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CRITICAL ANALYSIS OF TANKER OP-EX ADJUSTING CREW SYNTHESIS, AUTOMATION LEVEL, AND MAINTENANCE

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ABSTRACT

In this paper we will present a critical analysis concerning tanker operating expenses. In this context, we try to explore various possibilities for the combined adjustment of automation level and crew synthesis, in order to fulfill maintenance (operational) needs of tankers. Precedent research results have shown that by increasing vessel automation level a substantial decrease of crew synthesis is feasible, in terms of watchkeeping and safety redundancy; hence, a potential window for decrease of op-ex is produced. The crucial issues/constraints regarding the analysis for the operational viability are maintenance man-hours in accordance with policy issues on on-board workload and fatigue, and external costs in order to cover all corresponding tanker needs. This paper examines all recorded aspects of the specific problem and proposes a methodological framework. This is achieved by using certain statistical, analytical and simulation techniques so as to come up with solid results and conclusions. Main motivation for this paper is the oncoming increase of tanker build-in technological innovations versus the slowly changing policy for vessel crew synthesis. Finally, we will conclude this paper with interesting comments arisen from the aforementioned tasks.

KEY WORDS

maritime economics, human aspects, simulation models, maritime policy, on-board operations

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1. INTRODUCTION

One of the primary concerns of today's shipping industry is the adequate relaxation of the constraints regarding crew competence and fatigue in the shipboard operational environment. This effort is translated into numerous regular and predefined tasks that should be accomplished on a daily basis, in order for each ship to sail, navigate and reach to its destination with safety and error-free procedures (Smith, 2001). The maritime community acknowledges the fact that in some types of ships the introduction of minimal manning, difficult weather and traffic conditions, rapid turnarounds, and short sea passages may lead to crews without the necessary awareness and rest. Moreover, the technological upgrade of modern vessels (i.e. integrated bridges, central control systems etc) along with new practices, guidelines and regulations regarding human factor, human-equipment interfaces (HMI), marine safety and shipping operations create a demanding mix for capable, fresh and alert seafarers; this is a key element in the effort for feasible human task requirements, efficient crew resource management, and adequate situation perception and awareness (Booher, 2003).

This effort could be subsumed in the outline regarding the enhancement of EU maritime competitiveness. In particular, the merchant fleets of many EU flags have experienced a significant decline of competitiveness in terms of crew cost over the years; hence, this resulted into a considerable reduction of the number of ships for numerous EU flags. Moreover, it is common practice that crew composition is estimated by each Flag Authority according to its regulations for safe manning, therefore this is not a decision strictly taken according to operational or economic features. It is noted that the implementation of technological innovations on-board vessels (e.g. tanker ships) can lead to an important alternation of duties carried out by certain crew members both in qualitative and quantitative terms: the installation of an integrated bridge system may require advanced expertise in HMI, computer handling etc, but at the same time it will reduce the corresponding amount of watchkeeping load.

This paper addresses an important maritime issue; namely the dynamic interaction between vessel automation level and crew synthesis from workload and operational (maintenance) point-of-view. Is it possible for an advanced vessel and its *probably* reduced crew to cope with the maintenance or other needs (excluding watchkeeping duties)? An obvious answer could be that the technological retrofit would reduce the maintenance needs of the vessel and therefore, the corresponding standards would differentiate substantially from those of a standing conventional tanker. Actually, this is one puzzle for each ship owner to solve, in order to determine the "tolerable" level of amount for the retrofit cost aiming at a promising equilibrium between capital and operational costs (e.g. maintenance costs). In effect, crew decrease is restricted by safety *and* fatigue (workload) factors; it may cause an upward effect to crew overtime cost and external repair-team cost.

The relevance of an existing ship will be discussed throughout the predefined technological spectrum; that is from conventional to fully integrated. The case study is a tanker vessel with recorded needs of regular and non regular maintenance. Thus, this paper shows the level of decrease regarding maintenance (operational) needs that the investment should accomplish in order to overcome any fatigue or workload problems. In this context, the question is transformed into: *is crew reduction equivalent to operational cost cut-off*? Crew overtime and external repair-teams are two components that seem to be influenced significantly from crew reduction.

The rest of this paper is structured as follows. Section 2 presents STCW thresholds and guidelines on fatigue issues. Section 3 presents case study/vessel characteristics and maintenance database formulation. Section 4 gives the results of the implemented analysis and Section 5 concludes and proposes numerous issues for further discussion.

2. CREW WORKLOAD: STCW THRESHOLDS AND GUIDELINES

In this context, the issue of sufficient manpower (in terms of person-hours) for the mitigation of the recorded onboard maintenance (operational) needs acquires both organizational and safety characteristics. Methods of technological enhancement for ships followed with (justified) propositions for crew reduction, such as the one concerning the introduction of an advanced/integrated vessel (Dilzas et al, 2003) should take into account and not overlook the problems of crew overtime and fatigue. Ship maintenance (i.e. the PMS programme) is achieved on an overtime basis, in order for the vessel to maximize its productive period and corresponding revenues. This means that continuous ship operation should be complemented with qualitatively and quantitatively adequate crew – fatigue-free and trained seafarers capable to fulfill their obligations in the best possible manner thereof. Hence, the Authorities, the ship management and captain should provide for a productive environment for the shipboard personnel, with limited and predefined working hours, stimulating conditions and systematic organizational procedures.

The International Maritime Organization (IMO) and the global shipping sector have confronted the above described crew and fatigue-related problems with the International Seafarer's Training, Certification and Watchkeeping Code, STCW95 (IMO, 1996). More specifically, this instrument aims at establishing uniform standards in the shipping industry, regarding the training, certification, validation, competence, occupational safety, and fatigue of seafarers in a way that they can conclude their duties in a reliable and environmental-friendly manner. The basis for the estimation of the maximum permitted amount of crew working hours (including single, double and holiday overtime schemes) lies on the specific Convention and consequently on the national regulations. Thus, the limits regarding overtime hours can be extracted from the combination of the standard working period (8 hours per day) and the respective thresholds for rest hours. It is noted that it is common practice for the ship's captain and chief engineer to be excluded from the overtime schedule. Table 1 presents in its upper part the workload limits emerging from the examination of the STCW95 Code, while it's lower part delineates the corresponding figures from the Greek legislation regime.

According to guidance given in Section B VIII/1 of the STWC95 Code, the aforementioned minimum rest periods should not be interpreted as implying that all others hours should be obligatory devoted to watchkeeping or other duties (IMO, 1996). Nevertheless, for the purpose of this paper it is assumed that the implemented crew workload covers the entire permissible period provided by the STCW Code; that is an active period of 14 hours per day.

Table 1: Minimum limits regarding shipboard rest periods for seafarers, according to STCW95 & the Greek legislation regime.

Description	Minimum Limits (hours)
STCW95	
Rest period – regular conditions (per day)	10
Continuous rest period – all conditions (per day, up to 2 days)	6
Rest period – all conditions (per week)	70
Greek Legislation	
Rest period – regular conditions (per day)	10
Continuous rest period – all conditions (per day, up to 2 days)	6
Rest period – all conditions (per week)	77

3. THE CASE STUDY – VESSEL AND DATA PRESENTATION

The vessel under consideration is a tanker of 90,000 ton DWT and 10 years old. The vessel belongs to the conventional class, without any innovative technological system implemented on-board. The class notations that were selected, regarding the machinery operations and the navigational competence of a ship, are presented in brief below (Lloyd's Register, 2000). It is noted that the specific list does not include conventional vessels.

UMS	Denotes that all predetermined arrangements are such that the ship can be operated with its machinery spaces unattended. (*Unattended Machinery Space*)
CCS	Denotes that all predetermined arrangements are such that the ships machinery may be operated with continuous supervision from a centralized control station. (*Centralized Control Station*)
IBS	Denotes that an integrated bridge system is fitted to provide electronic chart display, track planning and automatic track following, centralized navigation information display, and bridge alarm management. Hence, it represents a combination of systems which are interconnected in order to permit central access to sensor information or command/control (MSC.64(67)). Moreover, the IBS standard has practically overlapped the *Integrated Navigation System* (INS, IEC 61209/Ed 1) in which the data from two or more exclusively navigation aids is combined in a uniform mode to provide an output that is superior to any one of the utilized aids. (*Integrated Bridge System*)

Hence, in the context of this paper the implemented approach regarding the examination and survey of the tanker's maintenance (operational) needs incorporated the following vessel classes:

- Conventional vessel;
- UMS;

- CCS; and
- IBS.

Moreover, a credible database for maintenance man-hours needs was developed in order to vest the case study with a realistic workload from an operational perspective. In effect, this database contains maintenance man-hours for all three vessel departments; namely the deck, engine and the steward/catering department. **Table 2** depicts the resultant crew composition.

Table 2: Incorporated crew ranks per tanker department.

DECK CREW	ENGINE CREW	SUPPORT CREW
Captain (*Inactive*)	Chief Engineer (*Inactive*)	Cook
Chief Mate	2nd Engineer	Steward
2nd Officer	3rd Engineer	
3rd Officer (or Apprentice Deck Officer)	Electrician (or Apprentice Engine Officer)	
Boatswain	Oiler/Wiper	
Able Body		

It is noted that the definition of maintenance overtime man-hours refers to additional working hours per month beyond the regular shift hours (i.e. wathckeeping duties). Overtime work comprises of Single, Double and Holiday hours depending on the maintenance needs and time issues. The collection of data covers a period of three years with a monthly step. **Table 3** presents a sample of overtime hours for the deck and steward departments for the first fifteen-day period of December, 1996.

Table 3: Overtime sample for December, 1996 (Deck & Support Crew).

Rank	**Department**	**Overtime 1 (Single Hours)**	**Overtime 2 (Double Hours)**	**Overtime 3 (Holiday Hours)**
2ND OFF.	DECK	73	10	50
2ND OFF.	DECK	73	10	50
BSN	DECK	80	23	48
PMN	DECK	84	46	46
A.B	DECK	135	-	-
A.B	DECK	112	-	-
A.B	DECK	110	-	-
O.S.	DECK	93	-	-
O.S.	DECK	32	-	-
O.S.	DECK	32	-	-
O.S.	DECK	69	-	-
O.S.	DECK	67	-	-
D/B	DECK	69	-	-
COOK	STEW	23	-	-
ASS.COOK	STEW	97	-	-
MESSMAN	STEW	97	-	-
MESSMAN	STEW	72	-	-

It is noted that daily operational needs, in terms of man-hours, is the sum of the regular shift workload plus the corresponding daily overtime. In effect, each crew rank/member has a specific operational role. For example, in a conventional vessel, deck and engine officers have an 8-hour watch obligation per day, whereas able bodies are mainly occupied with maintenance activities. In this context, **Table 3** is evolved into **Table 4** so as to include the total operational (maintenance) man-hours for the selected case study.

Table 4: Overtime sample for December, 1996 (Deck & Support Crew).

Rank	**Department**	**Regular Work**	**Overtime 1 (Single Hours)**	**Overtime 2 (Double Hours)**	**Overtime 3 (Holiday Hours)**	**Total**
2ND OFF.	DECK	0	73	10	50	133
2ND OFF.	DECK	0	73	10	50	133
BSN	DECK	0	80	23	48	151
PMN	DECK	160	84	46	46	336
A.B	DECK	160	135	0	0	295
A.B	DECK	160	112	0	0	272
A.B	DECK	160	110	0	0	270
O.S.	DECK	160	93	0	0	253
O.S.	DECK	160	32	0	0	192
O.S.	DECK	160	32	0	0	192
O.S.	DECK	160	69	0	0	229
O.S.	DECK	160	67	0	0	227
D/B	DECK	160	69	0	0	229
COOK	STEW	160	23	0	0	183
ASS.COOK	STEW	160	97	0	0	257
MESSMAN	STEW	160	97	0	0	257
MESSMAN	STEW	160	72	0	0	232

4. ANALYSIS AND RESULTS

In order to receive useful statistical results, the correlations between deck, engine and steward department are thoroughly examined. Cross Correlation (CCF) between deck, engine and steward crew overtime man-hours (Figure 1) shows that operational (maintenance) needs have a propensity of simultaneous appearance at all departments. This means that the periods of significant workload between the aforementioned vessel departments are identical, in terms of appearance.

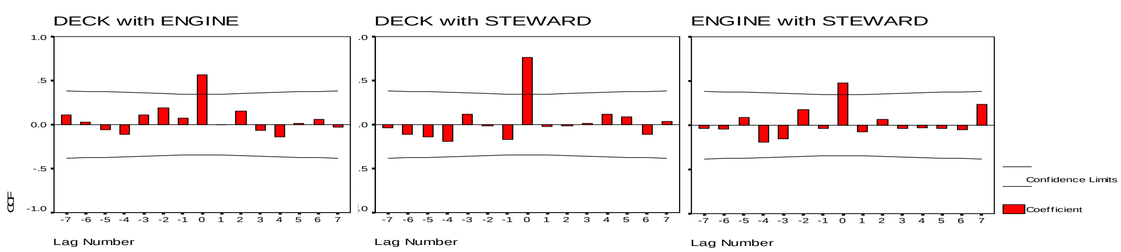


Figure 1: Cross correlation (CCF) between vessel departments.

Auto Correlation (ACF) and Partial Autocorrelation (P-ACF) for deck, engine and steward crew overtime man-hours –Figure 2– shows that there is no step dependence for each of the vessel departments. Hence, the overtime maintenance needs for a specific month does not reveal the corresponding overtime needs for any month leading or lagging in the time field. It is also clear that seasonality patterns of overtime work are absolutely absent in the database records.

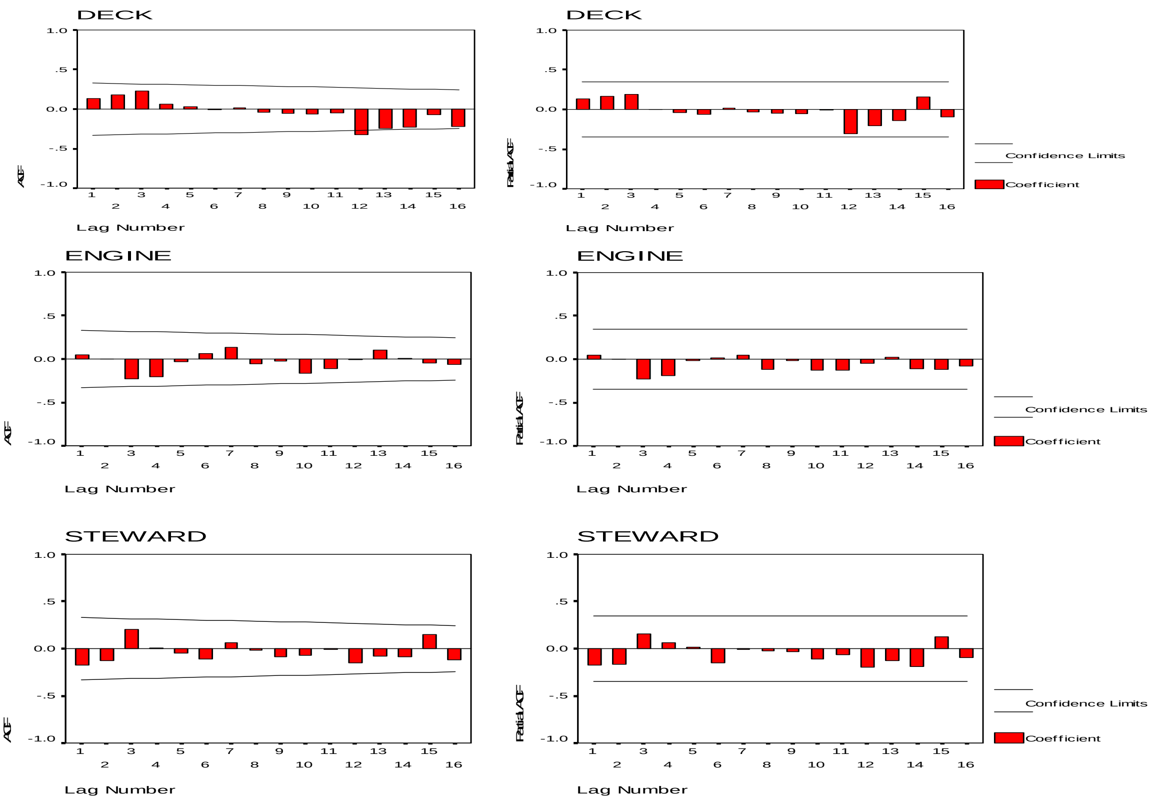


Figure 2: Autocorrelation (ACF) and partial-autocorrelation (P-ACF) for all vessel departments.

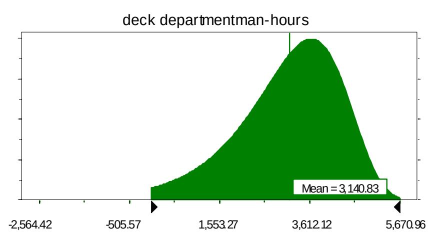
The estimation of the crew synthesis per rank for the specific vessel in all four possible automation levels was done through a specially developed software tool (we call it the Retrofit Strategy Tool, Dilzas et al, 2003). The input variables for the specific model are vessel's DWT, GRT and BHP. It is noted that the presented approach has incorporated the fact that certain crew ranks have watchkeeping duties (i.e. deck officers), whereas other ranks do not (i.e. seamen). **Table 5** depicts the manning output for the selected automation levels.

Table 5: Manning output for the selected automation levels.

Automation Level	Total	Captain	Deck Officers			Engineers				Bosun	Deck or Able Body	Wiper/ Oiler	Cook	Stewart
			Chief	2nd	3rd	Chief	2nd	3rd	Apprentice					
CM	28	1	1	2	2	1	2	3	1	1	7	5	1	1
UMS	17	1	1	2	1	1	1	1	1	1	4	1	1	1
CCS	13	1	1	2	0	1	1	1	0	1	3	0	1	1
IBS	11	1	1	1	0	1	1	0	0	1	3	0	1	1

Monte Carlo simulation is technique rarely used in simulation of shipping systems. Monte Carlo simulation permits the evaluation of system performance prior to the physical implementation. A proper data collection and analysis combined with statistical techniques, verification and validation of models are crucial and essential to obtain confidence for the results. Simulation process concisely is as follows: system model is defined and build along with all crucial input and an examinant output. “Although it is not possible to provide a set of instructions that will lead to building successful and appropriate models in every instance, there are some general guidelines that can be followed” (Morris, 1967). Using statistical calculus for every stochastic input variable, an assessment is made and a corresponding probability density function is constructed. During the simulation repetitions, for every stochastic input, a number generator produce values according to the relative probability distribution and the corresponding output is recorded. After an adequate number of repetitions (trials), a probability distribution is formed numerically for the examinant output. The method among others has a major requirement: a well defined and described system (Gentle, 1998). Hence, it is crucial to have absolute knowledge of system’s input variables, their effect to the system and the corresponding output. The stochastic input variables are the total monthly amount of work need for deck, engine and steward department of the vessel. The definition required knowledge of the statistical distribution of each factor. Past data collected and formed time series for the examinant factors. All three time series were fitted on an appropriate type of distribution. At this point it must be mentioned that data were fitted to various distributions and the most suitable was chosen according to goodness of fit test ranking. It was decided to use Chi-square, Kolmogorov-Smirnov and Anderson-Darling goodness of fit tests (Stevens, 1986, Kanji, 1990).

For the input factor of deck department man-hours work, fit process resulted into an Extreme Value distribution (Evans, 1993) with parameters as shown in **Figure 3**.

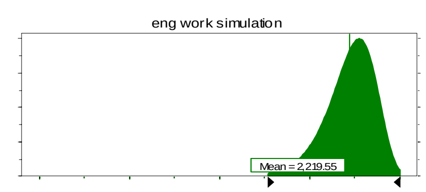


Extreme Value distribution with parameters:

Mode	3,612.12
Scale	1,029.42

Figure 3: Fit results for the deck department of the examined vessel.

For the factor of engine department man-hours work, fit process resulted into a Weibull distribution with parameters as shown in table **Figure 4**.

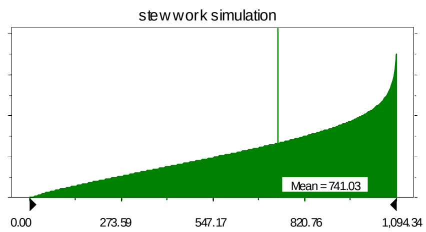


Weibull distribution with parameters:

Location	-6,259.45
Scale	8,763.35
Shape	15.00

Figure 4: Fit results for the engine department of the examined vessel.

For the factor of steward department man-hours work, fit process resulted into a Beta distribution with parameters as shown in **Figure 5**.



Beta distribution with parameters:

Alpha	1.80
Beta	0.86
Scale	1,094.34

Figure 5: Fit results for the steward department of the examined vessel.

Table 6 summarizes the goodness of fit results and the corresponding distributions for the three departments.

Table 6: Goodness-of-fit results.

	Chi-Square	K-S	A-D
Deck Department (Extreme Value distribution)	7.5882	0.1357	0.8524
Engine Department (Weibull distribution)	7.1765	0.1450	0.9113
Steward Department (Beta distribution)	6.7647	0.1133	0.7079

According to the correlation approach, deck, engine and steward department man-hours are positive correlated. Hence during simulation process these factors are not generated independently but correlation patterns were retained. Spearman correlation coefficient is then calculated for variable pairs to be used during simulation. **Table 7** shows bivariate correlations for deck, engine and steward departments.

Table 7: Spearman correlation results.

	Deck Department
Engine Department	0.40
Steward Department	0.72

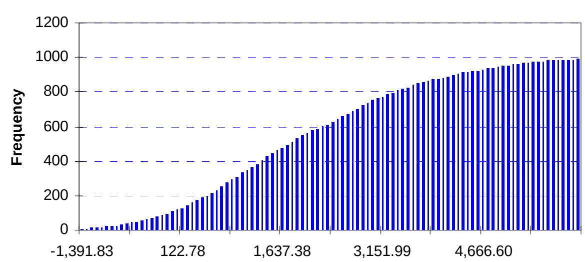


Figure 6: Total man-hour surplus – conventional level.

Simulation resulted into a numerical distribution for the total man-hour surplus for conventional level – **Figure 6**. **Table 8** shows the respective descriptive statistics. It is mentioned that the expecting value of the distribution is 1,992.30 man-hours that means that there is a significant surplus of man-hours covering 89.2% of the possible (operational) needs. According to this analysis, the crew synthesis of the vessel at conventional level is capable to fulfill necessary regular and extra work.

Table 8: Simulation results – conventional level.

Statistics	Value	Percentile	Value
Mean	1,962.30	0%	-1,661.39
Median	1,774.27	10%	-65.03
Mode	---	20%	525.30
Standard Deviation	1,667.56	30%	938.87
Variance	2,780,765.90	40%	1,345.51
Skewness	0.44	50%	1,774.27
Kurtosis	2.86	60%	2,250.56
Coeff. of Variability	0.85	70%	2,783.97
Range Minimum	-1,661.39	80%	3,371.61
Range Maximum	7,604.85	90%	4,252.73
Range Width	9,266.24	100%	7,604.85
Mean Std. Error	52.73		

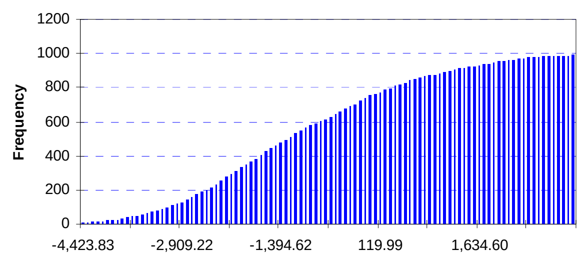


Figure 7: Total man-hour surplus – UMS.

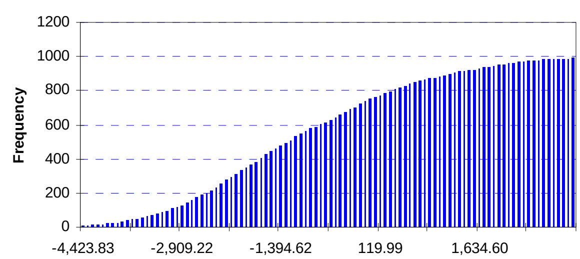
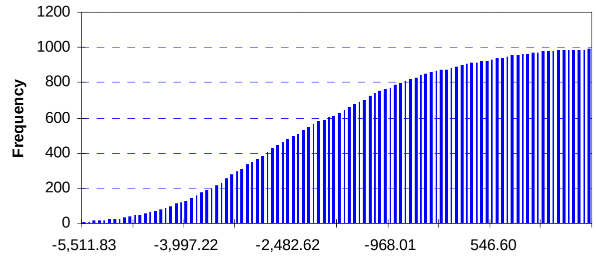


Figure 7 depicts the numerical distribution for the total man-hour surplus for the UMS. **Table 9** shows the descriptive statistics for the resultant distribution. Expecting value of the distribution is -1,069.70 man-hours, therefore crew synthesis of the examined vessel at UMS automation level is unable to complete all necessary regular and extra work in a monthly basis. In effect, the ship-owner should seek for external repair teams because the crew is sufficient only for the 24.7% of necessary regular and extra workload.

Simulation provided a numerical distribution for the total man-hour surplus for the CCS



level, as shown in **Figure 8**. **Table 10** shows the descriptive statistics for the resultant distribution. It is crucial to mention that the expecting value of the distribution has the significant negative value of -2,157.70 man-hours. This means that in this level of detail, there is considerable deficiency regarding the available man-hours since only the 11.5% of the possible needs is adequately covered. According to this analysis the crew synthesis of the vessel at CCS automation level is not capable to fulfill necessary regular and extra work and ship; therefore, the owner should consider the solution of external repair teams, when necessary.

Table 9: Simulation results – UMS.

Statistics	Value	Percentile	Value
Mean	-1,069.70	0%	-4,693.39
Median	-1,257.73	10%	-3,097.03
Mode	---	20%	-2,506.70
Standard Deviation	1,667.56	30%	-2,093.13
Variance	2,780,765.90	40%	-1,686.49
Skewness	0.44	50%	-1,257.73
Kurtosis	2.86	60%	-781.44
Coeff. of Variability	-1.56	70%	-248.03
Range Minimum	-4,693.39	80%	339.61
Range Maximum	4,572.85	90%	1,220.73
Range Width	9,266.24	100%	4,572.85
Mean Std. Error	52.73		

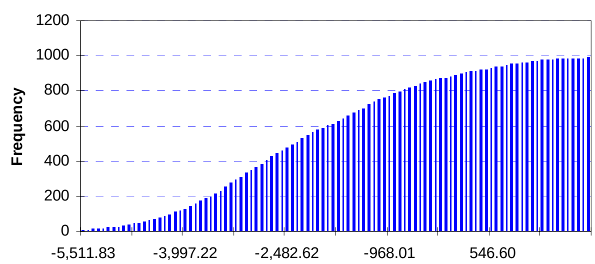


Figure 8: Total man-hour surplus – CCS.

Table 10: Simulation results – CCS.

Statistics	Value	Percentile	Value
Mean	-2,157.70	0%	-5,781.39
Median	-2,345.73	10%	-4,185.03
Mode	---	20%	-3,594.70
Standard Deviation	1,667.56	30%	-3,181.13
Variance	2,780,765.90	40%	-2,774.49
Skewness	0.44	50%	-2,345.73
Kurtosis	2.86	60%	-1,869.44
Coeff. of Variability	-0.77	70%	-1,336.03
Range Minimum	-5,781.39	80%	-748.39
Range Maximum	3,484.85	90%	132.73
Range Width	9,266.24	100%	3,484.85
Mean Std. Error	52.73		

Last level of automation in the presented study is the IBS. Simulation provided a numerical distribution for the total man-hour surplus as shown in Figure 9. Table 11 shows the descriptive statistics for the resultant distribution. This is the worst case scenario since the expecting value of the distribution has the significant negative value of -2,621.70 person-hours. This is translated into coverage of only 7.9% of the possible needs that might arise during vessel operations. According to the analysis, the crew synthesis of the vessel at IBS automation level is completely incapable to fulfill necessary regular and extra work and the adoption of external repair teams is the only feasible solution for the ship-owner.

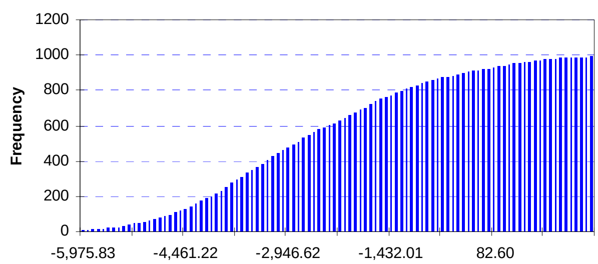


Figure 9: Total man-hour surplus – IBS.

Table 11: Simulation results – IBS.

Statistics	Value	Percentile	Value
Mean	-2,621.70	0%	-6,245.39
Median	-2,809.73	10%	-4,649.03
Mode	---	20%	-4,058.70
Standard Deviation	1,667.56	30%	-3,645.13
Variance	2,780,765.90	40%	-3,238.49
Skewness	0.44	50%	-2,809.73
Kurtosis	2.86	60%	-2,333.44
Coeff. of Variability	-0.64	70%	-1,800.03

Range Minimum	-6,245.39	80%	-1,212.39
Range Maximum	3,020.85	90%	-331.27
Range Width	9,266.24	100%	3,020.85
Mean Std. Error	52.73		

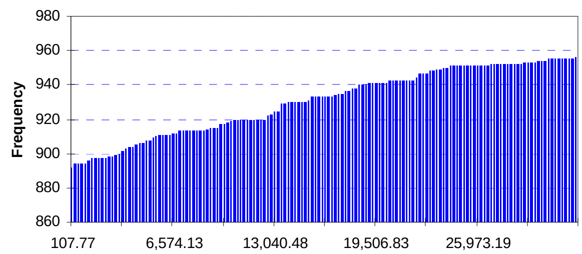


Figure 10: Total external repair cost – conventional level.

Additionally, the paper presents the results emerged from the calculation of the external repair tram costs for the selected automation levels. According to market data an amount of 50 € per man-hour is a reasonable respective remuneration. Making the assumption that the ship-owner is forced to hire an external repair/maintenance team every time the vessel crew is deficient to fulfill all regular and extra on-board workload, the simulation produced some interesting results. **Figure 10** gives the distribution of external cost for the selected vessel (conventional level). Mean value of this distribution is only 3,048.44 € per month.

Table 12 shows the descriptive statistics of external cost distributions for all four automation levels. It is clear that with current regular and extra work demands per month, the proposed crew synthesis (for the selected tanker vessel) is unable to fulfill its expected (operational) obligations. The ship-owner should consider the extremely extra cost for the appropriate vessel maintenance and work needs.

Table 12: Simulation results for external repair/maintenance team cost.

Statistics	**Conventional**	**UMS**	**CCS**	**IBS**
Trials	1000			
Mean	3,048.44	68,287.17	113,145.66	134,139.11
Median	0.00	62,876.60	117,276.60	140,476.60
Mode	0.00	0.00	0.00	0.00
Standard Deviation	11,262.82	61,006.17	73,394.63	77,004.99
Variance	126,851,107.52	3,721,752,310.70	5,386,771,223.08	5,929,769,050.82
Skewness	4.36	0.48	0.04	-0.10
Kurtosis	22.88	2.19	2.07	2.18
Coeff. of Variability	3.69	0.89	0.65	0.57
Range Minimum	0.00	0.00	0.00	0.00
Range Maximum	83,069.65	234,669.65	289,069.65	312,269.65
Range Width	83,069.65	234,669.65	289,069.65	312,269.65
Mean Std. Error	356.16	1,929.18	2,320.94	2,435.11

5. CONCLUSIONS

This paper attempts to establish a decisional framework for the critical analysis of crew size and automation level from an operational (maintenance) point-of-view. The presented methodology consists of adequate data collection regarding regular and extra workload, of crew size calculation as a function of the four selected levels of on-board automation (conventional, UMS, CCS and IBS) and of the analysis of the recorded and expected man-hour surplus and external repair/maintenance team cost using the Monte Carlo simulation technique. The specific model can be applied to any ship design and predict the corresponding man-hour surplus and external team costs for shipboard operational and maintenance needs.

This way, the ship owner is in position to know/predict the approximate man-hour surplus and the external repair/maintenance cost before purchasing a given vessel, or attempting any technological upgrade/retrofit on his vessel. Furthermore, it is shown that technological upgrades can result major financial modifications derived from changed operational cost components.

Therefore, we can now repose our initial question*: is retrofit towards higher automation levels profitable for the ship-owner?* An answer could be that such a retrofit does not represent a beneficial decision even though a significant crew cost reduction is expected. Nevertheless, there are numerous factors and components to consider before giving a realistic, reliable and solid answer. This paper shows the uncertainty that such a decision bears and points out for extreme caution when facing such issues.

Maintenance (operational) needs may show a decrease in relation to the retrofit level. It is difficult to answer for the extent of such a reduction, and probably a case by case analysis is needed; upgrade to higher automation levels means to replace or to renew part of the existing equipment. Another important issue is that a contract with external repair/maintenance teams under the provision of constant and regular services may be able to decrease cost significantly. Actually, it is a matter of market research to calculate the possible respective retrenchments.

Therefore, it is noted that retrofit activities towards a higher level of automation has to be examined on a case by case basis. It is expected that it is the special characteristics of the vessel that will determine the best equilibrium between automation level, crew synthesis and maintenance (operational) needs.

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