Designing Flexible Offshore Construction Vessels to Handle Future Uncertainty

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OBJECTIVES

The overall objectives for this thesis are summarized by the following research question: «How do we identify and value functional flexibility in OCV designs, subject to uncertain future operating contexts?»

INTRODUCTION

It is becoming ever more important to consider future uncertainty in the ship design process. Technical, economic, regulatory and physical risks and uncertainties can have a massive impact on the performance of vessels. This is especially true for Offshore Construction Vessels (OCV), that are able to perform a large variety of construction tasks. By designing for flexibility, we enable the vessel to perform missions previously outside their scope of operations. Flexibility allows stakeholders to capture upside opportunities, while reducing downside risks.

METHODOLOGY

Methodologies from several paradigms for decision making under uncertainty are investigated: the Epoch-Era Analysis (EEA) of the systems engineering community at MIT, and Real Options Analysis (ROA) with Monte Carlo Simulation (MCS).

EEA is an emerging approach for handling uncertainty. By defining static context representations, *epochs*, we can quantify the value of potential designs in many potential future situations. Uncertainty is quantified through epoch variables. By creating sequences of *epochs,* we obtain *eras*, that represent a possible realization of the system life cycle. Responsive Systems Comparison is used as the framework around EEA, and is shown in Figure 1.

ROA comes from finance and is a group of techniques used for valuing real options. Real options in design are sources of flexibility that can be triggered in order to mitigating risks or exploiting opportunities. MCS is the favored approach to real options, because it avoids some of the pitfalls that emerge when we try to apply financial techniques to complex systems and gives us an overview of the distribution of outcomes (Neufville and Scholtes, 2011).

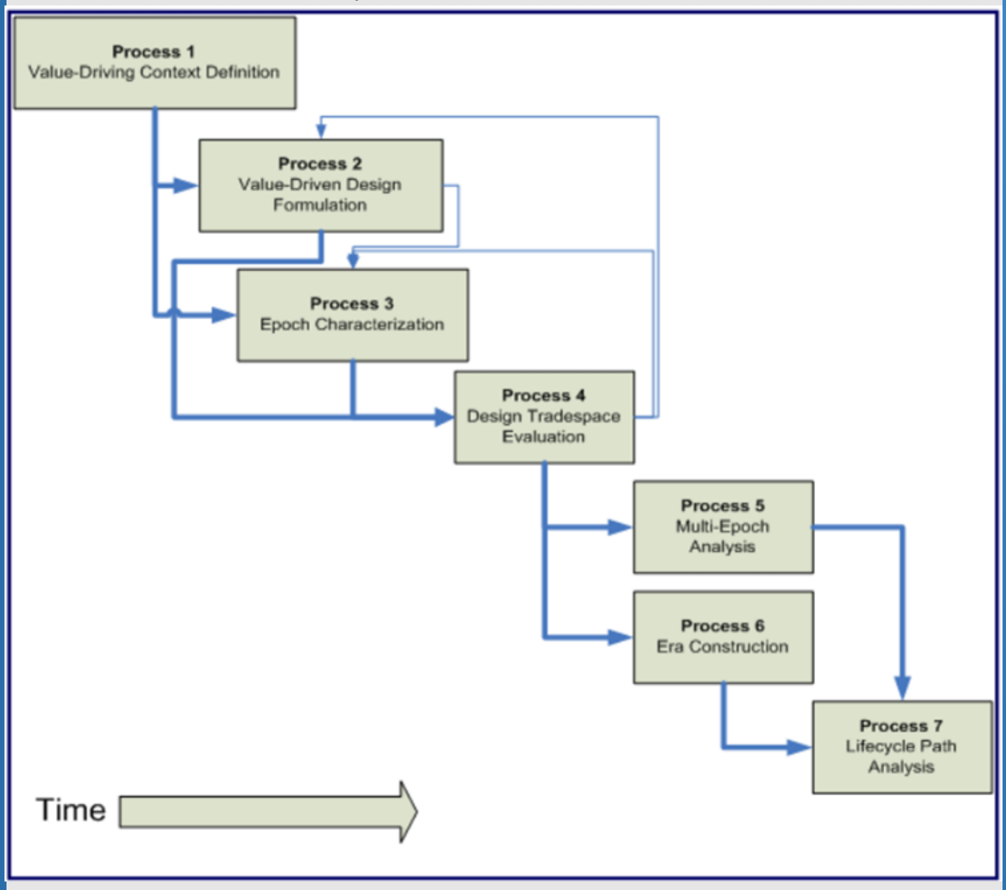

Figure 1: Responsive Systems Comparison flowchart, showing (Ross, et.al., 2009)

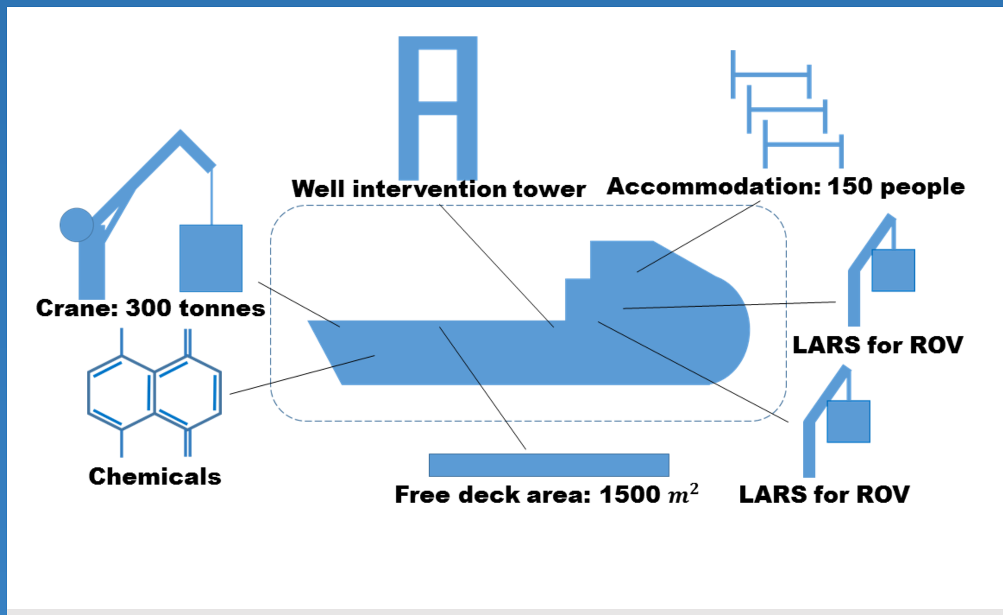

Figure 4: Vessel configuration for Design 51

CASE STUDY

The goal is to design a flexible OCV that will successfully generate value to the ship owner over its life time of 25 years. While an initial IMR (Inspection, Maintenance and Repair) is secured, the vessel needs to successfully compete for subsequent five year contracts in the IMR, SURF (Subsea installation, Umbilicals, Risers and Flowlines), LWI (Light Well Intervention) or DSV (Diving Support Vessels) markets. One contract period is used as a basis for the epochs.

The value proposition of the ship owner dictates that the design should create value through acquisition affordability, operational affordability, mission capability and mission flexibility. The value proposition is fulfilled through quantification of performance attributes, design variables and epoch variables. Epoch variables set the future requirements for contracts and determine the number of contracts available in each market. The contract requirements and number of contracts available have a large influence on how well each design alternative performs.

RESULTS

The results from using the RSC method with a ROA in the life cycle path analysis. Good design solutions are identified from looking at the set of Pareto optimal designs with regards to utility and costs. Tradespaces based on each epoch are generated in MATLAB. In addition, a multi-epoch analysis is done, calculating the utility when all epochs are weighted at once. This shows which designs are robust, and retain value throughout many epochs. A tradespace example is shown in Figure 2.

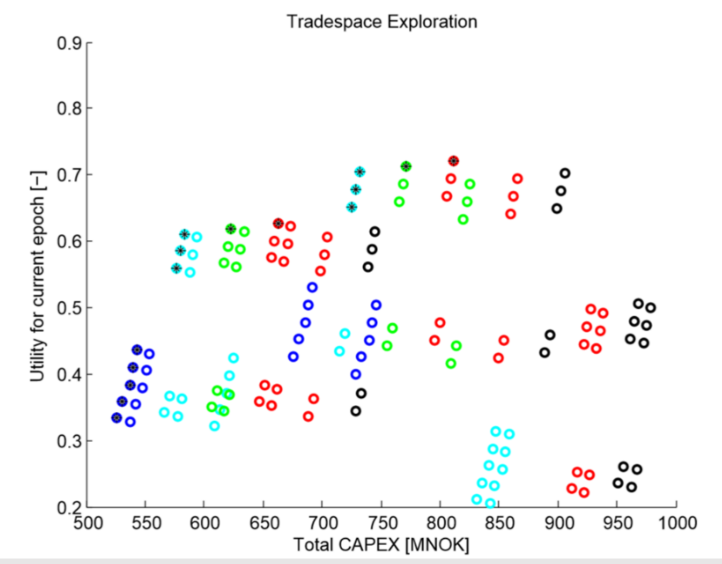

Figure 2: Tradespace exploration for Epoch 3. Pareto optimal designs are highlighted with a «», while the color codes classify the alternative designs according to the total deck area (used as a size measurement).*

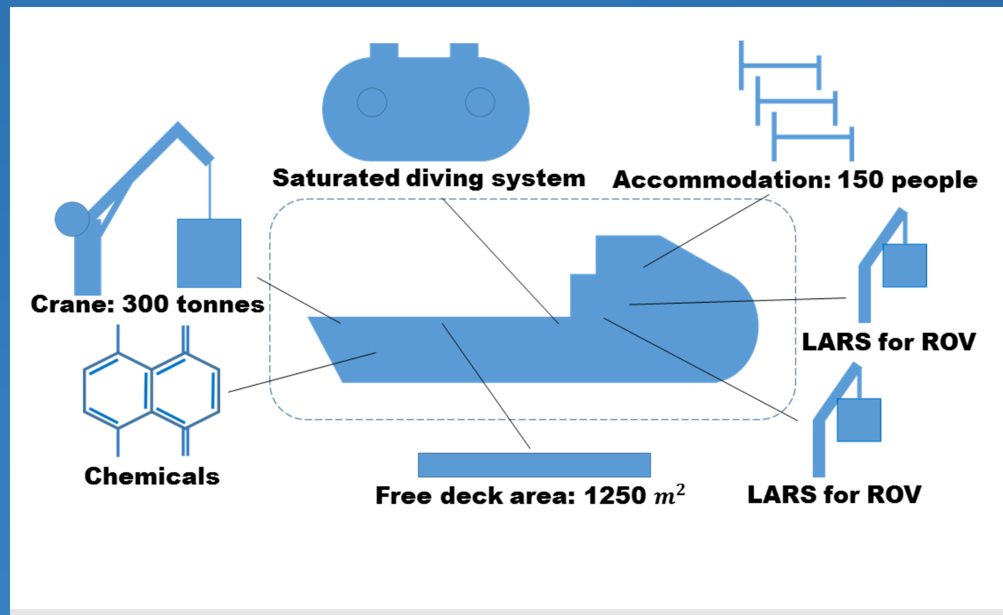

Figure 5: Vessel configuration for Design 21

RESULTS (continued)

The ROA is done with Monte Carlo simulation. As input for the ROA, the time charter rates of the four alternative market segments are used. Equally important as input is the eras that were constructed manually to account for the ship owners perception of which epochs seem most likely to be realized. Flexibility is exercised, through a transition between two of the designs in the tradespace if this is favorable. For each new contract, the transition selected is the one that maximizes the potential net present value (NPV) for this design. Figure 3 shows the cumulative NPV distribution from 10000 runs. A typical transition path exist between Design 51 and Design 21, shown in Figure 4 and Figure 5.

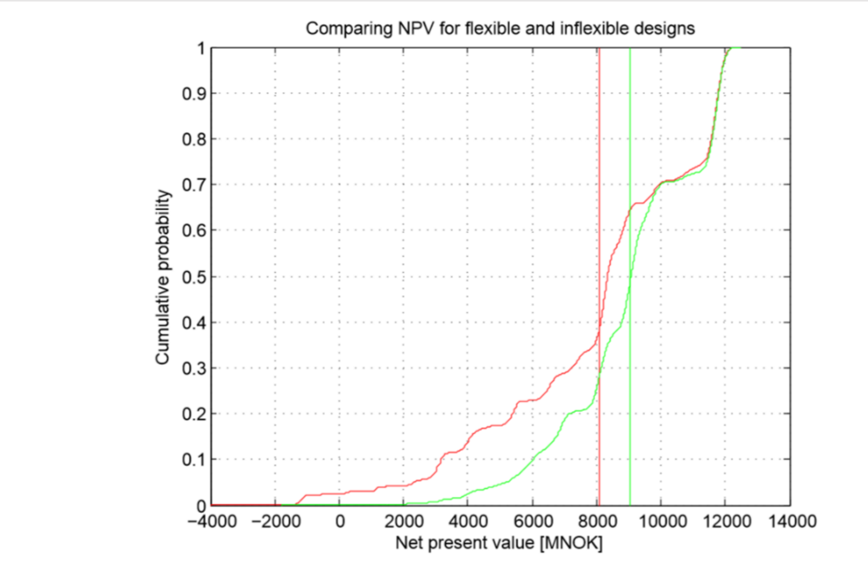

Figure 3: NPV distributions for a flexible (green) and rigid (red) design.

CONCLUSIONS

As a conclusion, we observe that EEA in general can generate knowledge about what aspects in a design that create value when subjected to uncertainty, by evaluating the whole design space in many possible contexts. Further, we see that the application of EEA within a RSC framework allows the incorporation of ROA, making it possible to value the flexibility inherent in each alternative design. The combination of EEA and ROA also provides us with suggestions for flexible design strategies to be utilized.

REFERENCES

de Neufville, R. and Scholtes, S. (2011). Flexibility in Engineering Design. Engineering Systems. The MIT Press, Cambridge, MA.

Ross, A. M., McManus, H. L., Rhodes, D. H., Hastings, D. E., and Long, A. (2009). Responsive systems comparison method : Dynamic insights into designing a satellite radar system. In AIAA Space 2009.

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