



The Influence of the Induced Maritime Accidents on the Maritime Safety

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ABSTRACT

Humanity system of life is highly supported by maritime transport when circa 8 thousand million people require about 8.800 million tons of merchandises by sea, going in some 105.000 merchant ships of over 100 GT. Those vessels sail every thinkable dangerous waters 365 days year 24 hours day. All that Enormous activity plus others different factors produce accidents, as is shown in an ascendant 1.7 rate related to ships lost with big number in life and cargoes losses, and pollution. That is why this study pretend to detect causes factors of maritime accidents, to try to reduce them, and with that target in mind it was tested the new theory of Induced Maritime Accidents, crossing its proposals with relevant sinisters of different times and circumstances, as Andrea Doria, Torrey Canyon, Costa Concordia, among others. Those cases were re evaluated to establish the key points of such theory, as they are the Production Pressure, the Risk Homeostasis, technological advances and the rupture of safety margin. Cases studies gave as result the existence of referred key points, in a manner combined that the chain of events derived to the fatality, and more than that highlights the possibility that been suppressed to acceptable limits the production pressure or the risk homeostasis, a permissible safety margin were been maintained, avoiding catastrophe

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1. Introduction

The International Maritime Organization, IMO, in Resolution MSC.255 (84) (International Maritime Organisation, 2010) establish that a marine casualty means an event, or a sequence of events, that has resulted in any of the following which has occurred directly in connection with the operations of a ship:

1. the death of, or serious injury to, a person; .
2. the loss of a person from a ship; .
3. the loss, presumed loss or abandonment of a ship; .
4. material damage to a ship; .
5. the stranding or disabling of a ship, or the involvement of a ship in a collision;
6. material damage to marine infrastructure external to a ship, that could seriously endanger the safety of the ship, another ship or an individual; or
7. severe damage to the environment, or the potential for severe damage to the environment, brought about by the damage of a ship or ships.

However, a marine casualty does not include a deliberate act or omission, with the intention to cause harm to the safety of a ship, an individual or the environment.

This match with Hammurabi Code of Babylonian wrote between 1955 1912 BC when stabilising that the accident is not an intentional act: In the sentences meted out to each offense, the code distinguishes whether or not there is *intentionality*, and which is the "category of the victim and the aggressor" and also: The penalty is increased if it has been done *deliberately* if you have been an accident and if the victim is a free man instead of a slave (clasica)

2. Dissemination of accidents

In regard to the public knowledge of these accidents, previously, cases such as Titanic, took more time to be disclosed, however at the present time, cases such as Prestige or Costa Concordia, among others, they do so in real time, which promotes a reaction of the public opinion more swift and forceful, and that joined with the maritime transport system supports to a large extent the life forms of humanity, whose international trade is transported by more than 90 %, by sea (International Shipping and World Trade¹) some 8408 million tons of various loads transported in 2010 (UNCTAD Review of

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Maritime Transport 2011, p.7) on board of 104304 = >100 GT merchant propelled ships, highlights the fact that this is not a system of which we can dispense with, and therefore it is essential to know the causes that motivate the marine casualties to minimize its recurrence.

This core activity of the maritime transport has been adapting to commercial and technological requirements, transforming what it in the past it was considered by society as a safe activity, to an insecure and high-risk in the present. The modest size of the vessels of the past, in contrast to the enormous today, in themselves represent greater risk potential, either by the loss of lives and/or goods, environmental pollution, etc.

Upcoming major technological advances to the ships to reduce the consumption of fuel, the use of liquefied gas as fuel, the hull lubrication by air to decrease the friction with the sea and consequently reduce the fuel consumption. In the bridge is already normal the use of integrated systems ECDIS (Electronic Chart Display and Information System), AIS (Automatic Identification System), LRIT (Long-range identification and tracking of ships), to electronic navigational charts, new methods of tracking of vessels, among others.

These technological advances assumptions to improve maritime safety probably are activated, as they did in the past, the adaptation and balance of the safety margin accepted by the operator (Homeostasis of risk) which could compromise for a period of time, the safety. (Montes de Oca and Martínez Marín, 2013, p. 42)

3. Fatal statistics & casuistry

The maritime accidents have left huge amounts of dead, in 1820 during the winter of the North Sea, more than two thousand (2,000) ships foundered with the consequent loss of the lives of more than twenty thousand (20,000) people², by then the United Kingdom (UK) adopted the Passengers Act, which led to the English Parliament to research on the causes of shipwrecks, focused on ten determinants, as the inadequate equipment, failures of construction, excess load or inappropriate assurance of the same, inadequate maintenance, incompetence of the Captain, etc. Boisson (opcit, p50). Later during 1848 France and the United Kingdom agreed to in writing the first regulating navigation at sea on the navigation lights, continuing with regulations to avoid collisions at sea. However, the reiteration of maritime accidents and multiple actions or regulations to minimize them, gender in the global maritime community, the need for their research and to identify causes and avoid as far as possible its recurrence. This has helped the international cooperation and the advent of the common ways to investigate them and in January 2010 came into force the Resolution MSC 255(84) that imposes mandatory internationally, the Code for the Investigation of Marine Casualties.

In spite of these efforts, however, the rate of losses of vessels has increased, from 1.3 in 2006 to 1.7 in 2010 (relation of

ships lost/total number of vessels = >100GT) (IMO document CWGSP12/3) and the index of spills to the sea from 1970 to 2011, indicates that the 2% are product of fires or explosions, another 2% due to collisions, groundings 3 %, failure of the hull 7 %, equipment failures the 21% and surprisingly 64% of the causes of such spills, it is for another reason or the cause is unknown (annual statistics from the International Tanker Owners Pollution Federation, ITOPF's) and even more, from 1989 to 2010 were lost (totally) 4443 ships and 18189 lives as a result (UPC, 2012) (Montes de Oca and Martínez Marín, 2013)

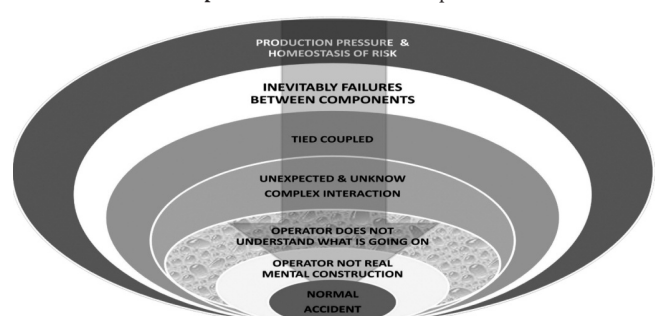
4. Analitical review & proposals:

Faced with this concern in various branches of industry, the scientific world has produced alternating thoughts, among them as indicated by Charles Perrow in his book (Perrow, 1999) which presents the theory of why accidents occur and some of them inevitably (the so-called Normal Accidents or System's Accident) due to the fact that the productive systems that builds society, are too complex and their components or parts can interact in unexpected ways by their designers or operators, thus leading to the accident. He also claims that with this new approach, it could be finalized with charges to persons and/or wrong factors, as commonly happens in the present, and also stop the attempts to repair the systems in a way that only make them more risky. (Montes de Oca and Martínez Marín, 2013, p. 43).

It is based on the fact that there isn't a good management of high-risk technologies, which the patient research of many disasters proves that in a certain time no one knew what was happening in reality, and even though they acted with the best practice, the results were worse. Highlights the gap between the human being and the technology (where the operator is left behind in the understanding of the given system). Perrow concludes, that the true cause of the Normal Accident is the complexity of the system because all the failures may be small in themselves and each to have a backup, but on the whole, it is their interaction (complex coordination of failures) that explains the accident, and these occur because the system is complex. (Montes de Oca and Martínez Marín, 2013 p. 43)

According to our interpretation of Perrow, (adding the risk homeostasis) develops this graph representing a possible sequence toward the accident. (See Graph 1)

Graph 1: Normal Accidents - Sequence.



Source: Montes de Oca and Martínez Marín (2013)

¹ Facts and figures (2009 p.7).

² Boisson (In "Le Courier" 5 mai 1822, quoted in "Le Bureau Veritas 1828-1928, Editions du Centenaire, Paris, 1928, p.10).

Another production of the scientific world that we might consider, in addition to Perrow, are failures of design raised by Henry Petroski (2010) or at the same time include on this vision of Petroski, modifications to the original design that might influence the failures, and negatively impacting on the couplings of some of the parts of the system before pointed out by Perrow, making them strongly bound or rigid, what would facilitate the generation of unexpected or unknown interactions. In order, we can assume the matrix of Perrow, enhanced by the vision of Petroski and this lead to the wrong mental construction of the operator and then take the wrong decision (although the operator was thought to be correct) and consequently detonate the sinister. (See Graph 1)

Recalling the case of the collision in July of 1956 of passenger ships Stockholm and Andrea Doria, it might be clear to us that if the ships had not had radar, the Andrea Doria has sailed at a slower rate in the dense fog prevailing, and none of the two has produced such changes of course. In the meantime the presence of radars and detection one each other, then the speed remained high, and in ships approximation both operators, of both bridges, generated mental images erroneous to the reality and consequently manoeuvred toward the collision, although they tried to avoid it. Resulting in loss of lives, the sinking of the Andrea Doria and considerable damage to the Stockholm.

In considering the catastrophic sinister happened to the oil tanker Torrey Canyon in March of 1967 that ran aground and break his hull with the consequent total loss of the ship and its cargo spill, generating this dreadful pollution in the waters around the semi-submerged reef Seven Stones, near the English coast.

With Dörner Dietrich's theory (Dietrich, 1996) we could consider that there was the decisions of the Captain of the oil tanker, when taking an unusual route and not recommended in defeat toward the port of Milford Haven, besides accepting as true the position given by guard's Pilot in the approach to the reef, as the cause of the catastrophe.

With the theory of Henry Petroski, we might want to consider that was the modification of the physical characteristics of the ship's hull (lengthening of its length for greater load capacity) leading to this loss of manoeuvrability due to that the rudder is not restructured for the new size of the vessel, which in the end caused the incident to not be able to fall on the port side quickly and avoid the reef.

With the theory of Charles Perrow (1999), we would consider that still so many commercial pressures and inaccuracy of the equipment that you've set up a gap in the dynamics of navigation that concluded in disaster.

It should be noted that in all theoretical scenarios of this case, the mental image wrong was present.

We can also infer that the operators of the bridge in the luxurious and ultra modern passenger ship Costa Concordia, generated, believed and decided according erroneous mental images, which allowed his ship will contact the submerged rock with the catastrophic consequences known. (Montes de Oca and Martínez Marín, 2013 p. 44)

Just thinking in the last three exposed cases, allows us to glimpse something prior to the act itself, had accumulated and

inter linking in parallel and with the consequent reduction of the appropriate margin of safety, to the point of inducing decisions that led to the accident.

If focussing on this final phase (decision) we can get closer to the theory of Dietrich (1996), recognizing and avoiding error in complex situations) in which he said that we are so prone to make mistakes ... Our brains are not fundamentally defective; quite simply, we have developed bad habits. When we fail to solve a problem, we do so by the tendency to make a mistake here, a small error beyond, and these accumulate, thus contributing to fail. Although he further maintains that the violation of safety standards by the operator is due to the fact that frequently has already violated before (negative reinforcement) it is well that Dörner postulates the complexity and operational intelligence. In summary, Dörner argues that the causes of our mistakes when handling complex systems are: the slowness of our thinking and the small amount of information that we can process in a given time, our tendency to protect our sense of competence, the limited capacity of income flow of information to our memory, and to our tendency to focus only on the immediate problems.

We have so that the human being is to some extent lags behind in the technological advances, and as a possible reaction the operator acts to balance its area of conformity / satisfaction (homeostasis of risk) which to my way of seeing is not another thing that modify the Risk (increasing), by the way of what I would call the Margin of Safety (downwards) (formerly did not have radar onboard and maintained highly careful attitude, while having them, increases the speed, or changes in direction, etc.) To this end, the proposal of the Slow Shipping to retrieve a greater margin of safety, lost through the rapid technological progress, the homeostasis of the risk in combination with the pressures of production, or in other words, keep the previous preventive attitudes (when the risk was greater without present technology) in conjunction with the positive technological advances in the decline of the risk. In this way avoiding failures (increasing the margin of safety by lowering the pressure of production with the Slow Shipping) could be generated sufficient time to adapt persons and systems to avoid errors in complex situations, which require that the design of such systems taking advantage of our natural talent of perception, presenting our attention to the precise information that we require at the exact moment.

5. The theory of the induced accidents

This leads me to try to launch the configuration of a new theory, which I will call initially as Induced Accidents, (Montes de Oca and Martínez Marín, 2013) based on the fact that accidents occur motivated to the infringement, decrease or absence of an acceptable margin of safety, generated among others due to the pressures of production, technological progress and the homeostasis of the risk. (See Graph 1 & 2) in an at least two of three combination.

As can be seen in graph 1, human being (in this case individual part of a ship crew) is doing his job on board to reach

target production with safety. What happens (first stage) is that in a particular moment these production pressures arise, pushing to more risky decisions, as per example to change a route with plenty room for a dangerous path because of thinking in an early arrival to profit the tide or pleasure because of shore close proximity, or to do not reduce speed or to do not make a clear change of bearing with enough time because of trying to maintain the schedule, or to do not use in parallel generators or helm mechanism in some special circumstances because thinking in save paying fuel payments or overtime, or because of the fact that these equipments were not 100% available due to insufficient or poor maintenance. *But what reason allows a person agree to take these risky decisions?* Well because each person (in our cases individual part of a ship crew – Routinely the Master, the Chief Engineer, the personnel in watch) have his own individual capability to accept risk, ICRSR (See Graph 1, Second stage), what we shall call individual comfort safety range to accept risk, or just: *Comfort to the Risk*. Being that this comfort to the risk in a normal situation in a well-trained crew is maintained within a range of preventive and precautionary. This range of comfort to the risk, it can be disturbed by both the pressures of production such as the sense of greater safety generated by technological advances, for example when the advent of radar, also appeared the super power of the vision even in thick fog or seeing through darkness, or with AIS appears specific ship in specific location, etc.

After receiving the influence from one or both of these factors (production pressure and/or technological advance) we

arrived at the stage two. This variation of comfort to the Risk range is so called Homeostasis of the Risk (Balance before the feeling of risk).

When in this second stage, the individual comfort to the risk range became bigger (so person accept more risk in a comfort way), it means to that member of the crew he will accept a smaller operational margin of risk (Third Stage), which will take us closer to the risk with the consequent increased likelihood of the occurrence of the incident. (See Graph 2, PP+TA Cone)

5.1. Homeostasis

The concept of homeostasis was created by Claude Bernard, often regarded as the father of physiology, and published in 1865.

The Homeostasis is a characteristic of a system, either open or closed, attributed to a living organism, either biological or social. This characteristic, this trend to balance allows them to regulate the internal or external environment to maintain a stable condition and constant that in our case of the proposed theory of induced accident we shall call as a individual comfort zone, more specifically *Comfort to the Risk*. The multiple adjustments of dynamic balance and self-regulating mechanisms make the homeostasis possible. (Bransiforte, 2009)

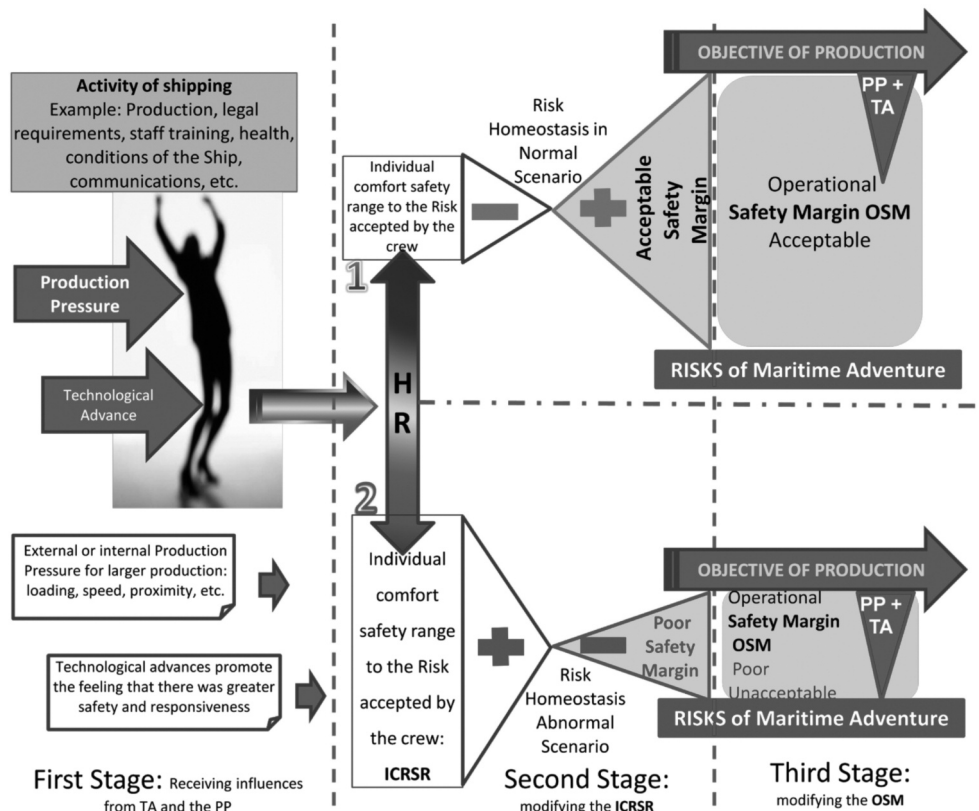
In the homeostasis participates all the systems and apparatus of the organism from the nervous system, endocrine system, the digestive apparatus, respiratory system, the cardiovascular system, etc. and responds to changes in the domestic environment if we are talking about a living organism and in the external environment if we are talking about interactions between agencies or individuals. The homeostasis is not synonymous with inaction or stillness. In reality, to produce and sustain homeostasis is required for a permanent job in the environment, due to the fact that every field has a constant dynamic and a trend toward the imbalance. When is disarmed or breaks this state of equilibrium is immediately put into action several mechanisms that try to reset it.

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5.1.1. Psychological Homeostasis

The term was introduced by W. B. Cannon in 1932, appoints the general trend of any organism to the restoration of internal balance each time it is altered. These internal imbalances that can occur

Graph 2: Homeostasis of Risk.



The diagram illustrates the relationship between standard activity of production, safety margin, risk, and accident. It features a large grey block at the top labeled "STANDARD ACTIVITY OF PRODUCTION". A large arrow points from this block to a box on the right labeled "PRODUCTION TARGET". Below the production block, a jagged line represents the "SAFETY MARGIN". A dashed horizontal line separates the "SAFETY MARGIN" from the "RISK" area below it. A vertical double-headed arrow on the right indicates the "Acceptable Safety Margin" (between the dashed line and the top of the safety margin) and "Unacceptable" (below the dashed line). A box on the right labeled "Risks of Maritime Adventure" is positioned below the "Unacceptable" section. A jagged line at the bottom represents the "ACCIDENT". A vertical arrow points from the "ACCIDENT" up to the "SAFETY MARGIN". A label "Up & Down of Safety Margin" with a double-headed arrow points to the jagged line. Two points on the jagged line are labeled "a1" and "b". A vertical arrow labeled "2" points from the "SAFETY MARGIN" down to the "ACCIDENT".

Avoidance: avoiding organism: minimize the internal variations using some behavioural escape mechanism that allows them to avoid environmental changes, either space (looking for microhabitats not stressful like caves, burrows; or on a larger scale, migration) or temporary (hibernate, drowsiness), As example from our case, when watch at the bridge avoids issuing contrary to the opinion of the captain when he commands the maneuver. *Conformity:* Conformist's organism: the internal environment of the animal changes in parallel with the external conditions. There may be a functional compensation with the acclimation or the acclimatisation, recovering from the previous functional speed to change. *Regulatory:* regulatory organism: a disturbance triggers compensatory actions that keep the internal environment relatively constant.

As can be seen in Graph 4, there are many causes that could lead to the disaster, many of those are show as blue rectangles. Also we can see failures of design or redesign (D*),

The diagram illustrates the relationship between various factors in an accident. It is organized into a grid with rows and columns. The top row is labeled 'RELATION' and 'OBVIOUS: Training, Health, R&M, Substandard'. The bottom row is labeled 'TIME' and 'INTENCIONALITY'. The right side is labeled 'ACCIDENT'. The diagram includes various boxes and symbols: 'P' (Pilot), 'N VT' (Not Visible to Traffic), 'D (R)' (Distance/Range), 'VSU' (Visual Search Unit), 'RC' (Route Clearance), 'P' (Pilot), 'T A R' (Target Area Range), 'HR' (Horizontal Range), 'I' (Intent), and 'VSU' (Visual Search Unit). The diagram shows how these factors interact to lead to an accident.

Source: Montes de Oca and Martínez Marín (2013)

ones so called immediate cause (I), others so called proximate cause (P), Root cause (RC), etc.

The ones we are talking about are from Production Pressure (PP), Technological Advance (TA), Homeostasis of Risk (HR), circumstances or events not very tied (NVT), circumstances or events very strong united (VSU). As told before Homeostasis of Risk (HR) can be generated by the Production Pressure and/or Technological Advances, so in a first consequence HR vary to accept a individual wide range of comfort to the risk, and in a second consequence to a shorter operational margin to risk, that in some cases lead to the disaster.

We should increase the margin of safety, one way could be by the "SLOW SHIPPING" which means e.g. Not recklessly increase the speed or changes of heading course due to technological advances that provide us with better information than before, encourage our biological tendency to balancing our sensations, and in this case, the risk.

The technological progress makes us feel safer and then the operator actuates until that feeling reach to the level of previous risk, with the following consequences already known: Fatal Accidents that cause damaged to the Human, to the Vessel, and very important also: To the Marine Environment.

To analyze, and open discussions on the academic's filed, having in mind the sail's experience, and also issue an study on board the vessels with the crews, will help to improve the maritime safety, knowing the human attitude with the new Technological advances.

5.3 Giving bases for the theory proposal

The study within the three theories of accidents of the authors Perrow (1999), Petroski (2010) and Dietrich (1996) have been carried out with a vision for epistemological to establish a specific structural base on the applicable concept to all of them. The same validation will have to be done with the theory proposal (Induced Accidents).

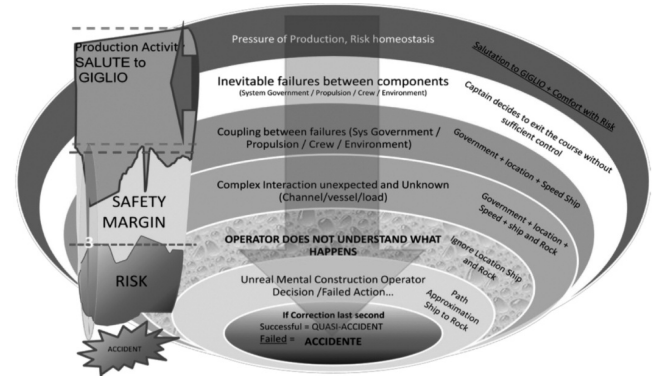
As planned, on the methodology of scientific research programs, from Lakatos (1978), in which there is a structure composed of: a *Strong Core*, where reside the basic assumptions or general hypotheses of the theory, center from which rotates the mentioned theory. A *Protective Belt*, with hypothesis assistants, definitions, basic conditions that serve to describe the uniqueness of the situation, since the basic assumptions contained in the nucleus are insufficient to predict or explain details. So that the belt is responsible for defending the core to be distorted. A *Positive Heuristics*, which represents the operational techniques, mathematics with which one can develop the research program on a methodology to enable it to explain and predict in cases before the reality of the proposed scenario. A *Negative Heuristic*, which puts the framework of what not to do because it is in conflict with the strong core (Lakatos, 1978, pp. 13, 66).

Subsequent to that part of the filter parameters of Lakatos, which made it possible to accept or not theories, then selected contrast them; we take cases of marine casualties for based on them, begin to experience the search for causes.

The famous case of the BT TORREY CANYON, in which after a sequence of events that inter reacted unexpectedly, the

operators of the bridge (we assume) generated an unrealistic picture of the reality that once they realized the same and they tried to correct, it was already too late. By applying the principles set forth in these theories we perceive that the incident is interpreted differently, depending on the precepts of the theory used. Not excluding each other, but rather, in my view, complementing each other. And so going deepen in these theories and begun to build and to propose one of our own, as has been outlined in previous pages of this study, the theory of induced accidents, motivated to the treatment given (or not given) to the margin of safety, in which not necessarily the factors involved are in the order plotted, these can happen or interact or interconnect, in a different order, free. (See Graph 4), as well as infer that the erroneous image was present as a factor, through the theory proposal, we can also observe how was violated the safety margin.

Graph 5: Induced Accident / Costa Concordia.



Source: Montes de Oca and Martínez Marín (2013)

In graph 5 is show a view of proposal of induced accidents theory, it is associate to the loss of the Costa Concordia, observe how the safety margin was declining violating the margin of safety to a point to be unrecoverable and the accident occur (in spite of the effort, in extremis, carried out by the captain to evade the obstacle).

To these effects of validation, the theory proposal of the induced accidents, suggests that:

Strong Core:

- That accidents are built hard by its protagonists (and/or predecessors) without them being truly aware of this;
- That this construction of the accident is based on the decrease of the margin of safety desirable;
- That accidents happen because the margin of safety, decreases to a intolerable point that enables us to reach the strip of risk, materializing the sinister (or quasi-sinister, if a successful last second action);
- Such a reduction of the margin of safety is product mainly (not exclusively) of the interaction of the pressures of production, the homeostasis of the risk, and technological progress (two of three at least).

Protective Belt:

- The events or actions (that weaken the safety margin real or that increase the real risk) (not the actors still

truly aware of this) will occur before or during the phase between the conceptual and the regular operations of the case which is concerned; overwhelming and entering a stage of sudden emergency that leads to the quasi-sinister (if mediate any providential action last second) or irreversibly the accident;

- The existence of a network of faults (factors that undermine the safety margin) that accumulated tuned violate suddenly the margin of safety;
- The margin of safety does not appear as a primary factor of decisions, in the chained actions toward the accident.

Positive Heuristics:

- The scope of calculation and determination of the level of risk in setting the margin of safety associated with a given scenario;
- The actions/decisions, training, skills, abilities, capabilities, environment, production requirements, health, fatigue, etc. Method: 1. -establish risk level 2. -establish wide safety margin 3. -set normatively 4. -set them on the conscience of the protagonists 5. -set them in the culture of the company;
- Set the Margin of safety as a primary factor of priority in operational decisions.

Negative Heuristics:

- When the intervening events or actions that lead to sinister are carried out with the intent to cause harm, may not be considered in this theory of induced accidents.

Looking at the foundations of the theory proposal of the induced accidents, you can highlight the concrete fact that the decisions taken in the approach to the sinister have arguments or databases that of undesirable and unconscious way, thus denying the reality that decision makers are living and coming increasingly. For this reason this theory points to a specific rationale, firm, and accurate for those decision-making in such circumstances of much information and time restricted to decide; as it was to rely (to focus) on the safety margin built, or set it to play previously.

As well it should never the Costa Concordia have such a degree of proximity to the coast, or the Andrea Doria wait so approximation to decide its navigation route, or the Torrey Canyon will lead through the restricted passage, or Titanic maintain speed.

6. Case study

CS Costa Concordia:

The information of the events comes from the report of the research carried out by the technical body of maritime accident investigations of the Italian Ministry of Infrastructure and Transport of the incident (MIT) that occurred on January 13 2012 Cruise Ship COSTA CONCORDIA - Email: investiga-

tivo@mit.gov.it Tel: +39 06 5908 3447 - The Investigative Body: investigative.body@mit.gov.it

This body of research operates under the authority of the Ministry of Infrastructure and Transport (the Administration) conducts investigations of accidents at sea and reported to the Administration of the circumstances and causes of the accident or incident. It has the responsibility to collect and analyze information relating to maritime safety, and uses the results of the research for the improvement of the safety of navigation and maritime transport. As well as the responsibility for the maintenance and update of the European Platform of maritime accidents (EMCIP) and the Global integrated system of information of Maritime Transport (GISIS).

Details of the incident: 4229 people were on board the ship - *Type of event:* Contact, Break, Loss of all Power - *Hour and Date:* January 13 2012 to 9:45:07 PM hours (VDR) - *Location of the accident:* contact against the rock "Le Scole", Island of Giglio, Mediterranean Sea – Italy – *Position:* LAT. 42 ° 22 ' 20 N - LONG. 10 ° 55' 50 E - *Weather and Sea conditions:* ROUGH - NE 4; Wind 17Knts E-NE, Visibility Partly cloudy to good. - *Operations:* In Navigation in part of the day from Civitavecchia to Savona - *Affected area of the ship:* left side of the hull at the stern - *Implications:* very serious accident, 32 people were killed or missing, 157 injured, of whom 20 required medical care in hospital, total loss of the Ship.

With the purpose of this induced accident theory study we shall use as example some of the information from this report, as follow:

According to the report of research mentioned above, summarizes the human element (whose key members of the crew showed a poor technical expertise) is the root cause in the accident, both in its first phase, as determined by the *non-conventional actions* that led to contact with the rock, as well as in the 2nd part of the management of the overall emergency later. (1- Underline by author – 2- For the objective that we occupies in relation to the theory proposal -Induced Accidents- we will only take into account the 1st phase of the sinister - "contact with the rock'-).

According to the verified evidence, it is established that the CS Costa Concordia on the afternoon of 13 January 2012 at the time of his departure from the port of Civitavecchia, fulfilled completely with all of the SOLAS³ requirements applicable. During the crucial phase prior to impact, in which successive actions that gave rise to the incident when the captain who guided the ship toward restricted shallow waters, and then a very small space in a parallel path to, and in a perpendicular too close to the coast by changing the course of navigation in a way very soft with the rudder to generate a small variation and leisurely pace of the course, but at the same time very wide.

- In the previous paragraph we can establish that the ship had sailed with all its margin of safety (see figure 2 yellow stripe) product to comply with all the enforceable requirements internationally in the area of maritime safety. However, it is observed the soft maneuver of Captain (usually for the best comfort of the trip).
- a - *View from induced accidents theory:* in this case involves the ignorance of the danger that was stalking and

³ SOLAS: Safety Of Life At Sea – Convenio Internacional de Seguridad de la vida en el mar.

which subsequently is expected to converge. These actions assist to decrease the margin of operational safety.

In regard to the organization, identifies the following problems:

- While the ship is heading quickly toward the coast, the Captain took the helm with sufficient time to enable it to have corrected the dangerous course on which the ship progressed, (not having corrected the maneuver represents an aggravating factor in his nautical conduct);
- b- *View from induced accidents theory*: allowing the ship forward toward the danger without any action to counter it, this is consuming the safety margin up to decrease it to an intolerable point.

The difficulties of the captain to read the radar (according to the testimony of the first officer, because at the time the lack of the reading lenses); c - *View from induced accidents theory*: if he does not know with precision (but assume that he knew) the location of the intervening elements (Ship/coastline) sailing now by his own image (unreal) of the scenario. Here we are in front of the decline of the margin of safety due to two reasons: (a. - ignore locations and b. - homeostasis of risk in the Captain overrating his control over the situation and continue with his navigation route.

- The use of a mapping (navigational charts) totally inadequate and the inappropriate use of the navigation systems (ECDIS⁴ and radar in the correct scale of rapprochement); d - *View from induced accidents theory*: Not knowing with precision (but assume that he knew) the location of the intervening elements (Ship/coastline) sailing now by his own image (unreal) of the scenario. We can see now the decline of the margin of safety by: (a. - which is, or represent homeostasis of risk in the Captain when overestimated his capacities and feeling in control of the situation ignoring to verify positions. Allow this condition reinforces the idea of the presence of the homeostasis of the risk in the Captain to sustain their decisions only in the belief of their expertise (by perhaps feel comfortable with a individual range of increased risk accepted and a safety operational margin declined - homeostasis of the risk) and did not corroborate with the navigational charts or require position to its team of bridge. This certainly puts yet another link in the progressive reduction of the margin of safety.
- The distraction of the captain due to the existing presence upon arrival at the command bridge, people of the department of hospitality and the telephone conversation sustained by one of them with a colleague from ashore; e. - *View from induced accidents theory*: Allow this situation implies the assumption that it had already happened before and it looks normal to them, also that

the approximation or greeting to Giglios was not considered a restricted maneuver but a navigation at open sea. Both of these considerations contribute to the decline of the operational margin of safety that should be, on the one hand due to waste of precious moments to the captain to realize the true situation, on the other hand the condition of normal navigation instead of manoeuvre conditions did not promoted the best attention from the staff of navigation on the bridge.. In our view because of an increased comfort to risk range of the Master and perhaps of all the bridge team on watch (Homeostasis of risk).

- The orders given by the Captain to the helmsman, assigning a course to follow, instead of telling the angle of the rudder. f. - *View from induced accidents theory*: Implies that the helmsman seek (to his own knowledge and understanding, at their own pace) to follow the course dictated by the Captain, while that of the Captain having ordered by position of the rudder, was direct order in condition for manoeuvre to be made directly and without any delay, which would place the ship on the course quickly. It also notes that the captain did not earn greater danger and therefore sailed comfortably. On the one hand and without doubt the safety margin is diminished with this form of sailing in these conditions and reveals the possible risk homeostasis in the Captain showing serenity when facing the facts and his control over them.

In regard to the specific requirements learned of the procedures of the ISM⁵ code, it is clear the failure of:

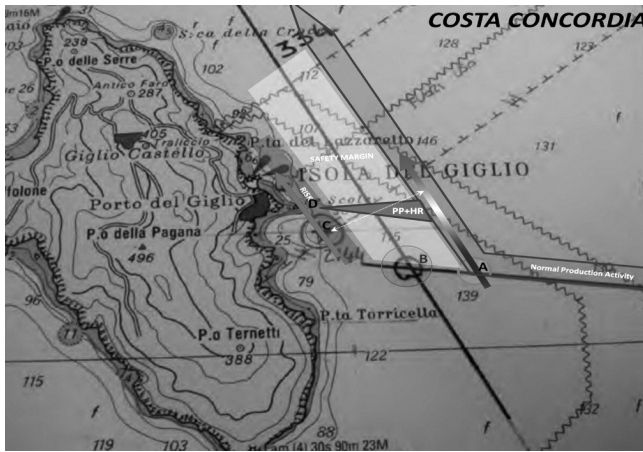
- The conduct of the attention to the watch on the bridge on the distraction of the motivated staff to the presence of strangers in the bridge; g. - *View from induced accidents theory*: Above-mentioned as promoted by the captain to navigate as if it were in the open sea, which, however, did not prevent the human team of the command bridge, to maintain a conduct to a great deal of attention to the navigation environment (perhaps the avoidance, as one of the three possible answers in the physiological homeostasis: *avoidance, conformity or regulation*). Coupled with the aforementioned distraction. This helped a lot to allow the gradual decline and increasingly alarming of the margin of safety.
- In addition the fails in regard to the verification of the position of the vessel, which was never done in this case (at least according to the audio recordings). h. - *View from induced accidents theory*: Exposed reflects the attitude of confidence of the Captain in the knowledge of the area and control of the situation (he supposed to have) generated by the possible homeostasis of the risk that he was invaded with).

Then, in this context looks clear anomalous the attitude of the Master not to check the original navigation plan (already failed as a result of the rapprochement to half nautical mile (0.5 nm) using a navigational chart totally inadequate) and go beyond the point of rotation provided without checking the actual

⁴ ECDIS: Res A.817 (19) de la OMI, es un Sistema de Información y Visualización de las Cartas de Navegación Electrónicas.

⁵ ISM: International Safety Management Code.

Graph 6: Costa Concordia / Safety Margin.



Source: (Chart) investigative.body@mit.gov.it - Explanation draw: The Author: RMR

distance to the coast (despite that was supported by the navigational equipment and bridge team). The audio recordings in conjunction with the collected evidence (2nd and 3rd deck officers, as well as the 1st officer, do not match) show the differences of the human team of navigation with the government of the ship. The passive attitude of the members of the navigation team of the bridge is reprehensible, and even the greater authority (after the Captain) the first mate (still in his watch) alerted or urged the captain to close/speed up the turn of the ship, nor did he give information of the imminent danger in spite of the fact that before the arrival (of the Captain) to the bridge had been sharply criticized and defined as a true madness the decision to follow that route so close to the coast. *View from induced accidents theory:* In regard to the attitude of the first pilot, it is clear that for this maneuver it was not a open sea case, however did not make any warning to the Captain, the reasons for such attitude we do not know (perhaps the avoidance, as one of the three possible answers in the physiological homeostasis: *avoidance*, *conformity* or *regulation*), but the fact of silent entity (not contradicting the captain, the captain is owner of command) can be between them. Without doubt, this contributed to the subsequent decline of the margin of safety. (Similar to the silence of the 1st pilot of the Torrey Canyon although before change correctly the course of the Oil Tanker).

It is also reprehensible the bad use of the three decks officers on the bridge, both during the phase of the watch of the first officer, such as when the Captain arrived at the bridge and took command of the vessel. Even if in the latter scenario, the first officer could have used the staff of the bridge

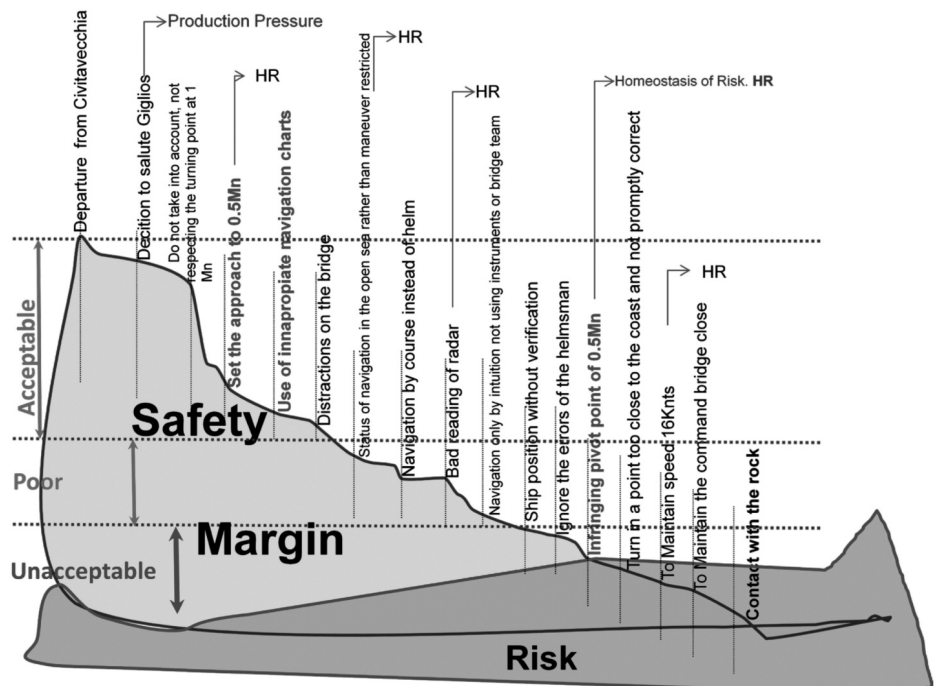
to warn of the dangerous rapprochement to the coast, rather than simply repeat the commands of the captain at the helm, or change the speed (perhaps the conformity as one of the three possible answers in the physiological homeostasis: *avoidance*, *conformity* or *regulation*).

As seen in graph 6 the Costa Concordia were complying her normal production activity but in point (A), Instead of turning to starboard within her normal activity of production and maintain its margin of safety, she decided to continue strait ahead approaching the coast (area of risk) of Giglios and reducing the acceptable safety margin in search of the previously calculated new turning point (B) (now located in a small safety margin) and not respectful continued her navigation up to another turning point (C) extremely close to the coast which totally violated the safety margin; After this, and with the failure of last second reaction to avoid the catastrophe, this became inevitable.

Can also be seen in graph 5 the production Pressure and Homeostasis of Risk (PP+HR) cone which represents the combination of factors which possibly led to the crew in charge of navigation to take those very wrong decisions. When production pressure push to salute Giglios it turn to a bigger Individual comfort safety range to the Risk accepted by the Master, and as a consequence to a smaller operational safety margin SM. Then after the breakdown of the SM the catastrophe befell.

In graph 7 can be seen a sequence of how the operational safety margin is loss when the decision maker (crew in charge of navigation) when they changed for a bigger than normal their individual comfort range of acceptance of risk, possibly as a result of the pressure of production by greet Giglios (homeostasis of risk), and as a result allow a safety margin very small to unacceptable limits (See point 2 of Graph 1)

Graph 7: Costa Concordia sequence of the loss of the margin of safety.



Source: Montes de Oca and Martínez Marín (2013)

Table 1: Induced Accident Analysis.

CASE STUDY	Production Pressure	Technological Advance	Homeostasis of Risk	Results	Induced Accident
Costa Concordia	Approach to the coast of the island Giglios (Yes)	Ultramodern vessel (Advantages Not used)	Decide upon a individual intuitive navigation type of the open sea without use of modern facilities of the ship, nor order condition of restricted manoeuvre, do not require support of staff on duty at the bridge, accept excessive proximity to the coast	Two of three (PP & HR)	YES
Torrey Canyon	To profit tide on arrival march 18 th or must wait till the 24 th to enter Milford Haven – Much time on board without vacations – Lengthening of ship (Yes&Yes&No)	Automatic steering (Yes)	Change from a plenty room navigation route to a dangerous path	Three of three (PP&TA &HR)	YES
Andrea Doria & Stockholm	To maintain arrival time - To take a shorter route to destination (Yes & (Yes)	Presence of Radar on both vessels (Yes)	The acceptance by both parties of an inadequate passing distance (too close) - Do not consider two ships navigations as a system - Do not slow speed - Do not make a clear change of bearing with enough time	Three of three (PP&TA &HR)	YES

Source: Cahill (1992, p197) – Collisions and their Causes pp – 3, 4 and analysis from authors

This sinister of Costa Concordia with others cases of study as Torrey Canyon and Andrea Doria / Stockholm are resumed in Table 1.

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