education gap is large and, if anything, growing. To meet this need, and the obvious mismatch between traditional engineering courses and the modern business requirement, the first signs of hope are emerging.

- An MSc degree course in Asset Management has been running in Aberdeen (Robert Gordon Univ.) for 4 years now, and is being spread to multi-industry, modular and *in situ* delivery for 2001. See*: http//univation.rgu.com*
- Various commercial organisations (including The Woodhouse Partnership Ltd) are offering short courses in the component techniques. See*: http//www.twpl.co.uk*
- The Institute of Asset Management has matured from a 250-strong group of enthusiastic individuals into a significant professional body (now endorsed and hosted by the IEE). See*: http//www.iam-uk.org*

Nevertheless, we need to increase the spread of understanding, of successes, failures and innovations at a greater rate. The business demands can only get greater, so all of us are under increasing pressure to improve professionalism, discipline and cost/benefit accountability. We cannot afford to reinvent the wheels individually or learn by trial and error - it takes too long and is too expensive. Just as importantly, however, we have also got to be interested in the methods for improvement, and to enjoy our jobs. Asset Management is complex and affects all parts of the business, but it hold massive opportunities and, providing we can keep our heads above the water, is good fun!

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Figure 9 Decision types and MACRO guidance

8 Putting the components together

Taking a step back, any integrated implementation of Asset Management must consider a mix of techniques, tools and strategies, customised for the profile of assets to be managed, the culture of the workforce and industry, the historical 'baggage' of previous successes and failures, and the degree of flexibility needed to cope with ongoing rates of technical and commercial change. To develop such a customised route-map, however, requires a) a good understanding of the current corporate strengths and weaknesses and b) a very broad awareness of what can be achieved in which areas, at what rate and with what benefit. Such a master plan can only be developed with strong management leadership, a perceived imperative to improve (survival or profit threats, technology or market changes etc) and some specialist expertise to navigate the over-familiar trees and woods.

The Woodhouse Partnership has recently developed an Asset Management version of the popular EFQM Business Excellence model – to help assess a company's present position, priorities and scope for improvement, and the integrated routemap for the creation and implementation of an Asset Management Regime.

This usually emerges as a 2-tier plan – a short-term realisation of known opportunities and "quick wins", often obtained by rationalising and coordinating existing fragmented good practices, and a longer-term programme of fundamental change (typically a 3-5 year or longer horizon). Maintaining momentum along this path is only possible if the short-term benefits are redeployed to deliver the long-term big prizes. Yet the payback for those who succeed is vast – ranging from company survival to substantial competitive advantage. A typical case involved a petrochemical plant with a 7-year Operational Reliability improvement initiative. On international benchmarks it rose from the middle of the 3rd quartile to number 4 in the top quartile, with systems availability rising from 77% to 98% and net cost savings of over £53 million/year. UK utility and railways industries are at the early stages of developing such an holistic approach, but can expect Asset Management to be one of the decisive factors in survival, regulatory treatment and company performance.

6. Conclusions

So, where do we stand? Much development has occurred, particularly in the work control and asset information areas. Computers have wheedled their way into the maintenance department, often despite the conflicting priorities of finance and production departments. It continues to be difficult to justify expensive new technology in an area where most of the benefits are felt indirectly or accrue in other areas of the company. Nevertheless the boardroom has increasingly acknowledged that a 'maintenance management system' is acceptable and necessary.

The front-line areas of innovation are those of condition monitoring, life cycle and reliability/ maintenance strategy analysis. In these fields, the techniques, tools and understanding are moving fast – in fact the technology is no longer the limiting factor. Simulation, cost/risk optimisation tools and sophisticated reliability modelling aids can handle almost any level of sophistication likely to be needed. It is now the understanding and the use of such techniques that are the limiting factors. The

7.2 Evaluation of Solutions

Most interpretation is still based on human judgement, using the basic logic/tools of root cause analysis and common sense. The same has been true for the next, quite separate activity - the cost/benefit evaluation of possible solutions (where the MACRO project has been focussed). Historically, decisions have rarely been able to consider the effects of changing maintenance intervals or condition reaction points upon system reliability or the total cost of ownership. The relationships are poorly understood, the mathematics are too nasty, and the available raw data is usually inadequate. However, much as changed through the MACRO project. Now there are techniques with wide practical applicability:

Decision Type	Cost/risk/performance evaluation of	MACRO module: PROJECT	LIFESPAN	MAINTENANCE	INSPECTION	SCHEDULE	SPARES	STOCK
Projects, Designs & Modifications								
Cost/benefit analysis	Equipment upgrades	X	X	X				
	Process changes	X						
	Procedure changes	X						
	Technology updates	X	X	X				
	Efficiency improvements	X						
	Problem priority/urgency	X						
	Problem-solving efforts	X						
	Investment paybacks	X						
	Compliance requirements	X						
	Public image/morale activities	X						
Life Cycle & Asset Replacement	Equipment selection	X	X					
	Vendor comparisons		X				X	X
	Capex/Opex trade-off		X					
	System configuration		X					
	Repair vs Replacement		X	X				
	Life extension projects		X					
Operating & Maintenance Strategy								
Performance/Reliability/Longevity	Optimum efficiency profiles		X	X				
	Optimum run lengths between shutdowns			X				
	Reliability, efficiency & longevity combinations		X	X				
Preventive Maintenance	Optimum PM intervals			X				
	PM task evaluation			X				
	PM opportunities			X				
	Time vs usage based PM			X				
	Optimum shutdown interval			X		X		
	Repair vs Replace options		X	X				
Predictive/Condition Monitoring	Inspection & CM intervals				X			
	CM cost/benefit justification				X			
	CM methods & performance				X			
	Function testing intervals				X			
	Failure finding inspections				X			
	Safety risk exposures				X			
Work Scheduling & Shutdowns	Optimum timing and intervals					X		
	Work groupings					X		
	Evaluation of Opportunities			X	X	X		
	Scheduling and task alignment					X		
Spares & Materials								
Insurance/slow moving spares	Stock holding levels						X	
	Whole units vs components						X	
	Shared or dedicated						X	
	Supplier A vs Supplier B						X	
	Pooled access contracts						X	
	Supplier held spares						X	
	Spares criticality						X	
	Optimum availability						X	
Consumables, stock, materials	Optimum stock levels							X
	Min/Max stock levels							X
	Reorder quantities							X
	Reorder cycles							X
	Supplier A vs Supplier B							X
	Pooled access contracts							X
	JIT/Supplier-held stock							X
	Optimum availability							X
	Storage requirements							X

- cost/benefit evaluation of RCM- or RBI-derived tasks,
- a ‘Reverse-RCM’ filter of existing or recommended work programmes
- the final optimisation of task groupings, schedules and shutdown/possession plans.

These represented the final bottlenecks to a fully integrated and auditable approach to maintenance strategy development/justification. The results of such a ‘mix-and-match’ philosophy have been staggering; typically 25-40% reduction in maintenance requirements for a given system integrity/performance, the right amount of shifting towards condition-based and predictive/preventive strategies and multi-million pound savings in shutdown/possession scheduling. The technical solutions contributed by MACRO include:

- APT-INSPECTION; evaluates condition monitoring & functional testing strategies to find the optimal inspection intervals, condition reaction points etc.
- APT-MAINTENANCE; optimises the blend of preventive, corrective and condition-reactive maintenance, including analysis of multiple parallel degradation mechanisms.
- APT-SCHEDULE; uses genetic algorithms to explore different bundles & timing of shutdowns or possessions. Finds the optimal work programme (blend of performance/ risk/cost impact for individual task timings and shared downtime advantages).
- APT-SPARES & APT-STOCK; evaluation of contingencies, supply chain options, inventory levels and purchasing strategy.

7 Continuous Improvement

The on-going requirement for decision support covers the cycle of problem identification and interpretation, the selection and evaluation of possible solutions, and the corresponding adjustment of strategy and resources.

7.1 Problem finding & investigation

At one level, the problem *identification* methods are well established. Top-10 reports of failure rates, total maintenance cost, downtime or spares consumption have been providing useful pointers to problem areas for many years. The advent of computers has been of great help, correlating failure types, producing rapid ranked lists and even allowing 'drill down' into whatever history has been recorded in the search for clues about root causes. In general, the technology has only succeeded in identifying where the problems lie, not in the *nature* of the problem or the reasons for it. A good example of this difference lies in the use of Mean Time Between Failures as a reported statistic: MTBF is very useful indeed for seeing where the problems are, and how big they are, but is it quite useless in determining *why* the failures are occurring and what, therefore, could be done to prevent them. For the latter decisions, it is the *pattern* of risk (how it changes with time/use/???) that matters. This is a whole order more difficult to establish from historical data - so engineering knowledge/experience, expectations, inference and range-estimating are the prime sources of information. Happily there are now some clever ways to a) ensure that the right questions are asked in the first place and b) use range-estimates and other approximate opinions.

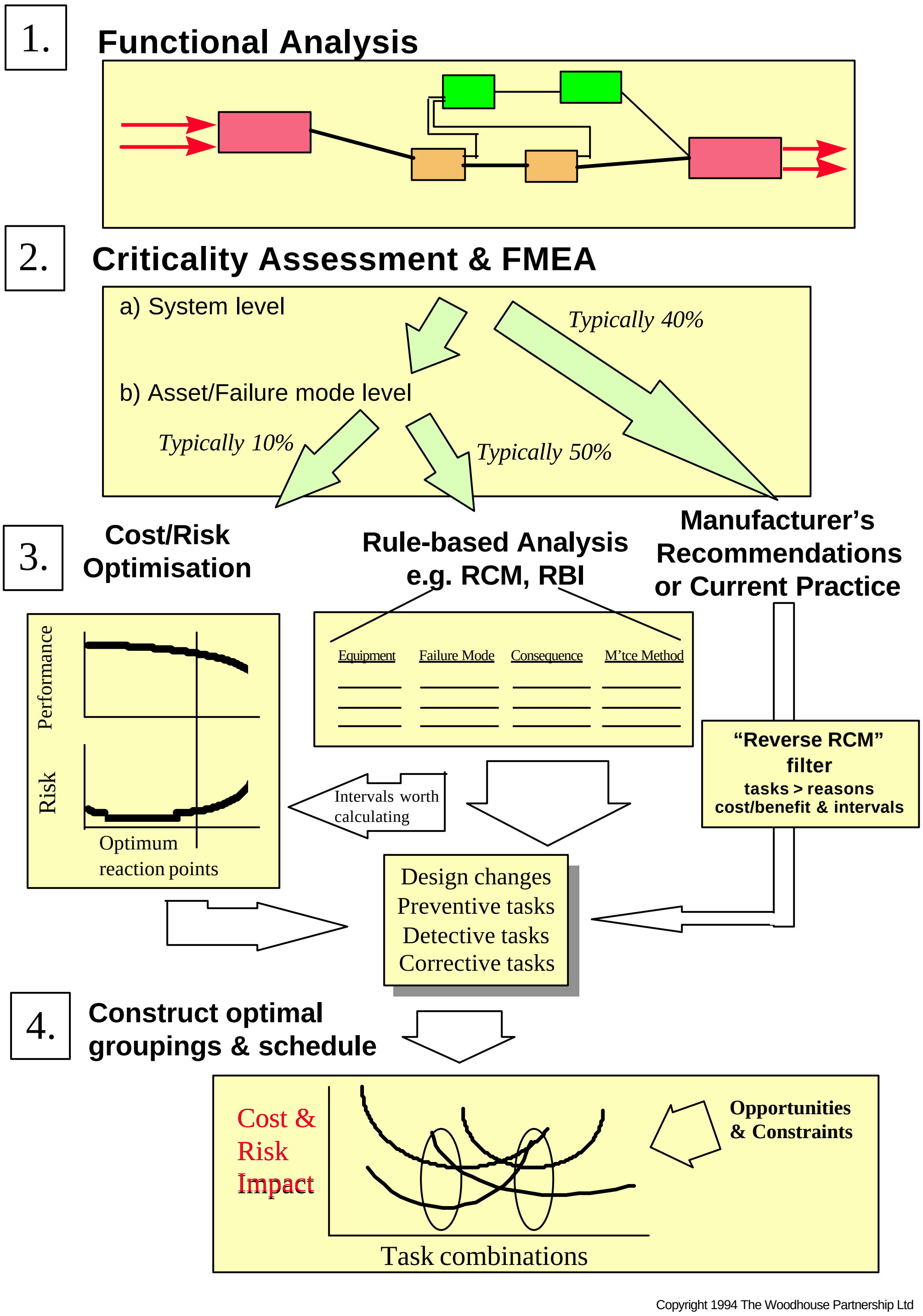

Figure 6. Combination of tools for "what maintenance & when?"

Functional analysis & mapping, criticality analysis, FMEA and several rule-based methodologies have been around for many years – it is the combined usage of them that is required for a successful implementation. MACRO has filled a few gaps in the total toolbox, namely:

- cost/risk/performance optimisation methods

6.3 Maintenance Strategies

Next let us consider the directional decisions about "what maintenance to do and when". Rule-based procedures such as the civil aviation MSG-3 and its multi-industry progeny, RCM, use key characteristics to choose between fixed-interval, inspection- or continuous condition-based maintenance and 'design out' options. The present enthusiasms and vast expenditures (one large UK company has spent $12 million on Reliability Centred Maintenance studies over the last 5 years) however, are undoubtedly due for 'rationalising'. Similarly, Total Productive Maintenance (TPM) from the Japanese motor industry tackles *parts* of the problem: the operator/maintainer interface, overall equipment effectiveness (OEE) measure and the "Cleanliness is next to Godliness" attention to detail. However it is unlikely that a single mechanism could ever exist to handle the variety of industrial operating constraints, reliability and efficiency characteristics, maintenance requirements and responsibilities, and cost/benefit evaluation of appropriate strategies. A blend of techniques will nearly always be needed.

MACRO has revealed that the appropriate tools, and levels of analysis effort that is worthwhile, should be based on the criticality of the plant & processes involved. Assigning such a criticality measure is not a trivial exercise. It must combine and merge safety priorities, performance factors (reliability, efficiency, quality etc), compliance obligations, public and customer perception measures. The resulting 'overall importance', however, is a direct reflection of the consequences of mistakes, or the importance of getting the right strategy. So it can be used to determine the depth and sophistication appropriate to find those right strategies.

Typically such an approach yields three bands of treatment: the top 5-10% 'vital few', for whom quantitative analysis is vital, and an optimal blend of preventive, predictive and contingency plans are needed. The next band typically covers between 30 and 60% of systems and equipment; the 'core' of the business but sufficiently large in volume to need templates and structured rules to determine the appropriate management techniques. The remainder comprise 'low criticality' items, individually not even worth even an FMEA study, but collectively responsible for large parts of the overall budget – here some 'structured common sense' filters can be used to make significant savings without the costs of a more rigorous, zero-based approach.

allows all sorts of projects to be individually screened (for cost/benefit and data sensitivities) and then ranked by objective criteria.

The results have been gratifying – in one case, 400 projects where evaluated by just two people in 3 weeks, showed immediate savings of over £2.5 million.   In another (the biggest oil refinery in the world), all change proposals are screened in this way, reducing the average evaluation time from 8 hours to just 30 minutes, *with greater consistency and auditability.*

Life Cycle Analysis

This tackles the combined evaluation of initial capital costs with future performance, operating and maintenance implications, life expectancies and eventual disposal or replacement. It opens up a big can of worms for performance and reward criteria, data uncertainties and long-term versus short-term priorities. In addition, there are technical challenges in correctly handling risk for various possible failure modes, and in the comparative analysis of options with different lifespans (where NPV techniques cannot be used).

The MACRO project has broken substantial new ground in this field – developing the numerical techniques as well as the analysis procedure for such evaluations. Not only can the evaluations take account of the usual capex and opex, but they can include various competing degradation mechanisms, the impact of non like-for-like replacements, and the optimal timing for renewal, refurbishment or disposal actions.

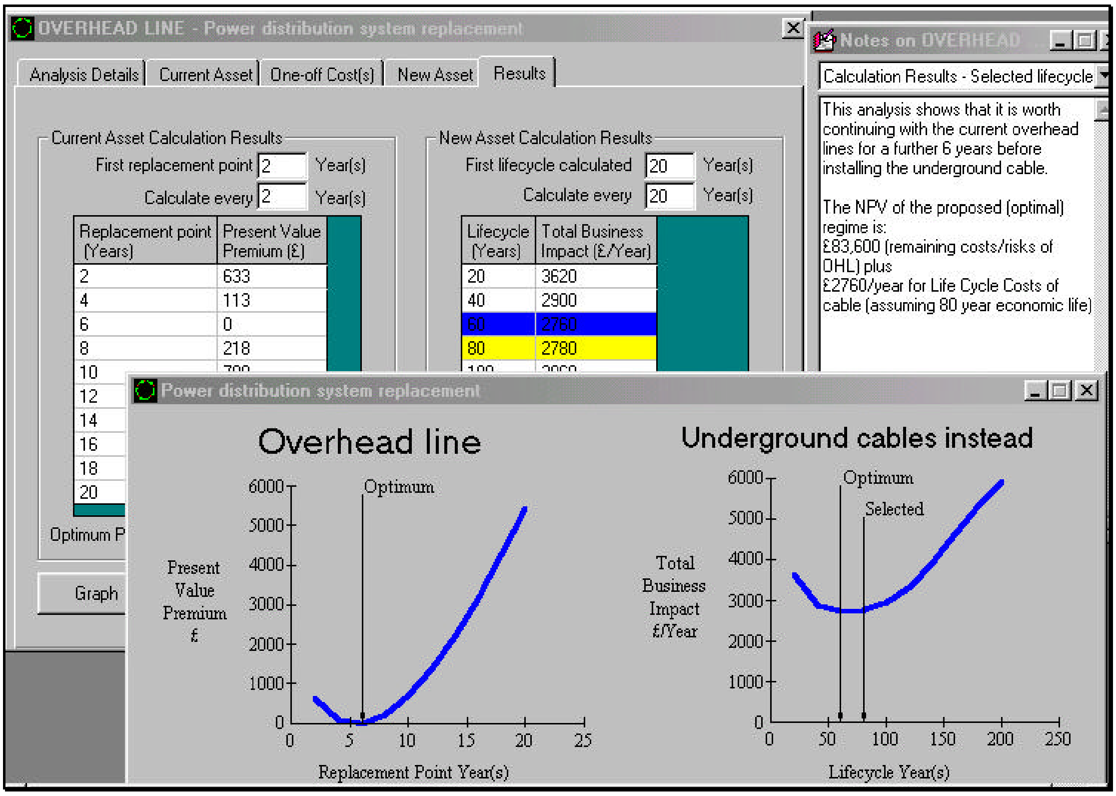

Figure 5. APT-LIFESPAN evaluation of optimal renewal/modification timing

(especially in the project phase, when no operating experience exists). The solution comprises two methods: range-estimating and sensitivity-testing. These techniques reveal a) the corresponding range for the optimum position and b) the significance of data uncertainty (i.e. what it could be worth to improve the data).

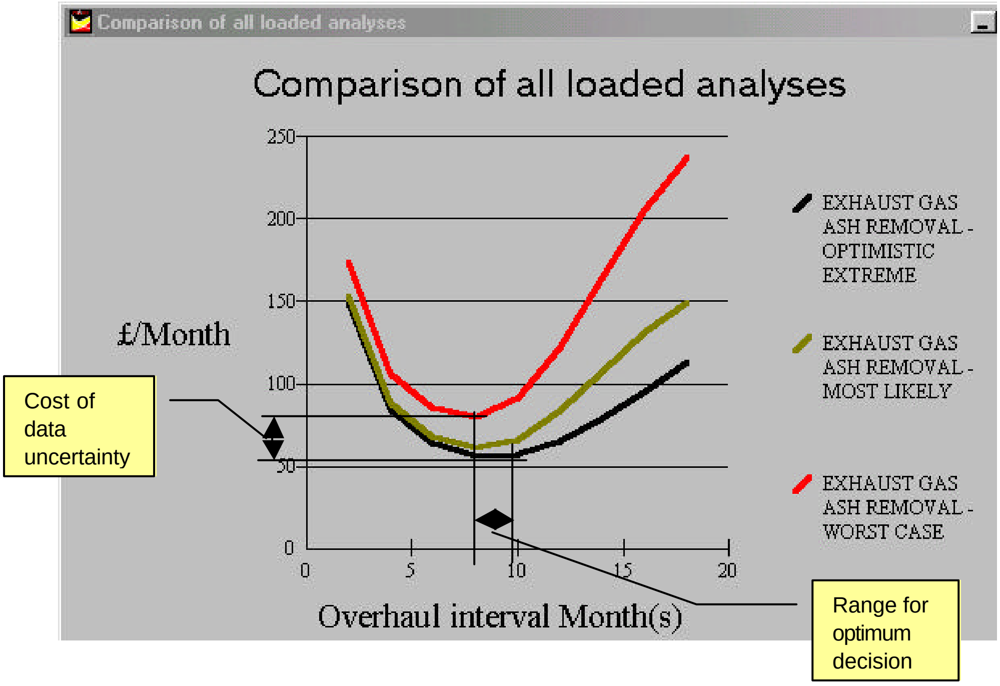

Figure 4. Analysing data uncertainty

6.2 Project Investments & Life Cycle Costing

The first major applications of such thinking are in the evaluation of discrete projects or investments. Various levels of sophistication exist, ranging from simple cost/benefit screening, to cashflow projections, financial discounting methods and whole system simulation and life cycle modelling. Two in particular need greater clarity of targeting:

a) the systematic evaluation and prioritising of minor projects (the 'small and many')
b) whole life costing of options, often having dissimilar life expectancies.

Screening & prioritising minor projects

In the first of these, the challenge is to get greater consistency and business discipline in the face of wide variation in project types, data quality, time available and capital expenditure constraints. The MACRO project approach has invested heavily in psychology – how to ask the right questions, how to get the originator of the idea to self-screen his or her proposal for RELiCS impact, how to determine if additional data is really needed and so on. The resulting methodology is a highly user-configurable evaluation tool ("APT-PROJECT"), with hand-holding guidance on company-specific generic or historical data (such as labour cost rates, production impact values, incident frequencies etc). It calculates all the usual cost/benefit attributes (NPV, IRR, payback etc) plus the 'premium paid for compliance' for those project that will go ahead despite inadequate tangible benefits. This

6 The next generation of thinking

The decisions about project investments, operating, maintenance and resource strategies are at the core of Asset Management. These are particularly acute when large sums are being considered, yet available data is scanty and speculative. The decisions break into two fundamentally different families: the 'one-off' investments (projects, constructions, modifications) and the 'cyclic' activities (periodic renewal, inspection, maintenance, shutdowns etc). In the first case, decisions involve identifying, quantifying and influencing the *levels* of performance, costs, risks etc. The second group deals with the further complication of *degradation* or *changing* performance, costs & risks. In both cases, the decision criteria can be broken down into structured checklists of the questions that need to be asked, and the range-estimation methods that are suitable if hard data is not available. In the MACRO project, these have been abbreviated to the (holy) **RELiCS**, covering all aspects of potential benefit for investment or expenditure:

- **R**eliability/Risk (specific events, such as equipment failures or safety incidents, comprising frequencies/probabilities x consequences)
- Operational **E**fficiency (performance while operating, such as energy/materials consumption and volumes or quality of output)
- **Li**fe Expectancy (deferment of capital expenditure, 'cost of money' etc.)
- **C**ompliance (regulatory, safety, environmental)
- '**S**hine' factors (public and customer impression, employee morale etc)

However quantified, these components often compete for attention – there is are trade-off's between performance and risk, for example, or between Reliability and Efficiency. This introduces the need for 'optimisation' – finding the right *blend* of costs, performance, risks etc. Decision support tools must assist in finding this optimal combination (and move away from the partial view of 'minimum cost' or 'maximum reliability').

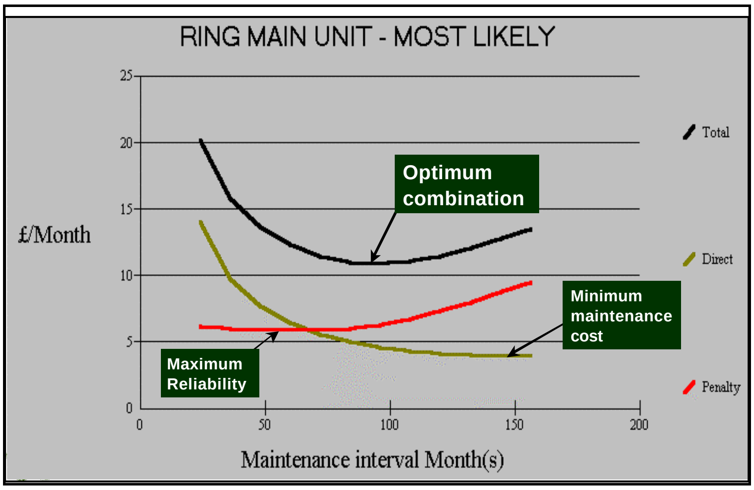

Figure 3. Cost/risk trade-off: the meaning of 'optimum'

6.1 Data uncertainty

A common concern with such optimisation concepts, is the lack of quality data. The 'garbage in – garbage out' maxim certainly holds true, and asset management information can be very rough wherever appropriate. Cost, risk and performance pressures must be considered, quantified and optimised. These are the areas where the big 'lost opportunities' are being wasted at present. It is the top (capex & opex strategies) and right hand (continuous improvement) sections of Figure 2 that holds the greatest scope for quantum improvement. In contrast to the successful implementation of a new Computerised Maintenance Management System (CMMS), which might pay for itself in 18-30 months, an appropriately targeted cost/risk review of projects and maintenance requirements will typically achieve net payback in 3-6 months.

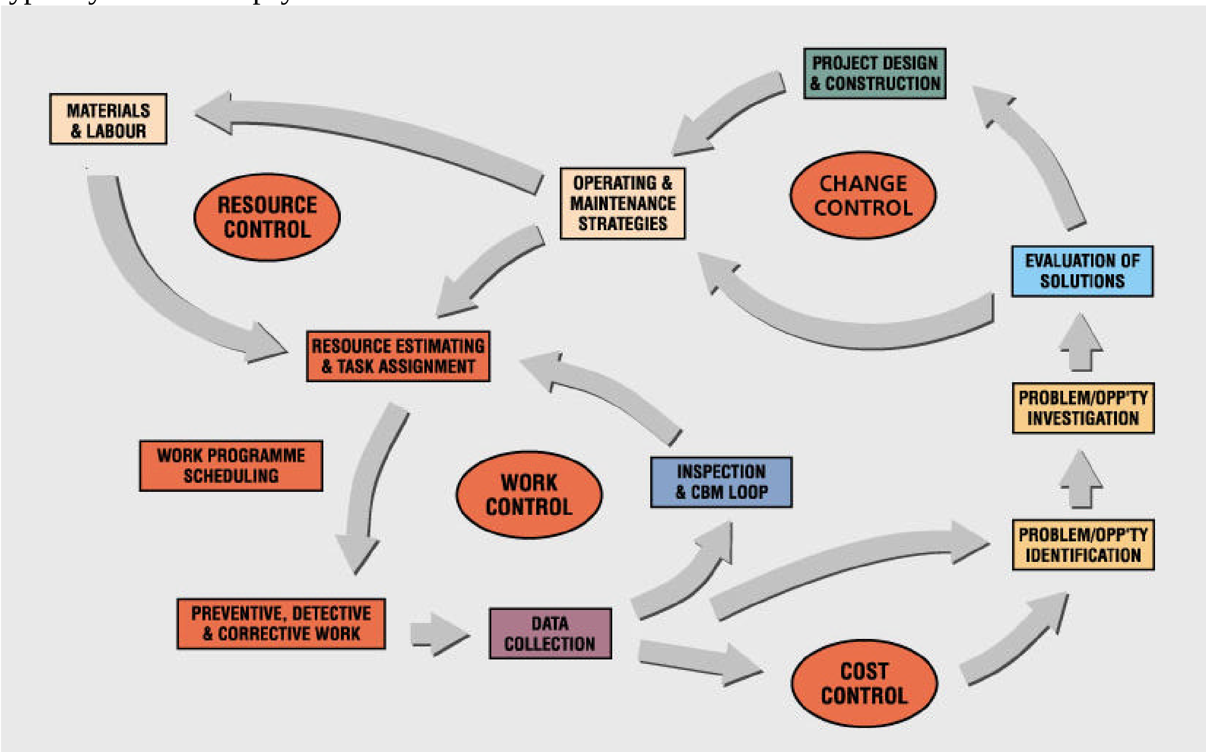

Figure 2. Asset Management Processes

5 Decision Support – the story so far

A number of disciplines and procedures have emerged over the last 20 years, mostly from the highly structured or regulated industries - the armed forces, airlines and nuclear sectors. The developments of Integrated Logistics Support and Reliability Centred Maintenance are good examples: both started in the '70s in earlier guises but are being widely adopted as standard ways of applying sensible logic without needing to be an expert. Their cross-industrial applications have often suffered from poor implementation, but the underlying rigour and logic is undeniable.

Another significant source of methods and understanding lies in the manufacturing sector. Here, particularly from the Japanese motor industry, the team-working, shared responsibility and continuous improvement processes have emerged. Total Productive Maintenance and Total Quality Management offer help in one of the most intangible of Asset Management responsibilities – the attitude, motivation and performance of the workforce.

3 Why is "Asset Management" difficult to implement?

From our work in hand-holding organisations in this area, we have observed most of the common constraints; they include:

'Silo' thinking – departmental or regional barriers, preventing collaboration and shared solutions. Usually due to previous poor experience of organisational change, strong local management personalities and/or badly structured performance/reward mechanisms.
Short-termism – especially in outsourced or project work, where success is often measured as 'on time' and 'on budget', irrespective of subsequent performance and value.
Conflicting Performance Measures – one group can only succeed at the expense of another: even 'balanced scorecards' can reinforce such competing priorities.
Business skills for engineers – engineers do not traditionally speak the same language as the finance director!
Risk Evaluation – the rational and consistent identification, quantification and management of commercial, technical, safety or customer/public perception risks.
Fire-fighting – in two respects: the reactive workload is too great to allow 'time to think', and/or 'competence in a crisis' is recognised and rewarded (even at the expense of avoiding the fires in the first place).
Data – too much of it, not enough of it, inadequate quality or the wrong sort: and what is it used for anyway?

There are common threads in several of these problems – in particular, the lack of structured, fact-based decision methods. Clear and auditable processes are needed to show what data is needed and how it should be used, take appropriate consideration of risks, financial and non-financial business objectives, short- and long-term consequences, and the inevitable 'trade-offs' that occur. These were the target of the recently-completed Eureka MACRO project; a 5 year multi-industry collaboration programme, supported by the EU and the DTI. The project and its deliverables are described in the appendix to this paper.

4 Strategy versus Delivery

One of the first key distinctions to be made is that between <u>directional decisions</u> (where we are going, and what we need to do to get there) and <u>administration efficiency</u> (how we organise what has to be done). While both are needed to correctly manage the assets, they do so by very different routes. Attention to the latter without addressing the former can result in "*doing the <u>wrong</u> work 10% quicker/cheaper*" – not a guarantee of better total performance!

There has been disproportionate attention applied to the administration areas (the solid ovals in Figure 2 below) over the last 10 years. Tens of millions are spent on creating master asset registers, customising and implementing work management systems and in supply chain initiatives. Computer-assisted generation of work orders, assembly of relevant resources and communication with craftsmen (radio links, hand-held terminals etc.) are all aimed at getting the jobs done more efficiently. Now it is time for a more balanced view, considering what work is worthwhile in the first place.

Simple but robust investment and project evaluation techniques are needed by engineers. Maintenance strategy has to move from the old time-based routines to condition- and usage-drivers

ASSET MANAGEMENT DECISION-MAKING

JOHN WOODHOUSE, The Woodhouse Partnership Ltd
November 2000

1 Introduction – to an "Asset Manager"

An Asset Manager has to be all things to all people. He or she is the point of contact between business objectives and the considerable complexities of technical and human issues. With business performance *accountability* and technical *responsibility*, the Asset Manager is a professional translator – converting options such as new technology opportunities, maintenance strategies, design changes or asset replacement decisions into business or economic language, often with little or no hard data to work with. The newly emerging management science of Asset Management is trying to deal with these requirements; equipping engineers to become businessmen, and introducing some structured methods for handling reliability, performance, maintenance, safety, environmental impact, customer & public image, staff motivation and other headaches.

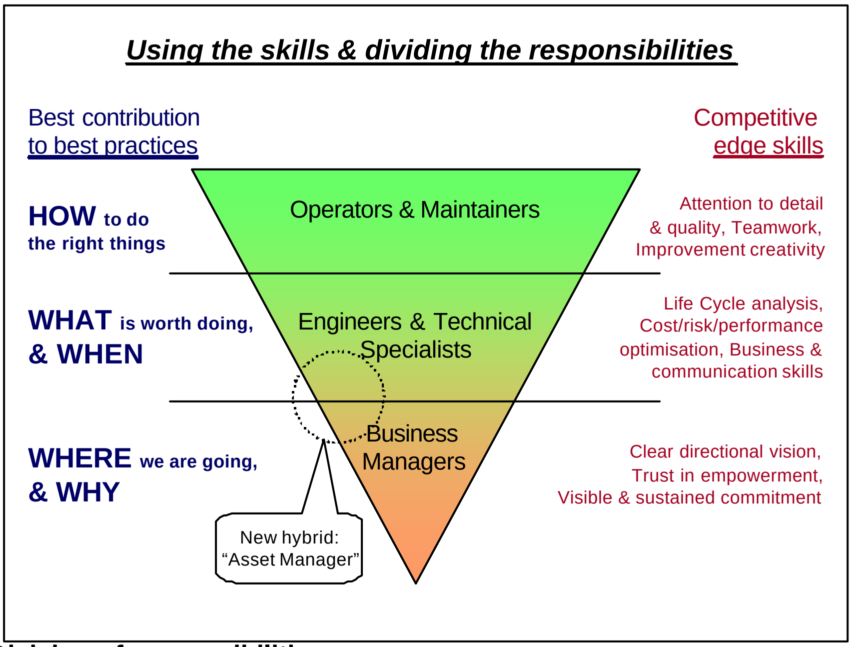

Figure 1 Division of responsibilities

2 An "Asset Management Regime"

An "Asset Management Regime" is being adopted by a number of organisations to integrate Best Practice in all aspects of designing, building, operating, maintaining and disposing of physical infrastructure. The relevant business disciplines include Life Cycle Costing, alignment of strategies to business objectives, cost/risk/performance optimisation and empowerment of staff and contractors. This comprises a challenging mix of technical issues, business awareness and personnel management and it takes considerable skill to combine them into an effective and self-sustaining programme. Only a few UK companies have fully succeeded in such integration but many are currently trying…