The ultimate goal of employing M&E systems is to bring maintenance inputs and costs under control. One element of maintenance that involves a lot of different elements and is complex is line and ramp maintenance. The ability of systems to control line maintenance and monitor its inputs is examined.

Monitoring & recording line maintenance inputs

Considerable efforts have been made by operators to improve the efficiency of base maintenance, airframe checks and engine shop visits in order to reduce the cost of aircraft maintenance, yet it is line and ramp maintenance that actually accounts for a high percentage of total maintenance costs. Despite this, operators have taken little advantage of the potential to reduce direct line maintenance inputs and related overheads. Line maintenance is the one element of maintenance that has to be reactive, in that many tasks must be planned and performed within a short period, and involves many complex steps, which are necessary to keep aircraft operational. These factors make it difficult for many operators to improve efficiency.

Technical defects that occur during an aircraft's operation result in unscheduled maintenance tasks which often involve the removal and replacement of rotable components. Many airlines generally provide large amounts of labour and rotable inventory in order to perform all line maintenance and to keep the fleet operational. The consequence of this is that operators often have little control over inputs, and only an approximate idea of the likely cost.

Line maintenance complexity

Line maintenance comprises several elements which make it difficult to control and monitor inputs. First, pilots are legally required to complete flight and technical logs, and cabin crew to complete cabin logs, for each flight.

These logs report technical defects to the airline's line maintenance and maintenance control centre (MCC). Defects generate fault codes from the aircraft's central maintenance computer (CMC) which are detected by built-in test equipment (BITE), although in some cases no fault codes are generated.

Fault codes can be transmitted to the ground via satellite or via aircraft communications addressing and reporting system (ACARS), so that they can be entered into the airline's maintenance and engineering (M&E) software system. Manually written logs are still legally required to record both types of defect. These logs are examined by mechanics, who try to clear some defects on the line, using the electronic versions of the troubleshooting manual (TSM) and the fault isolation manual (FIM) that are installed on portable computers on the flightdeck. Defects that are not fixed have to be manually typed into the M&E system, which may correlate the CMC fault codes it received while the aircraft was in-flight with the manually-entered technical logs. The M&E system can then analyse the fault, which is the first stage of planning for corrective action during line maintenance.

The inherent problem with this type of system is that there can be delays of hours or even days before defects are actually entered into the M&E system. Defects still have to be dealt with, even when they have not been entered into the M&E system, which means that it is possible, in the meantime, for line mechanics to incorrectly diagnose a defect and take inappropriate corrective action. As a result of such a mistake, the fault can recur on later flights, thereby incurring maintenance inputs and associated costs, while also increasing the stock of rotable inventory.

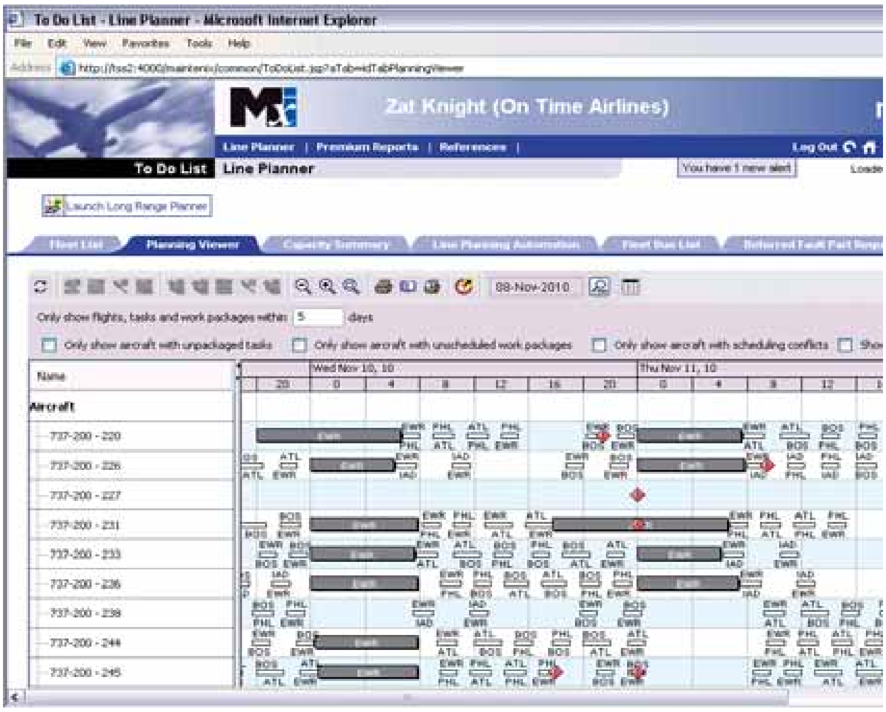
Rotable inventory

Another related issue involves tracking the use of rotable components. Defective parts are removed during line checks and replaced with serviceable items. There are two consequences to this.

The first is that an aircraft's configuration changes every time a rotable component is changed. An airline can monitor each aircraft's configuration through its M&E system, by using barcodes to track every rotable item's serial number. These barcodes are scanned every time a part is removed from an aircraft, sent for testing or repair, placed in inventory awaiting use, and installed on an aircraft. The rate at which each part number is utilised by the fleet will therefore influence inventory requirements.

"In order to keep track of each aircraft's rotable configuration, we start by defining the aircraft using a tree structure, ATA Chapters, and numbering systems," says Tim Alden, pre-sales director at Rusada. "There is also a list of allowable part numbers specified for each component in order to safeguard against the mechanics using the wrong part numbers. The system also shows how many examples of each part are installed on the aircraft, as well as each part's serial number, and the number of flight hours (FH) and flight cycles (FC) that it has accumulated since it was installed on the aircraft. A colour coding system indicates whether information on a part is missing, the part is being tracked, or the part is even relevant to the particular aircraft."

An inability to accurately track the configuration of each aircraft and every rotable unit can result in excessive amounts of rotable stock being held by operators. This is exacerbated by the removal of rotables in error when no-go faults have been incorrectly diagnosed and fixed by mechanics between flights, partly as a result of technical logs being entered only several hours after the flight



For maintenance planning, MXi's Maintenix system has a system of illustrating planned flights as white horizontal bars and planned maintenance checks as horizontal grey bars. Outstanding maintenance and out-of-phase tasks that need to be planned are shown as red diamonds.

and the related defect occurred. This increases costs. A shortage of rotables will lead to airlines having to borrow or purchase parts at short notice and high cost.

The cost of maintaining a sufficient inventory of rotable parts accounts for a high percentage of total maintenance costs, so accurately determining stock requirements provides a significant opportunity for cost reductions. "The planned work packages in Maintenix include a list of part serial numbers being removed and being installed," says Evan Butler-Jones, product marketing manager at MXi Technologies. "The system also records the man-hours (MH) that are used in component changes, and simultaneously tracks all changes in aircraft configuration. Maintenix then generates a list of all rotable component removals and installations, and lists these vertically with all relevant information to track accumulated removal intervals and generate removal statistics for reliability analysis."

Ramco Series 5.0 has some additional functionality for tracking rotables. "The system has a records dashboard, where the user can look at the serviceability of an aircraft's configuration," says John Stone, director product and market management at Ramco. "The report can list: the current number of FH and FC for each component; aircraft configuration errors; items that are incorrectly installed; and components that are overdue with respect to hard and soft removal times."

Routine line maintenance

The majority of operators follow similar line maintenance programmes for most aircraft types. These programmes include pre-flight and transit checks, daily checks and weekly checks. Daily check intervals are 24-48 hours, and the frequency at which they are performed depends on the airline's operation. Weekly checks are performed every seven to eight days in most cases. The next highest checks for most aircraft are A checks, with intervals usually being 400-700 FH.

Actual airline maintenance programmes vary, and intermediate checks or groups of tasks between weekly checks and A checks are common. The routine tasks included in these line checks come from the aircraft operating manual and the maintenance planning document (MPD), as well as additional tasks that can be added by the operator to suit their own requirements.

Electronic technical logs

The use of paper and manual systems in recording and dealing with defects results in inefficiencies. "These include delays in receiving information about defects, and diagnosing them long after the aircraft has departed for its next operation," says Mark McCausland, president of Ultramain.

The use of a manual reporting system requires a large number of staff to input defects into the operator's M&E system, and creates a large number of paper records. All PIREPs and records of aircraft defects have to be kept throughout an aircraft's lifetime. This alone is expensive, while actually retrieving the records also creates difficulties.

"One problem with manually entering information about defects is that data can get lost or misinterpreted, and mistakes are made," says Donal Van Tongeren, solution architect at KLM Engineering & Maintenance. "Entering information every day is laborious, so it is tempting to make shortcuts."

Electronic technical log (ETL) software on the electronic flight bag (EFB) hardware of an aircraft can replace the manual paper system used by most carriers for reporting technical defects, and lead to the realisation of several efficiency gains. "The ETL, aircraft EFB and ground EFB all work completely independently of M&E systems," explains McCausland.

The reason why the industry has not embraced the new technology of ETLs and EFBs sooner, is the large financial investment that it requires in aircraft and ground infrastructure. "It all started with the on-board maintenance terminal (OMT) on our MD-11 fleet, which is basically a laptop and a Network File Server (NFS) which connects to the aircraft systems," says van Tongeren. "This system gave us real-time information on the CMC messages. We soon found that pilot write-ups were leading in the preparation for the turnaround and the CMC messages were being used as additional information. We now wanted to have real-time information on the problems observed by the pilots, and looked at the OMT to see if it could be used as a platform for ETL. In those days (1996-2000) the airline and the industry were not ready for this step. When the 777-300 was introduced in 2008 it was decided to order it as an e-enabled fleet, so that it has the infrastructure with a server to connect several computers, including EFBs, cabin technical logs, and the internet, via a WiFi signal. This made it possible for us to have an ETL on the flightdeck and cabin, and to have terminals for the maintenance crews. We have selected Ultramain's ETL software, which KLM calls eATL (electronic Aircraft Technical Log). It gives unambiguous, real-time information on the aircraft's status (observed and CMC reports), which enables us to improve the planning of aircraft turnarounds."

Van Tongeren points out that a Class 2 or Class 3 EFB is required in the set-up that KLM has chosen. While a Class 3 EFB is fully integrated with the aircraft's systems, Van Tongeren comments that a Class 2 EFB is sufficient for eATL, and will probably be the future for the industry when airlines decide to retrofit existing fleets.

"ETLs can be used to record the non-CMC faults that occur during flight," explains Saunders. "The CMC faults are already being transmitted to the ground station by ACARS and other technologies. Only some CMC codes are displayed on the flightdeck. ETLs do not take CMC fault codes. The non-CMC faults and defects have to be entered into the ETL, and the software provides a menu for the flightcrew to select the correct defect description from a menu. The ETL can then transmit the defect in real time to the ground station. While the airline requires a receiver tool for the ETL messages, all defects and faults can be recorded and transmitted electronically while the aircraft is in the air. One clear advantage of this is that the mechanic no longer has to visit the aircraft after it has landed in order to read the technical log, because all problems can be reviewed during the flight. First, the defects and faults are fed automatically into the M&E system, so engineers and mechanics can troubleshoot and diagnose them with electronic versions of the TSM and FIM. They can then decide whether to attempt a fix if the problem is a 'no-go' item, or defer it - all before the aircraft has landed."

The standards for transmitting the data to ground stations are specified in Air Transport Association (ATA) Spec 2000 Chapter 17, in subset ARINC 633, Chapter 7. ACARS does not work over oceans, so aircraft operating over water require SATCOM communication capability. "The ATA Spec 2000 Chapter 17 standard means that the data received at the ground stations can be transferred to the airline's M&E system, and Ultramain's ETL can be interfaced with any M&E system," says McCausland. "This means that as soon as a failure occurs, the maintenance department receives real-time accurate data at source."

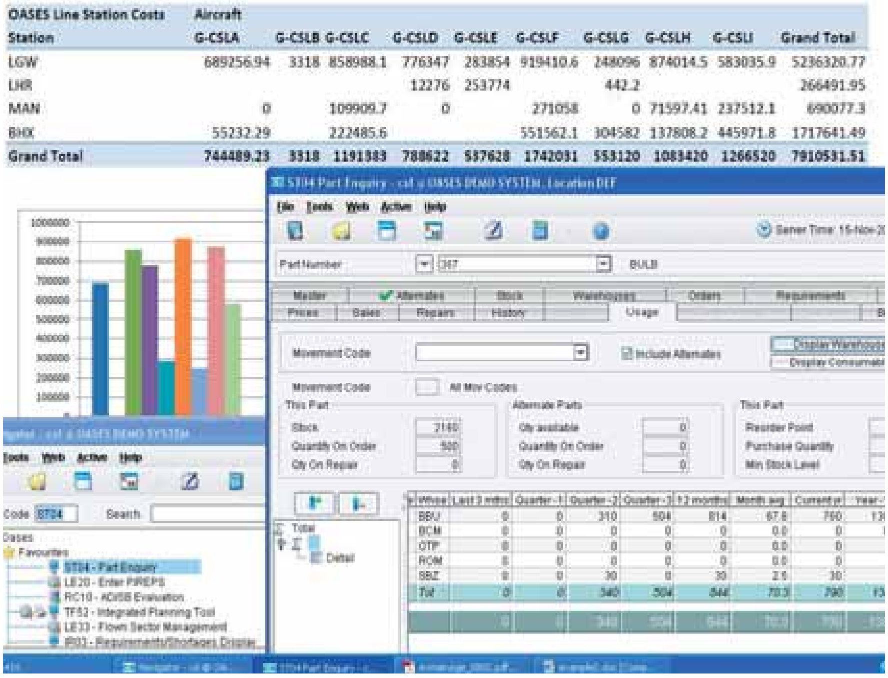
"The main advantages of using an ETL system are increased aircraft utilisation, reduced maintenance costs, and ensuring revenue generation," says van Tongeren. "The increased aircraft utilisation comes from us being able to analyse faults in flight, and to rectify them in less time than when using the manual system. This faster response time also saves us an average of 30 minutes of maintenance for each turnaround between flights. The faster correction of faults also means that we have fewer cancellations and expensive delays, and provide better customer service. Another indirect saving is that the system helps us better identify component failures where we are entitled to make a warranty claim."

Line check planning

Planning routine tasks and correcting defects in work packages is performed by maintenance planners. Most line maintenance capability will be available at an operator's main base, so the majority of scheduled checks will be carried out at home bases where possible. The interval of up to 48 hours for a daily check, for example, often allows it to be performed at its home base on long-haul aircraft. Checks that cannot be performed at home bases are often sub-contracted to third parties.

The need to plan and prepare for the clearing of technical defects at short notice, and to combine these with routine tasks is what makes line maintenance planning complicated.

"This is where reporting defects via an ETL system improves overall efficiency," says Saunders. "By reporting in real time, Ultramain can store all defects with their rectification time limits, and prioritise them, so that the



OASES Line Station Costs	Aircraft									
Station	G-CSLA	G-CSLB	G-CSLC	G-CSLD	G-CSLE	G-CSLF	G-CSLG	G-CSLH	G-CSLI	Grand Total
LGW	689256.94	3318	858988.1	776347	283854	919410.6	248096	874014.5	583035.9	5236320.77
LHR				12276	253774		442.2			266491.95
MAN	0		109909.7	0		271058	0	71597.41	237512.1	690077.3
BHX	55232.29		222485.6			551562.1	304582	137808.2	445971.8	1717641.49
Grand Total	744489.23	3318	1191383	788622	537628	1742031	553120	1083420	1266520	7910531.51

Commsoft's OASES can be configured to show analyse maintenance costs over a defined period for an individual aircraft or a fleet type at a particular maintenance station.

maintenance planners can see when and where it is best to clear each defect in relation to the aircraft's operating schedule. This information can be presented on a gantt chart, for example, as is the fleet's operating schedule. This eases line maintenance planning. In our case, the defects are loaded into the line maintenance plan, which is updated three times per day."

Analysing outstanding defects to show those that have to be dealt with most urgently is a task that needs to be managed by an airline's maintenance control centre (MCC). It also requires a specific functionality within the M&E system. "Our line maintenance module in our Envision system has several sub-modules that allow defects to be managed. These sub-modules can include the Fleet Defect Log, the Allowable Deferred Defects (ADD) management module, minimum equipment list (MEL) categories, and the handover diary," explains Alden.

"Once a defect has been entered into the system, this has to determine if it can be deferred in accordance with the MEL, or if it is a no-go item," continues Alden. "The M&E system needs to defer a defect, and create and manage a list of outstanding defects. If a defect is deferred it is transferred to the ADD and the Fleet Defect Log, and Envision automatically tracks it until it is cleared. Tracking and monitoring the list of outstanding defects at all times is required by each operator's airworthiness authority.

"The Fleet Defect Log within Envision maintains a list of all the outstanding defects in the fleet. Each one is listed with information that includes the status by colour-coding, the status of parts required to clear the defect, a description, and the time remaining to clear the defect. The Fleet Defect Log will list no-go items and deferred defects," continues Alden. "Further information on a defect can be obtained by drilling down.

"The ADD management module only includes defects that have a time limit for clearing. When a defect is deferred, Envision automatically raises a time limit to clear the defect in accordance with the MEL," continues Alden. "An airline's MCC department relies on the information in the ADD, and which no-go defects are listed in the Fleet Defect Log. The MCC operative using Envision can filter defects according to their status and time limits."

Envision also has a handover diary. "MCC operatives keep a diary of events that relate to the problems that aircraft experience," says Alden. "We have an electronic diary in Envision where the MCC operatives record all related events and issues. This allows other operatives to take over at shift changes without any information being lost."

The next step in the process involves planning the scheduled tasks and defects into line maintenance work packages, while also coordinating these with the flight schedule. "Our Maintenix system takes a fleet's planned schedule and illustrates it on a gantt chart. It then overlays the planned checks and defects on top of this so that maintenance planners have a visual presentation of what maintenance is due," explains Butler-Jones. "Planned flights are shown as white horizontal bars, and planned maintenance inputs as horizontal grey bars. These can be overnight or between flight checks. Outstanding unscheduled work packages and out-of-phase tasks that need to be planned into the scheduled packages are shown as red diamonds. The gantt chart displays the diamonds at their maximum deadline for correction."

Maintenix has various functionality tabs to assist in maintenance planning. One is a capacity tab, which shows the quantity of all the different resources available for each day. The fleet list tab lists each aircraft and the open faults for each aircraft. "The planning of work packages happens automatically in Maintenix," says Butler-Jones. "This considers the flight schedule, available downtime and resources, and tasks to be done. All scheduled and unscheduled tasks are grouped together. The system will then list any tasks or exceptions that could not be planned into the work packages. These have to be planned manually, but the automatic planning of most tasks cuts the time needed to do this by 30-60%. Maintenix then lists all the work that is due for the next 24 hours, as well as all the tools, parts, resources and labour required. This information comes from task cards and templates for fixing faults, which pre-define the labour, parts and tools needed."

Line check packages

Once tasks to clear defects have been planned into line checks and a complete work package has been determined, the MH, consumable and rotable part inputs required are estimated. It is here that one of the main losses of efficiency in line maintenance can occur, since in many cases there is little or no control over the total labour force and inventory of parts and materials that an airline has. The use of M&E systems enables airlines to maintain a greater degree of control at this level.

"Our OASES system uses a work order system for all levels of maintenance, including all line check packages," says David Pusey, director at Commsoft. "The work order includes and clearly lists all the tasks to be performed, and the assigned labour MH and materials for the task. This way all inputs are accounted for, and approved by the supervisor. Also, all parts are tracked using a barcoding system, so unused ones can be returned to stores and their associated cost deducted from the list of inputs used for the check.

"More detail can be obtained for all the parts required in a check. OASES uses a simple traffic light system for this," continues Pusey. "A green light shows the required part is in stock, an amber light indicates the part is on order but will not be available when the check is to be performed, and a red light means that the part is unavailable. The user can drill down into the system to find alternative sources for a part, or order them. The consumption of a part number can also be analysed.

"The process starts with the line maintenance planner, who works with an allocated work order number for each line check," continues Pusey. "The work order number is applied to an aircraft registration number. Information available includes the start and end times and dates, the aircraft location, the location of materials and parts that are assigned to the check, and the estimated labour required. The system can also forecast maintenance that is coming due over a certain period into the future. Tasks can therefore be allocated into particular work packages. The user can drill down into the detail of each work package to obtain the estimated MH for each task.

"The planner can also use OASES to requisition materials, parts and tools for the work order," adds Pusey. "The work order includes the details of all maintenance tasks, the cost estimates, and material consumption. OASES not only captures all the material booked for a work package, but also credits the related cost of materials and parts not used and returned to stores."

Maintenance execution

Following the precise planning of line maintenance workscopes, the execution of maintenance also requires the accurate tracking and monitoring of MH and materials used.

This is now possible through the use of barcoded task cards. Task cards are assigned to mechanics, who sign them manually or electronically when they are completed. Although many systems are capable of accommodating electronic signatures, aviation authorities usually also require a manual signature on a paper record, thereby effectively eliminating the advantage of electronic signatures.

Barcoding task cards and parts allows parts to be closely monitored. This requires workstations and computer terminals for mechanics, and for barcode swipes to be made when conducting hangar checks. Line maintenance requires more physical activity from line mechanics than hangar maintenance does. Line mechanics have to transit between the aircraft and the line maintenance offices and parts and tools stores several times in the course of carrying out each line maintenance activity. The use of tablet or portable computers is expected to ease the execution of line maintenance.

Air Canada Jazz has been conducting a trial to assess the benefits of using portable computers. "A mechanic needs all resources in one place for line maintenance, which a portable computer would provide," says John Hensel, manager of Trax continuous improvement group at Air Canada Jazz. "This includes the task cards, all manuals, and the ability to order parts and tools. This allows the line mechanic to remain in one place when dealing with a fault or a defect.

"The use of a tablet or portable computer, however, also requires a good wireless infrastructure to be available at the operator's hangars and gate stations on the line. It also needs barcode readers," continues Hensel. "We have conducted a trial with a Motorola barcode reader that we use to swipe task cards and parts packaging to record MH and other inputs. It is inevitable that you lose connection with a wireless system at some point during your maintenance activity. We have been able to develop a capability with Trax for all information relating to swipes to be stored on the barcode reader in the event that the wireless connection is lost, and for all this stored information to be transmitted when the wireless connection is restored." The barcode reader works together with smart cards, which allow mechanics to identify themselves and sign off task cards electronically.

Air Canada Jazz has selected the Panasonic Toughbook as its portable computer. "This has everything on it that a mechanic requires," says Hensel. "It includes a radio frequency identification (RFID) reader, a smart code, barcode reader, a camera and access to all the necessary electronic manuals. We have a fleet of 157 aircraft, and perform about 20,000 maintenance tasks per month for both line maintenance and airframe checks. We estimate that we can save about five minutes' walk time per task for the mechanics by using the Toughbook, while the time saved for line tasks is likely to be even higher. The use of tablet computers across the fleet could potentially save us thousands of MH per year in executing maintenance. Portable computers also make it a lot easier for mechanics to perform line maintenance in the dark or in poor weather. We need to finalise the software and wireless system first, but we expect to be using Toughbooks across our entire operation by late 2011."

Financial analysis

The ultimate goal of monitoring line maintenance inputs is to provide a precise view of what is being used for each aircraft, by each check type, the consumption of each part, and by each line station in the operator's network.

Records of MH used, and the associated materials and parts used, can all be exported into Excel for financial analysis. "OASES has a system for analysing the labour and material consumed in each check. Materials can be listed as batch numbers. The unit, mark-up and end cost of each part is also shown," explains Pusey. "For example, the budgeted and actual MH, labour rate for each skill, and total labour cost can also be analysed.

"OASES is able to define the mark-up bands and rates for different categories of parts. It also has the functionality to define business rules in order to keep control of costs, and to list the warehouses where parts and materials come from," continues Pusey. "The system clearly divides the inputs into labour and materials. The labour utilisation is tabulated in terms of the MH used for each task and skill level. The actual MH consumed are tracked, as is their cost. The materials used in each check are clearly listed, together with their actual cost, mark-up cost and final cost. The table of final costs is also updated in real time in order to monitor check inputs. The data can then be exported into Excel for analysis by the user. OASES is also able to analyse inputs for all line maintenance over a set of dates, using different criteria: by line maintenance station; by individual aircraft; by fleet type; or by check type. For example, OASES can provide a detailed analysis of the inputs used for weekly checks for each of the aircraft types operated by an airline over the previous two months."

Airlines will naturally be interested in further details. "Ramco Series 5.0 will list the total MH, open MH, completed MH and deferred MH used in a check," says Stone. "It will also list the split between routine and non-routine MH, and the details of all the MH used in each of the task cards. The system has other tabs that provide more information on component changes, material requests, and reports, as well as a functionality for comparing actual used MH with planned MH, so that MH forecasts can be updated and improved.

"The user is also able to automate the way in the data is reported and the way in which it is presented," continues Stone. "This way labour can be analysed by skill type, or split between external and internal labour rates." AC