Table 1 **Indicative design working life categories for maritime works**

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures [A)]
2	10 to 25	Structural parts designed to be replaceable within a structure or facility of longer design working life
3	15 to 30	Structures dedicated to non-renewable natural resources, petrochemicals or similar industrial or commercial applications (such as open-piled jetties, mooring and berthing dolphins, Ro-Ro linkspans)
4	50	Common port infrastructure for commercial and industrial ports including reclamation, shore protection, breakwaters, quay walls
5	100	Common port infrastructure including breakwaters for ports of nationally-significant strategic or economic value. Infrastructure for regional flood defence or coastal management infrastructure

A) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.

18 Vessel data

Comprehensive details of vessels to be accommodated should be established as part of the functional design basis for ports and marine terminals.

Such details should be obtained from the relevant authorities, end-users, owners and operators for the actual vessels to be accommodated and those likely in the anticipated lifetime of the structure.

Vessel details and characteristics that should be taken into account include:

- cargo type, including any potentially hazardous cargoes;
- size and shape (laden and in ballast), including overall length, beam, draught, flat of side extents, air draught, wind areas;
- vessel handling and navigational requirements;
- cargo or passenger capacity (measured according to cargo type in cubic metres, tonnes, lane metres, TEUs);
- cargo or passenger handling requirements;
- product transfer manifolds types and position (for liquid bulk tankers and gas carriers);
- mooring equipment, including deck plans of winch and fairleads, mooring line type and capacities and winch capacities;
- vessel servicing and waste reception requirements;
- propulsion systems, including thrusters and other water jets that can cause erosion and scour;
- allowable imposed loadings on the hull.

NOTE 1 Characteristic dimensions and hull forms of many ships vary considerably according to function, age and operational region.

NOTE 2 Key overall dimensions of length, beam and draught of vessels are provided for preliminary planning purposes in Annex D for the following shipand cargo types:

- *refrigerated gas carriers – LNG;*
- *refrigerated gas carriers – LPG;*
- *liquid bulk tankers (oil, oil products and chemicals);*
- *dry bulk carriers;*
- *container ships;*
- *general cargo;*
- *Ro-Ro ferries;*
- *cruise ships.*

These values are approximations and are intended to be used for preliminary purposes only. General guidance on vessel dimensions can also be obtained from the Lloyd's Register of ships *[36] and from commercially available online vessel databases.*

*NOTE 3 Vessel handling considerations are discussed in Clause **19** and Clause **20**.*

A vessel's nominal size, tonnage or capacity may be expressed or provided to a designer as follows:

- gross tonnage (GT), which is determined in accordance with the provisions of the International Convention on Tonnage Measurement of Ships, 1969 [13)];
- deadweight tonnage (DWT), which is measured in tonnes and provides an approximate indication of the carrying capacity of the vessel;
- the displacement of the vessel, which is the actual mass of the vessel and is therefore the significant parameter for computing berthing energies and for calculation of other hydrodynamic parameters.

In addition to the displacement at maximum rated cargo capacity, displacements in the unladen and ballasted state should also be established for design purposes.

NOTE 4 Gross tonnage (GT) is not to be confused with gross register tonnage (GRT). GRT is an obsolete term, although it is still used to describe vessel size by some parties.

NOTE 5 For the purposes of preliminary planning, the relationships given in Annex D, Table D.1 may be used to estimate full load displacement from DWT or gas-carrying capacity. These values are approximations and are not be used for detailed design unless confirmed by the actual vessel characteristics.

NOTE 6 Product transfer manifold configurations for oil and gas carriers are given in the following publications:

- *Manifold recommendations for liquefied gas carriers [37];*
- *Recommendations for oil tanker manifolds and associated equipment [38].*

[13)] See http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-on-Tonnage-Measurement-of-Ships.aspx [last accessed 23 September 2013].

19 Navigation channels and ship manoeuvring

19.1 General

*COMMENTARY ON **19.1***

The navigational ideal for the design and layout of channels and harbour entrances would typically call for:

- *straight, wide approach channels, the direction of which coincides with the direction of currents, winds and of the highest waves;*
- *a wide harbour entrance;*
- *a large area within the harbour for turning and manoeuvring to jetties and quays, and adequate separation between moored and passing ships.*

Such an ideal layout can seldom be achieved, particularly for harbours on the open coast, for the two following reasons: firstly, the dominant currents rarely coincide with the direction of the highest seas, and secondly, aligning the channel with the highest seas tends to maximize the wave penetration into the harbour. Ports located in estuaries, where the hydraulic conditions are determined mainly by the tides, normally offer better protection for seagoing navigation, and many of the larger existing sea ports are situated in such locations. Access problems can still arise, however, because vessels can be required to follow the sinuous course of a natural channel and finally cross the tidal currents to the harbour entrance or riverside quays. Often extensive dredging works have to be carried out to meet the increasing navigational demands of larger vessels, and considerable maintenance dredging operations might be needed to remove siltation both in the artificially deepened access channel and in the harbour itself.

The layout, alignment and dimensions of approach channels and manoeuvring areas for ships should be determined according to:

- the size and handling characteristics of the ships that will navigate to and from the facility;
- the need for other ships to use the approach channels concurrently;
- the marine traffic density, both initially and as forecast in the future;
- the availability, manoeuvrability and capacity of tugs;
- the hazards associated with the products carried by the ships;
- the meteorological and oceanographic conditions at the particular location;
- the engineering constraints of channel construction and maintenance arising mainly from soil conditions and the coastal or estuarial morphological environment.

*NOTE As noted in Clause **13** and Clause **14**, attention is drawn to the recommendation to involve appropriate operational personnel, such as experienced masters and pilots, in the planning of new and modified channels and manoeuvring areas.*

19.2 Planning and design studies

Approach channels should be designed in accordance with the recommendations set out in PIANC-IAPH PTC II Report WG30 [N6].

NOTE 1 Guidance is also given in PIANC MarCom Report WG116 [N4].

The scope of numerical simulation studies at the design stage should be sufficient for the quantitative assessment of DSOL for the facility, in order to inform the design stage assessment of weather downtime for the operations envisaged at the facility (see Clause **21**).

NOTE 2 Planning and design studies for channels and manoeuvring areas consistent with the PIANC methodology are normally carried out using a staged approach, summarized in Table 2.

Table 2 **Typical planning and design activities for channels and manoeuvring areas according to design stage**

Planning/design stage	Typical activities for each planning/design stage
Concept design	Relatively rapid assessment of principal dimensions based upon preliminary environmental data and physical site data, preferably informed by advice from navigation experts/master mariners and local pilots/harbour authorities
	Layout and dimensions based upon empirical rules and limited/simplified navigation simulations
	Further definition of vessel parameters and operational principles as the basis of detailed design
Detailed design	Development and refinement of the concept design informed by additional environmental and physical site data and by additional consideration of operating parameters and risks
	Metocean conditions for the proposed layout predicted using numerical simulation of wave and currents
	Real-time navigation simulations (preferably including full mission, but can be desktop when agreed with the operator to be appropriate for the planned operations) to fix and optimize layout and make assessment of operating limits on environmental conditions to be applied in the operating phase
	Morphological studies to assess potential for infill and optimization of capital versus maintenance dredging
	Dynamic studies of ship vertical motions to determine UKC requirements
Marine traffic assessment and quantitative risk assessment	Verification of design where required considering risk of collision or grounding on quantitative basis by marine traffic risk analysis and other studies, especially for: heavily utilized channels; busy ports with multiple terminals and mixed vessel types adjacent to multi-user channels; and hazardous cargoes
Operational planning	"Full-mission" simulations intended to define operating procedures in detail, for training/familiarization of masters, pilots and tug crews and to support risk assessment and contingency planning prior to the start of operations or introduction of different ship types in an existing channel or turning area

19.3 Vertical channel and manoeuvring area dimensions

19.3.1 General

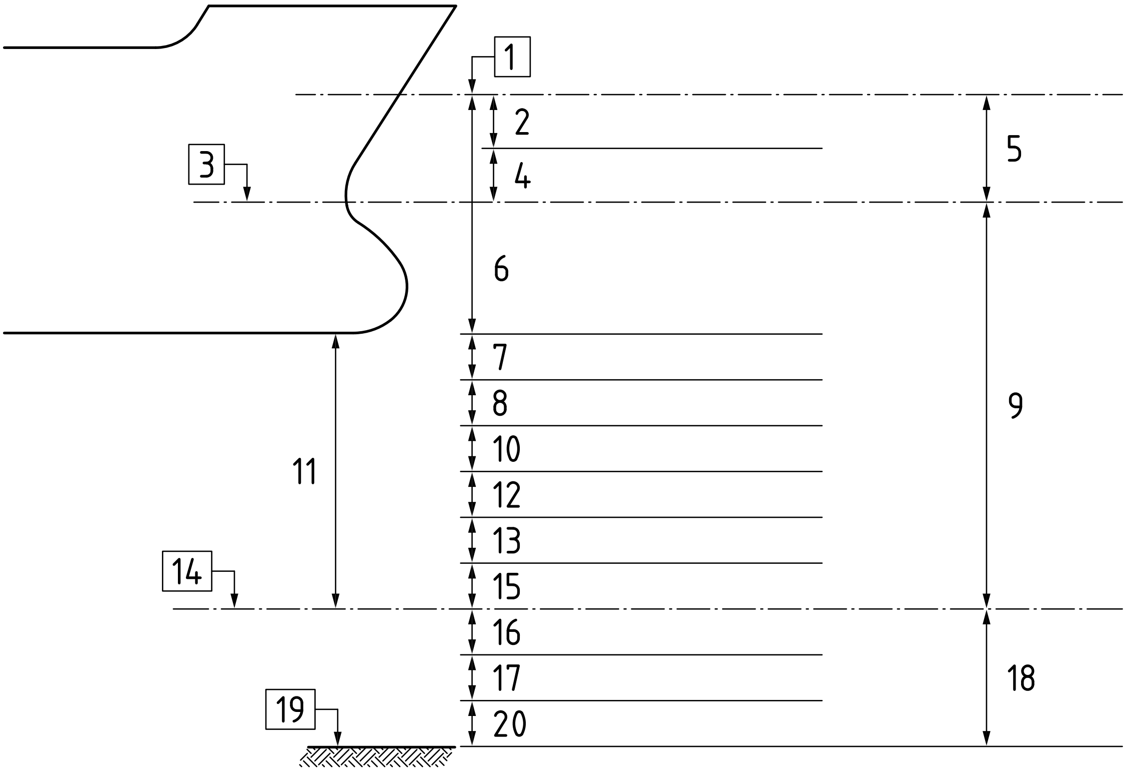
Vertical channel dimensions should be assessed based on the applicable depth factors and sub-factors set as follows:

- water level factors:
  - reference level (datum);
  - design water level;
  - tidal and meteorological effects;
- ship factors:
  - static draught;
  - allowance for static draught uncertainties including trim and list;
  - change in water density;
  - ship squat;
  - dynamic heel;
  - wave response allowance;
  - net UKC/manoeuvrability margin;
- bottom factors:
  - allowance for bed level uncertainties;
  - allowance for bottom change between maintenance dredging campaigns;
  - dredging execution tolerance;
  - muddy channel beds.

The depth factors are shown in Figure 1.

PIANC-IAPH PTC II Report WG30 [N6] provides "rule of thumb" guidance on nominal channel depths below design water level for preliminary use in conceptual design. These range from 1.10 × maximum design vessel draught in protected inner channels, with vessels at low speed, to 1.3 to 1.4 × maximum design vessel draught for outer channel environments subject to heavy swell. These factors allow for dynamic response of ships, including squat- and wave-induced motions, and should be taken into account only for draughts greater than 10 m. In any situation, additional allowances of 0.5 m (inner channels) to 1.0 m (outer channels) should be made to allow for the risk of bottom contact for firm or hard bottom types. Ship or fleet operators might have their own particular UKC policy, and should be consulted at an early stage in planning of a facility where such an operator is a stakeholder.

Figure 1 **PIANC channel depth factors**



Key

1 Design water level
2 Tidal offset during transit and manoeuvring [A)]
3 Reference level
4 Allowance for unfavourable meteorological conditions [A)]
5 Water level factors
6 Static draught
7 Allowance for static draught uncertainties
8 Change in water density
9 Ship-related factors
10 Squat
11 Gross UKC
12 Dynamic heel due to wind and turning
13 Wave response allowance
14 Nominal channel bed level
15 Net UKC
16 Allowance for bed level uncertainties (sounding and sediment conditions)
17 Allowance for bottom changes between maintenance dredging campaigns
18 Bottom-related factors
19 Channel dredged level
20 Dredging execution tolerance

NOTE This figure is based upon PIANC-IAPH PTC II Report WG30 [N6] and PIANC PTC II Report WG14 [39].

[A)] Values can be positive or negative.

19.3.2 Operational philosophy considerations

*COMMENTARY ON **19.3.2***

Key design and operational philosophy choices for a given location and range of design ship types and sizes are as follows:

- *acceptability of tidal limitations on entry or exit for some or all ships;*
- *maintenance dredging strategy, specifically:*
  - *depth of capital over-dredge to allow for siltation between maintenance dredging campaigns;*
  - *adoption of nautical depth approach for channels with beds comprising a layer of fluid mud of increasing density.*

The following factors should be taken into account according to the approach taken.

- Adoption of a tidal limitation can offer significant reduction in requirements for both capital and maintenance dredging, but results in limitations both on the overall capacity to handle shipping (and possible increased encounter frequency and collision risk of traffic in the channel during tidal passage windows) and in terms of downtime and waiting time for shipping. At some locations, tidal currents can also pose a limitation to channel transit or port entry or exit at certain stages of the tide. It might sometimes be possible to take advantage of reduced vessel dynamic response (a ship factor) at lower tidal levels if lower wave or swell action is present at times of lower tidal elevation.
- Adoption of the nautical depth approach can offer potential advantages in optimizing capital and maintenance dredging, particularly in areas of high siltation and other environments with near-bed fluid mud layers. However, there are significant practical issues and risks that should be addressed in implementation, including the following.
  - A practical criterion for the nautical bottom should be defined (e.g. selection of the physical mud characteristics acting as a parameter for the nautical bottom approach and its critical value).
  - A practical survey method should be proposed to determine both the acceptable level and the water–mud interface in an efficient and reliable way.
  - A minimum value for the required UKC relative to this nautical bottom should be established, noting the consequences of bottom "contact" for a fluid mud bottom, compared to a hard bottom.
  - The effect on the behaviour of ships in these situations should be assessed to the satisfaction of ship operators and pilots, coupled with training of operators, assessment of risks of adverse effects on controllability and manoeuvrability, and contingency plans to deal with such effects, if they are expected to occur.

NOTE 1 There is no guidance that specifies a particular density to define the nautical bottom, as there are many parameters that have an impact, including the density and rheological nature of the mud, which can vary from site to site and also within any particular site. As a consequence there is a range of values used around the world from 1 100 kg/m³ to 1 250 kg/m³, and in some cases there are multiple criteria, depending on the UKC. A pragmatic approach is to start with 1 150 kg/m³ unless there is clear evidence that 1 200 kg/m³ or greater is acceptable for the site in question, noting that it is a highly site-specific issue and will require a considerably detailed study to justify higher values. For hazardous cargoes such as liquefied gases or chemicals, ship operators are often less tolerant of grounding risk than for other types of shipping and might impose lower density limits for definition of nautical bottom than required by operators of other shipping. In addition, and in particular for gas carriers, the ship's cooling water intakes are generally located towards the bottom of the ship's hull and so can be affected if there is a high concentration of mud or sediment in the water.

NOTE 2 PIANC PTC II Report WG14 [39] provides guidance on development of maintenance dredging strategies which can be used for channel design optimization. For additional information regarding implementation of nautical depth in high turbidity regimes, see PIANC MarCom Report WG102 [40].

19.3.3 Ship factors

*COMMENTARY ON **19.3.3***

Channel depth assessment requires a comprehensive assessment of the dynamic behaviour of the design ship or ships when navigating through a channel or when manoeuvring in a port or near a marine terminal, including:

- *ship squat;*
- *dynamic heel;*
- *wave response.*

Squat is experienced by a ship as it moves through water, and the effect is increased in shallow water and in channels where hydrodynamic interaction between the water body and the moving ship is further affected.

The effect arises from the displacement of water, which causes an increase in return currents along the sides of the vessel and between the channel bed and the underside of the vessel. This is offset by a lowering of the adjacent water level, causing the vessel to experience sinkage and change of trim.

Additional squat is experienced by each of two ships when they pass, the effect being accentuated with reduction of UKC and vessel separation, as well as with an increase of speed. Additional sinkage is also caused by sailing in the proximity of a channel bank.

Dynamic heel arises during vessel turning and might be significant as a contributor to overall channel depth requirements in channel bends and in turning areas. During turning of a vessel, heeling can occur depending on a number of factors including ship's speed, rate of turn and tug line forces. Heel is defined here as the non-oscillating component of motion from environmental and tug forces, whereas roll is the oscillating component of ship response to waves.

The other component of the ship's dynamic response to channel depth requirements is the wave-induced response causing vertical and roll motions of the ship. The vertical component of response under waves and swell depends on the wave height and direction and the ratio of the wave length to the relevant characteristic dimension of the ship, i.e. length for pitch and heave and beam for roll. These factors determine the forces exciting the motion. The response of the vessel to these forces is mainly governed by the ratios of its natural frequencies in heave, pitch and roll to the encountered wave frequency, and by the damping of the motion in these modes.

In shallow water conditions the small UKC causes both the natural period, due to increase in added mass, and the hydraulic damping in each mode of movement, to increase.

The static draught of vessels for channel depth assessment should take into account:

- the maximum draught at the bow or stern if the ship does not have an even-keel draught;
- trim and list;
- the presence of thrusters or propulsion equipment which extend below keel level.

Given the complex hydrodynamics of vessel channel interaction giving rise to squat, there is significant uncertainty in the prediction of squat for channel design purposes using available empirical methods. This uncertainty should be taken into account in determining and optimizing overall channel depth requirements.

Response amplitude operators (RAOs) from numerical modelling of vessel response, or other suitable methods for assessing vertical ship response, should be used to determine vertical motions under expected wave conditions.

Physical modelling should be used as an alternative to numerical modelling in conditions of low UKC or other circumstances where numerical modelling cannot accurately simulate vessel dynamic response.

NOTE Use of physical models is less often required since numerical methods are usually adequate.

19.3.4 Net under-keel clearance

*COMMENTARY ON **19.3.4***

The gross UKC in channel design comprises all the components of draught and vertical dynamic response and then a further term referred to as the net UKC.

In preliminary concept design this net clearance can simply be taken as a figure of 0.5 m to 1.0 m depending on the nature of the bed, which in turn determines the consequence of contact between the ship's hull and the bed.

The definition of such a net UKC can also be used in detailed design in accordance with PIANC-IAPH PTC II Report WG30 [N6], where a deterministic approach is taken, but it is frequently more appropriate to adopt the probabilistic or semi-probabilistic approaches defined by PIANC-IAPH PTC II Report WG30 with a minimum manoeuvrability margin (MM) to ensure that reduced UKC does not result in inadequate ship manoeuvrability. Practically, this would normally be a concern only in sheltered inner harbour areas where the allowance for dynamic response caused by wave action would otherwise be low. PIANC-IAPH PTC II Report WG30 proposes a minimum MM of 5% draught or 0.6 m, whichever is greater.

The overall design gross UKC should be assessed by summation of the components of draught and vertical dynamic response and an additional net UKC to provide a safety margin against bottom contact.

19.3.5 Design philosophy

NOTE PIANC-IAPH PTC II Report WG30 [N6] envisages a concept design stage using simplified deterministic approach where applicable depth factors are assessed and combined arithmetically.

The detailed design should include a further assessment of depth factors using comprehensive analytical methods. When sufficient statistic characterization of the uncertainties and variability of the depth factors can be obtained, detailed design may allow for optimization of total depth requirements using probabilistic or partially probabilistic methods.

For probabilistic or partially probabilistic methods of depth assessment, limiting design criteria should be defined with respect to acceptable probability of contact between the channel bottom and the ship's hull or keel.

PIANC-IAPH PTC II Report WG30 [N6] indicates possible approaches to the definition of such criteria, but there are no internationally recognized criteria, and any such criteria should be agreed on a case-by-case basis with the operator in conjunction with ship operators and harbour authority when appropriate, taking into account the risks for different ship types, cargo types and channel bottom characteristics.

Probabilistic design methods should be used only when the quality and extent of the input data are sufficient for these methods. When only partially or incomplete data sets are available, partially probabilistic or empirical methods should be used.

19.4 Horizontal channel and manoeuvring area dimensions

19.4.1 Alignment and width of channels

NOTE 1 The width of access channels is governed mainly by the steering characteristics of the vessel in response to the pilot and helmsman when subject to external disturbances such as the hydrodynamic effects of cross-currents, wind, waves, bank effects and other traffic. Large ships normally take a relatively long time to respond to any change in circumstances, and can be rendered even more sluggish in their response to a given force applied by the rudder, due to the increase in the hydrodynamic forces and added mass of the ship when the UKC is small. Thus in negotiating channels with bends, large changes of helm and engine speed are common (although are often brief), and even in straight restricted channels vessels can take a sinuous course.

Channel width and alignment should be determined according to the recommendations of PIANC-IAPH PTC II Report WG30 [N6], using empirical rules for initial sizing and numerical simulation of vessel approach and departure to confirm and optimize the layout and horizontal dimensions in later stages of design.

Selection of channel alignment should be primarily by the needs of safe and efficient navigation, balanced against the constraints of physical and environmental conditions and the associated engineering considerations, such as the minimization of capital and maintenance dredging. To achieve enhanced operability and minimize weather downtime and navigation risks:

- bends or curves should be minimized, and bends avoided at or close to the ends of the channel and at harbour entrances;
- channels should be aligned, where possible, so that prevailing wind, currents, waves and swell are not acting across the channel (and thus causing the ship to deviate from its course).

The effects of cross-currents and wind on manoeuvrability have the greatest effect on a ship at low speeds in inner channels and final berth approach. Where strong tidal currents exist, it might be necessary to limit approach and departure to defined periods around slack water, which should be taken into account in downtime assessment.

NOTE 2 The definition of channel and fairway dimensions and elements of channel width as used by PIANC-IAPH PTC II Report WG30 [N6] are shown in Figure 2 and Figure 3. A fairway indicates a wider space that can be used by vessels with shallower draught than vessels using the main deep draught channel.