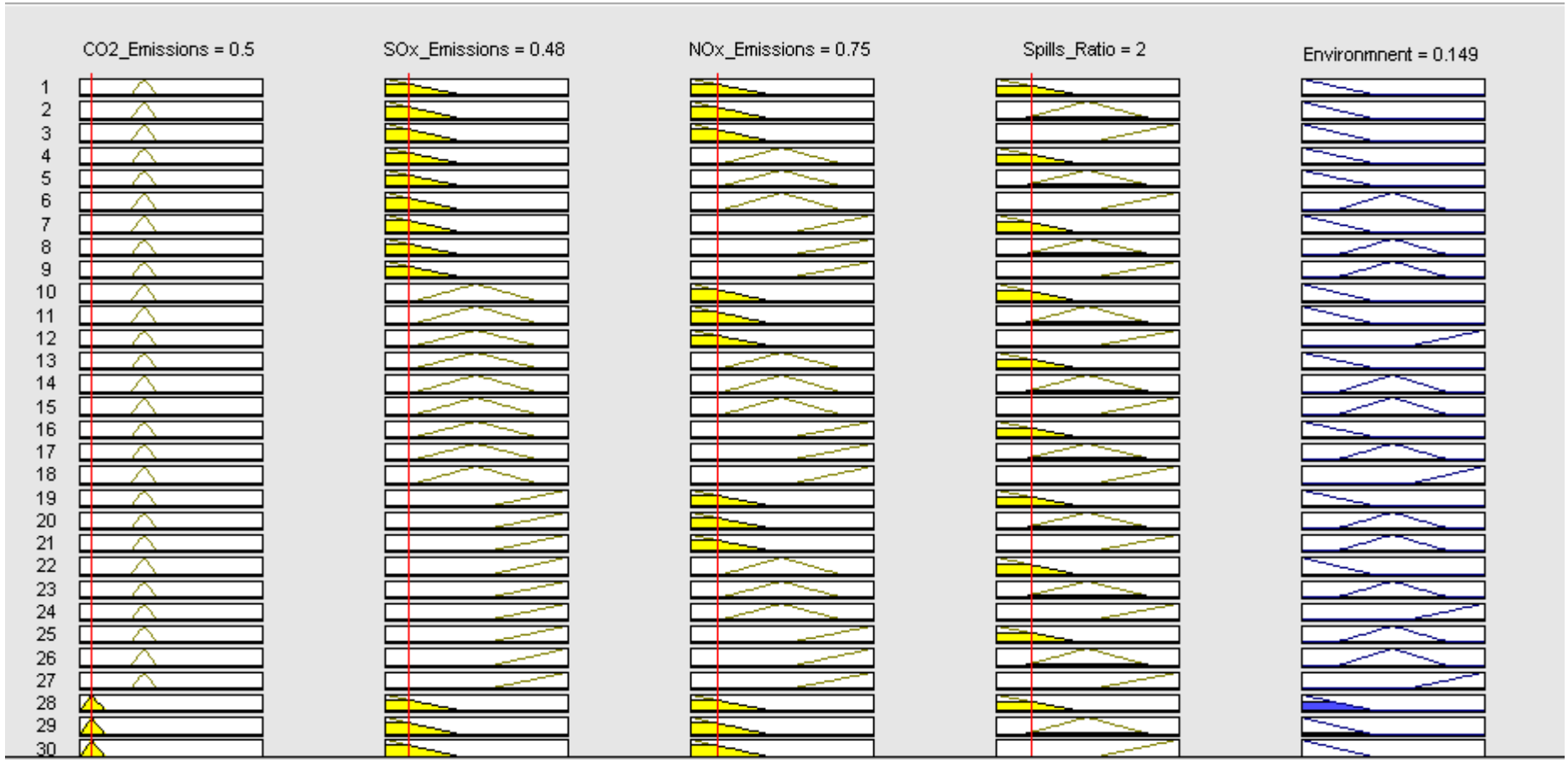
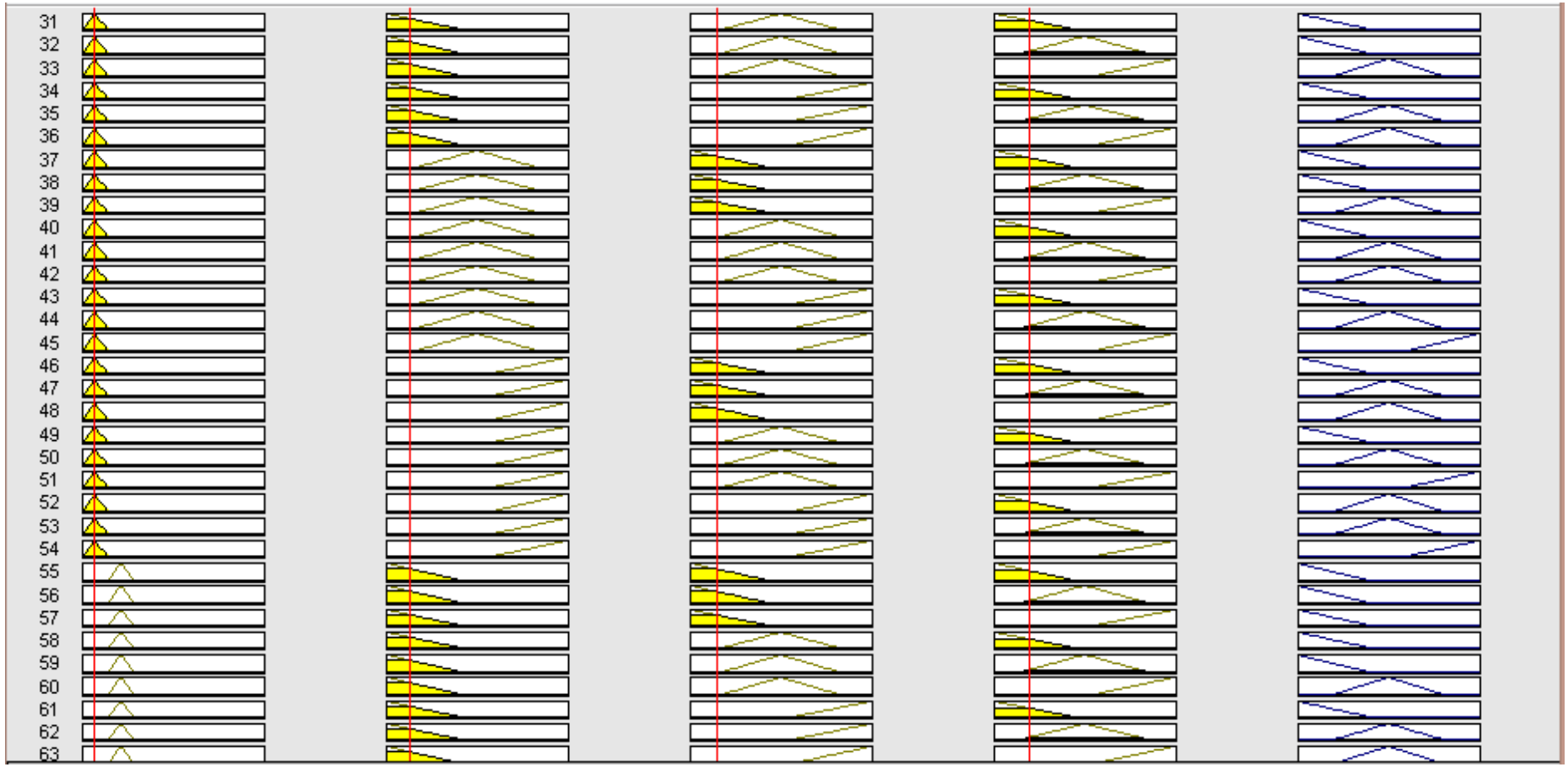


To sum up**, SECURITY PERFORMANCE** for tanker vessel **'' GATE''** is equal to:



***** Environmental Performance- Examined vessel ''GATE''*****

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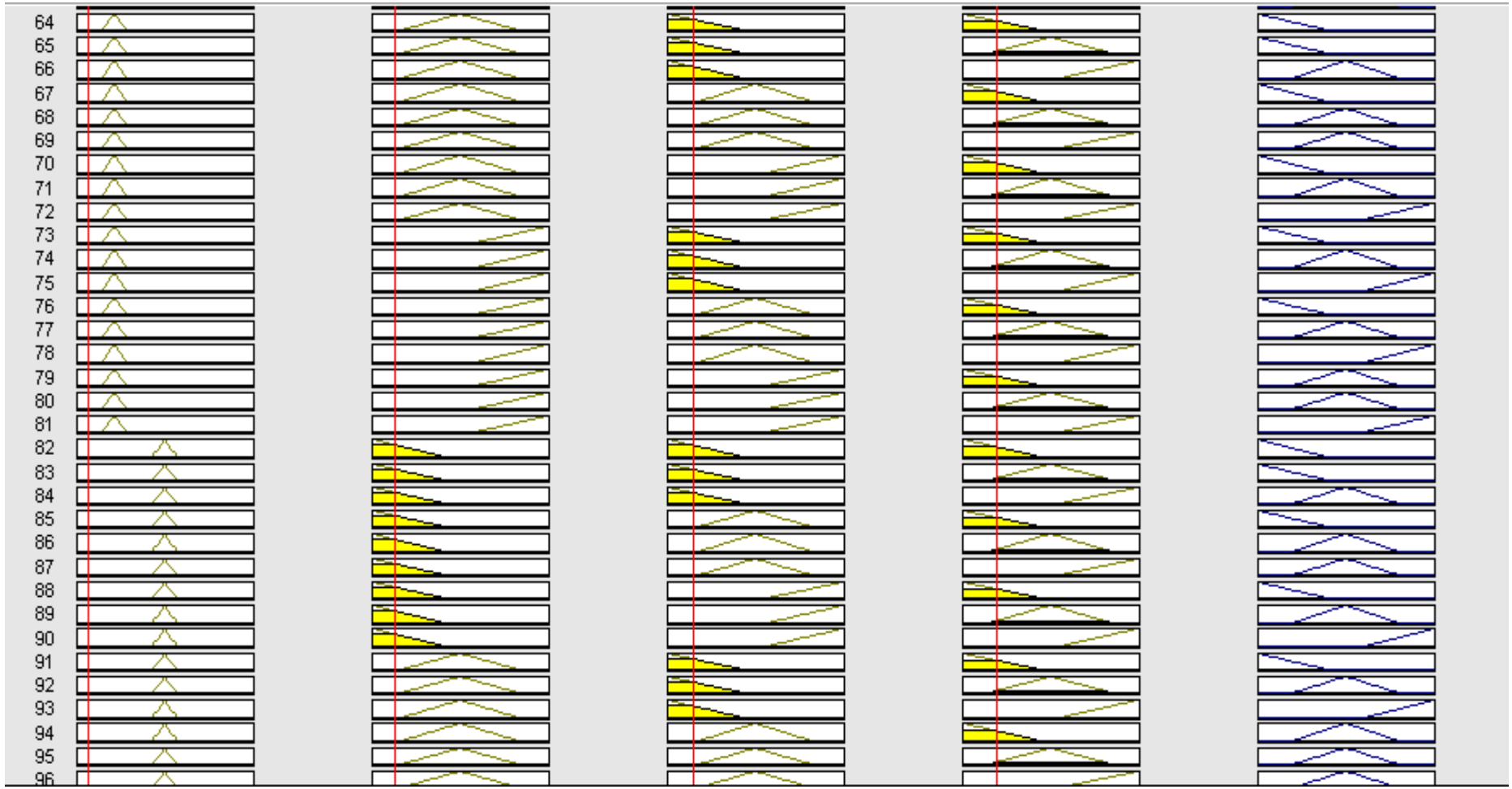
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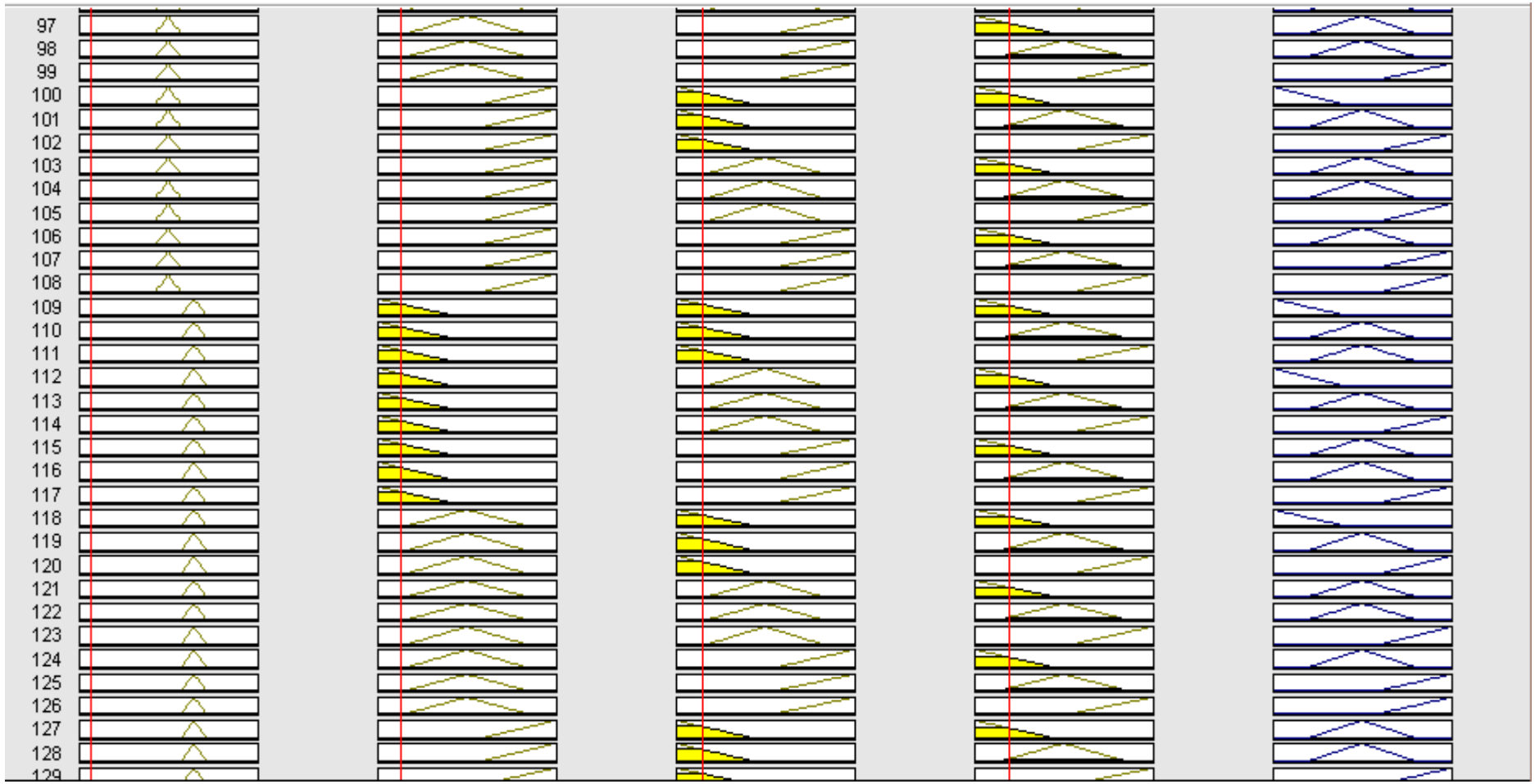
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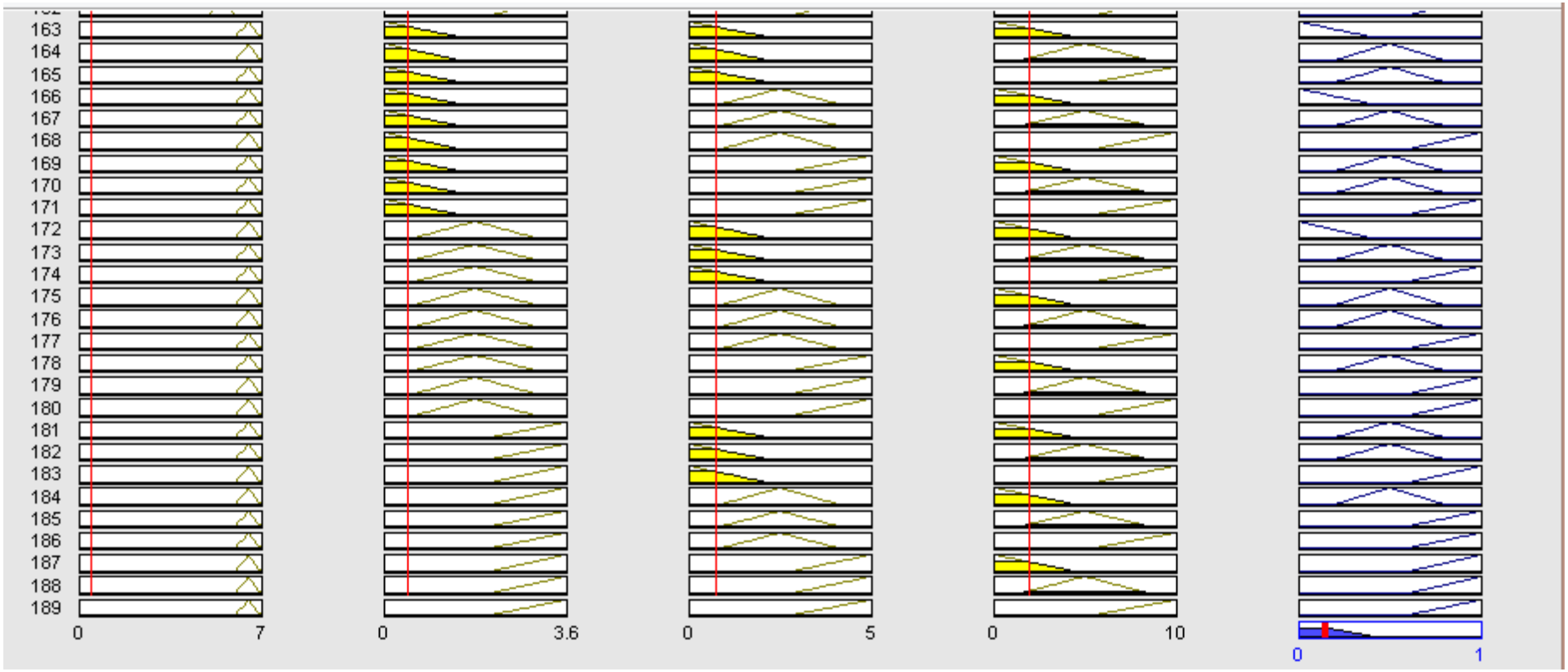
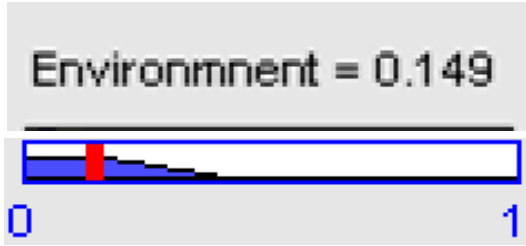
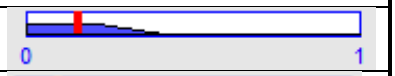
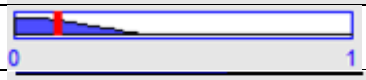
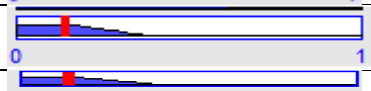
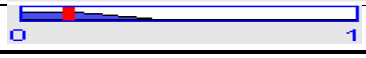


To sum up**, ENVIRONMENTAL PERFORMANCE** for tanker vessel **'' GATE''** is equal to:



As a conclusion regarding the performance of the examined tanker vessel ‘’GATE’’ in the following matrix all the performance values have been gathered:

EXAMINED TANKER VESSEL:	***'GATE''***	
PERFORMANCE	**VALUES**	
SAFETY	0,157	
HEALTH & SAFETY	0,136	
SECURITY	0,146	
ENVIRONMENTAL	0,149	

Matrix 47. Performance Values of Examined Tanker Vessel ‘’GATE’’

5.3. COMPARISON BETWEEN AVERAGE PERFORMANCE AND TANKER “GATE”PERFORMANCE

Last but not least, is the compare of the estimated performance of our examine tanker vessel ‘’GATE’’ with the average performance. In the following matrix we have gathered the performance values both of ‘’GATE’’ vessel and AVERAGE PERFORMANCE. In the last column you can find the absolute difference between them.

PERFORMANCE	***Tanker ''GATE''***	***Average Performance***	***Percentage of difference***	
SAFETY	0,157	0,2052	**(-)23,49**	%
HEALTH & SAFETY	0,136	0,2184	**(-)37,74**	%
SECURITY	0,146	0,2389	**(-)38,88**	%
ENVIRONMENTAL	0,149	0,1762	**(-)18,26**	%

Matrix 48. Compare of the Performance of the Examined Tanker Vessel ‘’GATE’’ to Average performance

From the above matrix we should conclude with the following observations:

- The examined tanker vessel ‘’GATE’’ has succeeded at all 4 fields (safety, health and safety, security and environment) performance better that the average performance.
- The smallest difference from the average performance has got as regards the environmental performance due to the lowest value of the average performance.
- The biggest distance from the average perofrmance succeeds at security due to the 0 values of the 3 out of 4 KPIs which are in real its goals.
- Health and Safety Performance has gained also a high value due to 0 values at 3 out of 4 KPIs which are again the best values – goals that these KPIs can take.

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APPENDIX

VESSEL No.2

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,149**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	30
HEALTH&SAFETY PERFORMANCE	**0,166**

SECURITY KPIs VALUES	
1. Damaged Cargo	7
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	65,22
SECURITY PERFORMANCE	**0,153**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,15
3. Nox Emissions	0,4
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,134**

VESSEL No.3

SAFETY KPIs VALUES	
1. Incidents	1
2. Training Achievement	86
3. Fire&Explosion	3
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,410**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	33
HEALTH&SAFETY PERFORMANCE	**0,158**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,65
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,23
3. Nox Emissions	0,29
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,133**

VESSEL No.4

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	3
SAFETY PERFORMANCE	**0,142**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	35
HEALTH&SAFETY PERFORMANCE	**0,153**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	8
3. Lost Cargo	5
4. Anti-piracy Measures	52,17
SECURITY PERFORMANCE	**0,440**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	2,5
2. Sox Emissions	0,4
3. Nox Emissions	0,19
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,138**

VESSEL No.5

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	93
3. Fire&Explosion	0
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,143**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	35
HEALTH&SAFETY PERFORMANCE	**0,153**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	100
SECURITY PERFORMANCE	**0,130**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	0,8
3. Nox Emissions	0,6
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,155**

VESSEL No.6

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	80
3. Fire&Explosion	4
4. Vetting Observations	5
SAFETY PERFORMANCE	**0,377**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	36
HEALTH&SAFETY PERFORMANCE	**0,151**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,56
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,7
3. Nox Emissions	0,5
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,151**

VESSEL No.7

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	87
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,165**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	39
HEALTH&SAFETY PERFORMANCE	**0,144**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	18
3. Lost Cargo	0
4. Anti-piracy Measures	56,53
SECURITY PERFORMANCE	**0,403**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,5
3. Nox Emissions	0,3
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,142**

VESSEL No.8

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	3
SAFETY PERFORMANCE	**0,142**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	40
HEALTH&SAFETY PERFORMANCE	**0,142**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,56
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,33
3. Nox Emissions	0,71
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,141**

VESSEL No.9

SAFETY KPIs VALUES	
1. Incidents	2
2. Training Achievement	82
3. Fire&Explosion	1
4. Vetting Observations	6
SAFETY PERFORMANCE	**0,427**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	41
HEALTH&SAFETY PERFORMANCE	**0,140**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	15
3. Lost Cargo	0
4. Anti-piracy Measures	56,53
SECURITY PERFORMANCE	**0,395**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,73
3. Nox Emissions	0,25
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,152**

VESSEL No.10

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	0
SAFETY PERFORMANCE	**0,130**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	42
HEALTH&SAFETY PERFORMANCE	**0,138**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	82,6
SECURITY PERFORMANCE	**0,155**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,9
3. Nox Emissions	0,6
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,161**

VESSEL No.11

SAFETY KPIs VALUES	
1. Incidents	1
2. Training Achievement	88
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,336**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	44
HEALTH&SAFETY PERFORMANCE	**0,135**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	91,3
SECURITY PERFORMANCE	**0,138**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,95
3. Nox Emissions	0,88
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,164**

VESSEL No.12

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,149**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	31
HEALTH&SAFETY PERFORMANCE	**0,164**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	8
3. Lost Cargo	5
4. Anti-piracy Measures	56,53
SECURITY PERFORMANCE	**0,351**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	0,86
3. Nox Emissions	0,7
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,159**

VESSEL No.13

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	1
SAFETY PERFORMANCE	**0,132**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	56
HEALTH&SAFETY PERFORMANCE	**0,135**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,65
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	2,5
2. Sox Emissions	1
3. Nox Emissions	1,3
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,166**

VESSEL No.14

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	66
3. Fire&Explosion	0
4. Vetting Observations	5
SAFETY PERFORMANCE	**0,161**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	93
HEALTH&SAFETY PERFORMANCE	**0,133**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	87
SECURITY PERFORMANCE	**0,146**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	2,5
2. Sox Emissions	2,5
3. Nox Emissions	2,9
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,211**

VESSEL No.15

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,149**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	94
HEALTH&SAFETY PERFORMANCE	**0,132**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,65
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	2,2
3. Nox Emissions	2,9
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,183**

VESSEL No.16

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	97
3. Fire&Explosion	0
4. Vetting Observations	5
SAFETY PERFORMANCE	**0,157**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	98
HEALTH&SAFETY PERFORMANCE	**0,130**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	91,3
SECURITY PERFORMANCE	**0,138**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	2,6
3. Nox Emissions	3
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,269**

VESSEL No.17

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	85
3. Fire&Explosion	2
4. Vetting Observations	5
SAFETY PERFORMANCE	**0,405**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	4,63
4. Near Misses	30
HEALTH&SAFETY PERFORMANCE	**0,166**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	78,26
SECURITY PERFORMANCE	**0,166**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	1,1
3. Nox Emissions	1,2
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,159**

VESSEL No.18

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	83
3. Fire&Explosion	1
4. Vetting Observations	13
SAFETY PERFORMANCE	**0,350**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	12
4. Near Misses	33
HEALTH&SAFETY PERFORMANCE	**0,318**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	60,87
SECURITY PERFORMANCE	**0,212**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	3,5
2. Sox Emissions	1,1
3. Nox Emissions	1,2
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,308**

VESSEL No.19

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	75
3. Fire&Explosion	0
4. Vetting Observations	6
SAFETY PERFORMANCE	**0,158**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	15
4. Near Misses	35
HEALTH&SAFETY PERFORMANCE	**0,384**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	52,17
SECURITY PERFORMANCE	**0,448**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,22
3. Nox Emissions	0,29
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,133**

VESSEL No.20

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	1
SAFETY PERFORMANCE	**0,132**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	16,25
4. Near Misses	32
HEALTH&SAFETY PERFORMANCE	**0,388**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	34,78
SECURITY PERFORMANCE	**0,500**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	3,5
2. Sox Emissions	0,8
3. Nox Emissions	1
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,219**

VESSEL No.21

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	91
3. Fire&Explosion	0
4. Vetting Observations	3
SAFETY PERFORMANCE	**0,149**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	30
4. Near Misses	30
HEALTH&SAFETY PERFORMANCE	**0,415**

SECURITY KPIs VALUES	
1. Damaged Cargo	2
2. Theft Cargo	5
3. Lost Cargo	6
4. Anti-piracy Measures	60,87
SECURITY PERFORMANCE	**0,319**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,11
3. Nox Emissions	0,23
4. Spills	2
ENVIRONMENTAL PERFORMANCE	**0,149**

VESSEL No.22

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	89
3. Fire&Explosion	0
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,157**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	16,26
3. Lost Time Sicknesses Frequency	25
4. Near Misses	57
HEALTH&SAFETY PERFORMANCE	**0,460**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	91,3
SECURITY PERFORMANCE	**0,138**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,3
3. Nox Emissions	0,3
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,135**

VESSEL No.23

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	3
SAFETY PERFORMANCE	**0,142**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	13
3. Lost Time Sicknesses Frequency	0
4. Near Misses	35
HEALTH&SAFETY PERFORMANCE	**0,370**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	56,52
SECURITY PERFORMANCE	**0,337**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	2,5
2. Sox Emissions	2,5
3. Nox Emissions	2,9
4. Spills	3
ENVIRONMENTAL PERFORMANCE	**0,389**

VESSEL No.24

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,136**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	5,51
4. Near Misses	28
HEALTH&SAFETY PERFORMANCE	**0,164**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	91,3
SECURITY PERFORMANCE	**0,138**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,1
3. Nox Emissions	0,1
4. Spills	3
ENVIRONMENTAL PERFORMANCE	**0,158**

VESSEL No.25

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	85
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,166**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	1
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	44
HEALTH&SAFETY PERFORMANCE	**0,865**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	87
SECURITY PERFORMANCE	**0,146**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,55
3. Nox Emissions	0,43
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,144**

VESSEL No.26

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,149**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	42
HEALTH&SAFETY PERFORMANCE	**0,138**

SECURITY KPIs VALUES	
1. Damaged Cargo	6
2. Theft Cargo	6
3. Lost Cargo	0
4. Anti-piracy Measures	56,52
SECURITY PERFORMANCE	**0,398**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,9
3. Nox Emissions	0,6
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,161**

VESSEL No.27

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	100
3. Fire&Explosion	0
4. Vetting Observations	2
SAFETY PERFORMANCE	**0,136**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	44
HEALTH&SAFETY PERFORMANCE	**0,135**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	12
3. Lost Cargo	20
4. Anti-piracy Measures	52,17
SECURITY PERFORMANCE	**0,725**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,78
3. Nox Emissions	1,1
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,154**

VESSEL No.28

SAFETY KPIs VALUES	
1. Incidents	2
2. Training Achievement	85
3. Fire&Explosion	0
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,343**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	43
HEALTH&SAFETY PERFORMANCE	**0,136**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	91,3
SECURITY PERFORMANCE	**0,138**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	0,98
3. Nox Emissions	2
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,165**

VESSEL 29

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	90
3. Fire&Explosion	0
4. Vetting Observations	3
SAFETY PERFORMANCE	**0,153**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	39
HEALTH&SAFETY PERFORMANCE	**0,144**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	100
SECURITY PERFORMANCE	**0,130**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	0,5
2. Sox Emissions	0,9
3. Nox Emissions	0,7
4. Spills	0
ENVIRONMENTAL PERFORMANCE	**0,161**

VESSEL No.30

SAFETY KPIs VALUES	
1. Incidents	0
2. Training Achievement	89
3. Fire&Explosion	2
4. Vetting Observations	4
SAFETY PERFORMANCE	**0,274**

HEALTH & SAFETY KPIs VALUES	
1. Fatalities	0
2. Lost Time Injuries Frequency	0
3. Lost Time Sicknesses Frequency	0
4. Near Misses	44
HEALTH&SAFETY PERFORMANCE	**0,135**

SECURITY KPIs VALUES	
1. Damaged Cargo	0
2. Theft Cargo	0
3. Lost Cargo	0
4. Anti-piracy Measures	95,65
SECURITY PERFORMANCE	**0,132**

ENVIRONMENTAL KPIs VALUES	
1. CO2 Emissions	1,5
2. Sox Emissions	1,5
3. Nox Emissions	2
4. Spills	2
ENVIRONMENTAL PERFORMANCE	**0,261**