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INTEGRATED APPROACH TO VESSEL ENERGY EFFICIENCY

Victor N. Armstrong[1], Charlotte Banks[2]

[1]Apollo Sustainability & Optimization Solutions Inc., 2267 Lorraine Avenue, Coquitlam, British Columbia, V3K 2M8, Canada. www.apollosos.com; vnarmstrong@gmail.com
[2] The University of Strathclyde, 100 Montrose Street, Glasgow, UK, G4 0LZ. charlotte.banks@strath.ac.uk

ABSTRACT

Energy efficiency improvements in the shipping industry are being driven by economics, compliance and customer requirements. Whilst various technological and operation improvements are known and available, with many being demonstrated to be cost effective and with savings reported in the industry, their take up in the world fleet remains low. This low take-up can be considered due to many different barriers, as explored in various research studies. However the aim of this paper is first to understand how these barriers are created by considering how ship operations function day-to-day within the context of mainstream business practice. A holistic view of operations is required and is presented in this paper, including consideration of business focus areas in parallel with the functions of technical, operational and commercial stakeholders. With this laid-out, gaps within existing operations are discussed in relation to areas for practical improvements.

Key words: Energy efficiency, Optimization, Fuel savings, Integrated management, Business process, Systems

NOMENCLATURE

AIS – Automatic Identification System
BAU – Business As Usual
CAPEX – Capital Expenditure
CSR – Corporate Social Responsibility
EEDI – Energy Efficiency Design Index
IMO – International Maritime Organisation
ISM – International Safety Management Code
ISO – International Organisation for Standardization
KPI – Key Performance Indicator
LTIF – Lost Time Injury Frequency
MRV – Monitoring, Reporting and Verification
OPEX – Operational Expenditure
PBCF – Propeller Boss Cap Fin
RCM – Reliability Centered Maintenance
ROB – Remaining On Board
RPM – Revolutions per Minute
SEEMP – Shipboard Energy Efficiency Management Plan
UNFCCC – United Nations Framework Convention on Climate Change
VDR – Voyage Data Recorder

1. INTRODUCTION

Energy efficiency, fuel consumption optimization and many other terms have been used synonymously to address issues and initiatives alike. The drivers toward addressing these issues and initiatives can be summarised into three main driver groups: economics, compliance, customer requirements. Elaborating on these groups, the need to achieve economic voyages is driven by bottom line profit margins. Given the volatility of daily charter rates, shipping demand and bunker prices (UNCTAD 2014), the objective is to minimise operational costs and to maximise revenue. How this is achieved depends on company organisational structure, ship type and services operated (Stopford 2007, Poulsen & Johnson 2015).

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The second driver group towards energy efficiency is compliance with regulatory requirements and company adopted standards. On 1st January 2013 the amendments made to the International Convention for the Prevention of Pollution from Ships (MARPOL) 1973/78, Annex VI, entered into force, forming the first regulations related to ship energy efficiency (IMO 2012a). The regulations require all new build ships to comply with the Energy Efficiency Design Index (EEDI) which targets ship design (IMO 2014), and all new and existing ships to have a ship specific Ship Energy Efficiency Management Plan (SEEMP), targeting ship operational energy efficiency (IMO 2012b). Development and enforcement of these regulations by the IMO was in response to the requirement to take actions under the Kyoto Protocol (United Nations 1998): an extension of the United Nations Framework Convention on Climate Change (UNFCCC) treaty (United Nations 1992), addressing the need to mitigate detrimental climate change via the reduction of anthropogenic carbon dioxide (CO_2) emissions (IPCC 2014). On average, between 2007 and 2012 it was estimated that the shipping industry emit 3.1% of global CO_2 emission, 2.6% from international shipping alone. If no actions are taken these emissions are expected to increase from the 2012 levels by 50% to 250% by 2050 (Smith et al. 2014). Therefore significant changes are needed to meet existing (focused within a 2°C climate change scenario) and future global emission reduction targets (Jordan et al. 2013). It has been identified that enforcement of the EEDI and SEEMP alone is likely to increase awareness and promote energy efficient ship design and operation, resulting in savings; but not to the magnitude required (Bazari & Longva 2011). Acknowledging one of the primary weaknesses of the current energy efficiency regulations, the EU adopted a proposal for Monitoring Reporting and Verification (MRV) in April 2015, which will enter into action on the 1st January 2018 (EU 2014). It is estimated that MRV could contribute a 2% reduction to BAU shipping emissions by 2030 by taking a first step towards reducing market barriers; particularly those related to a lack of reliable and robust information on ship performance (i.e. fuel consumption, and hence predicted emissions) (EU 2014). However, again there are concerns over the effectiveness of MRV in providing greater transparency. This is because the energy consumption monitoring practices are left to the industry to decide, which will not necessarily address the following four barrier challenges: data collection, misreporting, data analysis and feedback problems (Poulsen & Johnson 2015). Further, to regulations, International Standards adopted by companies also act as drivers toward implementing ship operational energy efficiency; such as ISO50001 (BS EN ISO 2011). An advantage of ISO50001 over the SEEMP is that it requires a verification method to be defined for each action (i.e. best practice) (Johnson et al. 2013). Further advantages of the ISO50001, and the codes such as the ISM code, over the SEEMP include: the requirement of mechanisms for reviewing energy demand, setting goals, monitoring performance; encapsulating company management rather than just ship specific management (Johnson et al. 2013). These are issues that still need addressing in the context of practical ship operations.

The third driver group toward the implementation of energy efficiency is customer requirements. Major organizations, i.e. those mostly listed in stock exchanges, promote the requirement for the vessels chartered to carry their cargo to follow sustainability initiatives and practices as part of their commitment to Corporate Social Responsibility (CSR). With rising concerns over climate change mitigation, as previously discussed, energy efficiency and low carbon supply chains have become increasingly more important to customers and within CSR (M&S 2015). There are several industry and working group initiatives and indices to acknowledge energy efficient ships and efforts. Svensson & Andersson (2011) discusses many of these in relation to their intended use, users (e.g. customers), basis and scope.

Marginal Abatement Cost Curve demonstrate that many energy efficient design and operational best practices are considered cost effective (Faber et al. 2011, DNV 2010, IMO 2009). However Rehmatulla (2012) describes a survey of primarily ship owners, charters, operators and management companies, that was carried out to assess the barriers to uptake of energy efficiency operational initiatives. The survey results demonstrated that even for the measures considered to have the highest potential for improving energy efficiency; only around 65% to 85% of the survey respondents had implemented them. A 90% to 100% response would have been expected for the cost effective measures with easy implementation and short payback periods (Rehmatulla 2012). An average implementation rate around 50% was observed across all the operational measures included in the survey.

With a low take up of energy efficiency measures in the industry studies have been carried to investigate different types of barriers. From the survey results Rehmatulla (2012) identified the most significant barriers to

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be the following: lack of reliable information on cost and savings; difficulty in implementing under some types of charter; lack of direct control over operations; materiality of savings. The survey results also revealed that smaller companies cited barriers more frequently than larger companies. Poulsen (2011) discusses and highlights the following as barriers: agency problems (split incentives); inadequate information and transparency for energy efficiency and incentive structures; information uncertainty; high discount rates being applied resulting in decisions made for short-term benefits. Poulsen (2011) also concludes that social science needs to be considered in addressing barrier to energy efficiency improvements, along with attitudes and incentive structures. Considering the perspective of 317 seafarers, survey results revealed the following as barriers to effective change: availability of education; communication between ship and shore, and internal and external stakeholders; transparency of limitations, capabilities, responsibilities and achievements towards energy efficiency improvements (Banks et al. 2014). Furthermore Poulsen & Johnson (2015) discuss the results from 55 interviews with technical and commercial personnel; highlighting data collection, misreporting, analysis problems and feedback as problems for energy consumption monitoring, which is a key barrier toward effective energy management.

In conclusion of the above, it can be considered that despite a body of knowledge, the adoption of best practices, lessons learnt, and new technologies continue to remain a challenge as part of mainstream business practices. Whilst different types of barriers to energy efficiency improvements have been explored it is first necessary to understand how they are created, as discussed in (Poulsen & Johnson 2015). The aim of this paper is therefore to explore exactly this by taking a closer look at how ship operations function day-to-day within the context of mainstream business practice. This is done by first explicitly laying out the focus areas, stakeholders and functions associated with ship operations in an understandable matrix that can be related to most organizational structures; Section 2 of this paper. With this laid-out, Section 3 looks at the type of gaps within existing operations that are discussed in relation to practical ship operations. Hull and propeller maintenance is used as a operational example, although similar principles could be applied to most decision making processes and best practices. The desired future for enabling the effectiveness of vessel energy efficiency via integrated operations is discussed in Section 4 before the conclusions of this paper are presented Section 5.

2. DEFINING AND UNDERSTANDING CURRENT PRACTICES FOR VESSEL OPERATIONS

In this section the major focus areas, stakeholders and functions of ship operations are defined to ensure understanding of current operational practices in shipping.

2.1. MAJOR FOCUS AREAS

To summarise the major focus areas of vessel operations, they can distinctly be grouped into four areas, namely; profitability, risk management, asset management and sustainability.

Profitability is a major area of focus leading to activities warranting an increase in the number of days a vessel is available for service, minimizing the number of days of off-hire from charter for reasons like maintenance, reducing the operational expenditure, maximizing revenue with better charter rates and enhancing commercial operations. This is a key to the success of the organization and its vessels' operations, which in turn can address any requirement for further optimisation as appropriate.

Risk Management actions relate to the monitoring, follow-up and close-out (i.e. implementation) of mitigation measures related to health, safety, quality and environment. This is expected to be a very transparent area often emphasized during audits and certifications, and more importantly demonstrates the organization's efforts and commitment to caring for its staff: thereby remaining a significant area of focus.

Asset Management is an area of focus where efforts are coordinated to retain the tangible asset value of the vessel, prolong the useful life of the asset and improving its reliability. Drydocking life cycle management, equipment life cycle management, including maintenance and capital projects, are undertaken to preserve the value of the asset.

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Sustainability is a relatively new terminology and area of focus used by the increasingly “world-community” conscious maritime industry. Often defined by three P’s namely People, Planet & Profit, these are fundamental building blocks to both the organization and the broader world community. A balanced approach to ship management is achieved by coordinating efforts through Corporate Social Responsibility (CSR) activities which include focus on emissions, training, awareness and well-being of its staff and the community around and of course the success of business itself in terms of its bottom-line profit.

2.2. MAJOR STAKEHOLDERS

Today the major stakeholders of vessel operations could be classified under three categories namely Technical, Commercial and Operational. Stakeholders under the “Technical” category include those responsible for strategic functions and services that support vessel operations strategically as an asset owner. Staff responsible for evaluating and approving capital projects, new building projects, standards and policies, and third-party service providers, are some of the major stakeholders in this category. In the “Commercial” category the stakeholders are responsible for revenue generation and commercial operations; including staff in-charge of voyage management, vessel trading, freight trading, chartering, insurance, demurrage. The “Operational Stakeholders” are the ones responsible for day-to-day operations of the vessel in general, including the technical superintendents, fleet managers, crewing staff and other supporting functions like procurement and training staff. They are expected to operate within agreed budgets and ensure the vessel remains operational for commercial use.

2.3. THE FUNCTIONS OF VESSEL OPERATIONS

Functions relate to the roles and responsibilities of the stakeholders. A conceptual framework has been presented in Table 1 to demonstrate the functions undertaken by different stakeholders in relation to the key focus areas. Whilst the presented framework is important for understanding how ship operations and functions can be perceived, it is important to note that no one company will follow the exact organisational structure.

For example, Table 1 shows that many of the functions fall under the responsibility of operational stakeholders. Yet in practice it is predominantly the technical stakeholders that are engaged in the energy efficiency discussions: i.e. via the design and choice of retrofits, upgrades and developing maintenance strategies (where decisions are made based on reported data and their analysis, reference data like model test, sea trial, shop trial and research). While Operational stakeholders have little experience in data analysis and developing trends, technical stakeholders have little involvement in holistic ship operations.

While effective communications between stakeholders could leverage the strengths of each other, current practices limit their interactions. Discussions are usually at the level of unit heads or department heads where strategic issues of priority are discussed. Tactical issues to be dealt with on a day to day basis by the middle management level staff tend to operate independent of each other. In conclusion, it is emphasized that an improved integrated approach to performing vessel functions needs to be introduced to vessel operations where all three stakeholder groups should be engaged in discussions to determine practical, holistic and most effective solutions.

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Table 1: Lay out of functions for vessel operations

<table>
<tr><th></th><th>TECHNICAL</th><th>OPERATIONAL</th><th>COMMERCIAL</th></tr>
<tr><td>Profitability</td><td>Minimise CAPEX</td><td>Minimise OPEX</td><td>Freight Trading</td></tr>
<tr><td></td><td></td><td></td><td>Chartering</td></tr>
<tr><td></td><td></td><td></td><td>Voyage Management</td></tr>
<tr><td></td><td></td><td colspan="2">Commercial Performance Monitoring</td></tr>
<tr><td>Sustainability</td><td>Retrofits</td><td>Crewing / Training / SEEMP</td><td></td></tr>
<tr><td></td><td colspan="2">Technical Performance Monitoring</td><td></td></tr>
<tr><td></td><td colspan="3">Optimization Initiatives</td></tr>
<tr><td></td><td></td><td>Health & Safety</td><td></td></tr>
<tr><td>Asset Management</td><td>Capital Upgrades</td><td>Dry docking</td><td></td></tr>
<tr><td></td><td colspan="2">Regulatory Requirements</td><td></td></tr>
<tr><td></td><td></td><td>Maintenance</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Hull & Propeller Cleaning</td></tr>
<tr><td>Risk Management</td><td colspan="2">Incident Investigation & Follow-up</td><td></td></tr>
<tr><td></td><td></td><td>Awareness</td><td></td></tr>
<tr><td></td><td></td><td>Surveys</td><td></td></tr>
<tr><td></td><td></td><td>Quality / Reliability</td><td></td></tr>
</table>

2.3 (a) Typical ship functions applied to vessel dry docking and energy efficiency effectiveness

Based on the systematic distribution of functions among stakeholders, an illusion could be created that all aspects of vessel operations related to efficiency are addressed effectively and there could be very little scope for further improvement. However, to demonstrate the gaps in the dispersion of responsibilities in an organization's structure, a snapshot of a vessel's hull prepared for coating during drydock is described in this sub-section.

Figure 2: Hull prepared for coating - Who's accountable & who's the beneficiary?

While it is common industry knowledge and there has been a lot of research on the significance of hull roughness and its impact on performance over the docking life cycle of a vessel, spot blasting practices of the hull (Figure 2) still continues to be a common practice (Anderson et al. 2003; Taylan 2010).

Drydocking of a vessel, usually every five years, is an operational requirement and considered to be an operational expenditure (OPEX). This activity is dictated by a budget decided almost a year in advance and mutually agreed between stakeholders amidst various other constraints in an attempt to optimize OPEX. When the vessel is in drydock the time and resources are limited for reasons like days out of service, budget

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constraints, off-hire and availability of dock: this takes its toll on the effectiveness of this major maintenance activity.

The operational stakeholders' responsibility is to drydock the vessel and complete the tasks (e.g. maintenance and surveys) within the specified time frame and budget. Therefore, the operational stakeholder's responsibility could be considered 'complete' when the vessel is picture perfect cosmetically and all survey requirements are completed at the end of the drydock. However, in this instance, the effect of increased hull roughness due to spot blasting and not full blasting, which heavily influences vessel performance, is subtly passed on to the commercial stakeholders. While the impact is not immediately obvious, over a short period of time, the added resistance increases steadily affecting ship's speed and increased fuel consumption. On some occasions, the quality of the chosen hull coating also plays a major role in the performance of the vessel over the docking life cycle.

If the commercial stakeholders were part of the drydocking planning process, an assessment of vessel's performance expectations over the docking life cycle, could be incorporated impacting docking requirements. Incremental budget to accommodate the performance expectations (e.g. full bare metal blasting of the hull up to SA2.5 standards, additional days required in drydock, better quality or additional thickness of hull coating) could all be proposed and approved.

To summarise, performing minimal maintenance at drydock to achieve savings of few thousands of dollars over the drydocking process is the mandate of the Operational Stakeholder and the fuel penalty costs after the drydock due to poor hull condition that could run into millions of dollars are borne by the Commercial Stakeholder. Moreover, such situations prompt the need for early or premature docking of the vessel before completing the normal life cycle of five years between drydocks. Challenges addressing such issues continue to remain, as one stakeholder's responsibility and accountability is not aligned with the other stakeholders but is the beneficiary of the outcome; thereby lacking coherence and synergy.

3. DISCUSSION OF WEAKNESSES IN THE PRESENT STATE OF SHIP OPERATIONS

3.1 MULTIPLE GOALS AND TARGETS

To summarize the present state of vessel operations, though the focus areas and the stakeholder responsibilities are clear, the major reason for ineffectiveness in achieving energy efficiency in vessel operations could be the lack of a coherent approach. Each of the focus areas exists as an independent entity for the organisation and there is very little coherence in their approach to efficiency, Figure 3.

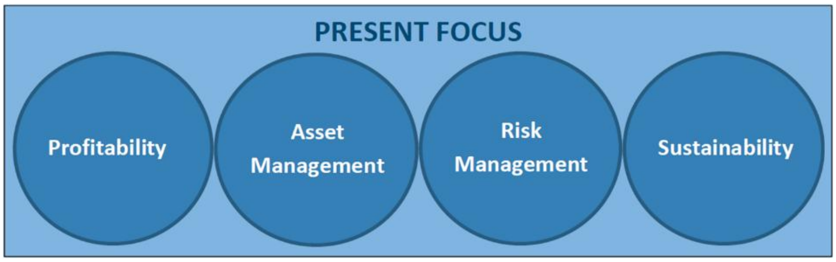

Figure 3: Present state of vessel operation, independent focus areas

There are multiple goals and targets to be achieved by the different stakeholders within the focus areas which are mutually exclusive. This leads to many challenges in adopting agreeable energy efficiency benchmarking practices within the organization and also the broader maritime industry. Focus areas are usually addressed through initiatives, and the success of individual initiatives add up to the bottom line profit, contributing to the efficiency of the organization.

As an example, Lost Time Injury Frequency (LTIF's) continues to be an area of focus and organizations drive initiatives and programs through the "Operational Stakeholders" to develop a safety culture onboard vessels. On

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the other hand, recent developments in large container shipbuilding where the design is mainly influenced by the “Technical Stakeholders” warrants shipboard accommodation in the midship section of the vessel while the engine room continues to remain in the aft part of the vessel. When the vessel is unmanned, either the duty engineer will have to race over 100 meters and then few staircases to attend to the alarm in the engine room in the middle of the night or else stay in the engine room overnight to attend alarms. Similarly, the cosmetic look of the vessels, which is a responsibility of the “Operational Stakeholders”, continues to be maintained at the expense of crew, carrying out risky maintenance work whilst hanging on ropes over the side of the ship’s hull whilst afloat.

3.2. PERFORMANCE MONITORING

Some of the commonly reported challenges with today’s vessel performance monitoring fundamentally revolves around data quality, which depends on the diligence of the crew recording the data (Logan 2011) and on the instrumentation, measuring equipment and practices followed onboard. Since it is challenging to arrive at valuable conclusion from analysis of the reported vessel data, installation of expensive automated data collection systems and fuel flowmeters are recommended. A reliable torque sensor and a Doppler speed log are also identified as important sensors to install for improved performance monitoring accuracy (Hasselaar 2010), yet they are not installed as a common practice and have their own uncertainties. The different performance monitoring methodologies and data collection practices adopted by different stakeholders and commercially available systems have led to inconsistent benchmarking practices and the origin of issues related to performance monitoring continue to remain a question.

Misunderstandings generated when vessel performance monitoring analysis results are not aligned with voyage performance analysis results, leads to lack of trust and issues of accountability. These impact follow-up and close out of anomalies, flagged by the vessel performance monitoring process. Elaborating on the differences between “Vessel Performance Monitoring” and “Voyage Performance Monitoring” practices followed, could explain the root cause for the challenges mentioned above. While voyage performance monitoring is more “Commercial” in nature, vessel performance monitoring based on benchmarking is more “Technical” in nature. Vessel Performance Monitoring is meant for providing a status update on vessel’s performance specifically the hull and propeller condition so as to plan maintenance as appropriate, while Voyage Performance Monitoring is required for minimizing voyage costs, maximizing voyage revenue and to identify opportunities to improve voyage efficiency. Since both monitoring methodologies use the same parameters like Speed, Power and Fuel Consumption, and due to their varied approach, ambiguity prevails. Some of the reasons are listed in Table 2 to enable comparison.

Table 1: Reasons for misunderstandings in performance monitoring

Vessel Performance Monitoring	Voyage Performance Monitoring
Technical Stakeholders interest	Commercial Stakeholders interest
Benchmarked for defined displacements of Laden and Ballast Conditions	Based on varying displacements, identified as Ballast / Laden passage, cited by vessel
Monitored for specific conditions referenced to Sea trial	Average Speeds & Fuel consumptions as performed by the vessel
Excluding the effect of currents	Includes the effect of currents
Slip is differentiated between weather & performance	Slip is the only criteria to ensure data quality
A 10% Slip is approximately 1-2 knots drop in performance depending on vessel type	A data filter of 10-15% Slip is applied to ensure data quality
Referenced to benchmark conditions	Referenced to warranted figures provided to the charterer
Considers actual fuel consumptions excluding wastage	Fuel consumptions & wastages grouped together
Fuel consumption based on flowmeter readings	Fuel consumption based on ROB from tank soundings.

The above differences contribute to most inconsistencies in performance monitoring practices. While there are various manual logbook entries made onboard, a common practice is sharing of operational data recorded at noon with the shore-based offices in electronic format, mainly meant for commercial use. Utilization of this data for Vessel Performance Monitoring poses its own challenges as noon data is a grouping of cumulative and instantaneous data. As an example, parameters like distance travelled and fuel consumed are cumulative data

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measured over the past 24 hours while engine power, weather conditions, currents etc. are instantaneous data. However accurate the analysis and benchmarking, more data will be required to observe meaningful trends. This leads to reactive maintenance of the propeller and hull after the deterioration is well established and confirmed rather than planning proactive maintenance based on forecast and projections.

4. THE PROPOSED DESIRED FUTURE: AN INTEGRATED APPROACH

Looking further, with independent areas of focus, there are multiple goals to be achieved which lack congruence. The key performance indicators of each of the stakeholders to assess their own performance are opaque and mutually exclusive lacking transparency and inclusiveness. Success of initiatives undertaken is independent and do not have the desired multiplier effect from synergy by collaboration. While there is some amount of success from individual initiatives contributing to the bottom-line profits, the cumulative benefits from leveraging each other is lost. In summary, the benefits are short-term focused which could also be resulting in long-term losses often being overlooked.

While there is a lot of overlap between each of the focus areas, as discussed in Section 2, the responsibilities and accountabilities continue to be independent of each other. It is considered that these also need to be integrated. Furthermore, focus on Sustainability for the sake of Corporate Social Responsibility remains an add-on effort and is vulnerable to market fluctuations. Instead, focus on “Sustainability” should be the backdrop or platform for the other focus areas as well. Since Sustainability focus addresses the profitability of an organization as well, the success of business always remains relevant. Figure 4 demonstrates an integration of sustainability, asset management, risk management and profitability.

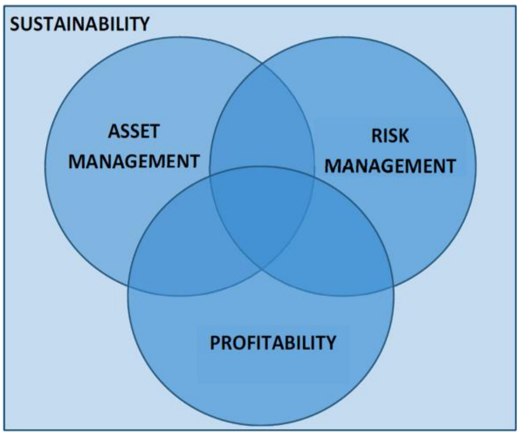

Figure 4: Desired approach for vessel operation, integrated focus areas

To achieve the integration demonstrated in Figure 4 and enable the effectiveness of vessel energy efficiency, the integration of Mandates, Processes and Systems is required. However, these desired integration areas need to be supported by the development of consistent and understandable benchmarking practices, sharing and acknowledging other stakeholder contributions and quantification of efforts and results.

Benchmarking practices are critical as a vessel along with its equipment, starts to deteriorate soon after it is delivered from the new build shipyard. Improving or enhancing the operational or performance efficiency of a vessel is about optimizing the rate of deterioration. It is therefore necessary to develop standard models for acceptable benchmarking practices for initial performance, actual performance and acceptable rate of deterioration over the asset’s life. This is necessary so as to quantify efforts and to demonstrate results. Since all stakeholders have varying educational backgrounds, experience, and expertise there are only certain terminologies that are commonly understood by all of them. Communicating inefficiencies, fuel penalty and cost avoidance by quantification in a commonly understood terminology (e.g. in terms of cost or lost revenue) effectively communicates gaps and consequences by simplifying understandability.

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While effective ship management, operations and revenue regeneration are equally important, recognizing and acknowledging each other's' contribution is critical. Organizationally, the few measures that could be taken to this effect include; the promotion of cross-functional training and education among stakeholders, pay parity and move away from the regular Annual Reports (which are mere financial reports) to Integrated Reporting which should include financial results, sustainability report and Corporate Social Responsibility (CSR) report. Integrated reporting recognizes the contributions and achievements of all stakeholders thereby improving transparency and perception of the organization within and outside. Initiatives undertaken to improve efficiency and reduce emissions, training and awareness campaigns for staff, combined with trends of key performance indicators, could drive organizations to fetch better charter rates and influence shareholders.

5. CONCLUSIONS

In review of this paper, it has been emphasised that to achieve practical energy efficiency improvements in the industry, technical solutions alone are insufficient. A systemic solution that undertakes an integrated and coherent approach to ship operations is required. Stakeholder engagement strategies, defined responsibilities and accountabilities, shared goals and objectives among stakeholders are required to enable realisation of improvements and effect energy efficiency. This could be achieved by ensuring that there are a defined set of key performance indicators for each stakeholder to address their own performance, but also a defined set that are shared across all stakeholders to meet common objectives. Moreover, interactions at all levels of the organisation and stakeholders are required to develop the synergy to explore and maximise optimisation potential. Sustainability should be the backdrop or platform for asset management and risk management practices as it addresses the profitability of an organisation as well as the business success; including caring for its employees, customers and the environment.

It is recommended that further research is carried out to identify, understand and address the barriers to energy efficiency improvement related to the functions of day-to-day vessel operations and the processes within the context of main stream business practices. For example, it is suggested that operations based on "Systems Thinking" are considered along with a review of business processes followed within other industries, such as the airline industry, to identify transferable mechanisms to enable and encourage efficient business practices. Additionally, development of models for acceptable rates of deterioration of performance over the asset life is an important area for research to quantify benefits and other benchmarking practices.

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