Marine Machinery Condition Monitoring

Why has the shipping industry been slow to adopt?

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***Abstract*— Fewer than 17% of the worlds classed ships operate with an approved planned maintenance system (PMS) which enables the chief engineer to credit allowable machinery items for the purposes of survey. Only 12% of these ships use Condition Monitoring (CM) to enable survey credit without recourse to strip-down inspection. It is surprising that so few ships are enrolled on PMS and CM schemes with their classification provider and that the majority of these vessels (70%) are managed out of Europe. As the reliability of marine machinery is critical to the success of the modern ship operator, it is curious that the willingness of companies to devise an optimal maintenance strategy based upon the needs of the machine as opposed schedules created by the manufacturer is not greater. The reason companies take this position is not so clear but may be rooted in the power shift where control has moved away from the ship towards the office. This position paper is intended to provide the reader with an understanding of some of these issues and secondly offer a suggested method by which companies can assess their own businesses in order to define a company specific improvement strategy. In addition it outlines the main issues facing the industry from the perspective of the classification society and the growing need to develop more useful and supportive relationships whilst maintaining the role as custodians of the rules.**

***Keywords*— Condition Based Maintenance, Condition Monitoring, Maintenance Management Optimisation, Classification Society, Marine, Shipping, Ship, Engineer, Maintenance Strategy.**

I. INTRODUCTION

The theory behind modern maintenance management which is based upon a detailed knowledge of the state of machines' critical indicators has been common knowledge for some time. The benefits however, are harder to objectively quantify because they rely upon an unknown potential for improvement in reliability, availability enhancements, spares bill reductions and efficiency savings which all result from doing more work that yields benefit and less that does not. That said, all involved within the field collectively appear to agree that this is the right direction in which the business of maintenance should evolve. This paper does not seek to justify or indeed identify tangible benefits, as this needs to be considered on a case by case basis. It does however, seek to highlight and stimulate discussion around the areas which are believed to have contributed to this. Moreover it is intended to lead to a greater discussion about how we, the shipping industry, can move forward to overcome the blockers to progress and enjoy the benefits of well managed and intelligently applied strategies.

II. WHAT IS THE OPTIMAL STRATEGY

A. General considerations

For every shipping operator/manager the question of what is optimal will have to be answered on a case by case basis. There is no benefit in maintaining a level of reliability that is not needed or adds cost to the business. In addition the value judgement will be different dependant upon the business objectives and key motivators of each organisation.

B. Maintenance Management Strategy Development

In simple terms the optimal strategy is one that delivers the ability to meet all functional requirements as defined by the business, for the minimal cost over the period under review. Therefore it is not always necessary or desirable for all companies to try to position themselves on the leading edge of maintenance strategy, but to ensure that the strategy is and remains optimal. Clearly not all companies who are considering making improvements in this area are in a position to move directly to an optimal environment and need to take a considered view on creating a programme of development to move their organisation towards their desired goals.

C. Current fleet situation

Throughout the Lloyd's Register classed fleet, the vast majority of operators can be considered to be performing at the "Compliant" level. There is evidence that there is growth in the "Managed" area, and to a lesser extent at the "Innovative" and "Leading" levels. This tendency to operate at the "Compliant" level is not surprising given that the industry is so heavily regulated and has become so much more so in the last 10 or so years against a background of reduced margins and skills shortages. Indeed the continual development of technology at new build has not been matched by the improvement in training for existing and newly qualified marine engineers. That added to the faster promotion rates to chief engineer fuelled by poor succession planning has placed greater reliance upon superintendent involvement at the routine level and a parallel increase in reliance upon specialist third party maintainers and repairers.

D. Stages of Development within Maintenance Management

In order to start to make improvements and to highlight where companies are, it is often of benefit to understand what is good and what could be improved. In order to define some degree of objectivity overall performance can often be understood better by defining at what stage of development the organisation is and thus where you believe it be. This approach can be useful to detail where within the mix of elements that make up a well structured system, efforts need to be targeted. This can be achieved via a metricated evaluation of each area within. The categories can be labelled thus;

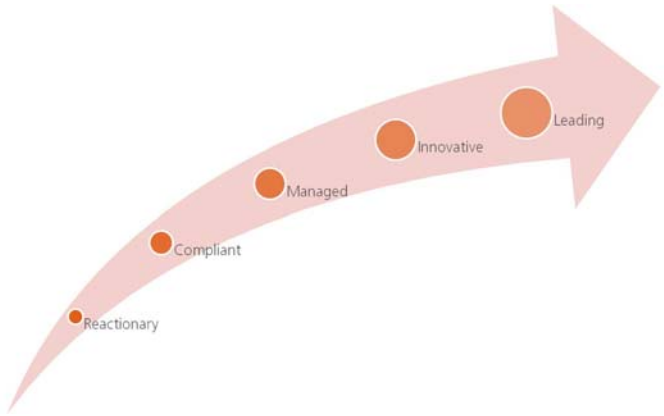

Fig. 1 Stages of Development

III. Stages of Development

A. Reactionary

Where the operator does nothing until there is some event, such as a failure. He will then react and fix the failure but not perform any further work to mitigate or prevent reoccurrence.

E. Compliant

Maintenance strategy is in compliance with the appropriate and expected legislative and industry requirements for the sector. This is effectively where the company performs only the minimum necessary to trade.

F. Managed

The operator is working to a formal maintenance plan - with some strategic and planned elements and stated goals. This exceeds the minimum requirements and is done to meet some other internal objective.

G. Innovative

The operator has established a managed approach and is now actively optimising and looking to innovate to ensure that a distinct and measurable improvement in performance can be achieved and also assist in the innovation of new solutions perhaps by allowing new devices and processed to be trialled and evaluated.

H. Leading

Having a managed and innovative approach embedded in the company culture now, the maintenance strategy has now become part of the overall business thinking and extends across the entire machinery register. Moreover the company demonstrates a desire to share experiences and to assist others to improve and optimise for the benefit if the community. It is indeed viewed by other innovators as a leading company.

IV. Approved Planned Maintenance Systems

One illustration of the current view of higher level maintenance management may be afforded by considering the current analysis of Lloyd's Register Approvals for Machinery Planned Maintenance Schemes (MPMS). As of 31st May 2012 this shows that 1046 ships have elected to seek approval and thus assigned the MPMS descriptive note. This means that these vessels not only use an approved Maintenance Management System but that they are choosing to engage the chief engineer to credit allowable items for survey at times when the maintenance requirements allow. Of these vessels 158 have adopted the additional Machinery Condition Monitoring (MCM) descriptive note, meaning that the chief engineers on these vessels can credit allowable items based upon the results of an approved condition monitoring scheme.

In addition, the total number of different ship types enrolled is broad (Number of specific types is 44), suggesting that the application of condition monitoring is widely considered. However "Oil Tanker", which is the most predominant group within the fleet, has a greater proportion of ships being subject to the application of CM notes suggesting that the additional assurance afforded by the application of CM for the tanker sector is considered beneficial.

This number of vessels as a percentage of the classed fleet is believed to be mirrored in the other major societies, suggesting that the lack of take up of condition monitoring is universally poor when compared to other industries. Of additional interest is that the geographical location of the operator for those within the Lloyd's Register fleet. Approximately 70% of these vessels are operated from Europe and the remainder split in equal parts between the Americas and Asia. This key point is potentially a reflection of the use of Classification societies local to controlling offices, but also clearly indicates that companies operating out of European countries tend to consider that maintenance management is more valuable in terms of classification strategy. The key question that results is whether the apparent lack of take up within the maritime community is simply a symptom of cultural differences between the industries or as a result of a tangible resistance or reluctance to take control, the industry preferring to remain compliance driven. Or is it indeed a direct result of the shift in power from the ship to the management office.

V. The shift towards remote management

We have seen over the last few years greater reliance upon direct office management support coupled with a greater take up of after sales support from manufacturers. This is due in part to manning and skills issues plus increased complexity of machine control systems and the incorporation of "black box" technologies which are not accessible by either the crew or shore based staff. In such a case there may be an argument for the legislators to facilitate a move towards a more intelligence driven approach to the co-ordination and execution of maintenance to minimise risks and to add further assurances. There is also the option of accelerating this shift by removing ships engineers completely, choosing instead to work a model of remote management which deploys engineers only when conditions dictate. Indeed the technology already exists to equip the vessel with the capability to be remotely managed and there is a likely cost benefit between models. However, there are clearly increased risks which would have to be mitigated but also a significant reduction in manning costs to fund it. In addition fewer routine maintenance actions produce fewer opportunities for maintenance induced failures and general incidents and accidents.

VI. Blockers to progress

It is apparent that the opportunities for improvement in maintenance effectiveness and optimisation of costs attributable to maintenance are real and have been demonstrated in other industries. It is also apparent that the drivers which have facilitated this are not present in the shipping industry. For example in offshore oil and gas, the penalties levied by the distributors in the UK are so significant that the cost to implement Condition Based Maintenance (CBM) as a protective device is insignificant. In the nuclear industry the clear risks to life, locality and reputation are such that a risk based approach with protective performance capabilities like CBM is attractive if not mandatory. In the rail industries the reputational losses for poor reliability mean fewer passengers and lower share value therefore reliability and asset management are central to the business. Within the shipping industry there is no single and powerful motivator, the business of shipping in the main is a covert operation in that minor issues surrounding maintenance are often not reported or considered normal operation. Hull and Machinery insurances costs are so low as to effectively create a tier of protection that mitigates the need to apply maintenance at anything other than a compliance level. That said many companies are now exploring their optimisation options so as to create differentiation for their clients and to reward the shareholder via enhanced reputation. However, there remain a number of issues that appear to contribute to a reluctance or unwillingness to embrace optimised maintenance practices and also the linking of these activities to the processes required by class.

VII. IMO Encourages risk approach

Changes came into force in July 2010 within the International Safety Management (ISM) code that affects the significance of how risks are to be mitigated. This revision, a seemingly minor amendment, has relatively significant implications in respect to maintenance management. In essence the wording appears to require an owner to adopt a risk-based approach to the management of his ships – with the methods adopted for assessing risk and establishing safeguards left to the Owner. This also represents a shift in core regulatory philosophy as the effect is to move away from rigid and prescriptive regime to one of "goal setting". Whilst not linked, this is similar in shift to the notion of goal-based ship construction standards that was introduced by IMO at the 89th session of the council in November 2002. Quoting from the IMO website; "IMO… state what has to be achieved, leaving classification societies, ship designers and naval architects, marine engineers and ship builders the freedom to decide on how best to employ their professional skills to meet the required standards." Thus the idea of risk or condition based maintenance is not new but has been, at least in principle accepted by the regulators in the industry.

TABLE I
PART OF ISM CODE CHANGE 2010

OLD	NEW
1.2.2 Safety management objectives of the Company should, inter alia:	1.2.2 Safety management objectives of the Company should, inter alia:
.2 establish safeguards against all identifiable risks;	.2 establish safeguards against all identifiable risks and assess all risks to its ships, personnel and the environment and establish appropriate safeguards;

Table I

The amended wording means that a risk assessment must be undertaken and the outcome used to protect the ship. This is inline with the majority of modern maintenance strategies such as Reliability Centred Maintenance (RCM), CBM, etc. It also provides significant regulatory direction for companies to explore. At the time of writing this area of ISM assessment and enforcement has not yet lead to issues of non-compliance but it is expected to be more widely enforced. When considered in conjunction with section 10 of the code – *Maintenance of the Ship and Equipment* and also in reference to IACS *Recommendation 74 "A Guide to Managing Maintenance"*, where the used of predictive maintenance techniques as a means to base maintenance interval upon is expressly stated, then the case for support becomes clear

VIII. ORIGINAL EQUIPMENT MANUFCTURERS

The Original Equipment Manufacturers (OEM) will provide all necessary maintenance guidance, but not necessarily from a conditional perspective. It can be suggested that the basis of all OEM maintenance plans are, by their very nature, likely to be sub-optimal. Why? Because they are not necessarily partial to the operating context of the installed item and certainly not aware of the quality of maintenance that the item will be subjected to. Therefore, it is likely that the actions and schedule detailed within the recommended maintenance guidance will be conservative and in the majority of cases over-maintenance will occur. It is also worth stating that apart from where it is expressly bound within the terms of the warrantee, the maintenance advised can only be considered as guidance. Yet we are aware that in certain cases deviating from the OEM maintenance plan post warrantee can be used to weaken any argument where failure may be deemed the responsibility of the OEM.

It is proposed that in future iterations of the supplied maintenance manuals that OEM's seek to offer alternatives dependant upon whether the user operates a calendar or CBM strategy. Certainly the consideration of a first pass Failure Modes and Effects Analysis (FMEA), which can be augmented to include detail pertinent to the installed machine, would allow CM and CBM practitioners the ability to align their working processes with the manufacturers support.

It is further suggested that when specifying machinery lists for new build projects that the maintenance and the maintainability of the machinery is included in the preferred design specification. This will then steer the manufacturers to provide an improved suite of maintenance data to enhance the value of their product.

IX. COMPLIMENTARY MAINTENANCE METHODOLOGIES

A. Performance Monitoring

There is a significant amount of data that is already recorded and used in the day to day operation of the ship. It is important to recognise that this data can also be used for the purposes of condition monitoring. The mode of failure for a pump for example may be the degeneration of an impellor/casing interface which may simply be represented by a reduced differential pressure. Also from the RCM perspective, the function of the asset is maintained. Therefore in the case of the aforementioned pump an inability to deliver fluids at ***x*** litres per minute, developing a pressure of ***y*** Bar could be the definition of a failure, not that the device is now out of action.

B. Total Productive Maintenance

In the onshore factory environment Total Productive Maintenance has for many years sought to optimise the act of maintenance by blurring the lines between production and maintenance roles. This is done by empowering production operatives to perform watch-keeping and basic machine minding skills. In the shipping world, we have traditionally and very clearly defined a structure for deck officers and engineering staff. Whilst the author does not advocate dismantling this tradition, there may be benefits to reviewing its relevance to modern practices especially in the light of the trend towards remote management as indicated earlier. This way there will be sufficient flexibilities to allow ship staff to obtain for certain ranges of performance and environmental data which may be used for CM purposes or to indeed act as the first line of defence when remote management requires ship support. For specialist vessels with very small crews – e.g. Off-shore supply boats and tugs there already exists a degree of co-operation and distinct multi-skilling which provides the basis for optimised maintenance flexibility. Aspects of this may be needed going forward towards fully remote management. However within the deep sea fleet, where staffing numbers are generally higher, the increased requirement for administration by engineers and deck officers already removes them from their traditional roles. This issue could be addressed by the introduction of administrative staff whose role is actively cross functional. This would free up time for both deck and engineering personnel to concentrate on their core functional activities.

X. TRAINING AND COMPETENCES

ISO 18346 sets out the standard for establishing an acceptable training and competency framework. This standard covers the main technical area such as Vibration Analyses, Thermography, Oil Analysis, Ultrasonics, etc. and details the requirements for qualification and assessment of personnel accordingly. Dependant upon the way that a shipping company sets up its maintenance management strategy these skills can be held internally or, as will be in most cases, specified as a minimum standard for specialist service providers.

As the realm of CM and CBM is a constantly evolving arena, it makes very good sense to ensure that such competencies are employed and independent certification sought to demonstrate competence. In shipping terms all qualified chief engineers will able to manage the CM function on board but may not hold the necessary diagnostic skills for each type of CM tool deployed. However, those who are engaged for instance in using vibration analyses data collectors and taking lube oil samples etc, will benefit from the certification at least at Category I, in their prime CM subject. Diagnosticians working for the specialists should be accredited to Category II and scheme managers to Category III.

It cannot be overstated that the use of certified practitioners should be demanded when building a service model which utilises a number of specialist providers. There is currently no mandatory requirement to be certified to practice therefore the onus is on the shipping company to ensure that each service provider is suitably and in preference, independently, certified.

[Note; VA Category IV is a supplementary Vibration Analysis Category – for normal cross technique comparison Cat I through III only need be considered]

XI. HUMAN ELEMENT ASPECT

A. Compliance Driven Industry

The shipping industry by its very nature and historical regulatory perspective has developed into an industry that is lead by compliance. The vast majority of ships are built and operated to a minimum standard. It has been the regulator and the enforcer's role to ensure that standards are sufficiently high enough to deliver an acceptable level of performance. In order to comply with these rules and regulations one must meet a minimum standard. Therefore it is by definition an industry that does not normally seek to exceed the minimum standard. In most other industries the expectation is to find a market where you can trade well and become the best, be better than all the rest. These companies are driven by excellence as it is by differentiation that they are enabled to become visible and therefore successful, not their mediocrity or their ability to comply with everyone else.

B. Changing trends

Due to the pressures to perform and differentiate a great many companies do buck this trend and seek to do better. There are companies who set out their brand to be "Environmentally Sensitive" or those who wish to distance themselves from the less favourably viewed within the industry. Sectors like the cruise industry are where mediocrity means direct loss of repeat business, due in part to the modern immediacy of issues being reported via social media and newsrooms across the word and also to the expectations of their clients and their intolerance to poor performance. The tanker business which is arguably less visible has had some variable press over recent years with spills and break ups being reported. To counter this, the tanker business has attempted to self assess and achieve ratings of excellence via the Tanker Management Self Assessment (TMSA) process devised by The Oil Companies International Marine Forum (OCIMF) and the relevant parts of the Ship Inspection Report (SIRE) programme. Though in reality and in specific reference to maintenance management, this device is not sufficiently developed to deliver a meaningful indication of performance beyond that required for basic planned maintenance.

C. People will be people

When it is considered against the background described above it is clear to see why any enforced changes can be difficult to implement, however it is a common fact that when humans get involved things go wrong. Therefore the need to reduce unnecessary interactions is real and leads to tangible benefits. However, the evolution from one state of operation to another has to be planned and executed carefully to ensure that there is sufficient allowance for the variety of issues that could arise through variations in experience, background, age, sex, ethnicity etc. In fact there are a great many ways in which the human element of a CBM system, or any other system that requires cultural change, can lead to a failure to meet what may have initially appeared to be well defined and achievable goals.

D. Successful CBM implementation

The core activity for the implementation process is to address the organisational integrity factors necessary for its successful implementation. The CBM system must be aligned to the management processes. The process of tailoring and adapting is specific to every implementation. There are a number of softer issues like motivation and role acceptance, of reassurance that change is not simply cost reduction and that changes are indeed in the pursuit of excellence an that real improvements will be made which will improve the working experience and the general working environment. What is clear is that where failures occur which have not been picked up by CM it is important to understand that this does not mean that CBM does not work but that further fine tuning is required. Failures will occur as the systems are imperfect and require constant review as we get to know our assets better and uncover the trends that link persistent reoccurrences of failure. It is a significant and key point that the success of any CBM implementation is the quality of the Root Cause Analysis (RCA) process that must be part of the normal management of the system. Furthermore the RCA must be sympathetic to the stakeholder and not seek to apportion blame so that there is no "loss of face". One way to do this is to see each failure as an opportunity to learn and design out the aspects of the failure that were unknown. It is highly unlikely that any recently developed CBM system will be perfect as not all failures are known and it is not commercially sensible or technically feasible to implement failure finding tools for every mode of failure that may occur. Therefore it must be expected that RCA applied lightly will be a normal and expected everyday feature of a well managed CBM system.

E. The need for objectivity

What is often performed in parallel to the development phases of the emerging CBM system will begin with a simple gap analysis to determine the specific requirements for successful implementation. This analysis examines the existing organisation of manpower, responsibilities, competencies and processes to determine their fit for the CBM system. It also looks for gaps in the CBM system for its complete integration with the ship systems and processes. The likely outcome from the analysis will be a set of requirements for implementation. These will likely include requirements for leadership changes and job role changes to accommodate the functional responsibilities of CBM. There will no doubt be demands for additional competencies on site to meet the needs of the CBM approach. This should be defined through an analysis of training needs and delivered through a training plan. Central to a successful CBM management system is the governance processes for continuous change and improvement. CM outputs must be tracked to ensure that base-line readings are appropriate for each installation and the mechanisms for continuous review and improvement established. CBM will introduce new task activities and procedures into the

organisation. These may involve inherently hazardous activities that must be risk assessed to identify the hazards and risks. Critical task analysis of new procedures will be conducted to identify the requirements for control of work measures for the new practices. Additionally, whilst the CBM process delivers the improved ability to plan maintenance based upon the early notification of change, there is also a need to remain flexible as it is possible that a number of issues may be raised concurrently which will require prioritisation and appropriate resourcing.

I. Maintenance strategy optimisation

There are a number of approaches that can be considered. One low cost method by which it is possible to assess the current situation is to perform a low level Needs Analysis based upon a maintenance maturity assessment. A simple maintenance maturity analysis will reveal how each company performs in regard to Strategy, Work Identification, Work Control and Work Execution. This will cover aspects of operation from business goals and key performance indicators, through work orders and work order processing to spares management, overdue items, productivity and training. Once a company has this it can set out a more detailed road map to target areas for improvement and thus minimise time wasting by improving those aspects that will yield the greatest reward.

A more specific and thus targeted method is to perform a formal consultative review of the current situation based upon a wider and less process based analysis using industry experts who have first hand experience of the difficulties faced in the application of efficient maintenance management practices. This approach is often preferred by the shipping industry as it recognises the specific issues faced by each company and is sympathetic to the idiosyncrasies of maritime operators and the legislative frameworks within which they are forced to operate. The maturity assessment approach outlined above performs a slightly different task in that it is quick, low cost and focuses the company on areas which would benefit from initial targeting. It does not offer guidance specific to the business but rather assists the company by highlighting strengths and weaknesses. The process can be repeated at stages throughout the optimisation cycle and serves as a useful metric on which to measure development and further identify the next stages on which to focus.

It is therefore suggested by the author that a combination of these activities would be ideal. Where the company can perform a **Needs Analysis** at regular intervals to track the progress of development, whilst performing more detailed consultative work in blocks, as each topic area becomes prioritised.

XII. CONCLUSIONS

It is clear that the shipping industry is keen to optimise its efforts regarding maintenance management but is struggling to find the best way to do it. As traditionally compliance means that they simply do what is asked, CBM requires them to do it for themselves. . Conditional aspects of operation will be more central to the future maintenance planning function of operating vessels. There are a great number of contributors to the body of competence from the regulator and the classification society via the original equipment manufacturer, the specialist service supplier and the various port state control entities and the insurers. Each one has a role to play in ensuring that any alternative approaches to maintenance provide at last an equivalent level of confidence in the ability to protect. Regulatory frameworks already exist and classification societies have processes that can be invoked. These can be arguably improved to align with best practice without, withdrawal of responsibility and in awareness of the business requirements of the industry. OEM's need to be more supportive and creative, Port State Control needs to recognise that alternatives to OEM guidelines may be acceptable, especially when controlled under an approved plan. New engineers and deck officers should be briefed, if not formally trained to understand the importance of maintenance and optimal maintenance management. In addition we should explore the notion of removing engineering staff from the ship and remotely managing vessels with support from strategically situated maintenance teams. Companies themselves should seek to elevate the maintenance policy to equate to the HSE and Quality policies and finally the opportunity to prepare for a further move into an Asset Management approach where ALL company assets are reviewed as a whole and inconsistencies removed so that modern companies who are inevitably part of one or more supply chains can integrate more fully and offer additional optimisations as a result, can be made.

Society as a whole is becoming more global and the flow of trade is continually moving as new players gain power, initially via cheap labour, but ultimately by becoming a useful part of the world economic model. In the future new trade routes will open up and less reliance upon fossil fuels may completely change the way we do business. Reliance upon the ship will remain as the most effective method of moving large cargoes of raw materials, passengers and finished goods to where they are needed. Maintaining reliable operations and meeting guarantees can only become more important. Therefore, it is crucial to ensure that we have the infrastructure and knowledge to meet our goals and to minimise the costs to achieve this.

Stakeholder	Source	Feature	Resulting Issue
International Regulations	IMO,SOLAS, ISM, ISPS etc.	Flexibility of regulations in relation to maintenance not widely understood	Regulations are created to prevent occurrence of known issues. When these are later mitigated by for instance improved systems, design and process, the regulation may not be amended to reflect current capabilities for some time
		Prescribed redundancy/use of stand-by systems	Redundancy means having multiple systems to maintain function in the event of failure. This acts effectively as a strategic barrier to optimization even though the function of all redundant assets is different from their in service counterparts and any hidden failures that may be present may not be not accounted for.
			Invasive, i.e. strip down or opening out survey is the norm but not actually prescribed by regulations. Rules are developed which are then interpreted to mean physical inspection. Re-interpreting rules based upon improved opportunities for optimization is acceptable and within the scope of the legislation but requires additional effort to ensure that any new regime is widely known, especially by third parties who may not be as up to date.
			Stand-by systems operation and function are not defined - therefore open to variation according to local staff - Note Main and stand-by systems have different functions and need to be assessed as such - They do not behave or deteriorate in the same way and should therefore not be subject to the same maintenance strategy!
Port State Control	Verification of regulatory compliance	Lack of experience of CBM systems	Risk of PSC not recognising CBM, therefore where items remain unopened there is a perceived risk of likely challenge. Keep classification records and descriptive notes available and up to date. Your society will support you in regard to any issue which may arise as a result of your approved PMS and maintenance strategy.
Business Drivers	Minimum costs to meet existing defined needs	Training of staff	Skills matrix dependant upon the cost balance between training existing staff and hiring specialists as required.
		Cost of capital investment	Often capital equipment costs are seen as unacceptable because they are viewed from the perspective of the current culture of maintenance. All CM tools that are purchased add only cost until their output is used to reduce unnecessary maintenance and focus attention upon emerging faults.
	Minimum costs to meet future defined needs	ROI needs for operational engineering investment are often short term	As CBM in shipping remains poorly developed, the ROI needs to include a period of consolidation and optimisation before benefits can be objectively assessed. Suggest payback should be following minimum 5 years after commencement of strategy. Adding set-up and development elements could make ROI near 7 years following initial investment.
		Strategies not geared for future world markets	Maintenance costs are next highest after fuel and suffer much less volatility, therefore longer term strategic plans need to be considered in the light of technological advancement, design for maintainability, skills and culture matrix, trade routes, spares procurement, "fix or replace" strategies etc. Especially relevant for the inclusion of new builds.
Specialist Service Suppliers	CBM Systems designers	Very few true practitioners exist	Should be by multi-party agreement drawn from specialists but managed by independent project management - classification and other consultant services may be beneficial in this role. Often companies opt for an early placement option where they chose a solution before the detail is worked out and they develop it in situ. This has clear advantages initially as the process can commence quickly, however the draw back becomes very clear when the solution does not meet expectations and falls into disrepair.
	CM Specialists	Biased Advice	Most Condition Monitoring specialists are tied to certain hard and software platforms so should not be considered free from bias when seeking guidance. Furthermore it is in the interests of all parties if a CM specialist discloses any interests early in the discussion.
		Not set up to service moving assets	Strategy can vary between training local ships staff and building in ad hoc specialist cover - however can be limiting due to costs of travel and non billable hours.

		No universally accepted standard of competence	ISO 18436 and other local standards exist but are not yet universally recognised and demanded
			Approved vendor schemes offered by Classification societies are general quality management devices which add CM and CBM competences to the core quality system expectations and are thus certified with a defined and verifiable range of core competencies
	CBM Project Management	Needs specific authority to perform	Often CBM project managers are part time and diverted from their main role. It is clear that CBM requires a full time specialist - as a direct employee or as a contracted entity supported completely by the senior management and given authority to act.
Classification/Survey Requirements	Survey Cycle(5yrs)	Expected to drive best practice and provide industry guidance	In general Classification societies do not fully understand the processes of CBM, TPM, HUMS and Asset Management and in general exhibit a highly conservative approach to innovation in maintenance management, yet when asked most respondents look to class for best practice guidance.
	Annual Survey	Alternative survey strategies allowed but poorly communicated and understood	Perception in market that classification societies are highly conservative and likely to create a barrier to progress. In addition where alternative strategies are allowed the perception is that the process will be time consuming, in efficient and expensive.
	Dry Docking	Items often not yet surveyed are consolidated in to a list for survey during dry dock- this is not necessary under alternative strategy via descriptive note.	When operating a vessel under MPMS and MCM items can be credited according to CM results supporting suitability for further service. This means that if items remain acceptable they can be credited for survey. This means that there is no need to perform dry docking for the purposes of machinery survey when due. Therefore unless there are items that cannot be credited for some reason or where other maintenance is required, which cannot be performed in water and it has been deemed efficient to credit for survey during docking then this makes sense. In the main however, survey credit should not be the driver behind the scheduling of docking. In addition there should be no reason to open any item at any time purely for the purposes of survey when the CM records show that the item is in an acceptable condition.
	Systems Approval	Planned maintenance systems, condition monitoring tools and techniques plus company wide Condition Based Maintenance strategies are normally required to undergo some form of approval and regular audit to allow the use of alternative classification survey strategies.	Currently there are no unified approval processes for this. As each approval is based upon the ship as the central entity each ship has to be assessed separately. This may lead to conflict where a fleet is actively operated with a number of classification societies as the requirements for each will vary. It is expected as CM and CBM shifts from alternative to mainstream that these variances will reduce and an agreed rules based approach will be developed.
Insurer	Compliance with Plan	Lack of experience re: CBM systems	No incentives for insurers to promote CM and CBM as the historical evidence within the shipping industry for improved reliability and reduced risk, is not yet in place. Most insurers recognise that improvements to reliability management reduce the risk of claim, but they will not offer financial incentives or indeed have no opportunity to leverage improved rates without sustained evidence of reduced risk. Again this will likely change as CBM becomes more conventional.
	Deductibles	Often the value of deductibles acts strategically to offset the costs of accepted unreliability. As machinery indemnity is relatively cheap poor reliability becomes acceptable even though the collective cost of "normal" maintenance is significantly higher than it needs to be.	It has been suggested that the greatest gain from CM is to be had in the reduction of losses below the deductibles threshold as these are minor but many in number. These are also classed as "the cost of doing business" but will be variable between operators. The knowledge of this variability is not accessible. However, it is likely that the major issues which occur do so in the main on poorly maintained vessels, whereas even well maintained ships may have higher losses in the sub-deductibles range which are simply not being picked up.

	Retrospective Negotiations	No benefit for improving reliability	Reducing insurance costs can only be done when you can leverage via demonstrable step change in reliability and reduced risk.
Equipment Manufacturer	Conservative Maintenance Plans	Maintenance information set to equipment not function, therefore to limit liability, maintenance plans offered by the OEM must assume a lower than average compliance and thus be inherently conservative meaning that there will be a tendency to "over maintain" unnecessarily	Warrantees only normally last for 12 months however other stakeholder may still use the equipment manufacturers recommended actions as a reference point meaning that moving away from this adds risk which may be unacceptable.
	Lack of Alternative Strategies	Few equipment makers set out alternatives to invasive maintenance, preferring instead to base tasks upon calendar intervals, yet the manufacturer in the most cases does not know what operating context the item will be put into rendering the calendar schedule meaningless.	Where possible all manufacturers must be encouraged to include alternative strategies in their maintenance guidance provisions. This is very difficult to do retrospectively therefore it is the designers and new build commissioners who must demand this if they are to be able to operate a ship the way they want to with minimal added cost.
	FMEA not available	Few equipment manufacturers carry out frontline high level FMEA which can thereafter be developed to account for local issues and intended function.	The development of local FMEA's is seen as a significant cost burden for machine users. Other industries demand this, e.g. aircraft. General basic FMEA's provided as part of the documentation at delivery would make CBM system development more accessible. Therefore makers who supply this information are likely to get more business.
	No motivation to optimise	Contacts with suppliers are traditionally based upon the value of the item and the logistics around the spares procurement and availability strategy. It is clear that to incentivise manufacturers to help ship owners and operators to optimise costs that they must be subjected to demands regarding maintenance flexibility.	The manufacturer must be supportive of the overall maintenance strategy so as to avoid the risk of issue should there be a legitimate claim for damages.
Shipping Industry Culture	Working Practices	Deck and Engineering roles	Total Productive Maintenance practice could be employed to improve vessel intelligence and feedback
		Current practice exploitation	Watch keeping and collecting data readings is common place yet the data is not used to compliment other CM or CBM data. The key to developing meaningful algorithms to protect devices and to ensure that developing faults are found early requires the fusion of data from a number of sources
	Training and Development	Out of step with other industries and not keeping pace with technological developments such that succession is becoming difficult and the route to promotion is much faster	Future opportunities to focus on multi-skilling and the management of physical assets via reliability improvement planning. In addition making the role more attractive as a modern industry where creative and innovative solutions for making improvements are clearly defined.
	Engineering and Maintenance	Ships are not routinely built with the interests of maintenance considered nor are core marine engineering values centred on reliability and asset optimization. The marine engineer is at his happiest when he is fixing a fault and getting the ship operational again.	The rewards system needs to change towards a culture where machinery failures are not tolerated. Ongoing reliability and an absence of issues should be applauded and all engineering activities and initiatives to support asset optimization should be acknowledged and rewarded. The value of working for an organisation that has modern values at its core and evident throughout all levels of the business will ultimately deliver a satisfied workforce. A business simply grounded in compliance and meeting the minimum requirement will not. Counter intuitively, a well managed ship should cost less to run!

REFERENCES

[1] Tanker Management Self Assessment (TMSA) 2nd Edition 2008 Element 4
[2] Ship Information Report Programme (SIRE) Rev 2 January 2012
[3] IACS Recommendation 74 A Guide to Managing Maintenance
[4] International Safety Management Code
Resolution A.741 (18) as amended by MSC.104 (73), MSC.179 (79), and MSC.195 (80) and MSC.273 (85)
[5] A.J.Mokashi, J.Wang, A.K. Vermar - A study of Reliability Centered Maintenance in maritime operations. Marine Policy 26 (2002) 325-335

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