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# Stochastic regression models on the safety perception on board cruise ships

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ABSTRACT

The paper evaluates the perception of safety by cruise companies on board a ship and its organizational management. The approach on the probability of a negative event incurring on shipping companies, passengers and environment affecting safety and it requires adequate and well-timed procedures on board. The methodology is based on negative binomial regression model on cross sectional data observed in t period based on frequencies of the events. The variables considered are collision, death, gastrointestinal norovirus, mechanical problems, fire, wounded, and general accident as dependent variable. This model reflects the condition that the event happens not infrequently in a certain period of time.

## 1. Introduction.

Each year the cruise companies transport on board of their ships millions of passengers. Since 1970 the cruise industry is growing in the holiday market exceeding 27 million passengers estimated at the end of 2020. This strong increase induces the cruise companies to more investments in vessel of 517000 passenger capacity with a relevant economic and environmental impact.

The aim of the paper is the evaluation of safety perception on board cruise ships.

The sad story of the sinking of Costa Concordia, with the shortcomings pointed out by the chain

of command in emergency management, led all owners and institutions to reflect on the problems of the sector and, in particular, the safety of large cruise ships.

Currently companies and major international research centers are studying new methods and technologies to reduce the accidents risk improving safety conditions on board.

The strengthening of the safety conditions in the history of the worldwide navy after the sinking of the Titanic in 1912 with 1,852 deaths, induced to the improvement of the splashdown lifeboats; their equipment must be sufficient in number on both sides of the ship for the evacuation of all passengers and crew. Their fast positioning and stabilization must also be made in difficult conditions of rough sea.

In the sinking of Andrea Doria, in June of 1956, died 56 passengers and in the collision Costa Concordia, in January 2012, died 32 passengers. In these three disasters occurred different conditions of navigation, caused by human error.

Costa Concordia bumped into the rocks of Giglio Island and shortly it begun to founder. Passengers were disoriented and terrorized, there was widespread panic in evacuating the vessel, at the time of the collision it transported 4229 people on board: 3206 passengers and 1023 crew members. Safety exercises on board for 696 passengers boarded in the port of Civitavecchia, on impact moment had not yet been made, (Baker, D. 2013).

The paper considers the safety management on board cruise ships in dealing with new technologies, some of which are lifeboats for 300 passengers' capacity, advanced rafts systems, slides of great dimension.

Among the most advanced safety navigation systems on board ships, there are procedures for remote control of ships by monitoring and routing traceability and detection in real time of routes and technological and environmental engines on board. The availability of information on the nature of accidents on board, provided by the (CDCP, 2018) and (IMO, 2012) and companies have enabled us to develop a model of risk percep-

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tion of cruise ships in case of accidents and evacuation troubles. (www.Cruise ship death.com, www.Cruise Junkey. www.Cruise ship accidents, 2017).

The risk of accidents can be classified into four macro events of study: collisions, mechanical errors, fire accident, gastrointestinal norovirus.

The methodology focuses on Poisson probability distribution and negative binomial model application. This analysis is based on the frequency of accidents and the likelihood of their occurrence in the short term.

## 2. Safety on board.

The safety of human life at sea is a priority of the institutions required to ensure the navigation. Effectively, in the management on board, the evacuation step in case of accident is an absolute necessity as well as a civil duty. In terms of efficiency and rapidity of the handling of the event there are significant differences in procedures intervention.

The shipping companies have the possibility of monitoring the location of each passenger on board in case of emergency; moreover, the last generation ships have a better control of stability in cases of grounding or collision. There is also the possibility the remote control of the routes even if located thousands of kilometers away from the command bridge. All this evidences the increasing of safety on board. Although the cruise ships have those systems supporting the chain of command, the accidents at sea still happen.

The routing is immediate and highlights the dangers along the way but human error is lurking and the behavioral one is unacceptable.

Errors like Costa Concordia cannot be accepted and therefore we must ensure that these will be no more! In effect it is necessary to invest on the safety management avoiding errors such as helmsman inexperienced not able to properly understand the orders of the officer in charge, or communication of alarm evacuation only bilingual, or slowness in declining the lifeboats, etc.

Although these negative events are well publicized, the number of accidents happened is low in respect to the total cruise passengers transported. The Concordia tragedy reinforced attention on the safety and security operative standards of the cruise ship industry.

Nowadays all companies are able to operate quickly with appropriate instrumentation to ensure the safety of navigation. These are: a detection system of the ship (QPS) by monitoring in real time all emergencies of the case; the monitoring systems (VP & MS) that allow the routes traceability of every ship with a high update frequency of a second refresh rate and a precision of less than five meters.

On the web there are the routing of all types of ships and is it is also possible to see the route followed by Concordia to the point of sinking. The figure 1 shows the phases of Concordia accident, the monitoring routing on board MSC and new life rats.

The modern cruise ships have usually technological equipment as computerized nautical cartography, bathymetry and engines data controlling from a shore department. Moreover, in MSC cruise vessels it is possible monitoring the emergency in real-time fire control system in remote.

So, the management of the safety needs more and more the presence on board of a highly qualified staff that can accompany or even replace the captain in charge of the evacuation

process. Today the seas around the world are navigated about three hundred cruise ships, especially at certain times of the year, creating congestion in traffic especially in access to more scaled ports with serious safety issues during the maneuvers to dock at the cruise terminal.

It goes without saying that the state of alert for safety is high.

## 3. IMO safety rules and main fatality causes.

The regulatory framework of the International Maritime Organization (IMO, 2007) ensures the minimum standards of the safety and security of cruise passengers and the environment within which they operate.

According to the Cruise Lines International Association, the cruise ship demand is increasing on time at a rate of 7% per year, (CLIA, 2018) nevertheless many efforts on cruise safety the accidents at sea and on board show no sign of decreasing.

The International Convention for Safety of Life at Sea (SOLAS IMO, 2011), defines the most important of all international treaties concerning the human life safety at sea. The SOLAS Convention was created in London on 17 June 1960.

One of the main safety rules is to have sufficient lifeboats for all passengers and the crew with adequate training in loading and lowering the lifeboats. Under SOLAS, all passengers' ships must reach rapidly lifeboats location, some of them can be integrated by life rafts and slides. Flag States are responsible for ensuring that ships under their flag respect requirements.

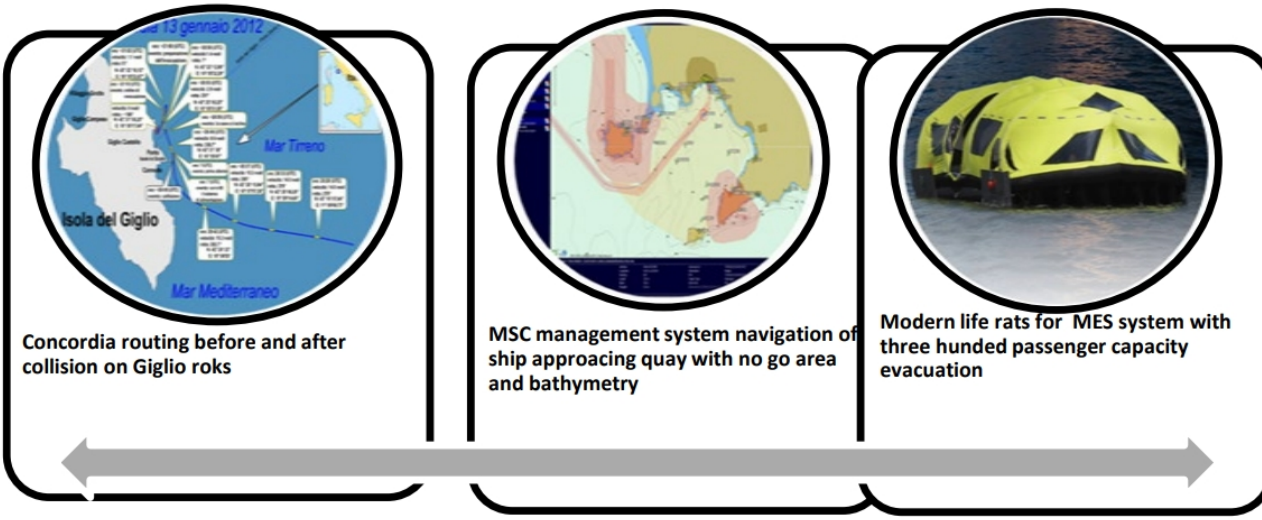
The International Safety Management (ISM) code provides an international standard for the safety management and operation of ships in case of accidents and for pollution prevention (González, A. et al., 2016).

The Safety Management System (SMS) code ensuring the safety of ships as a risk management activity it determines also the appropriated measures for prevention. The risk assessment matrix must be made in each particular case.

The purpose of the codes is to provide a standard framework for risk evaluating, enabling Governments to change threats with less vulnerability for ships improving also facilities port through appropriate safety rules. The safety pass also by clear messages and easy communication among command chain, passengers and safe guard operators. In the figure 2 it is possible to see the main maritime navigation IMO rules.

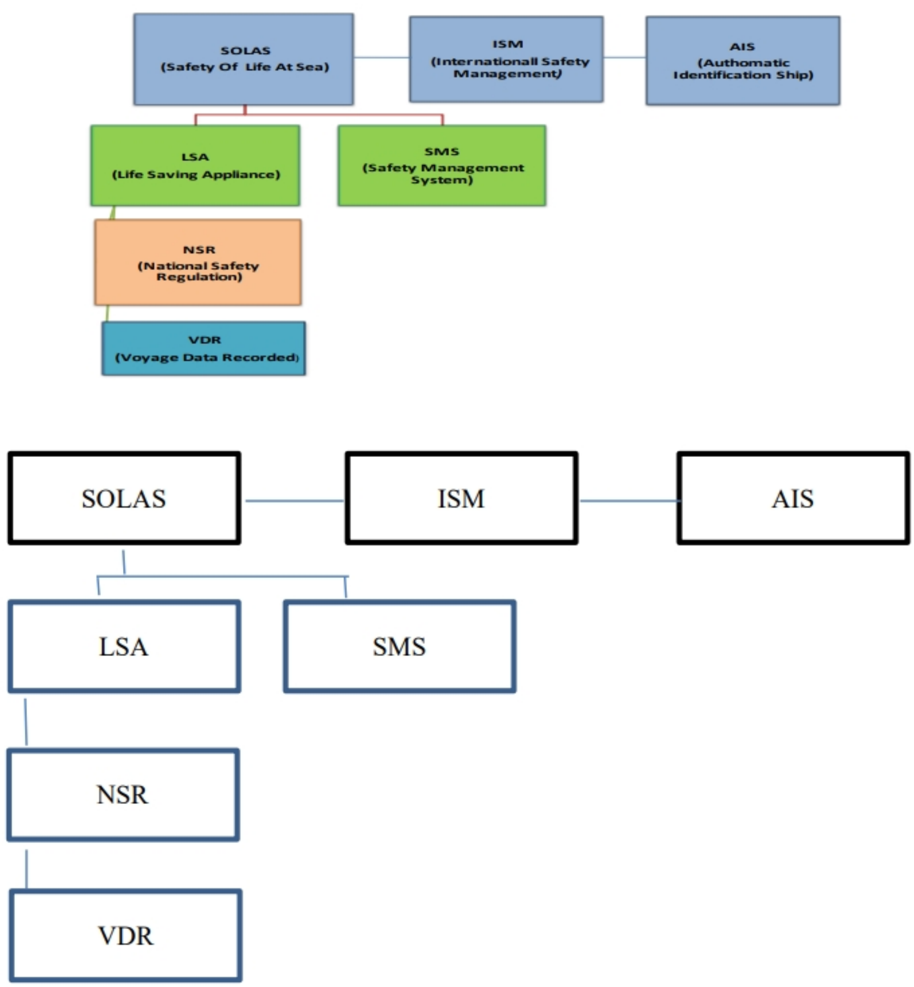
The data base used in the analysis consists of MSC data and other sources (G.P.Wild, 2015), (CDPC, 2015) and focuses its attention on accidents involving cruise ships operating over world.

Figure 1: Safety management.




Source: Authors.

Figure 2: IMO rules scheduling.




SOLAS = Safety of life of sea; ISM = International Safety Management; AIS = Automatic Identification Ship; LSA = Life Saving Appliance; SMS = Safety Management System; NSR = National Safety Regulation; VDR = Voyage Data Recording;

Source: Authors.

The main accidents that represent safety serious problems are gastrointestinal diseases (norovirus), fire, mechanical and technical failures, and collisions.

Considering the data of the total accidents, their number is increasing with an obvious and negative impact on ship companies anyway.

Improvement of all safety procedures, from the moment that the passengers get on board until their permanence is a priority of companies even if the safety must achieve standards of efficiency and efficacy much higher than at present.

Accidents prevention must also be extended to those areas particularly vulnerable as cruise terminal providing efficient gangways loading -unloading passengers operation. In many home ports there is a lot of local attractiveness and so an overcrowded traffic: in one day can dock also a dozen of cruise ships.

In these urban ports, there is a large flow of giant cruises, with grave polluting in terms of visual intrusion and environmental impact.

The checks and inspections of ships during approach to the coast should verify the use of fuels with low sulfur fuels content. But the protection of the landscape and the ecosystem is achieved by banning even risk maneuvers as longitudinal tilt of the ship, with the prow plunges as a greeting (bowing). These operations can lead to the relevant damages to the seabed and to the ship control (Costa Concordia). Among these delicate areas we can include Caribbean, Venice lagoon, Alaska and Arctic to the Antarctic ramifications.

## 4. The safety evacuation system.

The evacuation system of a large ship is very complex. The ability to manage the evacuation of thousands of passengers involves a series of steps to achieve life boats and saving rats such as: evaluating time of passenger's reaction from alarm to abandon the ship, wearing life vests, identification of the path of grouping passengers in presence of obstacles, poor visibility for smoke and fire, declivity of the ship and panic.

Under an analytical point of view, the mass evacuation, in rough sea conditions, is a problem that raises difficulties of study and application of the procedures (Lois, P. et al., 2004).

The evacuation was a priority within the International Maritime Organization (IMO) since 1999 when the SOLAS imposed the study, analysis, forecasting and management of evacuation programs included in the design phase of new cruise ship.

In this regard, IMO evacuation scenarios address issues related to the layout and the availability of the primary escape routes, at the time of distribution and reaction of the passengers. RINA (Italian Shipping Register) has developed and launched the first notation dedicated to operational aspects with help of the Center for Research of Stability of Ship (CRSS) implementing it on the class Spirit of Carnival Company's.

The Evacuation Time considers the following elements:

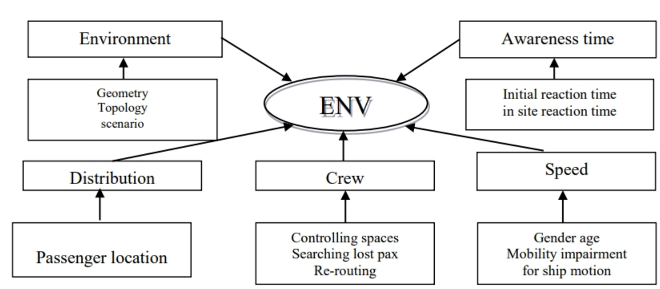
- Time awareness (A): reaction time to the emergency situation that starts after warning alarm and it ends the passengers moving towards a point of meeting. 10 minutes awareness time for night scenario and 5 minutes for daytime
- Travel time (T): time required for the movement of people from where they are at the time of alarm to the assembly stations and then to the boarding area
- Life boats launching time (L).

The IMO rules of safety system provide the total Evacuation Time (ET) of cruise ship is equal 1 hour, as sum of three time above: ET =A+T+L = 1h.

In the case of the Concordia collision the total time of evacuation was 7 hours, a very high time that caused deaths and injuries and must therefore be significantly reduced. Unfortunately, very often there are significant differences between the rules and their practical implementation. The fact remains that the cruise ships are becoming larger and the companies need to invest more to improve the technology of evacuation systems to ensure greater safety for passengers.

The concept of "evacuation" reflects the ability to evacuate a "ship environment" within "interval time" (time to sink/capsize) Vassalos, D. (2009). Specifically, evacuation is a function of a set of initial conditions directly connected and resulting from a scenario of loss and that provide a direct measure of the environment. In fact, there are several advanced tools for simulation of the evacuation of the passengers, some of whom are able to take care of the design and operational issues. Including simulation tools, special mention should be made of that ENV, it is a software used to simulate the movement of pedestrians in any environment H.R. 1485, ($111^{th}$) (2009). It has been widely used to model the circulation and evacuation of people on board ships, offshore structures and buildings. This simulation tool has several features that make it useful. Including its peculiarities, we find the ability of this software to provide 3D interactive simulation environments, the possibility to interact in real time for the different users that have access to the use of the program and also the evaluation of the impact resulting by critical events like a fire or flooding. See the successive figure 3.

Figure 3: ENV System.




Source: Vassalos, 2009.

The planning of Marine Evacuation System (MES) includes a series of activities linked to all critical events that ship has to handle. Below is an example of hazard situations that can be part of a MES figure 4.

Figure 4: MES system.

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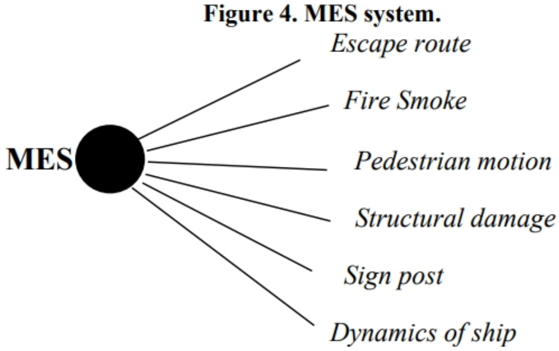


Source: Authors.

There are various MES for ship abandon. MES is technical safety tool currently adopted only a few passenger ships but are becoming more employed in the new vessels. They are located at the starboard sides. They are using as a replacement for davit launched of the life rafts as appliances for crew members, while lifeboats are the first life saving for the passengers. But the MES may be used also for passengers.

The MES allows the evacuation of a lot of passengers safely in the minimum time span as required by LSA code. It consists generally of 5 main components:

1. device for emergency launching
2. quick access and practicability of the stowage box
3. facilitate the boarding of passengers on the rafts by means the chute
4. suitable location of the rafts for emergency operations
5. check of the winch in the bowsing operations of the rafts at sea.

The management of safety systems should be organized as:

- security staff h24 located on each bridge to guide passengers in grouping areas towards the escape routes of ships
- away from danger footpath to reach the assigning post of evacuation
- possibility to advise with SMS the passengers
- security staff should ensure the availability of the seat on the rafts and life boats
- disabled passengers should have their own path towards escape routes.

The management in presence of the MES's should be organized as:

- passengers should be informed about the its use
- allocation of seats during the evacuation phase must be respected
- disabled passengers must avoid to go down the MES chute
- possibility to advise with SMS the passengers
- safety proofs for crew must be done in rough sea and impracticable conditions.

## 5. Negative binomial discrete random parameters distribution.

The probabilistic analysis of event incurring on board with a significant risk for person and environment has been implemented. The application refers to disruptive events at sea such as fires, collisions, mechanical failure and other risks on board.

In the literature there are evidences as regards collision risk derived from different sources, such as experimental data or similar cases distributions, CMPT (1999), Dale, C. and Anderson, T. (2009).

The probability evaluation should be the base for safety management with strategies to prevent and to mitigate the risks on board, including also the navigation control systems to avoid the collisions.

If it occurs an accident, it is a result of a combination of human error (e.g. poor judgement, inattention, fatigue or workload), mechanical failure, and fire on board.

The method evaluates the risk perception of accidents by negative binomial regression estimate (NBR) and supported by accident review assessments and their frequency. The database consists of data provided from cruise companies. As primary causes of 142 cruise vessel accident on the last years (2012/18) as MSC Cruise, CDCP, Cruise Ship Accidents, Wild GP, subdivided per day, months and types. The variables considered with general accident as dependent variable, are:

- general collision
- accident
- norovirus
- mechanical problems
- fires on board
- wounded
- death.

The estimated probability, of navigation risks, based on empirical frequencies by hazards identification, and cruise leader companies.

The frequency of negative events as collision actually is lower than others in consideration of more efficiency systems of navigation. On the contrary, some others accidents as the mechanical failure with loss of control, norovirus gastrointestinal disease and wounded on board are higher.

The negative binomial application to discrete probability distribution applied to a number of events occurred or notating a sequence of independent and identically distributed (i.i.d.) as (Bernoulli, Ahrens, J.H. Ulrich Dieter, U., 1974).

The probability mass function of the negative binomial distribution is:

$$f(k;r,p)(x+a)^n = \sum_{k=0}^{n} \binom{n}{k} x^k.a^{n-k} = Pr(X=k) =$$
$$= \binom{k+r-1}{k}.p^k(1-p)^r$$

for k=0,1,2....n

where ”$k$” is the number of events occurred, ”*truer*” and ”*falser*” not occurred. The value in parenthesis is the binomial coefficient, and is equal to:

$$\binom{k+r-1}{k}^n = \frac{(x+r-1)!}{k!.(r-1)!} + \frac{(k+r-1)(k+r-2)...r^2}{k!} + \frac{x^3}{3!} + ...,$$

This expression can be alternatively written in the following manner, explaining the name ”negative binomial”:

$$\frac{(k+r-1)...(r)}{k!} = (-1)^k \frac{(-r)(-r-1)...(-r-k)(x+r-1)!^n}{k!} =$$
$$= (-1)^k \binom{-r}{k}$$

Note that by the last expression and the binomial series, for every 0<p< 1, hence the terms of the probability mass function as:

$$(1-p)^{-r} = \sum_{k=0}^{\infty} \binom{-r}{k} (-p)^k = \sum_{k=0}^{\infty} \binom{k+r-1}{k} (p)^k$$

Under certain conditions, the negative binomial model differencing from normal distribution and gamma distribution (Greene W.H., 2004). The variables, in our application, are presented in the standard format, namely by reporting their estimates, their standard errors, T statistics and log likelihoods simulation function. The parameters distribution is synthesized below in figure 5.

## 6. Results of simulation model.

The results of the calibration of application based on NBR model evidence the good fit of parameters, with coefficients, standard error and T statistics, and Mean of x, reported in figure 5.

Figure 5: Negative Binomial Regression.

| Variable | Coefficient | StE | b/St.Er. | Mean of X |
|---|---|---|---|---|
| **Constant** | .709 | .111 | 6.387 | |
| **Collision** | -.709 | .587 | -1.207 | .023 |
| **Death** | .054 | .017 | 3.119 | .564 |
| **Norovirus** | .387 | .137 | 2.812 | .375 |
| **Mechanic** | .675 | .148 | 4.561 | .195 |
| **Fire** | .870 | .181 | 4.801 | .075 |
| **Wounded** | .950 | .003 | .030 | 1.706 |

Source: Authors.

The results of negative binomial regression model of variables distribution evidence for collision and fire a low value of T. The application reports a simulation log-likelihood -199.8.

The output reports for collision a low value of T statistics with the mean of x at lowest perception collision risk, but it is not a concern in terms of safety for shipping companies. This result does not reflect the gravity of the event since the collision is always a terrible and disastrous circumstance even if it happens rarely. The value of mean of x relating to the wounded variable appears very significant and it is a source of concern for shipping company.

The mean X for application evidences and reflects as a modest part of population (companies) is worry for the collision and fire on board, but this is implausible because they can induce a company to stop the cruise with evident economic and image damage for companies.

Major worries the companies have about norovirus, death and mechanical breakdown. On the contrary, the wounded trouble is much perceived.

We believe that the companies are very sensitive to business and to all the economic and financial aspects that cruises create by satisfying the needs and desires of travellers, perhaps underestimating the dangers in which passengers on board the ship could directly incur during navigation and excursions to land. However, travellers' risk perception of safety on board is undervalued, and so they may not confirm their loyalty to a specific cruise company.

Nowadays the cruise passenger, even habitual, not only pays attention to entertainment and good food, but he also considers potential dangers aboard and possible damage to the environment because he has become much more sensitive than in the past towards personal safety and the external environment.

## Conclusions.

The NBR model can be considered as experimental applications of cumulative probability distribution of the accidents. The application has been synthesized by a schematisation of the outcomes deriving from the simulations of the main phases of improvement the safety procedures on board a cruise ship.

Cruise companies must consider their perception risk of accidents without ever neglecting that millions of passengers because they are the first users of the cruise services, in this way will be possible to encourage the prevention of future accidents on modern cruise ships. The results of application model inform how the shipping companies and the passengers perceive the safety on board and the more significant variables which effect on the risk. Some of these, as collision probability perception, are statistically irrelevant with a lowest perception risk for the companies and the passengers but it can be due to the rare event.

As regards evacuation system, cruise companies operate in accordance with the strict requirements of the international maritime treaty under Safety of Life at Sea (SOLAS) Code, of International Maritime Organization (IMO). It may be insufficient because the management of the evacuation processes is the priority is the safety passengers and the companies must be equipped with sufficient lifeboats and life rafts, modern MES equipment with last generation slides to guarantee higher speed board evacuation.

Crews should undertake refresher trainings, certification and regular drills for emergency situations, including those more frequent and extensive ship evacuation. Safety must be improved and the new ships must consider the experience resulting from recent disasters. Pay attention also to the mechanical problems, fire on board and norovirus with adequate and severe rules of hygienic procedure to prevent epidemics on ship.

Further considerations can be done about safety ship management in presence of risk at sea and on board.

The environment safety in which a cruise ship operates is very complex and difficult to manage such as the control of great vessels and quantity passengers transported. The modern cruise ships must adopt advanced MES systems on board.

Accidents onboard can affect adversely on passenger's satisfaction and public image about cruising but the considerations and solutions should not penalize or inflate the holiday. Even if the future of the cruise industry looks bright, the cruise companies have the duty to invest in safety by providing ships higher standards to ensure the protection of human life on the sea and the environment. It is clear that cruise passenger's safety will depend on International Conventions, the design, layout and size of the ship, country of registry, crew training.

The results of this study reveal that the cruise supply chain is linked to safety but this aspect is not negatively affecting the entire cruise industry because the cruise represents always a complete and fascinating holiday model in all seasons of the year.

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