DISCUSSION

THE EXTENSION OF SYSTEM BOUNDARIES IN SHIP DESIGN

A Hagen, DNV/Norwegian University of Science and Technology, Norway
A Grimstad, DNV, Norway

(Vol 152 Part A1 2010)

COMMENT

Professor D Andrews, University College London.

This paper is to be welcomed as it argues for the broadening of ship design from what has generally been too narrow a focus in most cases due to the ship design process being a largely evolutionary approach. Given current environmental preoccupations, the authors' approach is strongly driven by concerns over sustainability, in contrast some other broadening approaches have, for example, done so with an emphasis on ship architecture [23, 24]. Thus the authors' approach seeks to make the profession recognise that even at the preliminary stages of ship design that it is complex and challenging but more appropriate in having a wider boundary than a directly (or simplistically) economic one.

The desire to be more comprehensive is perhaps overly constrained by the view in Figure 4 that all ships are part of a transport system, as such an approach would exclude all service vessels (e.g. OSVs, naval vessels, fishing craft, pleasure craft) and, perhaps, even cruise ships, which primarily entertain, rather than transport, passengers. Perhaps a better super-system is a fleet, which could encompass all form of transportation as well as ships that go to sea to conduct evolutions as part of a wider service system [25].

At the start of Section 3.1 the authors remark that the ongoing development of a ship design can influence the owner's views to the extent that "requirements themselves change". This is strongly supported as it is good (i.e. pragmatic) systems engineering, unlike the current obsession, in for example some naval ship acquisition, with Requirement Engineering. This, naively, believes that the customer can endlessly investigate a "functional" (i.e. non material specific) statement of the requirements, rather than adopt a Requirements Elucidation process, as advocated by this commentator [26]. However this support by the authors for a more sophisticated view of initial ship design is somewhat diminished in the next sub-section by reference to Dillon [15] and an apparent endorsement of the view that the "Owners requirement " is the design start point. This commentator is clear that a sensible owner should initially limit themselves to a broad expression of need and that this would then be much more consistent with the ship concept process being essentially a genuine dialogue, which would jointly elucidate the "wicked problem" [16] of what is sensible and affordable. It is also pleasingly noted that the latter problem has been recognised by the authors as fundamental to the nature of ship design.

The authors go on to argue for "rapid re-entry" or flexibility in tackling the steps in the design spiral (or 3-D cone) rather than a, seemingly, mechanistic sequence implied by the left hand "slice" of Figure 7. This comment well points out the danger in any attempt to describe the design process for physically large and complex systems, such as sophisticated ships. No representation is really without its flaws in trying to represent a very complex process [16]. Every design on which this commentator has been involved has been different from every other in the actual process and, importantly, each design's precise design driver(s), which should alert the design team to alter the design focus and even the sequence in which the various aspects are tackled. It was for this reason that this commentator has advocated every designer should at least use or, best, create whatever model of the process they feel most comfortable with. To this end, the recent IMDC State of Art Report on Design Methodology reproduced some 27 diagrammatic representations of the ship design process, each with key statements to show their particular merits or applicabilities [27]. The authors are therefore asked to comment on that set of representations to say which they find most useful and whether there are others that they might wish to see added to the IMDC set.

Professor V Bertram, FutureShip GmbH, Germany

I congratulate the authors to their article. The theme of "design for transport chain" comes at the right time and is highly important. Naval architects traditionally system designers. Considering larger systems like fleets or intermodal transport chains is a natural extension of the traditional single ship design. It adds an important and lucrative design level (both in terms of micro and macro economies).

The basic idea is not new, but largely forgotten or ignored. The concept of designing maritime transport chains dates at least back to the 1970s when Prof. H. Schneekluth presented economic optimization on fleet levels. [Aggregated summaries of his work in English can be found in Ref 28] However, legal and economic boundary conditions as well as technical options have changed drastically in the last 40 years. Unfortunately, as the authors point out so rightfully, the tools for single ship design have evolved much more and there are still very few models for addressing intermodal transport chain design.

There is moderate hope that this will change. In our own business experience, we have seen increasing interest in transport chain design over the last two years. So there is clearly a demand. There are several encouraging publications addressing intermodal transport chains involving ships. Do the authors have an explanation why these are mostly from Norway, Denmark, Germany and the Netherlands? Perhaps it is due to a combination of strong focus on environmental issues, where government funding was available to compare economical and ecological impact of alternative intermodal transport chains.

A large part of the world fleet is built for charter services, where transport chains are less clearly defined as for liner services. Can we envision a design for multiple transport chains for charter service ships or is a more pragmatic approach to generally design for flexibility in charters?

My final thought concern the time factor. Extending the traditional ship design to a top layer where the transport chain is designed considering the system element “ship” at a lower level with fast and more global design estimates is an important point for the maritime industries. Hagen and Grimstad have succeeded in communicating this point with their concise and well written paper. Should we as a community also address an extension of design in the dimension time? Today, ships are mostly designed for the present economic and legal environment (extrapolated perhaps to the date of delivery for legal requirements). Legal and economic conditions change often dramatically over 25 or 30 years, both for single ships and transport chains. How do we incorporate the future into single-ship design or transport chain design?

Professor A Papanikolaou, Ship Design Laboratory, National Technical University of Athens

I would like to thank the authors for a paper of strategic importance for future ship design. The authors propose a new framework for ship design and maritime transport, in which recent public pressure to reduce gas emissions from shipping plays a very significant role. May be the importance of greenhouse gases (GHG) in shipping is overstressed, but anyway as the reduction of GHG comes inherently together with that of fuel consumption and propulsive efficiency, this is to a great extent covered as a major objective of traditional ship design optimization, for which designers always need to care; it should be noted, however, that fuel and engine related technology and measures need to be considered separately.

The proposed framework is highlighting the importance of integrated shipping transport assessment tools (integrated software), in which first the ship design specifications need to be investigated and optimized, so that they satisfy the needs and expectations of all stakeholders of the maritime transport chain. This is known as ‘logistics-based design’ (LBD), a notion introduced and further developed by the EU funded project LOGBASED, see Brett et al [4], in which both DNV and NTUA significantly contributed. Regarding the exploration of feasible solutions, the LOGBASED methodology is indeed based on an extensive Excel spreadsheet (see footnote 1 of the paper and Ref. 29 for details of the LOGBASED modules). A further development of the LOGBASED methodology and the Parametric Design Tool developed by NTUA is presented in a recent publication, Ref. 30; there, a methodology for the optimization of ship design solutions within a multi-modal transport system, accounting for logistics, economics and environmental issues, is presented and its application to a typical shortsea-shipping scenario demonstrated. The introduced methodology reveals the benefits of a holistic scientific approach to the optimization of complicated transportation problems. The discusser thinks that this is entirely within the scope and objectives outlined in the present paper.

Some final more specific comments on the paper:

1. Figure. 2 outlines the various ways for reducing emissions (and fuel consumption); among them of significant importance is in my opinion optimization of weather routeing and loading condition (trim etc.), mainly for fast ships, but also independently for any ship type; it is a question how this kind of effects are today assessed onboard and whether they can be effectively integrated in relevant software platforms. 2.
2. Figure. 6 outlines the employed simplified model for the assessment of a transport scenario; it appears that this modeling takes care of only fuel consumption and emissions; however, required freight rate (RFR) will be one prime objective of the assessment and it appears missing from the shown model. 3.
3. The outlined unit change matrix (UCM) approach is indeed very effective to see trends, when changing parameters; it reminds me of the relational method of Normand, introduced some decades ago, for the estimation of ship weight components on the basis of a reference ship, when changing main design parameters; however, nowadays, integrated design software systems may generate very quickly exact parametric models, assuming an initial, reference design. Thus, a question arises, namely to what extent simplified models have still room for application today and when it is thought that they should be employed?!

AUTHOR'S RESPONSE

The authors are grateful for the comments by **Professor Andrews**, who has been a very important voice in the field of broadening the perspective and role of the ship design process. We appreciate the support.

Professor Andrews points out that we, with our focus on ships in a maritime transport system, seem to rule out ships that perform work and represent functions other than transport. This is a good point which could have been mentioned in the paper, but the discussion was omitted due to place constraints. Our aim is to enable any ship to be viewed as integral part in its overall system. Though transport work is a quite easily measured value and as such is well suited for the "extended system" approach, the principle that the design of a ship may influence the design of the system in which the ship is to perform should be universally valid.

He highlights an apparent inconsistency when we on one hand advocate that the ship designer should be free to influence the overall system in which the ship is to exist, at the same time as we in Andrews view endorses the "design spiral" view on ship design. We appreciate the opportunity to make this point clearer.

We actually intended to lead on to a critical view to the design spiral by postulating that "most prevailing models on the cyclic and converging nature of design attempt to defined more or less clearly defined stages…". Though the design spiral in our view is a practical and pragmatic, and very much pedagogic, description of how design is performed efficiently in a traditional manner, it is nevertheless risky in the sense that it argues for a sequential (though converging) orchestration of largely pre-defined activities. It may allude that the requirements are fixed once and for all at the outset. To be sure; our own view is (a) that it must be possible to re-negotiate the starting point at any time in the process and (b) to arrange, perform and revisit tasks upon need, even if this creates instances of divergence in a design process that is designed for convergence.

Professor Andrews notes that it is impossible to represent such complex processes in a flawless manner. We fully agree. Each design and each design process must be viewed for itself. That is also the reason behind our stance as indicated above; we implicitly argue for an ordered chaos; breaking up the rigorous models, allowing for divergence, allowing for changing the design premises and allowing for activities to be performed "out of order".

The mentioned State of Art Report on Design Methodology presented at IMDC 2009 [27] is an impressive collection of different models/visualizations. Place limits the extent of the discussion here, so we will be to-the-point.

As stated in our paper, we feel most at ease with the design spiral showing constraints. We also see inspiration in the design spiral as presented by Rawson and Tupper, given our comments above and provided we can use the spokes as "wormholes" – to rapidly/instantaneously move back and forth (or do entry and re-entry) in the design process.

However, we feel that a new model is needed that reflects the less rigorous approach we advocate, a model that reflects what both we and Andrews state; that it is actually first when we see that job at hand that we can construct a model of the design process. The most important is to be able to know what (analytical) resources and tools are available, a facility to monitor the designs and design decisions as they develop and mechanisms to make a rapid loop-out, change higher order premises that are affected by lower order decisions, for then to rapidly loop-in and not have to redo all the work! In effect, we would like to see a service oriented architecture of a design process.

We appreciate the kind words of **Professor Papanikolaou** and for his insightful comments. We have had the pleasure to meet with both the professor and Ms Ghokari and have also seen the PDT and its capabilities, and fully agree that this could be a valuable contribution and one step towards a more holistic design process as described in our paper.

Similarly, the LOGBASED project and the developed methodology are well known to us through DNV participation. Whereas we will agree that the chain view is prominent throughout the proposed design process, it does nonetheless retain much of the linear characteristic that we argue should be avoided.

To the specific comments:

1. The groups of measures identified in the Figure 2 contain both technical and operational measures, as pointed out. What we think is the most interesting aspect of this figure is that it points to a number of quick wins that are both easily implementable <u>and</u> that have a negative marginal cost, i.e. that the Owners will save money. Weather routing is certainly one such quick win, and also one that will not require any changes to the ship design. Trim optimization will both be an operational and a design issue, where the designer should try to balance the drop in hull efficiency for floating conditions offset from the design conditions, and the shipboard management should optimize the balance of the vessel accordingly. With the increasing use of CFD tools to complement towing tank tests, there really are no reasons not to include trim/ballast optimisation at design time. Onboard advice may then, on the back of such calculations, be provided through the

loading computer or a number of other alternatives, but the main conclusion is that it is neither particularly difficult nor very expensive to provide such tools or information for onboard use.

2. The authors agree that a (more) complete model will contain RFR as one of the main economic parameters. One shortcoming of RFR is that this a performance indicator that is focusing solely on the ship, whereas our scope may also include non-maritime parts of the total chain, in which case more general metrics will be proposed.

3. Prof. Papanikolaou here raises a question that the authors and, we suspect, the ship design community in general, have discussed at length for quite some time. The foregone conclusion on our part, as revealed by our paper, is that the earliest concept evaluation stages could, and perhaps also *should*, be made without leaning too heavily on advanced integrated design software.

There are a wide range of arguments supporting this position, or perhaps it is wiser to say “that have traditionally supported this position”, because many of these are primarily intuitive and non-quantifiable. To name a few;

The danger of fixation at a premature solution or stage in the process, whereby the designer or design team experiences that the idea generation or solution space is restricted by the tool, the model or even the mere *existence* of a model. The (perceived) amount of work associated with a redesign of a model, or also with maintaining a number of variants or scenarios, may inhibit the exploration of potentially viable alternatives; the scope is involuntarily and/or inevitably restricted. As we stipulated in our previous publication [31], we ultimately envision a design process that would propose a concept solution in one work day which, albeit more of a vision than a hard target, would point to another reason that we are not primarily looking in the direction of engineering grade tools or -processes.

The copy-paste dilemma, where solutions and choices embedded in the old solution (the template) may be carried over to the new product without being subjected to (sufficient) critical evaluation. The risk of ending up with a “default design approach” might be said to increase as a result.

Using advanced tools will make the design task less of a team effort and more of a specialist’s game. Team members that are not skilled users may not be aware of the limitations and possibilities offered by the tools, and the design process might suffer as a consequence.

Having said that, we feel that it should be pointed out that in our minds there are no contradictions or mutually exclusive relations between using estimation approaches – and making them more powerful and precise – and using advanced design software. If anything, our paper should be taken as an advocacy for formalising the groundwork for a full and detailed design task and, as the title (of our paper “The extension of system boundaries in ship design”) points to, to ensuring a more holistic basis for vessels and chain design.

The authors would like to thank **Professor Bertram** for his supporting comments and questions; they are very welcome indeed inasmuch as this will allow us to elaborate a bit on issues not sufficiently well covered in the paper.

The works of Schneekluth are part of the basic formation of naval architects also in Norway; it is tempting to assert that there is in fact a line going from Benford (and the Ann Arbor group) and Schneekluth, via the work carried out at the NTH (Norwegian Institute of Technology) and NSFI (Norwegian Ship Research Institute), to the newer tradition and practice related to integrated ship design that we are subscribing to. But that is another discussion, perhaps.

The first question Prof. Bertram raises is an interesting one: Why is it that the wider perspective – the transport chain approach – is more in focus in Germany, Holland, Denmark and Norway? The authors shall not claim to have the final answer, but we may name two general factors that will surely contribute:

1. A very mature shipping industry, characterised by
   a. Stability and long-term security (to try to avoid the typical boom-bust cycles), less asset play, shift towards specialized and/or high value vessels, in general a high presence of industrial shipping.
   b. Financial systems: tax laws, German KG system: Longer investment horizons favour more “industrial” sectors
   c. More focus on owning/operating than building
   d. Close links between ship owners and the cargo owners.

2. National focus, including political determination:
   a. Environmental issues in combination with transport sector problems, traffic congestion on land demanding a wide system perspective
   b. Long tradition of supporting holistic approaches through targeted R&D programs in the mentioned countries as well as EU in general.

That stated, we feel the need to point out that the main rationale for us has not been to promote any intermodal shift as such, but rather to identify and address inconsistencies and sub-optimal practice and –solutions in the ship design *basis* and the *process*: Where the "design brief" goes too far in presuming certain facts, the designer and indeed the design process should address this and potentially also identify the consequences of such constraints.

The second issue that Prof. Bertram is addressing is a part of the twin complex that is also the main challenge to our approach in terms of making it a *general approach* to ship design:

1. Much of the world fleet is not employed in what may be broadly categorised as "transport services", but serves other purposes: Cruise vessels, offshore construction vessels, icebreakers, etc. Where the "transport chain" concept is as vague as this, how then are the optimization criteria restated?
2. How may a vessel that is intended for the spot market, i.e. an unknown operating pattern, be optimised with respect to a transport chain?

One potential solution to the first part problem could be to define alternative definitions of "benefit" than transport work in the cost/benefit equation. In fact, such approaches are already widely used in the shipping business through benchmarks such as "fuel consumption per day in DynPos mode", "square km seismic data", etc. The main challenge is to define meaningful metrics that will apply to a wider segment and thus also have the potential to be a known and accepted parameter across the business. The objectives would in such cases be more focused on optimising a "mission" than a "transport chain".

The second part problem is more of a conundrum and most likely there is not a single solution. The authors have applied two different approaches in practice when this problem has come up: Either prepare a representative operating profile (or route, service, mission, loop) for the transport problem in question based on the available information and the knowledge of the design team, or use the more general approach of using representative trades for the vessel type. Quite often we find that even such small modifications to the design basis will have significant effects.

But having said this, what Prof. Bertram points at is indeed a major issue. The conclusion might very well be that the chain and vessel connection will be insignificant in the design problem, i.e. that the vessel and chain are decoupled.

The third and last issue that Prof. Bertram is raising relates, in the perception of the authors, to the *robustness* of the solution, i.e. the ability to cope with changes in the market or other operating conditions. One response would be to go "brute force" with simulations and scenario analyses, in contrast to more qualitative analysis techniques.

This is a very difficult issue. The design of a ship in a longer term perspective for a risk-prone client will expectedly differ from that for a risk-averse client, and it is thus difficult to find the correct measure to use in directing the design. There is, in our view, not one single approach to take.

Our aim is to be able to represent potential future scenarios (including different fuel prices, different environmental legislations), and present the effect of different design decisions on each of those. A designer will thus be able to view the potentially adverse consequence of optimising for one particular scenario (possibly based on the current situation) with respect to another scenario for the future.

The long-term task would then in theory be to give probabilities to these future scenarios, in order to optimise for a long-term perspective. However, the danger is that the design task becomes very complex and difficult to penetrate, in effect becoming a black box where the complexity itself becomes a risk to the client, who then may resort to the old "I know what I have, but not what I get".

In order to meet these concerns, we feel that we need to be able to adapt the toolkit and the process to the problem at hand. If the client is concerned about the performance in the future, we should be able to address those concerns in the design process through evaluating design scenarios. If not, we should at least be able to highlight hotspots by pointing at particularly sensitive aspects of the design with respect to risk.

REFERENCES

23. LEVANDER, K: "System Based Passenger Ship Design", IMDC 91, Kobe, May 1991.
24. ANDREWS, D J and PAWLING, R. "SURFCON – A 21st Century Ship Design Tool." Proceedings of IMDC 03, Athens May 2003.
25. KOENIG, P, CZAPIEWSKI, P and HOOTMAN, J C:" Synthesis and analysis of future naval fleets", SAOS 2008 Vol. 3 No. 2 pp. 81–89.
26. ANDREWS D J: "Marine Design – Requirement Elucidation rather than Requirement Engineering", IMDC 03, Athens, May 2003.
27. ANDREWS, D J (Ed): "State of Art Report on Design Methodology", in Proceedings of IMDC09 (Edited Erikstad, S O), Trondheim, May 2009.

28. SCHNEEKLUTH, H. and BERTRAM, V. (1998), Ship design for efficiency and economy, Butterworth & Heinemann, Oxford.
29. PER OLAF BRETT, EVANGELOS BOULOUGOURIS, RICHARD HORGEN, DIMITRIS KONOVESSIS, IVAN OESTVIK, GEORGE MERMIRIS, APOSTOLOS PAPANIKOLAOU and DRACOS VASSALOS, 'A Methodology for the Logistics-Based Ship Design', Proc. 9th International Marine Design Conference-IMDC06, Ann Arbor-Michigan, May 2006.
30. GKOHARI, C., PAPANIKOLAOU, A., Optimization of Ship design within an Integrated Multimodal Transport System, Journal of Ship Production-SNAME, Vol. 26, 1, pp. 47-59, Feb. 2010, ISBN 8756-1417, ISSN: 1542-0469
31. GRIMSTAD, A.; HAGEN, A., "Customised ship design = customised ship design environments," COMPIT 2008, Liege, Belgium

