

# Safety of LNG shipping around ports and terminals

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## Introduction

The design of port layouts and terminals suitable for LNG carriers has to meet exceptionally high safety standards. The highly sensitive subject is always treated by responsible parties with the utmost concern for the design of inherently safe terminals. This is reached through the careful choice of the terminal location within the port and the definition of strict nautical procedures for the entrance, transit, mooring and loading/unloading of the vessel.

In this article, an outline of the maritime issues to be addressed if LNG offloading is envisaged is given. The issues are grouped around four main themes:

- Port infrastructure design
- Nautical ship operations
- Overall port shipping safety
- Training

The above themes are interrelated. In greenfield sites, many issues are free to determine, hence laying great emphasis on the design of the total (port) operation. In existing ports, often the port infrastructure (layout), supporting services (tugs, VTS, aids to navigation), and the other port users are boundary conditions in the process of defining the ship operations and in the assessment of the overall risk. However, the primary importance of safe LNG operations often allows changes and adaptations to the existing (supporting) infrastructure, traffic flows and operational procedures in the port.

Marin is covering a good deal of the above-mentioned nautical safety aspects because of its high quality modelling for manoeuvring, safety and mooring purposes. One of its latest LNG projects in Ferrol (Spain) is amongst others, a good example of an integrated, safety-driven terminal development project; some

details of this project are included at the end of this article. This article focuses on the inshore LNG offloading terminals and jetties and does not cover the exposed offshore offloading concepts.

## Themes in introducing LNG offloading in ports

### Port infrastructure design and nautical ship operations

The objective of the port design is, first of all, to guarantee the safe approach into the port, the safe berthing at the jetty and calm mooring at the same jetty as much as possible. Secondly, the infrastructure and operational procedures in place should enable the safe arrival and departure from the jetty or abort any entrance manoeuvre during an on-board or on-shore emergency.

Greenfield port development sites or dedicated harbour basins require a port layout evaluation in relation to wave calmness (safe mooring) and the required stopping and manoeuvring space – obviously all against the background of port development cost optimisation and an acceptable downtime.

Natural or existing ports do not focus on port layout design in the first place (apart from minor adjustments), but evaluate admission policies in relation to downtime of the port against direct risks associated with critical entrance manoeuvres and the moored ship motions (wave penetration). The issues addressed during these evaluations result in:

- A validated port (dimensions of approach, entrance and basin) and jetty lay-out
- A safe port entrance and berthing envelope (weather window)
- A safe and calm mooring position
- An optimised tug assistance (escorting) configuration

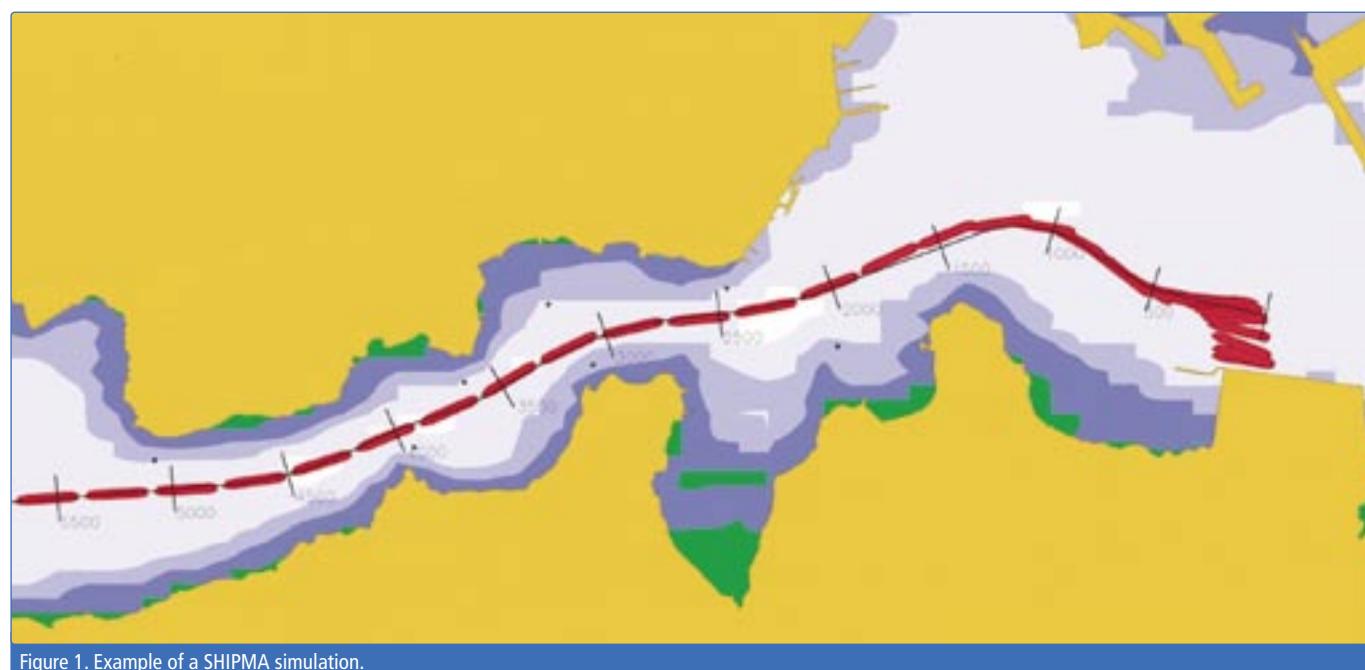




Figure 2. Traffic flow inside the port.

- An aids to navigation plan to facilitate the port entrance and departure manoeuvres
- A ship and port operations manual covering all relevant procedures and nautical information
- Additional measures to cope with the evaluated emergency (risk control options)

The above types of evaluations require the use of (fast-time) simulation tools regarding the moored ship motions and the ship manoeuvring capabilities (or real-time simulator). Marin's Nautical Centre, MSCN, closely cooperates to this end with Delft Hydraulics to assure high quality environmental input on currents and wave penetration.

#### Overall port shipping safety

The above issues are focusing on the direct day-to-day safety of operation of individual vessels; however, public enquiries or port authorities additionally need to know the total safety level of the LNG shipping operation in the context of the existing infrastructural and surrounding shipping movements. It addresses the risks related to collisions, groundings, contacts, fire and explosion on board, eventually leading to the release of gas and the consequences thereof.

In both design situations, the general risk assessment within the Formal Safety Assessment (FSA) framework requires the use of nautical risk models to identify areas where traffic risk control options are to be applied. The Marin SAMSON risk model is one of the very few models that can quantify these risks and assess the consequences.

Once moored along the terminal, the 'industrial' and remaining nautical risks (passing vessels, squalls) need to be evaluated. MSCN/Marin works in close cooperation with several partners to assess consequential risks to the environment due to leaking LNG following loading or collision emergencies.

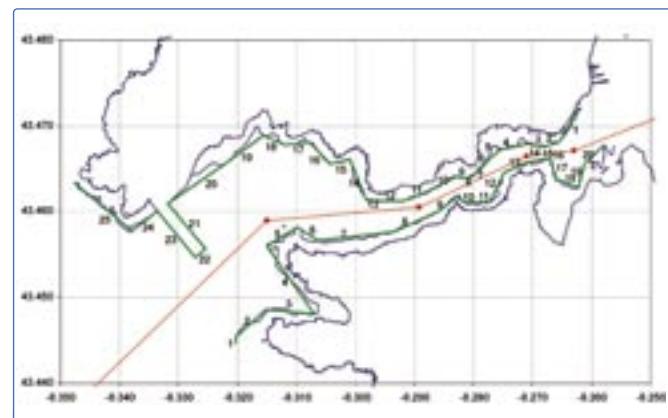


Figure 3. Schematisation of route and grounding lines.

#### Training

The above studies can lead to recommendations (risk control options) on the training of involved nautical personnel like pilots, tug masters, traffic controllers both for normal operations and emergency response.

### Nautical and safety study executed for the Port of Ferrol (Spain)

This is an example of a typical port safety study executed for a new facility for storage and handling of LNG in the Port of Ferrol.

#### Objective

The objective of this study can be divided into the following elements:

- Determine the required, minimum channel dimensions
- Study the risks involved in the handling of large LNG carriers, during channel passage and when moored at the terminal
- Determine the nautical procedures for handling large LNG carriers, during both normal operations and emergency situations

The content of the study can be divided into the following main items:

- Determination of the required minimum channel dimensions
- Risk studies
- Moored ship study
- Real-time simulations
- Nautical procedures

#### Determination of the required minimum channel dimensions

In this study item, the available channel dimensions were checked against criteria published by PIANC and ROM3.1-99. The PIANC rules for channel dimensioning have been programmed

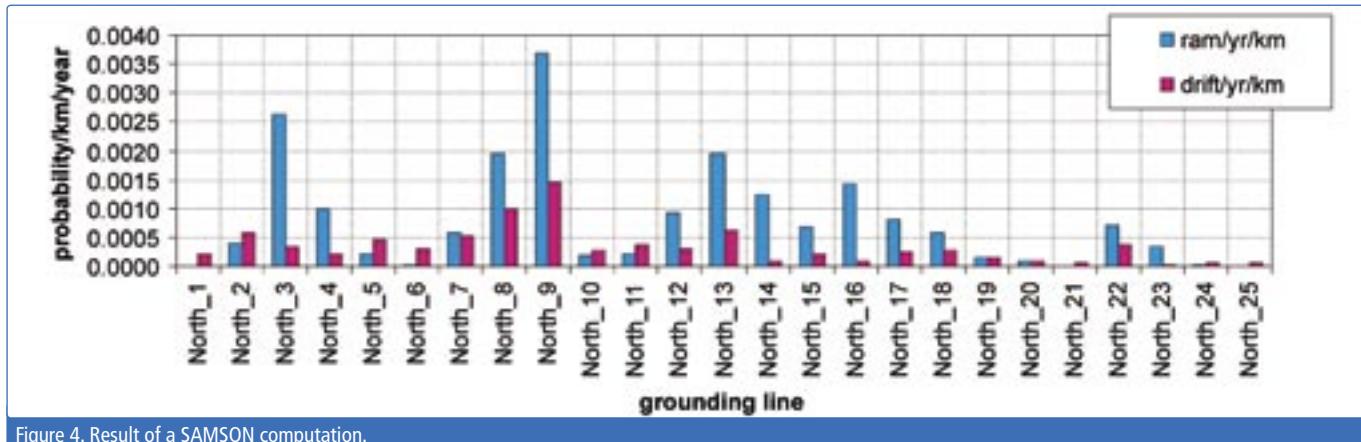


Figure 4. Result of a SAMSON computation.

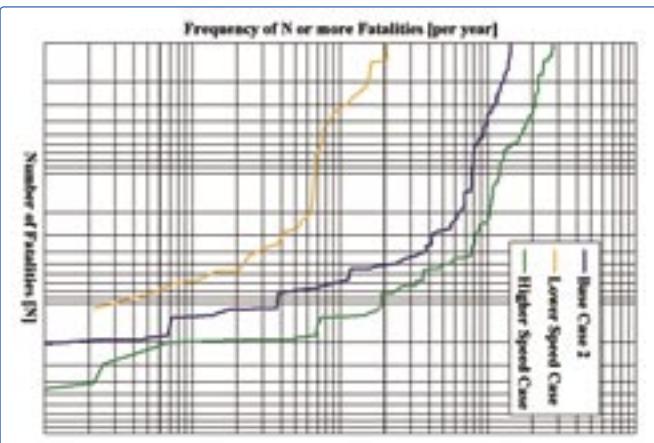


Figure 5. Overall safety of channel passage.



Figure 6. Simulator bridge as an ASD tug.



Figure 7. The simulator database.

by MSCN. This programme (available for free) has been used to make a first judgement of the required channel width.

These first findings were checked with a series of fast-time simulations. These simulations were executed with the fast-time simulation model SHIPMA. The programme uses a predefined ideal track combined with a sailing strategy and a sophisticated autopilot to perform the manoeuvres. These simulations confirmed the results of the ROM/PIANC study regarding the channel width. It also showed that the proposed tug assistance scenario is effective, especially for keeping the ship speed low in the inner channel. An example of a SHIPMA simulation for a part of the channel is shown in Figure 1.

#### Quantitative risk assessment studies

The risk study executed for Ferrol is divided into three elements:

1. Traffic forecast and traffic intensity.
2. Grounding and collision risks.
3. Risk analyses of LNG transportation and unloading.

The traffic forecast and intensity study provides input for the grounding and collision risk study, but it also gives insight into the effect of increased traffic intensity on waiting times and the availability of tugs. The traffic flows to the various locations inside the port are shown in Figure 2.

Computations were made for the present situation and a number of future scenarios, regarding the development of the LNG terminal and the new outer port. As large ships entering the Ria are restricted to entry on high water only, it was concluded that some traffic scenarios might result in congestion of the port.

The grounding and collision risk study is executed with the SAMSON model. SAMSON stands for Safety Assessment Models for Shipping and Offshore in the North Sea. This model has been developed, extended, validated and improved during the last 20 years in studies performed for the Dutch Ministry of Transport and within many European projects. Although initially developed for the North Sea, the model is built up modular and can be used for any location in the world. This model includes the probability of human error and mechanical failures, and from that it computes the probability of grounding. The probability data included in the model is based on worldwide statistics, and updated regularly.

The starting point for the computation is a schematisation of the route and the grounding lines. This schematisation is shown in Figure 3.

The result of the computation is the grounding probability per year for each section of the grounding line. Two classes of grounding are distinguished; the first is 'ramming' resulting from a navigational error and the second is 'drifting' resulting from a mechanical failure. A typical result for part of the route is shown in Figure 4.

The total risk analyses of the LNG transportation and unloading is based upon the aggregated probabilities of accidents and their related consequences in terms of gas spills. The final gas spill amounts and their respective probabilities are first reduced on the basis of effective measures, and afterwards used for the calculation of the consequences following the release of a gas cloud. The cloud itself can be used for the assessment of the risks of ignition and combustion, and thus the individual and societal risks involved. This procedure is repeated to study the effect of certain measures on the overall safety of channel passage. Such a result is shown in Figure 5.

This shows the effect of the ship speed on the probability of fatalities. The middle (blue) line is the result for the basic speed scenario, the lowest (orange) line for one knot slower and the highest (green) line the result for one knot faster. The axes are on a logarithmic scale, and the graph shows that reducing the ship speed by one knot results in an increase of the safety level by a factor 10!

Consequently, the approach in the real-time simulations should be to develop procedures that make it possible to pass the inner channel at low ship speed. By reducing the ship speed, the risks involved in the operation become much lower than the normally accepted standard.

#### Real-time simulations

A simulator database of the Port of Ferrol area was prepared for Marin's nautical simulators. In total, three simulation sessions were executed, with pilots from Ferrol executing entry and departure manoeuvres. During the last session, an experienced tug captain participated in the simulations sailing an ASD tug from a second simulator bridge, shown in Figure 6. A picture of the simulator database is shown in Figure 7.

Simulations were executed under extreme environmental conditions, e.g. spring tide and strong winds. From the results, the probability was computed that the channel boundaries are exceeded during normal passages and during failures. It was found that the 1 per cent exceedance probability line stays within the 10 metre depth contour line. It should be noted that this is not the grounding line. An example of such a result is shown in Figure 8. The simulations showed that it is possible to transit the channel at a relatively low ship speed.

It was also concluded that it is essential to have two escort tugs assisting at the stern of the vessel during channel transit. The role of these tugs is to keep the ship speed low and to assist in case of an emergency. Two tugs are essential to control the vessel during specific failures and to remain under control when one tug fails or when a towing line breaks.

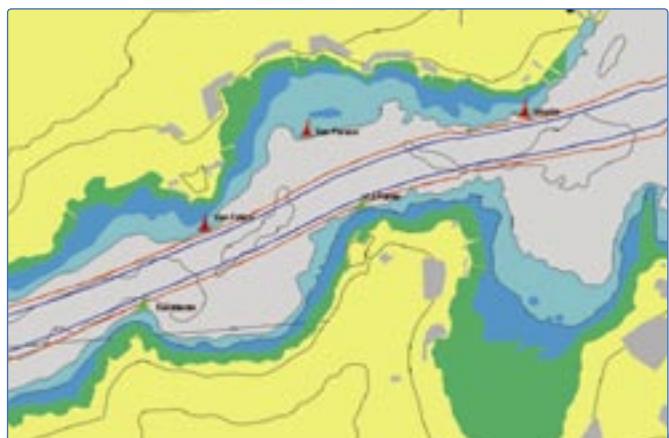


Figure 8. Example of 1% and 10% grounding lines.

#### Procedures

On basis of the manoeuvring studies and the moored ship studies, a detailed overview of nautical procedures, entrance rules and limiting environmental conditions was prepared. This was all summarised in a 'nautical summary' that is used to develop the port procedures.

#### ABOUT THE AUTHOR

Jos T.M. van Doorn graduated in 1982 from Delft University of Technology in Naval Architecture (ship hydrodynamics). He then worked for ten years at Delft Hydraulics. As a specialist in ship hydrodynamics he contributed to port and fairway design studies. In 1992 he started working at Marin's Nautical Centre MSCN, active in shipping, safety, consultancy and training; becoming manager in 2005.

#### ABOUT THE COMPANY

The **Maritime Research Institute Netherlands** (MARIN) has been dedicated to furthering maritime understanding and knowledge since 1932. Today, they are an internationally recognised authority on hydrodynamics, involved in frontier breaking research programmes for governments, the maritime and offshore industry, and navies. MARIN also provide commercial shipbuilders, owners, propeller manufacturers, naval architects and the offshore industry with state-of-the-art performance predictions, design consultancy, testing services and simulation and training consultancy.

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