Fast-Track Vessel Concept Design Analysis (FTCDA)

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This paper presents the Fast-Track vessel Concept Design Analysis (FTCDA) tool, a unified design platform integrating a set of interconnected vessel concept design analyses modules. The holistic view of the FTDCA tool combines technical, commercial, and operational perspectives. Using regression and multivariate based approximations, the time of vessel concept design development has been reduced to hours, rather than weeks in terms of process time. The overall performance of the developed concept designs is benchmarked with peer vessel alternatives.

1. Introduction

In the early phases of conceptual ship design important decisions must be made for system design concepts. Detailed evaluation of each possible solution is costly in both time and effort. So, an effective and efficient method is needed to explore the design space in terms of critical system parameters. Ship design companies typically are challenged by the need to incorporate among other perspectives; flexibility; innovation; speed; and agility to their business model. The conventional vessel concept design development process, based on work processes relating to the traditional vessel as a design spiral, has proven to be ineffective in later years, when it comes to ensuring very short customer needs response time and securing sufficient accuracy and robustness of the solutions developed. It is, very often, too time consuming and resource demanding to evaluate the appropriateness- and goodness of fit of the number of necessary vessel concept design solution alternatives to be developed and investigated for feasibility. On the other side, it is seen based on some factual numbers from designers, while conceptualization of new product consumes less than 5% of total project design and construction time, almost 90% of possible innovative design solutions take place in this step where knowledge about final product and its overall performance is still shallow, Figs.1 and 2.

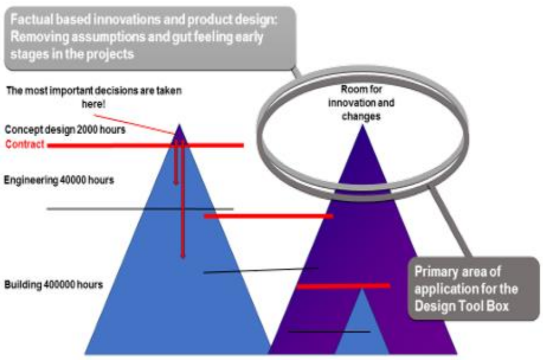


Fig.1: Room for innovation in design

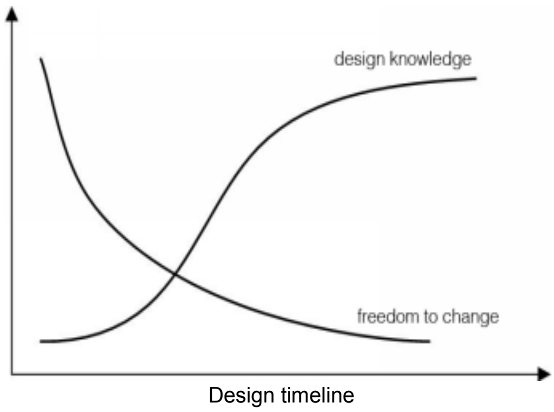


Fig.2: Design knowledge and design timeline, *Erikstad (1996)*

Ulstein has over the years introduced and implemented an Accelerated Business Development methodology (ABD) to enhance and strengthen its capability to effectively solicit relevant stakeholders´ expectations and desires when it comes to the realization of ship designs and new building projects, *Ulstein and Brett (2012)*.

The core elements of the ABD approach, which aims to better guide ship designers, yards, cargo, and ship owners in realizing a business opportunity within intermodal transport or offshore field development work whereby ship design is utilized to achieve a competitive advantage. The approach advocates that a new or improved solution system, where the ship plays a significant role, shall fulfil the needs and expectations of all the involved stakeholders in the best possible way through the multi-attribute decision making ABD-approach. This approach makes it possible to follow the complex and normally fragmented processes of business development related to maritime transport, offshore oil & gas field, and the pertinent ship design in a systemic and explicit way. As a continual process to its ABD approach and as a response to the need of rapid solution generation and performance evaluation, in the recent year Ulstein has developed a set of interconnected vessel concept design analyses modules into what is today known as the Fast-Track vessel Concept Design Analysis tool and approach (FTCDA). By the means of different multivariate data analysis in addition to other statistical and traditional naval architecture approaches in an integrated tool environment, it has been possible to reduce the time of vessel concept design development, with acceptable accuracy and robustness, to hours, rather than weeks in terms of process and response time to the costumers and the tenders.

This paper presents the FTCDA approach as an integrated conceptual ship design and benchmarking tool that exploits synergies across different design disciplines/modules, in a unified digital analyses platform. This is to empower the designer with the ability to rapidly develop sets of viable vessel concept design solutions, rather than one solution, with permissible accuracy and robustness. The overall performance of the developed vessel concept design solutions is benchmarked with peer vessel alternatives, including existing, relevant vessels in the market, all integrated in the tool data sets for input and output. A holistic approach applied in the FTDCA-tool combining technical, commercial, and operational perspectives, ensures a more balanced and robust design solution, compared to existing and traditional naval architectural and marine engineering work processes and practices.

In this paper, by the use of some practical design cases, it is reviewed and discussed how fast the FTCDA approach can produce the full configuration and balancing of vessel design alternatives and alterations by varying main particulars and mission required equipment in the very early ship design phase. It is also discussed and shown by specific examples, how such an approach can cater for the necessary sensitivity analysis. The paper also discusses how analytical simulation of the small changes in design particulars and mission equipment on technical, commercial and operational performance of concept design solution, can produce their resulting implications and consequences.

2. Fast track design and construction

Typically, up to mid-20th century common project delivery process has been sequential design–bid–build, with a time period between the completion of one phase and the start of the next one. However, reacting to rapidly changing market dynamics and meeting project timeline in the lowest cost have always been on the mind of project owners. Shorter schedule can lead to shorter manufacturer's time-to-market and reduce the cost of construction financing and overhead costs for the design and construction organizations. The fast-tracking of the project is therefore achieved through the integration of design and construction phases. The fast track project delivery strategy is developed to leverage the ability to perform design, procurement and construction phases simultaneously to enable project schedule reduction substantially. In this context, concurrent engineering created the necessary foundations for Fast-track design-construction. Concurrent engineering developed by Toyota in 70th generally defined as a production management philosophy, which has been widely used in the manufacturing industry over the past several decades to achieve as much as 50% reduction in product development cycle, *Bogus et al. (2002)*. The reduction in schedule is achieved by using concurrent, overlapped processes instead of sequential product and process design. Fast tracking is generally defined as the compression of the design and/or construction schedule through overlapping of activities or reduction in activity durations, *Cho et al. (2010)*. On the other sense, Fast track is commonly entitled to the projects executed using the principles of concurrent engineering to symbolize the reduction in the total schedule from design to commissioning. The design phase assumes increased importance in fast track projects because design and construction are executed almost simultaneously with tiny or no lag between design and construction. The design of industrial projects involves the design of complex and interconnected systems in which design teams from various disciplines need to continuously interact and use data from each other to ensure accurate and safe design. The performance of the design phase is dependent on smooth and timely flow of accurate information from a variety of stakeholders from different organizations that come together to execute the project. The fast track project delivery strategy is being used ever more aggressively in industrial projects to reduce the time to the market, making the study of best practices for management of design in fast track industrial projects more forceful. The traditional approach to communicating the initial ship design process is the “design spiral”, *Evans (1959).* This model emphasizes different design tasks should be considered in sequence, in increasing detail in each pass around the spiral, until a single design which satisfies all constraints and balances all considerations is reached. Such an approach requires a number of iterations around the spiral which is generally limited by the available time and budget. In general design spiral, follows the principals of design-bid-build approach. Ulstein FTDCA is based on concurrent engineering philosophy to shorten conceptual design process time.

A fast track conceptual design process and its related design tool box is developed to shortcut the iterative process in early design phases guiding the designer to the right design direction in the very early phase. Reduction in the time spent for iterations and eliminating part of non-value-added design works frees up the time of designers for more work on innovative solutions. Based on practical design experience in Ulstein, shorter design/project initiation lead time, less resources for concept development, better decision making support, better market fit for design solution and final product, enhanced advice to clients and increased design capacity, are expected achievements of applying a fast track approach in the early design phase, Fig.3.

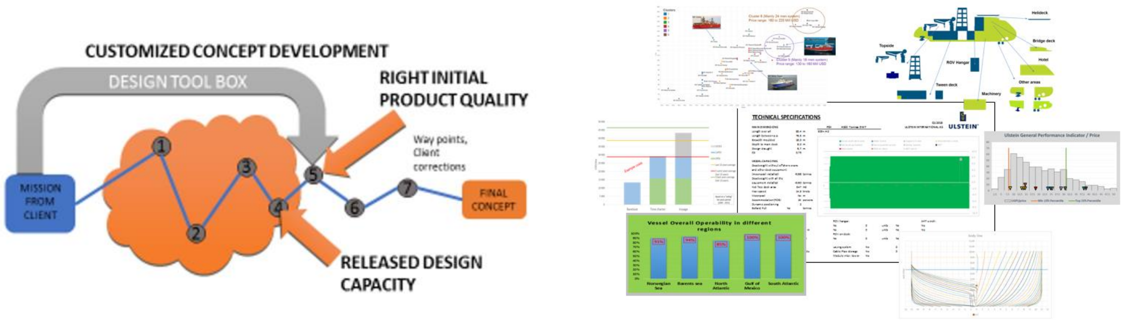


Fig.3: Fast track design approach

2.1. Time and accuracy trade off

The existence of trade-offs between response time and accuracy is an important interpretative problem in choice of reaction time experiments, *Wood (1976)*. Systematic evaluation of the achieved accuracy over the allocated time to produce, conceptual design solution (response time) is a challenging issue for ship design companies. In the past, some ship owners have commented that Ulstein produces early design concepts with high precision, nonetheless at relatively higher response time compared to the competitors which has reduced the chance of further progress in some projects due to delayed response. On the other hand, it is always a risk, when designers are compelled to act quickly, they emphasize on speed rather than accuracy might lead to end up missing the goal of the task entirely or developing solutions not fulfilling the expectations or early design solutions which can be considered faulty. Hence it is realized over the time, response time and accuracy requirements are both important in design tasks but they are sometimes contradictory. *Heitz (2014)* suggests that, often the best way to approach these type of conflicting tasks is to try to move as fast as possible without sacrificing accuracy. In such circumstances making proper balance between response time and accuracy of the solution is critical early design phase decision making criteria.

Permissible achievement of accuracy level in fast track design approach is eminent issue which might lead to less optimal solution in case of negligence of appropriate balance between time and accuracy. According to practical design experience exploiting empirical equations available in the literature normally is the quickest and cheapest way to identify relevant dimension in early design solution, however lower accuracy compared to model test or hull line and 3D model generation approach creates disputes inside organization to choose the direction. As of practical experience, normally, empirical equations in the books, creates 80% computation accuracy compared to model tests. However, this value varies among vessel segments. For instant equations for straightforward less complex ship types like tankers or bulkers can achieve up to 90% accuracy level while in offshore vessel or cruise ship design, accuracy of the calculation based on empirical equations drops in some cases even below 70%, *Ebrahimi et al. (2015a,b)*. Considering time and cost for running different type of analysis it is experienced, while vessel solution dimensioning based on empirical parametric equations in naval architecture books requires around 1 to 2 days, such response time increases up to 40 days when hull line generation, 3D modelling and CFD analysis are taken into place.

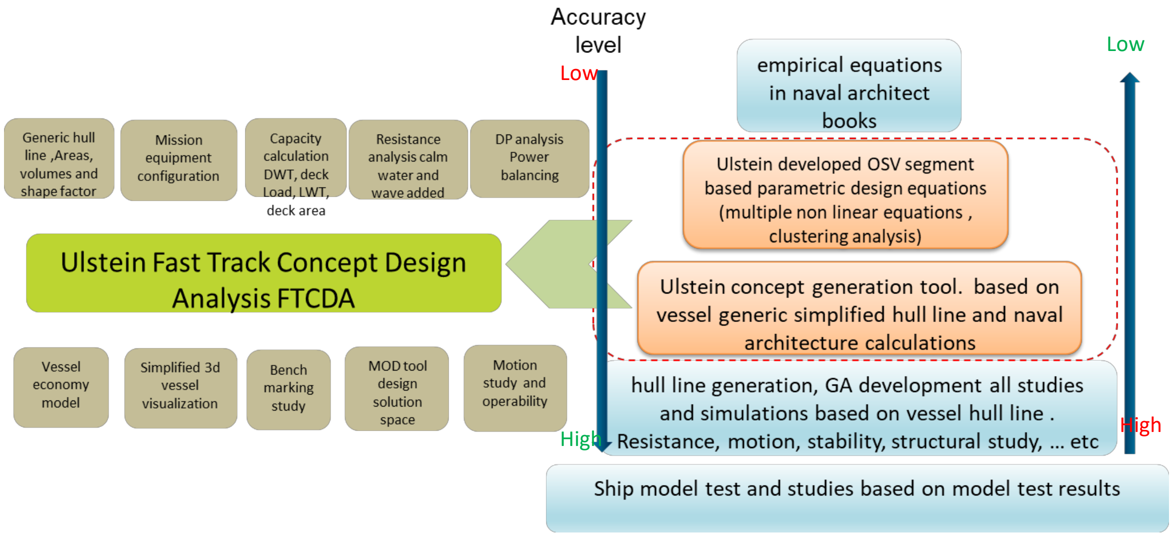


Fig.4: Fast track design time and accuracy trade-off

Fig.4 shows Ulstein FTCDA schematically. The approach is a multidisciplinary design tool developed to fill the gap between empirical calculation and final hull line and GA development, maintaining a permissible accuracy level of the calculations. Such development has led to shorter response time compared to hull line generation and model test approaches. FTCDA as an approach is the combination of internally developed parametric models of cleaned data sets for different vessel segments besides calibrated models on weight and power estimates based on actual data from Ulstein built vessels. Verification of the results of the tool in different conceptual design cases, has proven that, 95% confidence level is achievable. Such a significant accuracy level achievement compared to the result of model generation in different technical, commercial and operational aspects of concept development in a very short analysis time has been considerable and greatly appreciated by people especially sales and design.

2.2. Open source tools overview for fast track design application

Application of different open-source web-based tools in ship design is comprehensively discussed by *Gaspar et al. (2014)*. Open source is a development methodology (or philosophy) that is developed in a collaborative public manner as a prominent example of open collaboration, where monetary profit is secondary. Free access to the software code, allowing users to modify and improve the code is the main characteristics of open source approach. In addition, room for customization by users and independency from developer of the tool is achieved with open source technology. Higher flexibility, adoptability and less cost are other achievements in this context. Famous examples of open-source software are Linux operating systems (e.g. Ubuntu, Gentoo) and the Mozilla Firefox browser.

To develop FTDCA user-friendly and easy to implement in the organization, combination of open source web based tools with Microsoft excel dash-board interface environment is used as a basis for the development. It is observed Excel based environment, simplifies connection of the tool to available data sets which are mainly spread around organization in different Excel sheets. However, detailed mathematical analysis is executed in visual basic and macro coding ability of the excel sheet, whilst Web-GL application in java script coding connected to the tool provides 3D model generation capability of the tool. brief overview about tools used in FTDCA is given in the following topics.

2.2.1 Microsoft Excel dash board and Visual Basic coding

A dashboard is a visual representation of key metrics that allows to quickly view and analyse data in created user-friendly interface. Using dashboards not only provides consolidated data views, but a self-service business intelligence opportunity, where users are able to filter the data to display just what's important to them. Even though it can be argued Microsoft Excel is not open source tool and requires subscription, but it should be considered internally developed applications in the basis of excel functionalities contains some of the main criterion of open-source web based tools. For instance, while there is no possibility to make substantial changes in MS Excel software, but dashboards and tools developed in the MS Excel environment provides unlimited access to the user to implement required changes or protect the worksheets from any single changes. Visual basic and macro codes are easily accessible and sufficiently flexible to adopt developed tools to new needs of organization/market.

The Ulstein FTCDA initially developed to support the conceptual design of platform supply vessels, while in a meantime the tool is expanded to provide early conceptual design for anchor handlers and offshore construction vessels. In the recent years, Ulstein shifted from designing OSV to cruise ships and fishing trawlers. In such circumstances, due to the flexible nature of the tool, Ulstein FTDCA was adopted and adapted to new segments on the basis of preliminary developed platform. Within development, implementation and the performance of the FTCDA feed backs from designers and the sales people has led to more functionalities being added to the tool or some being removed or modified to make it more conversant to the needs of the end users. It is seen how capabilities of Microsoft excel as a popular office software is used to develop technical tool to handle conceptual design of the ship with lower price and higher flexibility compared to more comprehensive and costly tools available in the market with its relative pros and cons. Fig.5 demonstrate partial interface of the cruise ship conceptual design tool and its related VB code for wave added resistance calculation. Based on the discrepancies in the functionality of the segments inputs vary among OSV and cruise ship tools, while generic platform and interface of the tool colour codes are almost similar. As of the tool now, Ulstein OSV fast track tool covers PSV, AHTS and OCV segments and Ulstein cruise ship tool covers cruise/exploration, RoPax and luxury yacht segments.

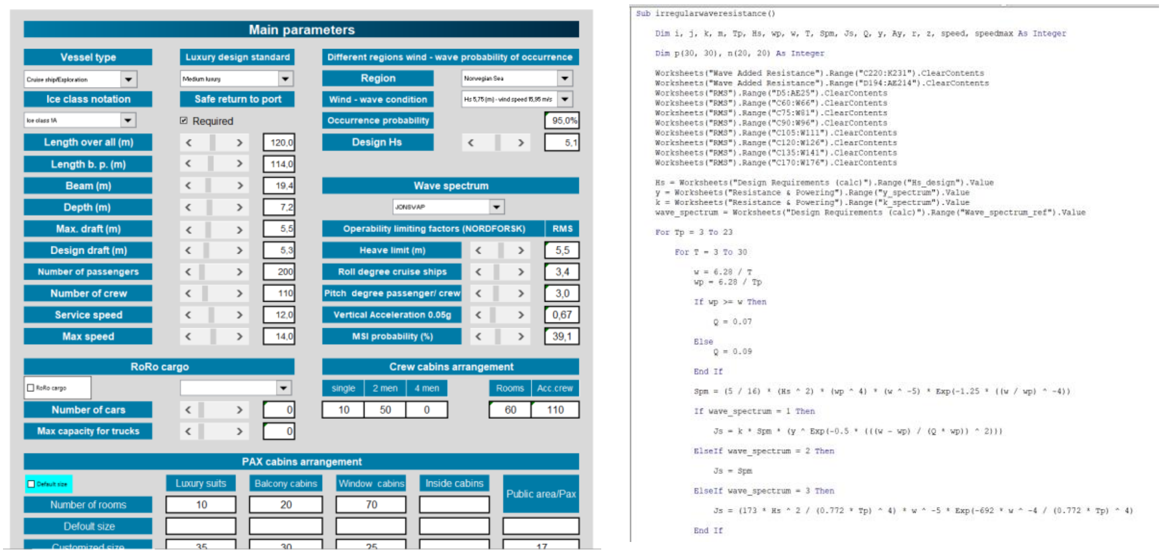


Fig.5: Cruise /exploration FTDCA interface and back ground VB code

2.2.2 WebGl and Collada

WebGL (Web Graphics Library) is a cross-browser JavaScript library/API, which is used for rendering complement. It allows interactive advanced graphics to be rendered within a web browser and optimizes the hardware use. WebGL does not use plug-ins and there is no need for installs or updates, which is significant advantage compared to the decaying Adobe Flash. WebGL has been used in applications from gaming to science.

Collada (COLLAborative Design Activity) is a file format used to transport 3D assets. It is capable to carry more information about the 3D environment (including geometry, materials, shaders, effects, lights, or even physics and animations), *Gaspar et al. (2016)*. In principle, 3D parts, objects or modules are created in separate 3D software and saved as JSON format. That enables WebGl, collada to read the file in web-based environment and create new 3D models by parametrizing the objects and adding or removing the functional equipment's. Java script code is used to connect WebGl to Ulstein FTCDA. such functionality enables to visualize schematic 3d model of the concept with good enough resolution after defining vessel inputs in the FTCDA tool, Fig.6.

Fig.6: WebGL connected to FTDCA excel interface for 3D visualization of design configuration

3. Ulstein FTDCA development methodology

The Ulstein's Fast Track Concept Design Analysis Tool (FTCDA), is an open source internally developed tool for fast evaluation of different vessel concept options. Exploiting FTCDA, primary vessel concept design is developed rapidly at any place, requiring almost no extra computational power. The FTCDA has two main applications, being used as a selling or a design support tool. As a selling tool, it is used to present quietly a solution concept to the client, addressing his/her main expectations and the consequence of variation in design and decision making parameters in the performance of final product. Moreover, as a sales support tool FTDCA caters real market data of vessels that are already in operation and benchmarks performance of costumer expectation with indicative market vessel. As a design tool, it is used by the design team as a mean of exploring design variations before they are further developed into a single solution which will be developed in Basic and Detail design steps.

3.1 FTDCA structure

Vessel design consists of three main steps of Conceptual design, Basic design and detail design. Concept design practice is typically a decision-making process where the results of simulations and model tests are the inputs of decision making process to balance the vessel design solution. Moreover, available technical, operational and commercial data of similar designs are considered as background data in the new vessel concept development. Following concept development is a basic ship design process where rule proof and prepared for designs and calculations, are taken care of. In the latest stage of ship design, normally, detailed structural modelling, piping and electrical distribution designs including 2D and 3D drawings are generated for production purposes. Fig.7 shows three main ship design phases and differentiates between the concept design process as an "upstream" decision making process compared to a detailed and production planning oriented design activity as a "downstream" engineering activity.

Ulstein FTDCA functions as a bridge between vessel Concept and Basic design phases, where critical system decisions being made. Such early decision making process requires appropriate inputs presenting the implications and the consequences of any single decision on the final performance of the ship design solution, in a very short and limited concept development time. FTDCA makes eminent role to provide sufficient and accurate enough information for fast and robust, vessel conceptual design decision making process.

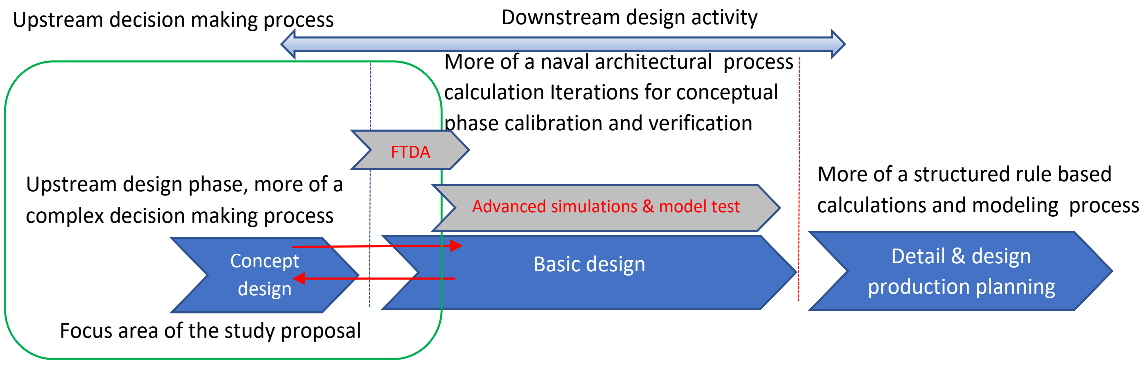


Fig.7: Ship design steps and FTDCA

The FTDCA is consists of several connected analysis modules (or excel spread sheets). Each module is responsible for handling specific parts of the design process, receiving and providing data from and to other modules. Generic structure of FTDCA, different contributing modules and their internal interactions and dynamics in the tool are represented in Fig.8.

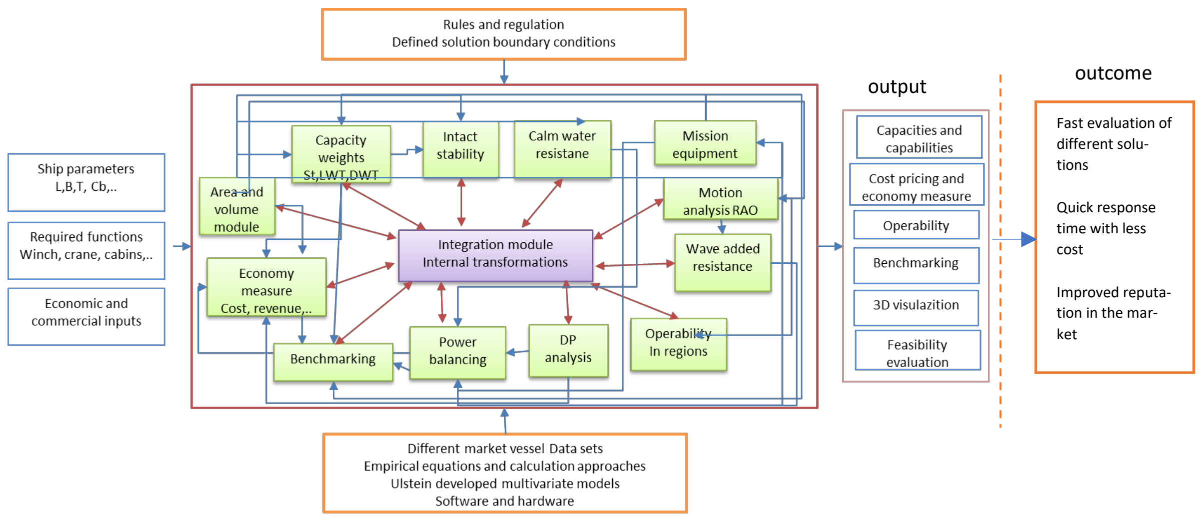


Fig.8: FTDCA modules and internal interactions

Fig.8 shows, Input data including vessel main dimensions required mission equipment and economic and commercial factors including, loan and equity percentage, country of built, fuel cost, etc. are defined by the user. In the transformation and the calculation phase inputs are used in different modules whilst result of some modules are also fed to other module in the tool due to the type of data required for calculation. For instance, calculated areas and volumes are transferred to calm water and wave resistance modules, and on the other side output from these modules are input to power balancing module which has another input from DP calculation as well. Output from power balancing is fed to economy and benchmarking modules for cost estimation and benchmarking calculation, additionally it is stored to be presented in the output sheet as total installed power. Brief insight to each module and methodology of calculation is given further in the following subchapters.

3.1 Design requirement sheet

The design requirements sheet is the main interface between the vessel configurator and the user. This spreadsheet receives all required inputs for vessel configuration purpose as aforementioned. Besides statistical, historical and database values, regional weather scatter tables, are stored in the tool as a supportive resource of data for further analytical transformations. This spreadsheet is formatted to be printed in A3 format, in colour or black and white, being part of the tool documentation output to be used as a report for the design team or client, Fig.9.

3.2 The output specification sheet

The output specification sheet is the main interface between the vessel configurator results and the user. This spreadsheet presents the main outputs for the vessel configurator, including main dimensions and capacities, deck layout, equipment data, benchmarking analysis, economic analysis and operational scenarios. Results from the different calculation modules are integrated in the output sheet to be communicated in a professional way with the user. A3 communication techniques are used as a basis for layout of input and output sheets (system practice). Moreover, priority of given information, readability of the data and maintaining interactive interface are considered in the development of the input/output sheets. Colouring and layout of the interfaces is developed in consultation with communication technology experts in Ulstein. This spreadsheet is formatted to be printed in A3 format, colour or black and white, being part of the tool documentation output to be used as a report for the design team or client.

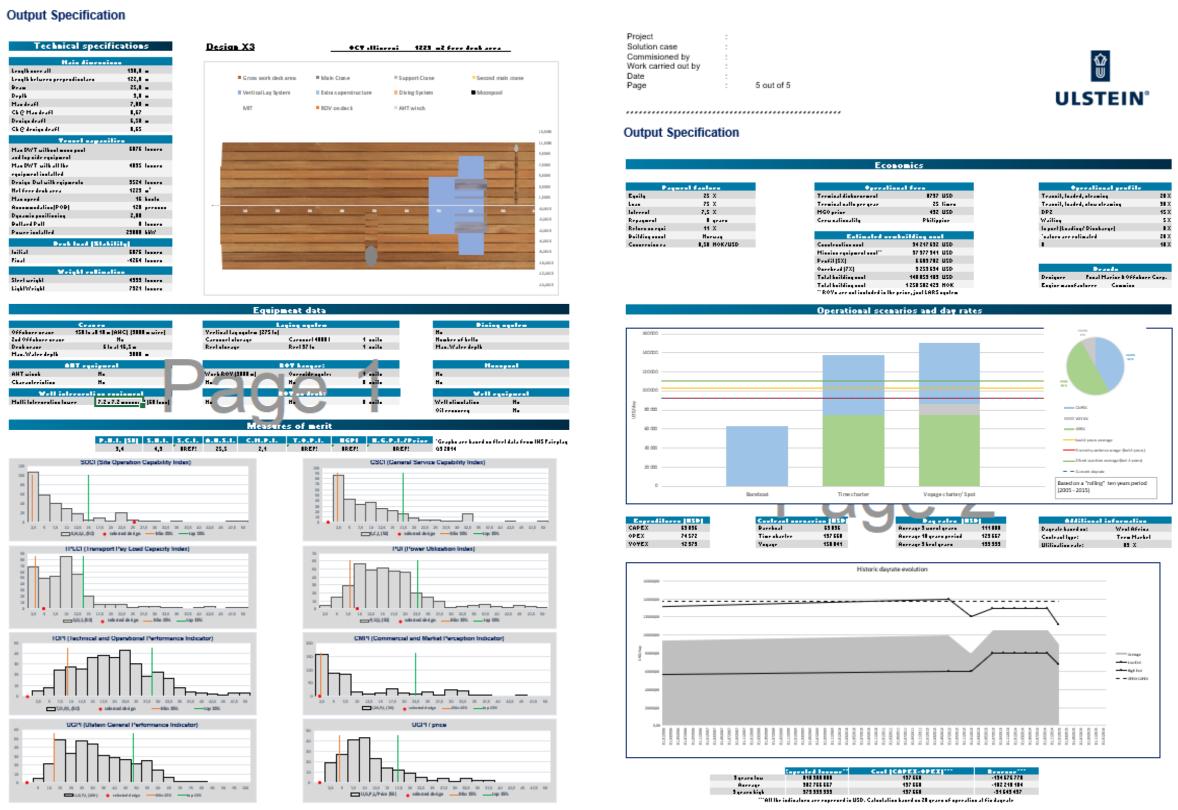


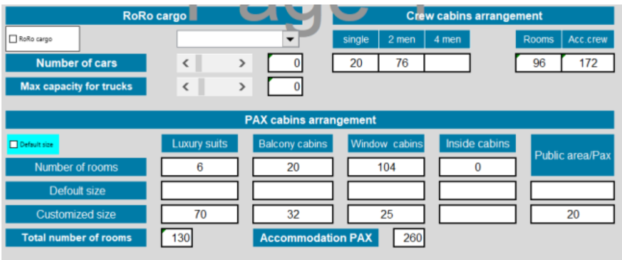
Fig.9: Offshore vessel FTDCA output sheet

3.3 Calculation / transformation modules

3.3.1 Volume and area calculation module

Vessel volumes and areas in the tool are calculated based on system-based design approach in super structure and accommodation part. The buoyancy volume calculation model is used for the calculation of volume for the marine platform. In the accommodation part, tool serves an opportunity to define required areas both in a manual or automatic way. In the automatic approach, default values for different zones of accommodation are the basis of analysis. These unit areas are the result of statistical analysis on the GA of other Ulstein built and competing market vessel in the segment. Accumulation of the defined vessel areas and volumes creates vessel total required area both in accommodation and hull part.

The vessel GT is the consequence of the total calculated volume based on rule equation. Fig.10 depicts input sheet for cabin configuration and related analysis in volume and area module of the tool based on input data from user. In RoPax vessels, selecting RoRo cargo generates superstructure deck to position expected number of cars and trucks. Out puts from this module are fed to weight and capacity calculation, power balance and price estimation modules.



Accommodation		Unit Area	Number of rooms
POB	432,0		
Area required for Lux suits	420,0	70,0	6,0
Area required for balcony rooms	640,0	32,0	20,0
Area required for window rooms	2600,0	25,0	104,0
Area required for inside rooms	0,0	0,0	0,0
Area required for crew single cab	240,0	12,0	20,0
Area required for 2-men cabin	1140,0	15,0	76,0
Area required for 4-men cabin	0,0	15,0	0,0
Average public area for pax + area for no room pax	5200,0	20,0	260,0
Average facility area for crew	2064,0	12,0	172,0
Total required super structure area	12304,0		
Number of accommodation floors above main deck	6,0		
Average accommodation length	107,0		
Accommodation height	17,4		
Ks	1,5		
Top accommodation length	40,0		
Area	553,8		

Fig.10: Cabin configuration and area calculation examples cruise ship FTDCA

3.3.2 Weight and capacity calculation

A classic weight calculation approach is applied in the tool. Vessel light weight is estimated based on steel, mission required equipment and outfitting weights. Different equipment weight are accrued in top of the calculated LWT as manual input or exploiting available values in stored data base in the tool. Hull steel weight estimation equation, is the result of internally developed parametrization of generic mid ship section for each vessel segment and calculating the weight for each combination based on rule loads. Nonlinear multiple regression analysis is applied on the results and a generic equation is created to estimate main hull steel weight. The weight for superstructure and accommodation is estimated based on calculated areas, volume and number of accommodation decks. The OSV main hull steel weight equation (Eq.1) as an example is given here. Developed equations are calibrated and verified based on available steel weight of Ulstein built vessels.

$$\text{(Eq.1)} \quad Weight_{Hull} = (1.2 \cdot 0.17 \cdot {k_s}^{\alpha} \cdot Loa^{\beta} \cdot B^{\gamma} \cdot D^{\delta} + 1.2x10^{\kappa} \cdot (Loa \cdot B \cdot D)^{\rho} - 9x10^{-8} \cdot (Loa \cdot B \cdot D)^{\nu} + 0.027 \cdot (Loa \cdot B \cdot D) - 223.64) + Weight_{Cb}$$

$$\text{(Eq.2)} \qquad k_s = \frac{L_{OA} \cdot D}{L_{BP} \cdot T_{Max}}$$

3.3.3 Calm water and wave added resistance modulus

3.3.3.1 Calm water

The calm water resistance module is responsible for estimating the propulsion and resistance parameters for the vessel in calm water condition. It is an evaluation sheet, that does not require inputs from the user. In order to evaluate the vessel resistance, the ITTC 1978 method is used. The method considers that the total resistance coefficient can be decomposed as Fig.11.

Speed power result curve for different cases is calibrated with CFD and model test results. wave making resistance coefficient is finetuned accordingly for X-bow and bulbous bows in the tool. Fig.12 depicts such validation and calibration where almost 5% deviation is observed in the result of the tool compared to CFD results in the speeds above 15 kn.

The wetted surface area is estimated using the calibrated expression from Holtrop and Mennen:

$$S = L \cdot (2 \cdot T + B) \cdot \sqrt{C_M} \cdot (0.453 + 0.4425 \cdot C_B - 0.2862 \cdot C_M - 0.003467 \cdot B/T + 0.3696 \cdot C_{WP}) + 2.38 \cdot A_{BT}/C_B$$

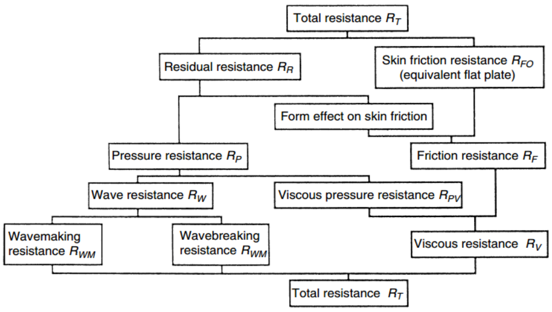


Fig.11: Calm-water resistance decomposition, ITTC 1978

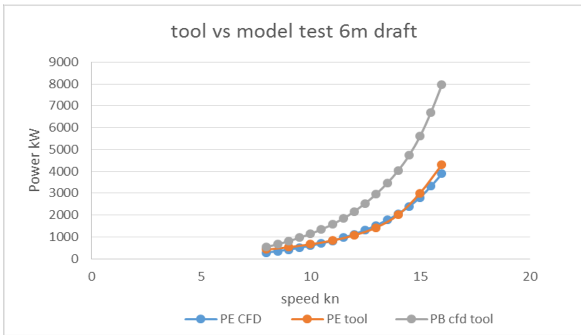


Fig.12: FTDCA speed power curve calibration and verification with CFD

3.3.3.2 Wave added resistance

Ship moving in waves will dissipate more energy than one sailing in still water. This extra-induced loss of energy is called added resistance in waves. Ship motions, in particular, the vertical motions heave and pitch have the largest effect in wave added resistance. Energy and moment method in visual basic coding is used in the tool for wave added resistance calculation, *Perez (2007)*.

$$R_{AW} = \frac{\omega_e^3}{2g}(b_z z_a^2 + b_{z+\theta} z_a \theta \cos\varepsilon + b_\theta \theta_a^2)$$

Or made nondimensional:

$$\sigma_{AW} = \frac{L\omega_e^3}{2B^2\rho g}\left\{(RAO_z)^2 b_z - \frac{2\pi}{L_W}(RAO_z)(RAO_\theta)b_{z+\theta}\cos\varepsilon + \frac{4\pi^2}{L_W^2}(RAO_\theta)^2 b_\theta\right\}$$

To be able to simplify the model and parametrize it based on main dimensions and shape factors as an innovative approach for WM resistance calculation closed form expression is used, *Jensen (2004)*. Heave and pitch RAO, and sectional damping calculation are calculated based on closed form expressions, where results are exploited in energy model. Different spectrums are used in the tool which is defined as an input for root mean square calculation. Fig.13 is the schematic process of wave added resistance calculation model in the tool. Output from calm water and wave added resistance calculation is transferred to power balance module for vessel installed power calculation. Total power required for different operational mode and mission required equipment, is calculated in power balancing calculation module.

$$A = 2\sin\left(\frac{\varpi^2 B}{2g}\right)\exp\left(-\frac{\varpi^2 T}{g}\right) = 2\sin\left(\frac{1}{2}kB\alpha^2\right)\exp(-kT\alpha^2)$$

$$R_{AW} = 2\int_0 S_\zeta(\omega_e)\frac{R_{AW}}{\zeta_a^2}(\omega_e)d\omega_e$$

Forcing functions:

$$F = \kappa f\frac{2}{k_e L}\sin\left(\frac{k_e L}{2}\right)$$

$$G = \kappa f\frac{24}{(k_e L)^2 L}\left[\sin\left(\frac{k_e L}{2}\right) - \frac{k_e L}{2}\cos\left(\frac{k_e L}{2}\right)\right]$$

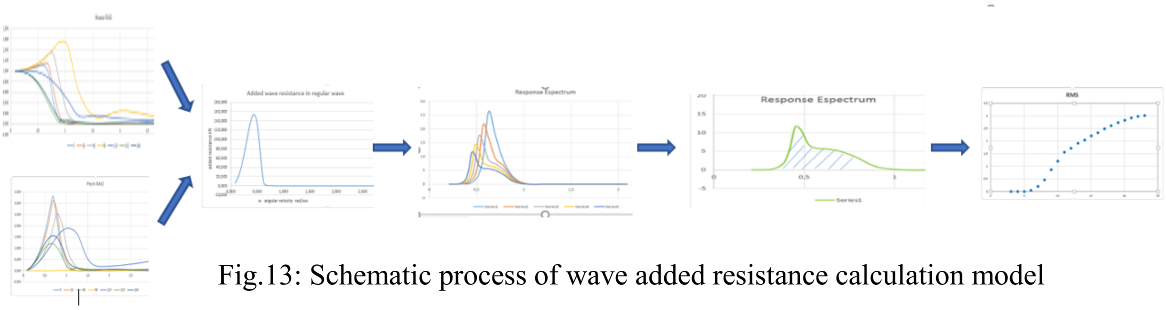


Fig.13: Schematic process of wave added resistance calculation model

3.3.4 Performance benchmarking module

The performance module of FTDCA is responsible for calculation of the performance measures of merit for developed designed solution and comparing it with market vessel peers. Different vessel benchmarking indexes are developed by Ulstein over the years and explained comprehensively in some conferences globally, *Ulstein and Brett (2015), Ebrahimi et al. (2015,2018)*. Pareto-front and frequency histograms are used in the tool for peer benchmarking. Fig.14 presents performance benchmark of the developed solution in both graphs for Technical Operational Performance Indexes (TOPI).

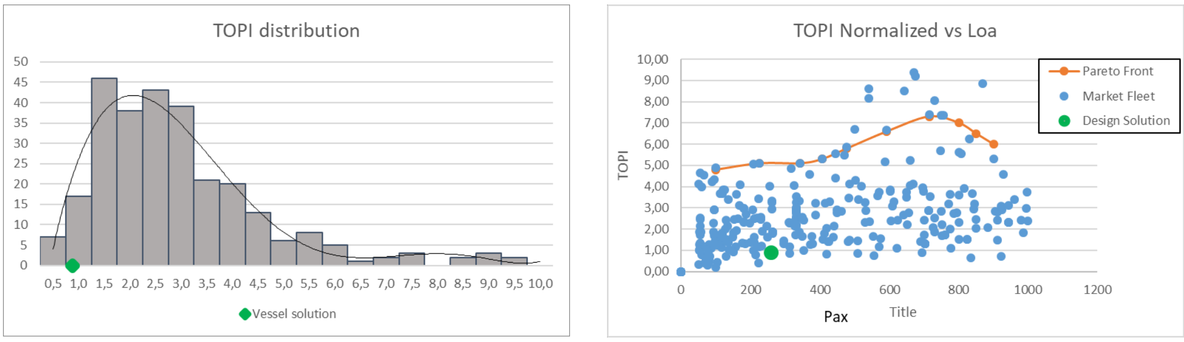


Fig.14: Benchmarking representation of the developed solution in FTDCA

Payment factors	
Equity	50 %
Loan	50 %
Interest	10 %
Repayment	20 years
Return on equi	10 %
Building counti	Norway
Conversion rat	8.50 NOK/USD

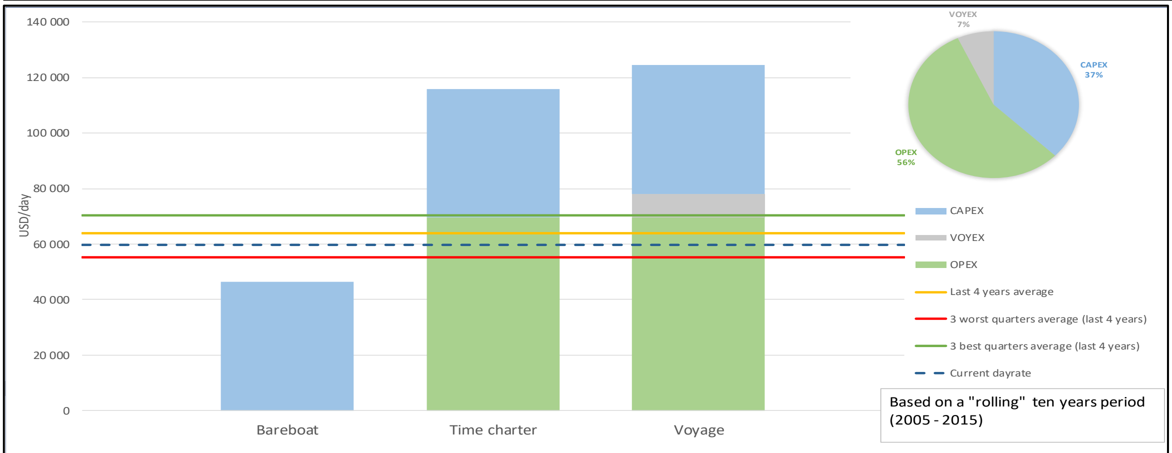
Operational fees	
Terminal disbursement	13938.89114 USD
Terminal calls per year	35 times
MGO price	369 USD
Crew nationality	Philippine

Estimated newbuilding cost	
Construction cost	60 582 963 USD
Mission equipment cost**	78 235 294 USD
Profit (5%)	6 940 913 USD
Overhead (7%)	9 717 278 USD
Total building cost	155 476 447 USD
Total building cost	1 321 549 804 NOK

** ROVs are not included in the price, just LARS system

Operational profile	
Transit, loaded, steaming	37%
Transit, loaded, slow steaming	0%
DP2	29%
Waiting	3%
In port (Loading/ Discharge)	10%
*values are estimated	10%
0	11%

Brands	
Designer	Focal Marine & Offshore Corp.
Engine manufacturer	Cummins



Expenditures (USD)	
CAPEX	46 315
OPEX	69 575
VOYEX	8 587

Contract scenarios (USD)	
Bareboat	46 315
Time charter	115 890
Voyage	124 477

Day rates (USD)	
Average 3 worst years	62 667
Average 10 years period	72 667
Average 3 best years	80 000

Additional information	
Dayrate based on:	West Africa
Contract type:	Term Market
Utilization rate:	88 %

Fig.15: Example of economy performance calculation and representation FTDCA

3.3.5 Economy measure and cost estimation module

The economics section presents information related to the designed vessel economic measure of merit. Bottom up structure of the cost model based on 3rd level SFI cost break down approach is used in economy model. Inputs from different modules including, volumes/area's, steel weight and outfitting weights, installed and propulsion power and required mission equipment are input to this module. Unit costs for material and construction are used based on Ulstein shipyard practices with permissible level of accuracy to estimate vessel construction cost. Labour cost and material cost differences compensated with labour productivity in some other countries like China, Poland and Turkey also are inserted in the tool to calculate construction cost in other countries than Norway. Beside vessel Capex calculation, operational cost of the vessel due to its type of operation, number of crew, maintenance and insurances costs are included in the tool. More over the tool encompasses the Voyex based on fuel cost and operational profile of the vessel, adding the cost for port calls and number of disbursements. Revenue making capability of the tool depends on vessel type and calculated based on stored day-rates for offshore vessels since 2007 or passenger and cargo transportation rates for cruise ships in different cruising routs and luxury classes, Fig.15.

4. Case study

The case study part of this paper is related to the design of an exploration cruise to be operated in Norden Europe area with the following expectation criteria from costumer, Table I.

Table I: Design expectation list

Number of Pax	Number of Crew	Max speed	Ice class	GT
250-280	160-180	17 kn	1B	~10000

To approach this design problem, 6 alternative design solutions are generated with FTDCA, Table II, in the conceptual phase, to fulfil expectation criteria by varying main dimensions, cabin sizes, number of crew and vessel luxury level. Among the solutions, solution D is larger solution well-fitting with premium-high luxury where alternative A3 resembles a modest-medium luxury solution in the requested size. This variation among the solutions is to depict the influence of different design technical and operational aspects on the commercial factors. Demonstrating the implications and the consequences of different parameters on vessel particulars, performance and economy measure in a short time span is the main objective of the FTDCA compared to traditional design approach.

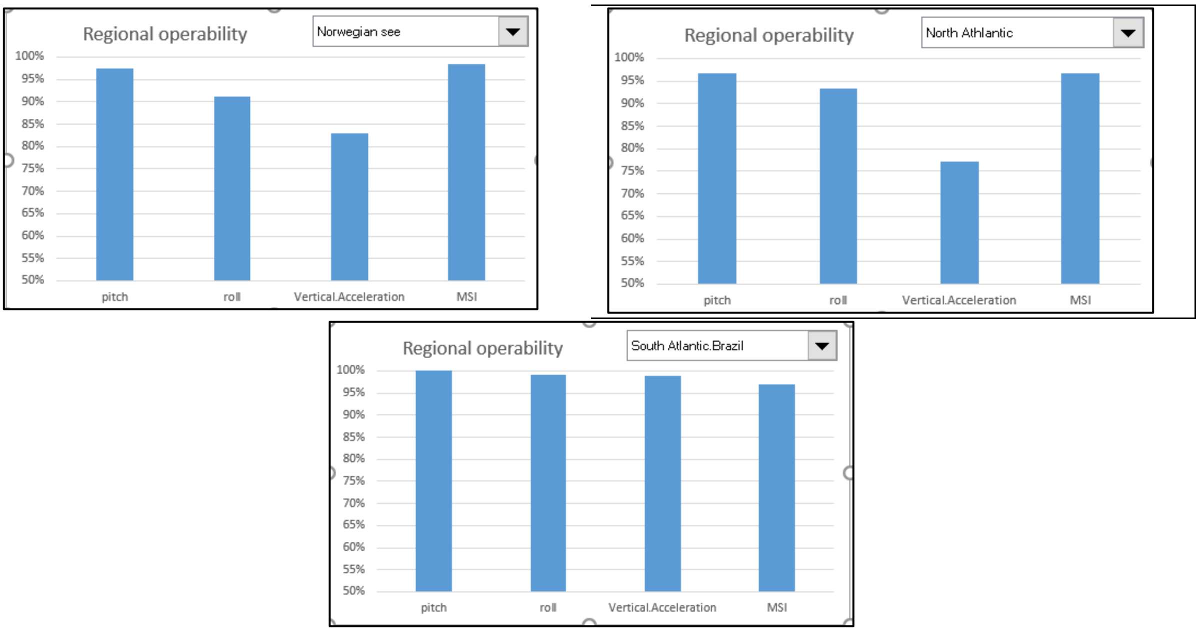


Fig.16: Sensitivity of vessel operability to weather condition in different region

Table II: Alternative design solutions

Solution Proposals						
	Alt A1	Alt A2	Alt A3	Alt B	Alt C	Alt D
Luxury standard Interior	Medium	Premium Lux	Medium	Medium-Premium	Premium	Premium-high
Ice class notation	Ice B1	Ice B1	Ice B1	Ice B1	Ice B1	Ice B1
GT	10400	11700	9100	10250	10750	14900
LOA	130	130	130	120	130	150
LBP	120	120	120	110	120	140
Beam	19,5	19,5	19,5	20,0	19,5	21,3
L/B	6,15	6,15	6,15	5,50	6,15	6,57
Depth to main deck	7,3	7,3	7,3	7,3	7,3	7,8
Max. Draft	5,5	5,5	5,5	5,5	5,5	5,7
Design Draft	5,3	5,3	5,3	5,3	5,3	5,5
Passengers	260	260	250	260	260	260
Crew	172	172	125	172	130	200
Crew/Pax	0,66	0,66	0,50	0,66	0,50	0,77
Gust Cabin arrangement (Qty*area) Luxury suits balcony large cabins Window cabins	6*70 20*32 104*25	6*70 20*32 104*25	5*50 20*32 100*26	6*70 20*32 104*25	6*70 20*32 104*25	6*70 20*32 104*26
Public area/Pax m^2	8,0	13,0	6,0	8,0	12,0	20,00
Crew cabin Arrangement	12*single 80 * 2 men	12*single 80 * 2 men	12*single 80 * 2 men	12*single 80 * 2 men	10*single 60 * 2 men	20*single 90 * 2 men
Dwt	1 420	1 230	1 550	1 350	1 320	1 600
DWT/Pax	5,5	4,7	6,2	5,2	5,1	6,2
Engine_KW_Total	10 000	10 500	9 700	10 500	10 150	12 300
Propulsion Power	6 800	6 800	6 800	7320	6800	7 450
GT/Pax	40	45	36	39	41	57
Max. Speed (knots)	18	18	18	18	18	18
LWT	6200	6400	6100	5900	6300	8 500
St weight	3150	3260	3100	2980	3220	4 350
Number of accommodation deck excluding top deck/bridge	5	5	5	5	5	6
MSI Operability in 5.1 Hs 30% from LCG Norwegian Sea	98,0 %	98,0 %	98,0 %	98,0 %	98,0 %	98,0 %
Vertical Acceleration Operability .05*g limiting 30% from LCG	79,0 %	79,0 %	79,0 %	78,0 %	79,0 %	83,0 %
GM	1,58	1,38	1,73	1,93	1,45	1,55
Natural Roll Period sec	11,8	12,62	11,3	11	12,21	13
SFC Ton/day	20	21,1	19,5	20,3	20,2	25,3
Spped * GT /Power	18,72	20,06	16,89	17,57	19,06	21,80
Price/Pax night break even point USD @ 75%	510	570	440	505	480	700
USD/GT	9 087	9 231	9 341	9 122	9 023	9 396
Opex/Day	53600	59700	51700	53400	47500	67000
USD_Newbuilding_Price adjusted	94 500 000	108 000 000	85 000 000	93 500 000	97 000 000	140 000 000
USD /L*B*D	5 107	5 836	4 593	5 337	5 242	5 618
USD Price /pax	363 462	415 385	340 000	359 615	373 077	538 462

This type of analysis and plotting developed solutions in different market data analytics graphs serves information to figure out ill positioned solutions based on market place data quickly. As a consequence of applying such rapid solution development process is to guide the designers and decision makers into the right track in early design phase. Sensitivity analysis of the vessel operability in different regions is another valuable achievement of fast track tool. Fig.16 shows the variation in design solution operability by making variation in operational region for four different seakeeping criteria. Such type sensitivity analysis demonstrates the impact of different influencing parameters on the performance of final design solution and opens room for further investigation of design improvements in early phases within a short time span.

4. Concluding remarks and discussion

In this paper, fast track conceptual design approach is defined and explained comprehensively. Similarities and differences between classic design spiral which is based on sequential design approach and fast track approach coming out of the concurrent engineering thinking is explained in this paper. Structure of Ulstein FTDCA is explained and discussed how FTDCA as an open source internal concept design technology, exploits combination of MS excel interface, VB coding and web based open tools including Java coding, WebGL and Collada. Different analytical approaches and computing modulus of the tool explained in detail. Accuracy level of the tool compared to imperial equation, CFD and model test and it is argued in the paper how gap between empirical equation and CFD/ 3D model creation approach is filled by Ulstein FTDCA. It is argued how 95% of accuracy compared to the result of comprehensive and more complex design tools is achieved in FTDCA. Time and accuracy trade-off in vessel conceptual design phase is discussed in the paper and presented how Ulstein FTDCA, resolved the challenge of these contradicting objectives in conceptual design phase where in a very quick response time, computational power with permissible accuracy level is achieved by the tool. It is shown in the paper by practical cases Ulstein conceptual design response time shorten from an average of 25-30 days, to 2-3 days depending on the type, size and budget of the project as a substantial improvement in conceptual design phase.

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