Using Epoch-Era Analysis in the Design of the Next Generation Offshore Subsea Construction Vessel

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Introduction

A competitive ship-building industry has an objective to swiftly deliver high quality, complex and customized ships to the global market. Upholding this objective in practice entails an exorbitant number of challenges impacting the design task. Epoch-Era Analysis provides the means with which to instinctively and systematically analyze a system's performance over *time* and across different *contexts*. Inherently, it illustrates the effects time and context have on stakeholder value in a natural and intuitive way. By modelling all possible exogenous circumstances in conjunction with a set of design options, lifecycles can be generated, which directly builds a correlation between unknown future operating conditions and perceived value.

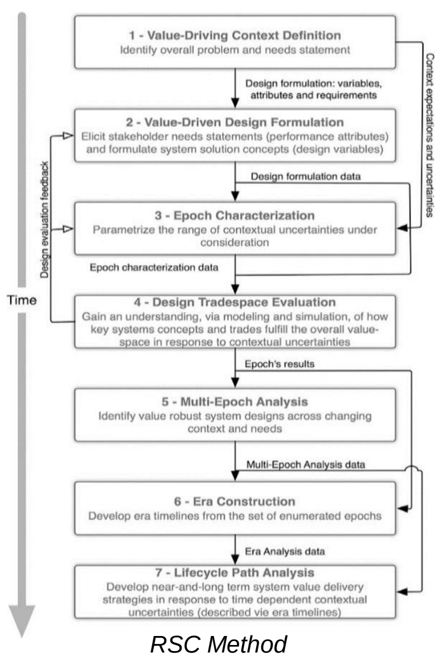
Objective and Scope

The overall objective of this thesis is to investigate the plausibility of an Epoch-Era Analysis and whether it can deliver sustained value to stakeholders over time in a complex, uncertain and changing operating context, and, additionally, how to evaluate and interpret the results of such an analysis.

Main activities include a simplistic case to illustrate general principles; a discussion of alternative strategies for providing flexible design solutions with improved capabilities for handling uncertainty into this market; a comprehensive market analysis of the current state and development trends of today's OSCV market; and to identify the most prominent developments from the market analysis and use them as main parameters in a realistic case study utilizing Epoch-Era Analysis.

Methodology

The Responsive Systems Comparison method [1], illustrated below, is utilized in order to diminish the amount of non-quantifiable information and handle aspects of complexity in an efficient manner. This method is designed to handle complexity by decomposing and encapsulating necessary information to define the system and aims to generate knowledge about tradeoffs, compromises, risks, and the identification of concepts that are value robust.



RSC Method

JavaScript

Because there is no commercially available software capable of performing an Epoch-Era Analysis, the methodology was implemented in a JS script that uses an HTML form as input. This enables an interactivity between the number of variables to base calculations on, as well as the degree of complexity.

```
    };

// Calculate Utility
function calc_util(minv, maxv, value){
    return(Math.abs((value-maxv)/(maxv-minv)));
}

// Calculate Utility for inverse values
function calc_util_i(minv, maxv, value){
    return(Math.abs(value-minv) / Math.abs(maxv-minv));
}

// Returns the attribute calculations to results_instance
function calc_attrib(des,epo){
    capex = calc_capex(des);
    fuel_cons = calc_fuel(des)[0];
    opex = calc_opex(des,epo,fuel_cons)
    co2 = calc_fuel(des)[1];
    result_instance = [capex,fuel_cons,opex,co2]; // Attribute result array

    return(result_instance);
```

JS Code Snippet

Results

Preliminary Tradespace Exploration Dashboard

The results so far indicate that an Epoch-Era Analysis has the ability of absorbing an immense amount of complex variables and decomposing the complexity in a coherent and logical way, making features easily understandable and interpretable to the human eye.

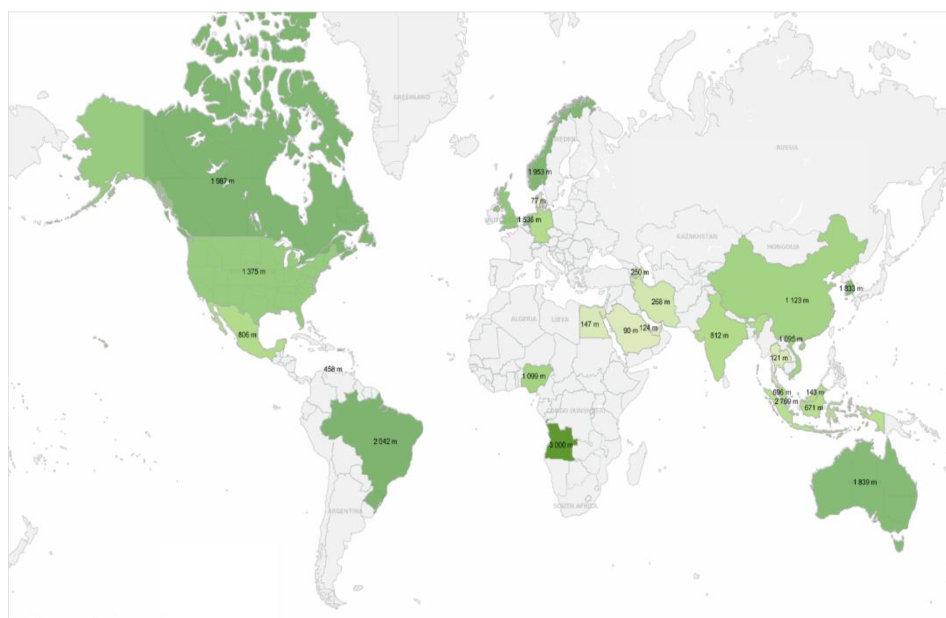
In addition to decomposing almost indiscernible amounts of information, the ability to incorporate any thinkable exogenous circumstance and compare it to a range of computable designs, provides us with an option to include probable future scenarios. For instance, adding scenarios where the oil price suddenly drops below 100 USD/bbl. will undoubtedly cause oil companies to downsize certain operations which again will impact the amount of offshore contracts available and, inherently, potential profit margins. Moreover, towards a scenario where perhaps an increased amount of political pressure is raised in favor of greener operations, this will result in more stringent emission regulations being imposed at an uncertain time frame. All conceivable possibilities can then be modeled and weighted with a fitting probability distribution to see which investments will yield the highest return, operate with the lowest cost, or provide the most value to stakeholders over time.

This type of modeling could prove to be paramount to designers gaining invaluable insights into the consequences of their decisions in the market, if incorporated at an early stage during conceptual design. It also contributes to significant ease of communication and the bridging of what can arguably be construed as a somewhat notorious relationship, between business and engineering. By having a common ground where both parties' interests are upheld, both stakeholder utility and technical marvel can be achieved instead of one being gained by cost of the other.

The illustration above reveals a developed dashboard for interpreting output from a preliminary Epoch-Era Analysis. At this point, it only shows the CAPEX, OPEX and utility of produced designs given certain constraints. However, it is clear from the figure which designs are preferable in a certain scenario by minimizing operational and capital expenditures and maximizing stakeholder utility. By using the utility slicer and eliminating designs that don't meet requirements one easily highlights those that are cheapest to build and operate but at the same time produce higher degrees of value. Furthermore, by selecting the best designs additional calculations are performed to discover and compare emissions, fuel consumption, and other features of interest.

Observations

As indicated from the performed market analysis, the subsea market is driven mainly by three concepts: (1) Ultra Deep Water (UDW), (2) Increased Oil Recovery (IOR), and (3) Inspection Maintenance and Repair (IMR). These factors all contribute by pushing the subsea industry towards operations farther from shore, at deeper operational depths, in harsher and colder climates, and working with larger modules. Each of these factors result in offshore activities becoming more and more complicated, subsequently demanding a proportional increase in offshore vessel capabilities such as crane capacity, storage capacity, seakeeping and stationkeeping abilities, number of ROV hangars and their corresponding depth capabilities, number and size of moonpools, and not the least the ability of handling multiple mission types increasing the vessel's versatility.



Average Operational Depth by Region

The figure above to the right is a developed geographical heatmap taking into account the operating depth of registered oil rigs during the course of 2013. It clearly illustrates that by number of occurrences and arithmetic mean, the "golden triangle" between Brazil, the Gulf of Mexico and West Africa are market leaders when it comes to operating at deep waters. Fresh markets in the same category include Australia, parts of Indonesia, East Africa, and the Mediterranean.

References

[1] GASPAR, H. M., RHODES, D. H., ROSS, A. M. & ERIKSTAD, S. O. 2012b. Addressing Complexity Aspects in Conceptual Ship Design: A Systems Engineering Approach. *Journal of Ship Production and Design*, **28**, 145-159.

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