DISCUSSION

HANDLING TEMPORAL COMPLEXITY IN THE DESIGN OF NON-TRANSPORT SHIPS USING EPOCH-ERA ANALYSIS

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COMMENT

Mr G Machado, Sólido Engenharia Ltd, Brazil

The paper is very good, it makes us think that the "requirements of the owner" it is not so simple to achieve. The difficulty is the assembly of the various future scenarios and the care that must be taken in order to reduce the evaluated eras but not removing a likely to occur era.

Did the authors perform a sensitive analyses of the figure of merit to evaluate the effect of the increase of the weight of the short term epoch, where uncertainties are lower, on the resultant optimum ship? If the weight of the short term is very high, I believe the resultant vessel shall be the vessel with lower cost that fulfills the short term contracts. How to calibrate this number and get the appropriate result?

Professor D Andrews (FRINA), University College London, UK

The authors are to be congratulated on presenting a design paper on the Epoch-Era approach, which provides a wider perspective on the economic analysis of vessels that are not part of a larger transport system, whereas measures, such as required freight rate, can be used for transport vessels as the main measure of merit. The authors use the term "non-transport ships" to distinguish those many vessels not part of such a transport system, which while being correct in the negative sense this discusser prefers the designation "service ship or vessel". The latter term is seen to be more descriptive, in that such vessels essentially go to sea to undertake an activity at sea (e.g. military missions, support to offshore rigs and structures, surveying, dredging).

The authors also adopt the term "changeability" to capture the need to meet future market and contract opportunities. This is very similar to the terms "flexibility" and "adaptability" used in a particularly demanding class of service vessels, namely, naval combatants. Of the two latter terms this discusser prefers the adaptability (Reference 20) as flexibility has unfortunate structural response connotations. The taxonomy used to capture the complexity of such vessels in Section 1.2 can be seen to match the term "style" used by this discusser and spelt out in Reference 21, both in regard to the different aspects addressed and its importance in being (consciously or unconsciously) selected at the earliest stage of the concept design process (see Figure 6 of Reference 22). The behavioural aspect being derived from the "form-to-function" mapping is seen as yet a further verification of the denial of the "functionalist" approach behind the aberration of systems engineering that is "Requirement Engineering" argued in Reference 8 of the paper and Reference 23. However having said that, Figure 7 of this paper seems to imply a similar arbitrary selection process is necessary to move from Epoch to Era through" consistency rules, preference and continuity constraints". However these rules may not be readily conceived in less predictable scenarios than the energy exploitation domains for which the particular service vessels exampled in the paper are intended? Perhaps the authors could provide further details, presumably presented in depth in Reference 15?

Given the applications provided in the paper are for "commercial" non-transport/service vessels, the authors are asked to speculate as to whether the overall Epoch-Era approach could be readily applied to the assessment of investment in "adaptability" in naval combatants, where the range of future missions are necessarily highly un-predicable.

Mr A Grimstad, DnV, Norway

First of all, I would like to commend the authors on a very interesting paper on a subject that has been at the centre of many a design-related discussion: how to make a ship (design) perform well in a volatile and inherently unpredictable environment? The scope of the paper is wide; so much so that it must be assumed that several of the minor or less pivotal discussions have been culled from the paper. I thus fully expect that the authors have considered most, if not all of the comments provided in the following.

On a general note, to this particular reader the paper seems to implicitly propose a new design paradigm for complex vessels: The complexity aspects defined in Sec 1.2 are applied in defining how a methodical review of a series of simulated – and presumably increasingly uncertain – assumptions regarding the future state of events should affect vessel design choices. This is a very interesting approach, in that it stands somewhat in contrast to the "traditional" ship design approaches taught in schools and universities, but also as it expands on the "design –ilities" viewpoint explored in previous work by A.O. Ross.

Section 1.1, 2nd col, 1st para: The term "far-term leasing contracts" doesn't sit well with me. May I suggest a "long-term (charter) contract" or something to that end?

Section 1.2 (general): The five main aspects of complexity listed are in no way independent of each

other; Figure 2 also alludes to this fact. The text doesn't indicate that they are, but this reader is missing the authors' position on this issue: will the co-dependency or interrelatedness issues be of material importance to the problem, or the formulation of the problem?

Section 2.2 (general): I have problems fully accepting the premises in Sec. 2.2 for several reasons, of which I shall only go into two in more detail. Firstly, unless assuming implicitly that the argumentation or problem formulation applies to a certain market segment or sub-set of vessels, I find it hard to accept the premise that an epoch shift should occur simultaneously and across the board. In other words, epoch shifts are not (necessarily) clear-cut dislocations of reality, nor necessarily discrete events, but may also be gradual changes for which a tipping point or something to that effect may only be identified or pinpointed in arrears.

Secondly, the four categories defined for context parameter values to me again seem to be a sub-set of the total representation. As an illustration I may propose the lack of the human element or societal dimensions that would also be powerful drivers of change for the contextual demands to the system. This could span the range from living quarters and working conditions onboard (single cabins, broadband access/communication, crew rotation, cost of labour, shortage of skilled seafarers, etc.), to the branding of a company and their ethical standards. Clearly, the modelling of such elements in a model like the one proposed in the paper is not straightforward, and should perhaps be avoided altogether for the sake of clarity and verifiability, but I should nonetheless like to see a discussion on the completeness of the representation.

Section 4, para. 3: 6th and 9th bullets: Recognising the need for simplification in a model formulation (process), I still find that bullets 6 and 9 to a large degree contradicts the very premises on which the problem is based: Much of the reason that the future economic performance of a vessel is very hard to predict is that the revenue side of the equation is hard to predict. (Much more so than the cost side, I will also stipulate at the same time, but that is perhaps a different debate.) If you remove the market fluctuations from the model (6th bullet) by stating that revenue is proportional to duration and capabilities (which is in itself a very "socialist" take on the shipping markets) you fail to represent the seasonal variations, the spot market, the "player" mentality of the market. Whereas it may be argued that numbers even out over time, the effect that fluctuation have on the behaviour of the market may perhaps not?

Stating that the cost of each vessel is proportional to its capabilities (9th bullet) is also in sharp contrast with the situation that may be observed in "the real world": Same-day price differences for a single, run-of-the-mill vessel design may vary by 20-30% depending on your yard of choice, country of build, and of course the timing of the contract. Again, stating that the considerations in the model are applicable and valid within a given segment or market might help in this respect.

Section 4, page 8, 2nd col., 1st para. ("Non-transport ship designs …"): The last sentence in this paragraph states that "The only isoperformance indicator in this case is economical: revenue for epochs and profit for eras." Whereas this is a fully understandable and reasonable assumption or simplification for model formulation purposes, studies show that AHTS (Anchor-Handling Tug Supply) vessels in the North Sea/Norwegian Sea spend in the region of 50% of their operational life just waiting, whether this is waiting on the rig, on the weather or for other reasons. This will at least indicate that for instance sea-keeping capabilities and/or size/power are significant performance variables, albeit high-level ones. For a practical application of the proposed methodology, have the authors considered how also other (and in some senses more complex) performance indicators could be included in the structure?

AUTHORS' RESPONSE

Dr. Machado warns about a classical challenge for any designer, which is *How to properly weight the model parameters, for instance the most likely to happen future scenarios or vessel's KPIs?* We are aware that each weighting will bring "collateral effects", such as the selection of a less costly (and probably less risky) vessel when giving too much importance for the near term contracts, and the paper does not intend to solve this dilemma. In few worlds, it must be part of the designer task to properly adjust it to each condition.

We did not include a sensitivity analysis of the weighing between the short term and long term requirements in our study. We do agree that it is important to calibrate this to reflect the decision maker´s preferences and risk profile

Professor. Andrews discusses many points of the paper, which we divide into 3 categories:

Non-Transport versus *Service Vessels:* We agree that the term "service" sounds more descriptive (and probably less negative), and it is used in many other references to describe such type of vessels. The choice for the "non-transport" term, however, is based on previous work developed by our group when contrasting the "transport vessels" commented by IMO in several documents.

Changeability and Epoch-Era Consistency Rules: We agree with the similarities that the definitions of "adaptability", presented by Prof. Andrews, and "changeability", discussed in our paper. A detailed explanation of our point of view for the definition of "changeability" and other main "ilities" can be observed in Reference 24.

As for the rules in less predictable scenarios, we are aware of this "trap", and research towards a more robust era-level metrics is observed in reference 25 and 26. Reference 25 illustrates an era-level analysis applied to a simple system (space tug) for purposes of showing how to perform such analysis. The example has 8 different possible missions that must be satisfied during an era, and different means for changing the system are valuated with regard to era-level metrics. Reference 26 describes multi-epoch analysis and is a companion to paper 25, taking into account the concept of "strategy" for simplifying the possible change paths open to achieve "changeability".

Speculation of EEA applicability in naval combatants: A partial response to this last statement depends pretty much on what Prof. Andrews means by "necessarily highly un-predictable." Does it means unknown or unknowable? Can we anticipate, but be unsure whether it will actually occur? We have a suite of approaches depending on the type. Epoch-Era Analysis is useful for anticipatory reasoning, that is for cases where we could propose/enumerate possible futures. In that case we have metrics that can help us determine whether/when/what type of changeability is valuable. Without being able to anticipate, we can consider just the presence of options that give us changeability is more useful than not, but it is difficult to say what that is worth. This is why we use "filtered outdegree" as a proxy metric for degree of changeability in the latter cases and we can do better with fuzzy pareto shift when considering value of changeability for enumerated/evaluated alternative futures, such as in reference 14 of the paper and reference 27. Epoch-Era Analysis was originally developed through application to aerospace and defence systems, which face a fair degree of uncertainty in missions over their lifetime.

All the reference cited in this answer can be easily found at http://seari.mit.edu/.

Mr. Grimstad discusses many points of the paper, which we divide into 4 categories:

Near/Far term: The use of "near-term" and "far-term" may sound strange at first reading, but we deliberately decided on this unusual construction, since the known "short/long-term" construction could bring mixed meanings during the reading, when contrasted with the classical economical concept of "short/long-run", used many times in the text.

Co-dependency of the five aspects: We are certainly aware on the co-dependency of the five aspects, and more, to handle it is one of the challenges faced not only in this, but also in complementary research in complexity. The EEA goes in line with the "decomposition & encapsulation" technique to handle complexity (and consequently these dependencies), discussed in reference 28 and 29.

Epoch shifts and categories: Our main argument is that a significant change in the context will trigger a new epoch. Although the example presented may lead to the idea that the epoch shifts are "punctual", the model does accept gradual changes within epochs, and such parameterization of an epoch shift after a "range of changes" can be incorporated in the model without severe modifications. The concept of "epoch" is used to encapsulate uncertainties and to aid in conceptual scenario development and analysis; EEA does not require that epoch shifts occur on regular time periods, but it does require a discrete change in context variables as an approximation of reality. The extent to which a context factor changes between epoch vs. within epochs is entirely up to the analyst and in the limit, context variables can be continuously varying. Discretization aids both analysis (in terms of computational burden) as well as conceptualization (in terms of making more distinct the differences between contexts), but as the reviewer points out, such discretization may deviate from strict reality and shifts may not be identified until they have already occurred.

As for the sub-set of the categories, the paper focused mainly on the temporal aspect of complexity, and intended to create a coherent list of categories for the contextual elements considered. When the five-aspects framework is used, the more abstract parameters, that is, the "human-elements" commented by Mr Grimstad, can be taken into account in the "perceptual aspect", as presented in reference 29.

Revenue, Cost and KPIs simplifications: Mr. Grimstad points to the simplification made by considering only the revenue of each contract and the vessel cost, and his argumentation is correct as far as it goes. One could use more complex (and realistic) revenue/benefit models, but authors felt this was not necessary in this particular demonstration case. The objective of our work was to introduce and establish a sound mathematical model for a simple situation. In line with Dr. Machado's answer, we reiterate that the model is robust enough to incorporate these "real world" requirements without extensive modifications on its modus operandi.

As for the performance indicators, we have not considered in this work drastic differences in the operational profile and consequently the KPIs, but as observed in reference 14 of the paper and reference J, EEA is powerful enough to take into account this other indicators when combined with other design techniques.
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