

Landing Craft - Choosing the Right Tool for the Job

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ABSTRACT

Far from being 'simple ships' [Ref 1] the design of landing craft poses some unique and often taxing problems to naval architects and engineers. The increasing speed and safety aspirations for the next generation of landing craft further exacerbate these issues. This paper illustrates how small changes in the needs of the end user can have a significant effect on the design, leading to the need for radical changes, if cost effective and appropriate technologies are to be incorporated.

The paper identifies how the end user's requirement for offload of vehicles and troops by sea, dictates the cross-over point between the choice of a standard or more exotic hullform for a landing craft. The paper also discusses the impact on the design as a whole, in particular on propulsion equipment selection. The background to this investigation is a BMT concept design for a higher speed LCM.

Designers must ensure that they have the knowledge to properly understand the solution space. Without this they cannot be in a position to advise on how the best and most cost effective balance between desired capability, operating concept and vessel design may be achieved.

INTRODUCTION

Outline

Landing craft may seem relatively simple vehicles given their role, but a closer look at the environment in which they operate and the evolutions they perform shows that the designer has a number of complex challenges to overcome. These challenges are amplified given the design's sensitivity to requirement change. The paper explores the impact of this sensitivity in the context of the need to apply cost effective and appropriate technologies to landing craft design, with the objective of ensuring that the requirement sponsor understands how to ensure that they obtain the right tool for the job.

Context & Background

To provide context it is necessary to briefly describe the characteristics and role of the landing craft for which the arguments in this paper apply. The paper discusses issues associated with landing craft of the size normally labelled LCM (landing craft medium) or LCU (landing craft utility): approximately 25 to 30 metres in length with a loaded displacement ranging from around 120 to 240 tonnes. It is these craft that are often transported by and/or are interoperable with a large amphibious ship with a well dock such as an LPD (landing platform dock) or LHD (landing helicopter dock).

Typically, an LCM is used to transport vehicles and troops from the host ship to land and vice versa. Historically, the host ship has operated relatively close to the land in question (say 5 to 10 nautical miles). Many navies now seek to adopt a concept of operations that offers increased operational and tactical surprise whilst reducing the vulnerability of the host ship to inshore threats. This inevitably leads to a requirement to launch assaults using landing craft, from further offshore.

REQUIREMENTS AND CONSTRAINTS

The Need for Speed

When considering the procurement of a new landing craft to meet a new user requirement, or when developing options with existing landing craft to meet a change in the user's requirement, the designer must ensure that the basis of the performance requirement (for example payload capacity or speed) is properly understood.

Consider an example of an amphibious assault being conducted using a fixed number of landing craft within a fixed period of time. If a requirement exists to launch the assault from further offshore there is a direct requirement to either increase the speed or payload capacity of the landing craft. It is in this situation where a traditional landing craft design may no longer be appropriate. Determining the point at which this occurs and how this is influenced by the user requirements is an important part of ensuring that a cost effective solution can be obtained.

The relationship between speed, payload capacity and range for a single landing craft is summarised in Figure 1.

Total payload to be transferred:	M
Total period to transfer payload:	T
Payload transfer distance:	d
Payload capacity of craft:	m
Time to load and unload:	c
Number of transfers required:	$n = M/m$
Period for one return trip:	$t = T/n$
Mean speed for return trip:	$V = 2d/(t-c)$
Kedge distance:	d_k
Kedge speed:	v_k
Time to transit surf using kedge:	$t_k = d_k/v_k$
Maximum speed ratio (light/deep):	r
Maximum speed light:	$V_{lmax} = r \cdot V_{dmax}$
Maximum speed deep:	$V_{dmax} = (d-d_k) \cdot (r+1) / (r \cdot (t-c-2t_k))$

Figure 1 – Terminology / Speed and Range Relationship

The relationships in Figure 1 assume the following:

- The time to accelerate to maximum speed and also that to return to a standstill is negligible;
- The variance in turnaround time is small – i.e. term ‘c’ remains fairly constant across the range of payloads and landing craft designs;
- Other factors such as the keedge speed and distance are constant.

For an example total payload (‘M’) and transfer period (‘T’), the relationship between speed and range is illustrated in Figure 2.

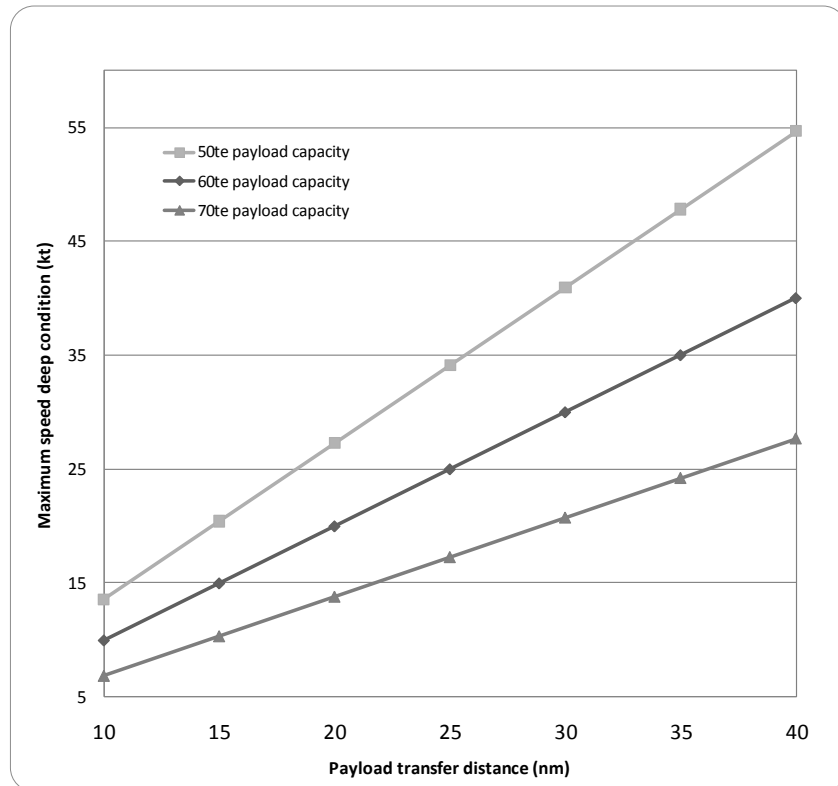


Figure 2 –Example Speed and Range Relationship

As one would expect, it is possible to see even from this crude example that the speed requirement is strongly influenced by both the distance through which the payload must be transferred and the payload capacity. Given the number of transfers required must be an integer (‘n’ in Figure 1), payload capacity should be tailored to ensure that the speed requirement is minimised. This is easier said than done as the influence of the propulsion system on the general arrangement is significant. Finding the right balance between payload capacity and speed can be challenging when considered in the context of the whole design.

Safety Issues

With regard to stability safety, some navies aspire to operate landing craft with levels of safety commensurate with other naval craft, or commercial craft of a similar nature. This brings into play alternative, more appropriate rules for damage stability than may have been applied in the past, for example, a requirement to withstand two compartment damage. When this is combined with other requirements associated with high speed operation (for example the requirement to survive bottom raking damage defined in the IMO High Speed Craft Code 2000) it will drive the arrangement of the internal subdivision and intensify the challenge for the designer.

The increasing of speed of operation requires careful consideration of the human factors aspects of the design. An example is the requirement for crew and passenger seating: provision of the latter in particular has the potential to severely constrain the payload capacity of the craft if not dealt with carefully in the early stages of the design.

Geometry Constraints

Landing craft will usually have a shorter service life than their host ships and not always will both the host ship and landing craft replacement programme coincide. Therefore, despite logic dictating that the host ships should be designed around the landing craft which they carry, invariably, the landing craft must be designed to fit existing well dock dimensions. A further requirement for interoperability across the fleet and amongst allies can effectively freeze the dimensional footprint of landing craft from one generation to the next.

Length and beam are constrained by the plan geometry of the host ship well dock. The draught and air draught constraints are more complicated and must include consideration of the relative motion of the landing craft and the host ship.

The constraints on landing craft geometry in the vertical plane are illustrated in Figure 3. The relative vertical motion between host ship and the landing craft will dictate the magnitude of the motion allowance above and below the landing craft ('c' and 'd'). These dimensions, in conjunction with the well dock height ('e') will define constraints on the draught and air-draught of the landing craft. Determining the relative motion is a highly complex problem, and it is likely that the designer will include some additional margin of safety to avoid problems which further constrains the landing craft dimensions.

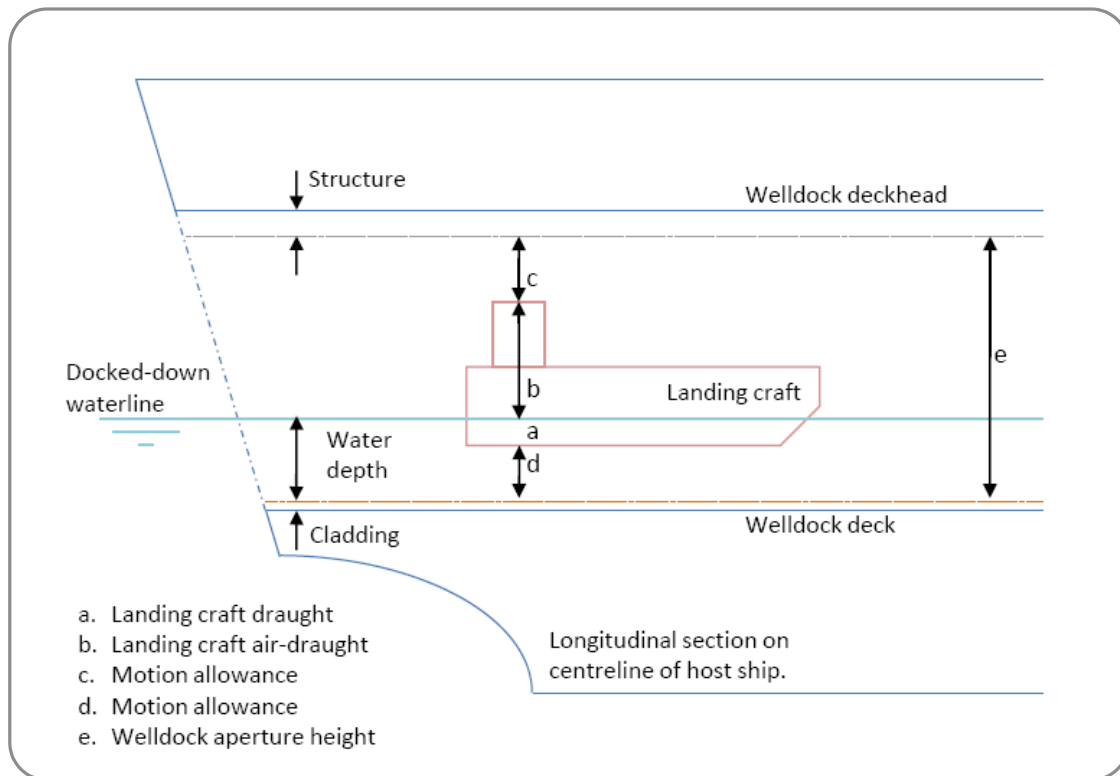


Figure 3 – Well Dock & Landing Craft Vertical Constraints

These dimensional constraints define the solution space within which the designer must strive to develop a design that meets the speed and payload requirements. In addition, mass may also be constrained by the structural properties of the well dock deck.

As the designer looks towards lower resistance and higher power solutions, the dimensional constraints will serve to hamper progress; for example the lower resistance hullforms with less waterplane area generally require a deeper draught ('a'); the internal payload area of the landing craft is influenced by not only external dimensions, but also the propulsion machinery arrangement (especially maintenance access, exhaust and air intake arrangements).

In summary, due to the constraints on landing craft geometry, the increasing speed requirement is likely to have a more significant impact on the design of the landing craft, than it would for other larger vessels.

THE IMPACT OF REQUIREMENT CHANGE ON SPEED

Hullform & Propulsion Variations

Figure 4 illustrates approximate resistance - speed relationships for three different landing craft designs in calm water. Each design can carry the same payload deadweight of around 60 tonnes; and each can operate in conjunction with the same generic host well dock equipped ship.

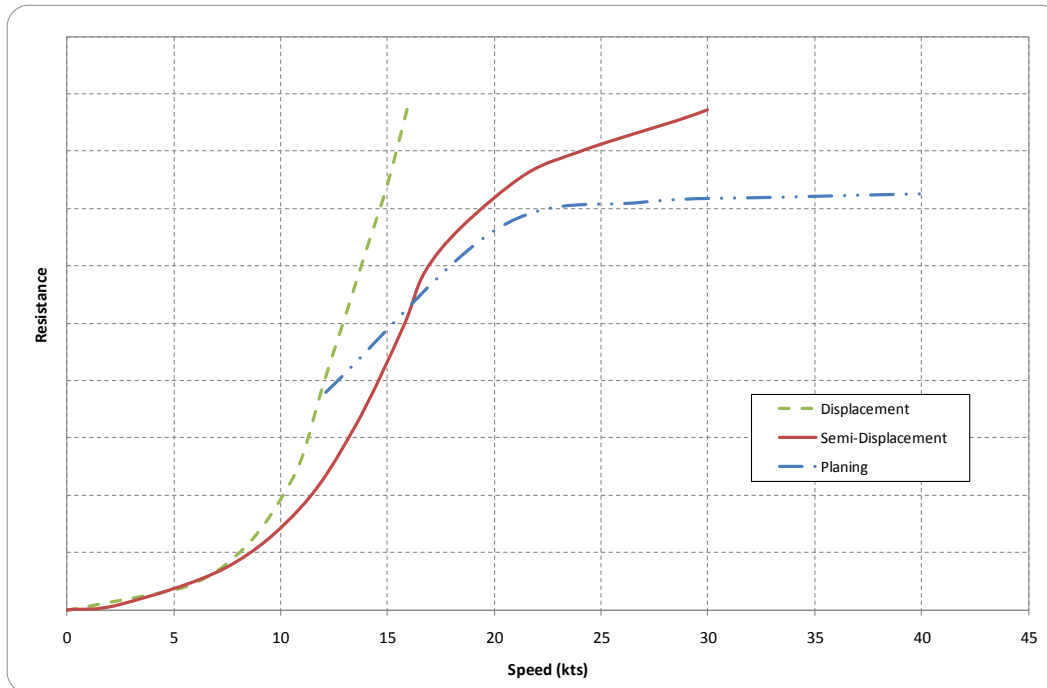


Figure 4 – Resistance/Speed Relationship for Alternative Landing Craft Hullforms

Each of the designs operates in a different regime: displacement, semi displacement and planing. The semi displacement form is represented here by a 25m long BMT LCM design that uses a derivative of the BMT Tri-Bow Monohull hullform [Ref 2]. The displacement and planing designs are representative examples of similar sized designs.

There are also differences in the power and propulsion systems for each of the designs. These differences ultimately manifest themselves as technical risk and cost. As one would expect, in broad terms, the faster you want to go, for the same capability, the likelihood is that you will pay more per knot.

Note that the curves presented in Figure 4 are for calm water. In a moderate sea state (e.g. Sea State 3 to 4) the speed loss due to waves for the planing form is likely to be significantly greater than for the semi-displacement BMT LCM design [Ref 2]. If assaults are launched from further offshore, the landing craft will become increasingly exposed to fully developed seas and it may be argued that in operational areas it will be subject to higher sea states for a greater proportion of its time at sea.

Assuming that the hullform and geometry remains constant, it is self-evident that as the speed requirement increases the thrust and installed power must also increase or the displacement must decrease. There will be a corresponding increase in both the initial procurement and through life cost. However, with no corresponding increase in the available weight or space budgets, the designer must be increasingly creative with how they install the required power and deliver the thrust.

Taking the case of the conventional displacement hullform, the power curve presented in Figure 4 demonstrates that the additional power required to achieve each additional knot of speed increases exponentially. In response to this, for small increases in the speed requirement, the designer may initially simply choose to specify larger engines and propulsors. However, there comes a point where larger engines and propulsors can no longer be accommodated in the existing hullform. This may be due to clear deck height in the machinery space or draught limiting the propulsors dimensions for example. The designer then may consider specifying a greater number of smaller engines and propulsors. There is potentially now a step change in cost as an additional entire drive train has to be procured and maintained through life. However, each case should be considered individually as there are some exceptions to the rule associated with specific engine size and manufacturer selection.

Once this avenue is exhausted the designer is left with looking for greater power density and an efficient means of delivering that power as thrust. Greater power density is likely to mean specialist engines from a high speed engine supplier. These are likely to be extremely costly as they are manufactured in small production runs and built using exotic materials to achieve the high power density. So not only does the power requirement increase exponentially, so does the cost associated with integrating that power into the craft.

It is also necessary to take into account the weight that the additional power will add to the craft; this not only exacerbates the power problem further but also will force the designer to consider reducing either payload deadweight, fuel or lightship weight in order to maintain the same loaded displacement. The impact of adjusting payload capacity on the speed requirement is demonstrated earlier in Figure 1 and Figure 2.

It is not only propulsion costs that will increase with an increasing speed requirement; other areas include the structural design. The structure will need to withstand increased loading, particularly at the forward end of the hull form and the ramp. Also, in response to the increasing mass of the propulsion system, the designer may be forced to use aluminum rather than steel as the main structural material, further increasing build and through life cost and reducing the resilience of the design.

Cost - Performance Balance

The problem obeys the law of diminishing returns. There comes a point where the investment required to achieve a little more speed, exceeds the return in performance. Figure 5 illustrates this for the conventional displacement hullform. The curve is theoretical and is provided solely as an illustration of the problem.

The curve is of design performance plotted against cost and shows that once a certain performance level is achieved, further expenditure will only return a very limited increase in capability. In terms of speed there is ultimately a physical limit on how much performance can be achieved from a certain type of hullform. In the context of the discussion regarding speed, this physical limit may be defined by the balance of installed power and payload capacity, the ability to control the craft at higher speeds or a point where the safety and comfort of the crew and passengers is jeopardised due to the seakeeping response of the landing craft.

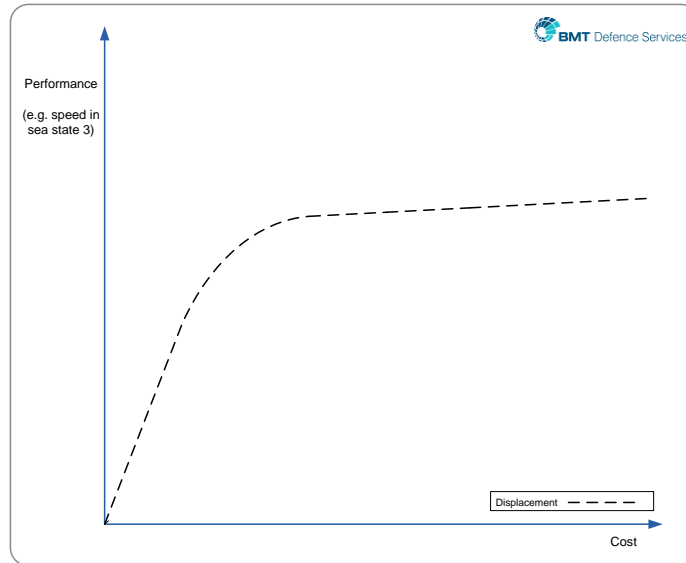


Figure 5 – Cost / Performance Curve for Displacement Hullform

Figure 6 includes the curves for the planing hullform and semi-displacement hullform. Each hullform has a unique cost/capability curve dependent on its relative effectiveness over the range of performance. The planing form curve increases at a shallower angle than the displacement form indicating a greater cost is required to achieve the same capability at the lower levels. This is due to the higher costs associated with the design and build of a more complex planing craft (for example: increased build accuracy, increased material and equipment cost etc). However, there comes a point in the level of investment where the two curves cross. Beyond this point the landing craft owner will begin to reap the benefit of the higher investment as greater capability can be achieved for lower cost. Identifying where this point is in terms of speed and then range is important for the designer.

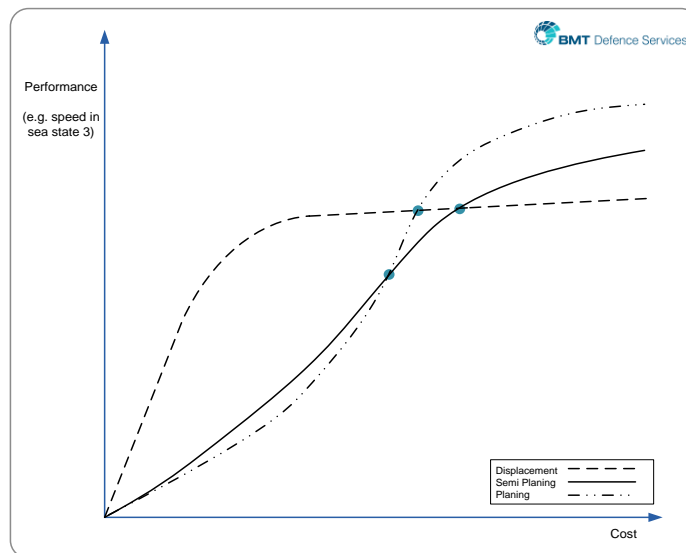


Figure 6 - Cost / Performance Curve for Alternative Hullforms

The curve for the semi-displacement hullform is a slightly different shape again. The curve rises initially at a slightly shallower angle than the planing hullform reflecting the possible additional build cost of the complex shape of the BMT Tri-Bow design. The curve then rises more rapidly to cross both the planing curve and the displacement curve before tailing off as it reaches its point of diminishing returns. This reflects the efficiency of the hullform – i.e. reducing the propulsion system requirements (in comparison to the planing form for increase speed in a moderate sea state).

The three intersections of the curves are the balance points between the various designs and dictate the cross-over point where a more exotic hullform may offer a more cost effective solution to the problem than a more traditional form, or where the converse is true.

Figure 7 illustrates an example situation where a designer may have selected a traditional displacement form for a landing craft designed to meet a particular speed requirement (the design point illustrated by the red cross on right hand side of figure). Further parametric investigation by the designer will show that a more efficient, less costly solution may exist via adoption of a more exotic hullform – something that may have been dismissed as too costly at the outset.

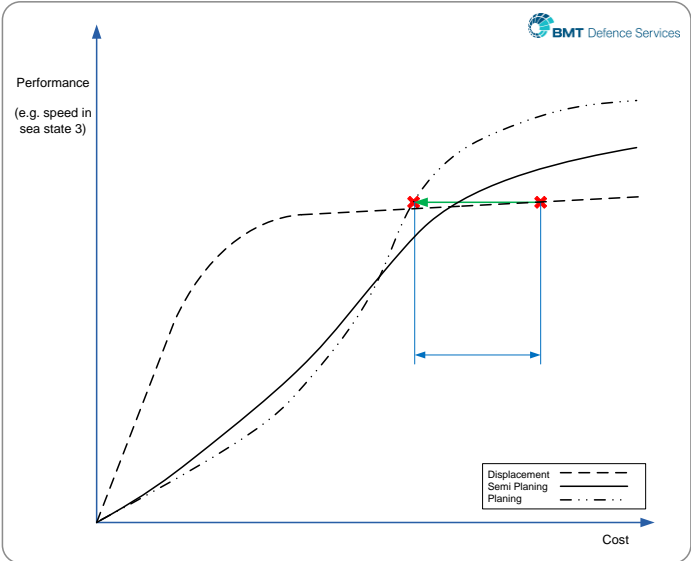


Figure 7 - Cost / Performance Curve – Example of Inefficient Solution

Figure 8 illustrates a second example situation where given the speed requirement the designer has been forced to move away from a displacement hullform and adopt a planing form for the design. However, it is clear from the plot that if the capability requirement could be reduced very slightly, the design could return to the displacement hullform option and the subsequent cost savings could be very significant.

