



Influence of marine operations on site selection and design of marine terminals

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This paper examines the benefits achievable during the design and construction of a marine terminal if those involved understand the ultimate purpose and operational parameters of the terminal from the very beginning of the project. It provides you with an overview introducing key issues that should be considered before site selection and initial conceptual design are started. This paper also considers the influence marine operations is beginning to have on site selection and design issues, especially with risk mitigation for shipping and the efficiency of the port in general. The process is similar no matter which location is being considered, the only difference being the variance of factors taken into consideration to ensure safety and efficiency remain paramount. One does this by considering operational methods of controlling the passage of vessels within confined waters especially port areas using modern handling methods including the use of tugs, the use of modern navigation and docking aids, effective training and familiarization with vessel types of those handling the vessels as a team, the use of sophisticated integrated simulators, provision of real-time and forecast meteorological and oceanographic information, and overall management of port operations.

Keywords: marine and port operations, wind, waves, currents, vessels and tugs

En este artículo se analizan los beneficios posibles de lograr durante el diseño y construcción de un terminal marítimo si aquellos involucrados entienden el propósito último y los parámetros operacionales del terminal desde el inicio del proyecto. Se introducen aspectos claves que deberían ser considerados antes de elegir una ubicación para el terminal e iniciar el diseño conceptual. También se consideran la influencia de las operaciones marítimas en la elección de la ubicación del terminal y aspectos del diseño, especialmente los referidos a la mitigación de riesgos para las naves y la eficiencia del puerto en general. El proceso de estudio es similar, independiente de la ubicación elegida, siendo las únicas diferencias las variaciones de los factores considerados para asegurar que la seguridad y eficiencia sean primordiales. Esto se hace al considerar los métodos operacionales de control del paso de naves dentro de aguas restringidas especialmente en áreas que rodean a un puerto. Para ello se usan métodos de manejo modernos, los cuales incluyen remolcadores, asistencia a la navegación y atraque, capacitación adecuada y familiarización con los tipos de naves para aquellos que manejan naves en equipo, el uso de simuladores sofisticados, entrega de información en tiempo real y pronósticos meteorológicos y oceanográficos y administración de todas las operaciones portuarias.

Palabras clave: operaciones marítimas y portuarias, viento, oleaje, corrientes, naves y remolcadores

INTRODUCTION

Over the years ships have got larger and ports have typically become more congested. Whilst the optimum would be to locate a marine terminal close to open and deep water away from other traffic and port users, this is very seldom the case particularly when it is more economic to site a terminal close to the supply or market. Today the number of ships serving a terminal can be a larger investment than the terminal itself, as they carry ever more complex cargoes many of which are hazardous to the general public and the environment. Therefore it seems only logical that the potential risk

a vessel poses whilst in confined waters is taken into consideration at the outset of any project. The same can be true of vessels within port limits, or off the coast, where other factors additional to those it encountered in deep water come into play. Local topography and the infrastructure around a port influences the localised wind flows, and often results in wind funnelling and turbulence which can adversely act on any ship within that location. Similarly the relative shallowness and contours of the sea bed, together with tidal ranges, can give rise to irregular and stronger currents and influences the nature of the waves.

Shallow water effect on waves is common along any shoreline, which together with wave reflection and refraction, alters the wave spectrum within the port area unless it is very well sheltered by a breakwater or similar construction(s). Whilst advocating the benefits of proper marine input at the beginning of any marine project, it is essential to understand that there is always a balance to be had at each and every proposed site location. One site might have a very easy, short and safe transit between the edge of the port (e.g. Fairway Buoy or Pilot Boarding Area) and the terminal's berth in question, whether close or a long way from the supply or market, and another might have a very long and hazardous transit between the edge of the port and the berth. The amount of risk between the edge of the port and the berth depends on many marine factors, which must be known and understood in order to ascertain whether the vessels can make safe transits to and from the berth under the maximum meteorological and oceanographic parameters allowed by the Port Authorities. This will include the layout of the port and the amount of congestion within the port already established by other port users. Whilst it would be nice to say that all vessels can be safely controlled within any port area by using a number of tugs, the increasing size (both above and below their water line) and displacement of vessels have reached a point beyond which even the largest and most manoeuvrable of tugs find it difficult to control them except in fairly benign metocean conditions.

SITE SELECTION

A good site location can be considered to be one whereby any vessel visiting that port or terminal can be safely handled between deep water and the berth in question by using sound manoeuvring knowledge and experience, the correct number, power and physical size of tugs in the most effective way, proper simulator familiarization including emergency scenarios, to facilitate a safe transit of any vessel up to the maximum allowable metocean conditions allowable by the port and/or terminal. Such maximum allowable metocean conditions should also be conducive to maximizing the berth availability (normally at least 95%) to provide the terminal with the minimum schedule delays based on their required occupancy needs.

Working closely with the Port Authorities, Pilots and the existing port users ensures any proposed new berth can be effectively integrated into an existing port area in such a way not to impact the safety and operations

of the existing users, or at least minimize the impact for the benefit of everyone whilst enhancing the economy of the region.

The correct design of the ship/shore interface for the range of ships expected to call at the berth should as a minimum cover certain marine criteria. This would stem from the expected average berth availability required by the client, which is determined by ensuring the correct alignment and design of the berth for the chosen location under certain predetermined metocean conditions. This is to make sure the vessel does not break out of the berth as it moves about whilst alongside, because of the effects of adverse wind, waves and/or currents. The correct selection of fenders, mooring hooks and mooring arrangements complying with PIANC and OCIMF recommendations, and other structures and equipment used to provide a 'Safe Berth' and a safe and efficient means of transferring cargo and personnel, are also some of the factors that should be considered at the commencement of design.

Whenever considering one or more existing locations (*i.e.* within an existing port), or new locations, various marine issues should be considered and addressed to ensure the final site selection is suitable for shipping as well as for the terminal. Every location is different, and will be subjected to its own diverse and unique influences that will need to be studied and understood by the designers for the chosen site to be safe, operable and commercially viable.

The meteorological and oceanographic (metocean), topographic and geological (including seismic), and bathymetric influences are essential in gaining a high level overview of the area being considered. Topographical and bathymetric data is more constant, and is therefore easier to gather and more accurate from the outset compared to metocean data. Whilst there is usually ample historical metocean data available, especially covering the busier parts of the world, the advent of climate change means there is a greater tendency for historical information to be incorrect and therefore out of date. Unfortunately, many projects do not go beyond using historical data for their studies, which ultimately can compromise the design and operations of the terminal at a later date in the form of accidents or near misses. More knowledgeable project teams and designers understand the need to gather the most accurate metocean information available if they are to build the most economic marine terminal and berth(s) to withstand the maximum metocean



parameters in that location, including possible extraordinary events such as tsunamis, storm surges and seiches. They therefore understand the need to collect real-time metocean data to compare against historical data to provide accurate hind-cast data for modelling.

As a minimum, a weather station should be placed close to the terminal site on land, and an instrument for measuring near-shore waves and currents (*e.g.* an Acoustic Doppler Wave and Current Profiler) should be placed close to where the final jetty/berth location is to be established. If the location is in a bay, or the terminal is exposed to the effects of wind waves and/or swell waves (even if reflected and/or refracted), then an offshore instrument (*e.g.* wave-rider buoy) should be located in a suitable deep water location. This can be close to any Fairway Buoy, or where the pilot would embark or disembark the vessel. The purpose of a wave-rider buoy is to enable a comparison to be made between the off-shore and near-shore wave patterns, which in turn will make any mathematical modelling used in studies much more accurate.

Similarly, the importance of obtaining a recent bathymetry survey around the berth and any areas such as headlands, which would influence the accuracy of modelling and navigation simulation, cannot be emphasized enough. This need for accuracy becomes more evident when there is little water beneath the vessel and the sea bed (*i.e.* under keel clearance), or on either side of the vessel (*e.g.* channel width), whilst transiting to and from, and manoeuvring off, the berth. This degree of confinement around the vessel increases risk whether caused by natural boundaries, or by neighbouring terminals. Using an effective number of tethered tugs of sufficient power and manageable size in a pre-determined and proven way will always substantially reduce such risk if used to their best advantage by knowledgeable mariners. Other shipping moving in the area also increases risk. Proper control of traffic within confined areas such as port areas greatly reduces this risk if managed correctly by the Port Authority.

Existing Ports

A new terminal, or the upgrade of an existing terminal, quite often lies within the limits of an existing port area. Whilst the same basic studies would apply to either a new terminal in an isolated location or one within an existing port, the latter is more complex

because of additional interactions with other port users and the confines of the port itself. To avoid numerous pitfalls from the outset, additional studies would be required if the success of the project is to be ensured.

Whenever considering introducing a new berth within a Port, whether for a new Terminal or an existing Terminal, there are many factors to be considered. Some will be found to have a negligible impact on the Port and other port users, whilst some factors may be deemed to have a significant impact. Whatever the situation, most adverse factors can be mitigated by working closely with the Port Authorities and other port users by using marine consultants who have a very comprehensive and clear understanding on all of the issues involved, and who will be respected and understood by those they will have to converse with. The best option here is to employ very experienced Master Mariners, preferably those with a background, *inter alia*, in commerce, marine law, port operations, tugging, meteorology, oceanography, electronic navigation aids, as well as ship handling covering many types and sizes of vessel.

Other marine factors should also be considered from the beginning of a project, which will greatly enhance the acceptability, design and schedule of the project. Working closely with the Port Authorities and port users always helps to ensure any proposed new berth can be safely integrated within an existing port area minimizing the impact on safety and operations of the existing users or the port. Knowing the types of vessels, and the frequency of their visits, calling at other terminals helps in understanding the general flow of traffic in the port with the objective of realising any potential impact (favourable or adverse) the proposed new berth may have on the existing berths and Terminals within the port. This is typically defined within a Traffic Study which looks at existing traffic, the impact of new traffic to the proposed new terminal, and the effects of envisaged expansions by existing port users over the next five to ten years.

THE VESSELS

Vessels come in all shapes and sizes, and carry a multitude of different cargoes. They have a variety of propulsion systems of differing power to size ratios, and nowadays various means of steering. Without going into specific types of vessel, suffice to say that all vessels are designed and built to meet the demands of their trade at the lowest capital expenditure (Capex)

of their trade at the lowest capital expenditure (Capex) and operational expenditure (Opex) achievable.

The Naval Architect has to juggle a multitude of requirements set by the intended trading pattern of the vessel, and the vessel's owner, to ensure the space available for cargo is the most ergonomic possible. As a result vessel designs vary between flat bottom barges to streamlined passenger, LNG and container vessels. Even tugs have recently undergone major transformations in design to accommodate the additional power required to handle the ever increasing size, windage, draught and displacement of modern vessels, whilst maintaining manoeuvrability at all handling speeds.

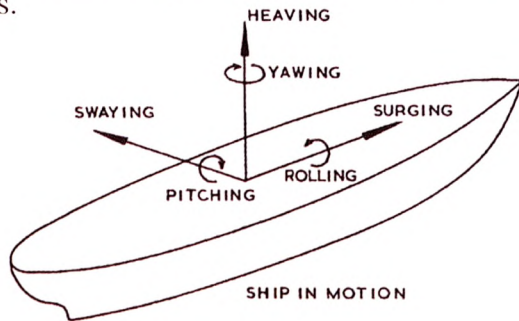


Figure 1: Six Degrees of Freedom, 6 DoF

All vessels have six degrees of freedom (see Figure 1), which is unique to that particular vessel. These are defined as:

- a) Rolling - A transverse oscillation about a longitudinal axis
- b) Pitching - The longitudinal oscillation about a transverse axis
- c) Yawing - The angular horizontal movement about the vertical axis
- d) Heaving - The vertical linear movement
- e) Surging - The longitudinal linear movement
- f) Swaying - The transverse linear movement

The 6DoF determines how a vessel will move through water and/or certain wave spectra, and how it will handle at full sea speed, manoeuvring speeds including slow manoeuvring speeds whether in deep water or shallow water (*i.e.* within port limits and confined waters).

Ship's Rudders

The rudder on any vessel is the most important ship control surface, and dates back to before historical records began.

For simplicity, we shall only consider the most common type of rudder still used today, which can be found on small and large vessels of all types. There are many types of rudder (*e.g.* balanced or semi-balanced), and rudder to propeller configurations. However only a common cross section will be used to explain how a rudder actually works.

A rudder acts like an aircraft wing, in that when it is angled in a flow of water an increase in pressure is created on the front side (with a reduction in water flow) whilst a decrease in pressure is created on the back side (with an increase in water flow) of the rudder. When placed in a water flow at an angle (known as the angle of attack), this produces a force F which is a combination of the differential pressure between the front and back (see Figure 2). This resultant force has a component Q normal to the rudder and a component C along the longitudinal axis of the rudder. Q depends upon the angle of attack, the area, shape, the square of the velocity of the water flow, and the density of the water.

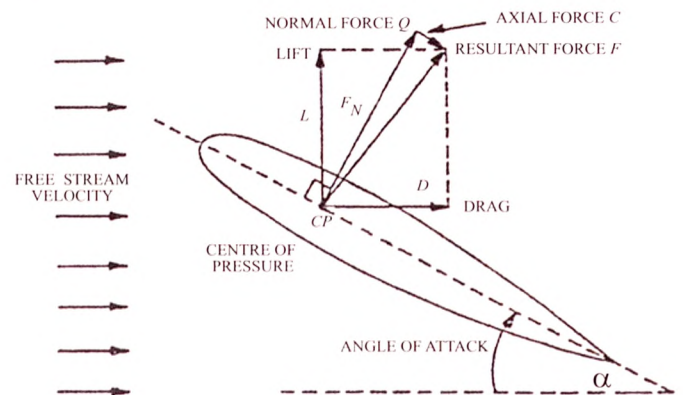


Figure 2: Forces acting on a Rudder in Water Flow

A Lift force L and a Drag force D are also created as components of the Resultant force F . The Lift force steers the stern of the vessel in the direction of the lift force, and the Drag force slowly reduces the speed of the ship whenever the rudder is put at angle other than in-line with the free flow of water. The lift and drag forces increase when a) the rudder angle is increased relative to the water flow and b) the velocity of the water flow over the vertical surfaces of the rudder increases.

The design and shape of a rudder, especially its aspect ratio (*i.e.* the ratio of the mean height, called mean span, divided by the mean width, called the mean chord, or the ratio of the mean span squared divided



by the profile area), will determine its efficiency and its Stalling Angle (*i.e.* the angle at which there is a large drop in the lift force due to changes in the direction of flow). It is important to understand that the Lift force reduces as the speed of the ship decreases, requiring a greater angle of attack or an increase in water flow using the vessel's propeller to try and re-establish the Lift force. A vessel therefore requires alternative means of steering and positioning, typically using tugs and/or thrusters, when manoeuvring at low speeds.

Table 1 illustrates the variation in rudder forces for different speeds using two sizes of tanker. It clearly shows that there is relatively little difference between small and large rudder angles for any given speed, but a large difference for the same rudder angle for various speeds. At speeds below 6 knots the decrease in effectiveness is substantial.

Table 1: Typical Rudder Force Comparisons (in tonne - f)

Tanker speed knots	100,000 dwt oil tanker Rudder angle:			200,000 dwt oil tanker Rudder angle:		
	15°	25°	35°	15°	25°	35°
6	30	45	30	50	60	50
8	55	75	60	85	115	90
10	85	120	90	130	185	145
12	120	175	135	190	260	205

A Vessel's Inertia

The inertia of an object with mass changes relative to the forces acting upon it, and exists whether the mass is at rest or moving (Newton's first law). All vessels have mass and Potential Energy, which transforms into Kinetic Energy once the mass begins to move through water. KE increases proportionally to velocity squared ($KE = \frac{1}{2} mv^2$, or $KE \propto v^2$), therefore there is a relatively large increase in energy and inertia for every small increase in speed.

A vessel's inertia is affected by external forces such as wind, waves, and currents, and under certain instances topography and bathymetry. The greater the inertia of a vessel the more difficult it is to control as it passes through water, and the more difficult it becomes to reduce the vessel's velocity by dissipating its inertia.

Controlling a Vessel's Inertia

Generally in deep unconfined waters vessels can usually proceed at full sea speeds without much risk, as any failure will usually not incur loss of life or damage to the vessel or its cargo. The Master may have to slow

down however if the weather and/or seas have any adverse effect on the vessel, in order to maintain a low risk situation. In restricted waters (*i.e.* within port limits, Straits, Passages, channels, *etc.*) any mechanical failure or human error is potentially a high risk, which is likely to result in vessel damage, cargo damage, have an adverse impact upon the environment, and possibly result in loss of life. It is therefore essential that measures are taken to control the vessel's inertia at all times during such transits. This usually takes the form of duplicating critical machinery on board the vessel, and increasing staff levels in operational areas such as the Navigation Bridge and the main Engine Room. Additionally, a vessel's inertia can be controlled by using suitable tethered escort tugs, and the experience of well trained pilots, tug masters and ship masters throughout the transit between clear and open water and the berth.

Use of Tugs

The use of tugs as a means of controlling the inertia of the various types and sizes of ships visiting a port and terminal, even under emergency scenarios, is a skilled and precise operation. It takes many years for pilots and tug masters to become familiar with the unique limiting metocean conditions in the area they operate, and be trained to use a tug to its best ability to protect the vessel, the port, other port users and the local environment even in an emergency scenario. The pilot must satisfy the vessel's master, and the Port Authorities, that the number, type, size, power (relating to certified Bollard Pull), and methodology of operation of the tugs will prevent an incident within the port, especially in any emergency situation.

The effectiveness of a tug depends upon the water in which it is operating, and the speed of the vessel it is assisting. Waves, wind, currents and the available area in which it is required to operate restricts the ability of the tug to manoeuvre, but if it has to keep pace with a vessel travelling above 5 knots, its ability incrementally diminishes simply because it has to use most of its engine power to keep pace with the vessel. Escorting can be either passive (when the tug is not attached to the vessel by towline) or active (when the tug is attached to the vessel by towline). Many studies have shown it is always better to make tugs fast to the vessel in case an emergency situation should occur, simply because more force can be applied through the towline to successfully resolve the situation. Studies

have also shown that using a tug to push a vessel produces a lesser force than when a tug pulls on a towline using the same tug. In Figure 3, the tug effectiveness curves illustrate the reduction in effective towing force that can be applied in short waves (H_s). The blue line shows how the effectiveness falls away when a tug is exposed to waves increasing in height whilst pushing a vessel, whilst the magenta line shows the reducing effectiveness of the same tug whilst pulling on a line whilst exposed to the same waves increasing in height. The red line shows how the effectiveness only reduces to around 60% whilst escorting vessels using an indirect pulling technique, which is a lengthy subject, so will not be discussed here. None of these curves takes into consideration the further reduction in effectiveness resulting from the tug having to keep up with the speed of the vessel, when the tug's power needs to be split between station keeping and applying the towing force to the towline. Knowing the capability of the tugs used for any escort duty or manoeuvring operation in all types of metocean conditions and emergency scenarios is paramount to handling a vessel safely, and protecting the environment.

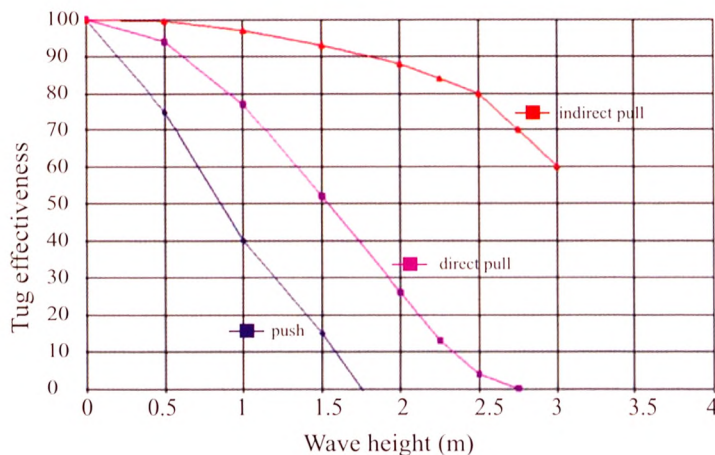


Figure 3: Tug Effectiveness in Short Waves

One of the most effective uses of a tug, especially whilst escorting a vessel through confined waters, is to tether it over the stern of the vessel (see Figure 4). This tug then effectively becomes the vessel's rudder whilst manoeuvring at low speeds, as it is able to apply a greater steering force than the vessel's own rudder. This is particularly important should the vessel incur a major mechanical failure to one or more of its critical machinery. In addition this tug becomes a means of arresting the vessels forward motion in the event that the vessel's main engine becomes unavailable, or the pilot does not wish to move the vessel's pivot point or

swing the vessel's heading by the transverse thrust from the rotation of the vessel's propeller.



Figure 4: Tanker being steered using a tethered stern tug

MARINE RISKS

Whilst at sea a ship's master is fully aware of the limitations of his vessel, and mentally (or otherwise) constantly monitors the risks to his vessel and staff on board. When approaching confined waters (*e.g.* port entry or a passage through a strait) the level of risk increases, therefore measures are routinely undertaken on board to mitigate such risk. This will include bringing on-line critical machinery and equipment, particularly for navigation, steering and main propulsion. Man power is also increased in the main areas of activity such as the bridge and engine room. When the risk increases to a level where mechanical failure or human error may incur damage to the vessel, impact the environment, possibly endanger life, and invite reputation damage to one or more companies and/or authorities, ship owners/charterers employ experienced pilots and tugs to ensure their vessel transits safely between the pilot boarding area and the chosen berth in the port. The pilot brings local knowledge and experience to the vessel's bridge team, which is invaluable to the ship's master who may never have visited that port before.

When in confined waters a vessel's master is fearful of the following credible emergency situations occurring:

- a) Steering failure resulting in rudder not moving
- b) A hard over rudder failure whereby the rudder swings to either hard over to port or starboard



- c) Main engine failure resulting from either a failure of the main engine or some machinery critical to the running of the main engine
- d) An electrical black out, but where the emergency switchboard cuts in the emergency generator after a period providing electricity to some critical equipment including on the bridge
- e) A full black out where the emergency generator fails to start up, resulting in a "dead" vessel.

The pie chart shown in Figure 5 provides a breakdown of the major risks to vessels whilst transiting and manoeuvring within confined waters. This is taken from statistics from ports around the world, and shows quite clearly that the major risk to a vessel is grounding during a transit or manoeuvre.

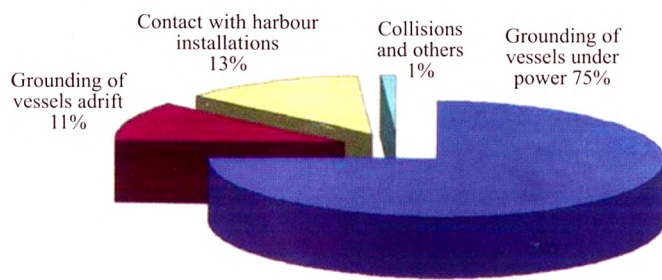


Figure 5: Breakdown of risks within confined waters

To avoid a vessel going out of control, and possibly grounding or colliding with other vessels or structures within the confined area, prudent and experienced mariners ensure there are sufficient tugs tethered to the vessel with sufficient capability to mitigate any major risk. This has been particularly recognised by the LNG industry, which is one of the reasons they have such an enviable safety record compared to other industries. Clients are therefore becoming more discernible when it comes to locating and the design of a modern marine terminal. Figure 6 provides a representative view of the primary risks to a vessel whilst in confined waters, together with the representative effects of risk reducing measures. You will note the least risk occurs when an experienced pilot with sound local knowledge handles a vessel using a sufficient number of adequately powered tugs for the prevailing metocean conditions encountered throughout the transit and manoeuvres.

As part of their training senior mariners (*i.e.* masters, pilots and tug masters) are well versed in the intricacies of design and manoeuvring capabilities of all types of vessels, from small mooring boats to the largest vessels

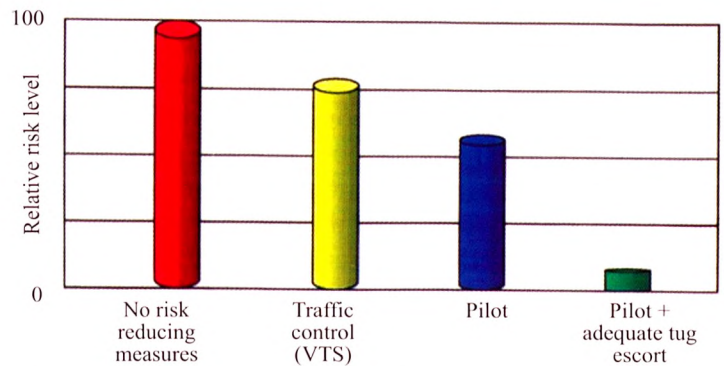


Figure 6: Representative effects of risk reducing measures

afloat. This includes the many designs of tug that are used for escorting and manoeuvring vessels in confined waters around the world. They also have a good knowledge and understanding of meteorology and oceanography (metocean), and in particular wave theory. In the marine world most things are sinusoidal; therefore understanding a vessel's six degrees of freedom as it moves through wave spectra at various headings and speeds is paramount to the survival of that vessel and its crew in adverse conditions. The Naval Architect designs a vessel taking into consideration the worse wave spectra likely to be encountered in open water covering the vessel's actual trading area, and ensure the vessel's movements remain as far away as possible from resonance with the anticipated wind and waves. Of course this cannot always be the case with large ocean going vessels; therefore the ship's Master is trained to avoid such situations occurring by taking whatever practical evasive action is required. Any incident or accident will have a damaging impact upon the reputation of any company, or port authority, particularly in today's negative media which has means of circulating the news around the world very quickly after the incident or accident has occurred. For this reason large companies are now realising the importance of introducing tougher safety regimes and policies associated with vessels that operate in a fluid marine environment. In the past they have concentrated on the safety of public perception of the shore terminal, but such marine accidents as the Amoco Cadiz, Torrey Canyon, Metula and Exxon Valdez have driven home both the high cost and reputational damage such marine accidents has on the rest of a Company. Law suites and insurance premiums are also very costly, so one should always have such matters in mind when designing a terminal, and ensure that all marine aspects are considered and incorporated very diligently.



Navigation Aids at the Berth

The sound use of a VTS (Vessel Traffic System) and electronic navigation and monitoring aids as a means of effectively managing the port, navigating the vessels safely within the port, and monitoring security under the ISPS Code, is practised in most ports around the world. From the terminal's perspective, the evaluation and location of suitable navigation and docking aids, especially the latest electronic navigation and docking aids, provide pilots with very accurate tools to assist in the manoeuvring and docking of ships even in reduced visibility conditions. Any new terminal design should therefore ensure these instruments are understood and installed correctly to provide the most benefit to the master and pilot whilst manoeuvring the vessel alongside so as not to damage the fenders or dolphins. Any such incident may also lead to penetration of the vessel's hull, which may impact the vessel's stability or expose the environment to possible damage.

More and more ports are introducing PPU (portable pilot units) so their pilots can safely navigate vessels within the port with pre-installed passage plans right up to the berth (as required by IMO) with a very high degree of accuracy. The benefit of these units is that they belong to the pilots, therefore they are well cared for and set-up to suit the pilot's individual needs. They also provide the pilot with constant information such as accurate distances off objects and other vessels, real-time metocean information, and AIS information. Some terminals are now incorporating the use of PPU as their main docking system. Using a DGPS-RTK Base Station located at the Harbour Office provides the pilot with more accurate and consistent information than traditional laser docking systems. Moreover some of these systems are designed to provide this information even if there is an interruption in the signal between the PPU and Base Station, giving the pilot sufficient time to either continuing berthing the vessel or abort the operation.

RESEARCH SIMULATORS

Today there are many navigation simulators located around the world. These have been built to provide the shipping industry, and any Navy, with a means of training deck officers in Bridge Resource Management and basic ship handling in accordance with the requirements of the STCW convention. These are becoming more complex as simulator schools ply for business, and many now have typical modern bridge

layouts and excellent visual displays covering from right ahead to at least two points abaft the beam on either side. Some of the latest simulators in fact now have full 360 degree visual displays. These simulators are very professionally run, usually by experienced senior mariners who are well versed in the training of deck officers, pilots and tug masters. There are only a few research marine simulators in the world with sufficient sophistication to ensure the accuracy of any research work needed to ensure the viability of any chosen jetty or berth location. What makes these simulators so different from the training simulators is the accuracy of the information being fed into their data base. This is derived from both live tank modelling of vessels where wave paddles can mimic the actual wave spectra at any time in any berth location, and from complex mathematical modelling of winds, waves and currents of the area confined by details of the actual topography and bathymetry around the location. Such information is compiled by experts in their own chosen field (*e.g.* oceanographers, meteorologists, mathematical modellers, *etc.*). Having this input of complex and sophisticated data compiled by individual experts is what distinguishes a research establishment and simulator compared to a training simulator. Unfortunately, this distinction is not always recognised, and a project can be left with incomplete or inaccurate studies as a consequence.

Research simulators are now also being used towards the beginning of project (usually at the start of FEED) to evaluate the correct location of a berth, using as much information that would be available at that stage. This is why it is important to get metocean equipment installed as soon as possible, so the real data can be added to the historical data to compile more accurate hind-cast data suitable for modelling the simulator data base. This should include the latest bathymetry available, and the local topographical limits affecting the location. Once set up the navigation research is undertaken using experienced senior mariners who are used to handling and manoeuvring the types of vessel visiting the berths and the tugs to be used. The vessels themselves are modelled from actual vessel data, and undergo sea trials in the simulator the same as in real life. If a pilot does not feel the vessel is reacting as it should in the simulator, then the research cannot continue. Research simulators also provide an initial estimation of the limiting metocean operating parameters for safely handling the ships whilst in confined waters, together with the minimum effective static Total Bollard Pull required to ensure the safe



and that berth, including credible emergency scenarios, in order to eliminate or minimize incidents and accidents as well as safeguarding the surrounding environment (especially in a hydrocarbon port). An additional benefit of using a research marine simulator for a project is they can be used for familiarising the local pilots and tug masters, including emergency scenarios, prior to them handling the first vessel to the new berth. This is usually done using a fully integrated simulator where there is a Full Mission Bridge and at least two electronically integrated, but separately located, Tug Simulators.

SUMMARY

Several complex topics have been briefly described in this paper to hopefully provide an overview of the types of marine issues that should be considered at the very beginning of selecting a workable and economic marine terminal site location. It should be part of due diligence, and a way of reducing risks on the project's Risk Register to at least ALARP as long as projects are open enough to include marine risk on the register whilst designing and constructing a *marine* terminal.

What complicates the site selection process further is that there is never one answer or set of marine studies that would provide the necessary answers for all sites. Successful site selection should always be based on sufficient and accurate data that has been compiled and analysed by those who are experts in their own disciplines. From the marine perspective, these would include experts in such fields as meteorology, oceanography, tank and mathematical modelling of wind, waves and currents, and include such experts as pilots, tug masters, master mariners, naval architects and simulator operators. A research simulator is merely a tool used by research establishments to demonstrate to its clients (the vast majority of who do not have any marine or shipping understanding and knowledge) the outcome of all of the studies undertaken on behalf of

the project. It provides an easily understandable way of presenting the information and results to the client, and has helped them many times in understanding the content and results to what to them must be very complex issues. Furthermore the time in the simulator allows the client to participate in the research, and try things they may have thought about but prevented by cost from pursuing. The research simulator is a very cost effective tool in this respect.

DEFINITIONS

Some nautical expressions/words and industry acronyms have been used throughout the text which the reader may not be familiar with. Explanations of these are provided below.

AIS	automatic identification system
ALARP	as low as reasonably possible
bollard pull	bollard pull is the pulling force of watercraft, particularly tugboats
DGPS	differential global positioning system
displacement	displacement refers to the mass of the water that the ship displaces while floating
draught	the vertical distance between the waterline and the bottom of the hull (keel)
EPC	engineering, purchasing and construction
FEED	front end engineering design
IMO	International Maritime Organization
ISPS	the international ship and port facility security code
LNG	liquefied natural gas
LNGC	liquefied natural gas carrier
metocean	meteorological and oceanographic
OCIMF	oil companies international marine forum
PIANC	international navigation association (PIANC)
RTK	real time kinematic
STCW	standards of training, certification and watchkeeping
tug	a tugboat (tug) is a boat that manoeuvres vessels by pushing or towing them
windage	that part of a vessel above the waterline, and subject mainly to wind forces