The MD-11, A330, A340 & 777 have similar seat capacities, but represent different generations of technology. Maintenance is an element of cash operating costs where one type can display an advantage over another. Airframe & component maintenance charges of the four types are compared.

300-seat widebodies: maintenance analysis

The A330-300/340-300, MD-11 and 777-200 have similar seat capacities and are designed for similar missions. Some airlines operate mixed fleets of these types. The long-term viability of each type depends on its performance and seat-mile cost. Since maintenance costs account for a large portion of seat-mile costs, the airframe and component maintenance costs of these aircraft are analysed and compared.

There are four main elements of total cost per flight hour (FH) for airframe and component maintenance: line maintenance; base maintenance checks; heavy components; and rotable and LRU components. Refurbishment of interiors is usually included with base checks. Heavy components include wheels and brakes, landing gears, auxiliary power unit and thrust reverser. Rotable and LRU components include items that can be exchanged on the line or during line checks, and held in an inventory or pool.

Line checks greatly influence total maintenance cost per FH because of the large number completed in a given period or maintenance check cycle. LRUs and rotables also account for a high percentage of total maintenance cost.

Aircraft in operation

Style of operation, in particular FH to flight cycle (FC) ratio, has a large influence on maintenance costs per FH. Line checks and components with FC related intervals have escalated costs per FH for aircraft operating short cycles.

Aircraft utilisation also affects maintenance costs, since some elements of maintenance have both FH/FC and calendar limits, such as daily and weekly checks. These have escalated costs per FH for aircraft operating short cycles.

Operating pattern is also important. The A340, for example, has a C check interval of 15 months, and a five-year structural inspection of 60 months. The C4 check can therefore be combined with the five-year check, since combining the checks reduces downtime and man-hour (MH) expenditure. Those operators that require their aircraft during the summer months are forced to have C checks annually, and so perform the C4/5-year check after four years, thereby losing a year of the interval.

The A330/340 are used as a medium- and long-haul aircraft. This means the A330 on medium-haul operations has average FC times of 3-4FH, and generates about 3,000FH and 1,000FC annually. Aircraft used for long-haul operations of about 7.0FH per FC generate about 4,000FH and 570FC each year. Other airlines, such as Aer Lingus, use the aircraft for mixed medium- and long-haul operations. Aer Lingus has an average FC of 4.5FH, since it operates the aircraft on mainly transatlantic operations, but also flies the aircraft between Dublin and Shannon.

The A340-200/-300 is used on purely long-haul missions, by operators including Lufthansa, Iberia, TAP Air Portugal, Air France and Air Canada. Typical average FC times are 7.5-9.0FH, and generates 4,600-5,000FH per year are generated.

There are several gross weight 777-200 variants, and the aircraft is used on a variety of medium- and long-haul operations. Average FC times and annual utilisations are similar to those achieved by the A330-300/340-300. Air China and Cathay Pacific, for example, use the 777-200 for regional Asia Pacific routes and have average FC times of about 2.8FH.

The MD-11 is used almost exclusively as a long-haul aircraft. Key operators are KLM, Finnair, Alitalia, Japan Airlines (JAL), Delta. Other major operators which have already retired all or most of their MD-11s are American, Korean Air, Garuda and China Airlines. KLM uses the MD-11 for its lower density long-haul routes and has an average stage length of 6.14FH, and achieves 3,800-4,500FH per year utilisation.

Maintenance programmes

Maintenance programmes and schedules are key to maintenance costs. This is especially since man-hours (MH) consumed in line checks will multiply up and contribute the largest portion of labour used in a complete maintenance cycle.

The maintenance programmes used by various MD-11, A330, A340 and 777 operators are summarised *(see tables, pages 24 & 26)*.

Line maintenance strongly influences cost, since the high frequency of line checks means that a large number are performed each maintenance cycle, thereby increasing total MH consumed. Swiss, for example, reduces line checks by incorporating daily checks into pre-flight checks for its MD-11s and A330-200s.

Most line maintenance programmes include pre-flight daily checks, performed at the home base when the aircraft is in operation, and pre-flight transit checks. Transit checks are performed before all other flights operated each day, at both outstations and the home base in the case of high daily frequencies.

In the case of the A340, transit checks can be performed by the flight crew, saving maintenance MH inputs. "Technical problems during transit checks can be dealt with by having contracts with vendors with large A340 capability at outstations. This reduces the need to place your own line mechanics at every outstation," explains Rufino de Oliveira, aircraft maintenance director at TAP Air Portugal.

"While transit checks are simple checks on items like wheels, daily checks

MD-11 MAINTENANCE PROGRAMMES

Operator	KLM	Swiss	Delta	VARIG
Pre-flight check		Each FC	Each FC	Each FC
Transit check	Each FC			
Daily check	up to 48 hrs			
A check	700 FH	700 FH	500 FH	600 FH
C check	6,000 FH	6,000 FH	3,000FH/ 7.5 months	6,000FH/ 15 months
D check	30,000 FH/ 72 months D1	30,000 FH/ 72 months D1	30,000FH/ 72 months D1	24,000FH/ 60 months
	22,400FH/ 60 months D2	30,000 FH/ 60 months D2	24,000 FH/ 60 months D2	

A330 MAINTENANCE PROGRAMMES

Operator	Aer Lingus	Swiss	Sabena
Pre-flight check		Each FC	
Transit check	Each FC at outstation		Each FC at outstation
Daily check	Each FC at homebase/24 hrs		Each FC at homebase/24 hrs
A check	500 FH	500 FH	500 FH
C check	15 months	15 months	15 months
IL check	60 months	60 months	60 months
D check	120 months	120 months	120 months

A340 MAINTENANCE PROGRAMMES

Operator	Air France	Iberia	Lufthansa	TAP
Pre-flight check				
Transit check	Each FC at outstation	Each FC at outstation	Each FC at outstation	Each FC at outstation
Daily check	24 hrs at home base	24 hrs at home base	24 hrs at home base	To 36 hrs at home base
Weekly check				Up to 8 days
A check	700 FH	500 FH	550 FH	500 FH
C check	7,500 FH/ 18 months	15 months	18 months	15 months
IL check	72 months	60 months	72 months	60 months
D check	120 months	120 months	120 months	120 months

provide an opportunity to clear problems with minimum equipment list (MEL) items, plus work on the daily check list and some cabin work," explains Eugene O'Sullivan, engineer services manager at FLS Aerospace. "Aircraft used on Etops missions will also have heavier line checks compared to those not used on Etops missions."

Aircraft used on long-haul missions generate about two FCs per day in operation, with days in maintenance or lighter schedules reducing the annual average. Aircraft thus have a similar number of daily check and transit checks each year.

In the case of A330s and 777s used on medium-haul missions, a daily check is still performed each day of operation prior to the first flight, while a higher number of transit checks is performed for all other flights. Utilisations are typically three flights per day, so about twice as many transit checks are completed for each daily check.

Line maintenance programmes

The MD-11 is used almost exclusively in long-haul operation. KLM has a system of a 'Platform' check which is completed every FC, which covers transit and daily checks. KLM also has non-MPD intermediate checks between A checks called TD checks. These are used to correct deferred items. It also performs two hangar checks every six months to rectify airworthiness directives and other items.

The A330 will have a higher number of transit checks when used in medium-haul operations rather than long-haul. The A340 will similarly have a low number of transit checks.

The 777 is used in medium-haul and long-haul operations. Like the A330 and A340, the 777-200 therefore has patterns of operation which are close to about three FCs per day for medium-haul and about two FCs per day in long-haul.

The A330/340 and 777 have pre-flight/transit and daily checks followed by weekly checks, or checks with a similar interval *(see tables, this page & page 26)*.

The highest check in most line maintenance programmes are A checks. The MPD intervals are similar in the region of 500-700FH for all aircraft types. The 777, however, does not have a defined A check, but operators have a generic one in their programmes. Some airlines have been able to extend their intervals to about 700FH.

MH expenditure per FH for the A check cycle depends on the number of FCs performed during the cycle, since it affects the number of pre-flight/transit checks required. MH expenditure per FH will be reduced by higher rates of utilisation, since the number of daily and weekly checks will be fixed.

In turn, the MH expenditure will depend on the requirements of the operation, efficiency of the maintenance programme and efficiency of operator or maintenance provider. There is little variance in MH expenditure for daily and weekly checks between different operators.

Check interval utilisation also influences MH expenditure per FH and A check cycle. Airlines typically achieve 85% of interval utilisation, while more efficient carriers gain more.

777 MAINTENANCE PROGRAMMES-MEDIUM-HAUL OPERATIONS

Operator	Cathay Pacific	Air China
Pre-flight check		Each FC at outstation
Transit check	Each FC	Each FC at home base
Daily check	up to 36 hrs	24 hrs
Weekly check	up to 8 days	7 days
A check	500 FH	500 FH
B check	150 days	
C check	12 months	750 days
SC check		

777 MAINTENANCE PROGRAMMES-LONG-HAUL OPERATIONS

Operator	Air France	United	Delta
Pre-flight check	Each FC at outstation		Each Etops flight
Transit check			Each non-Etops flight
Daily check	Each FC at home base	Every 24 hrs to max 48 hours	Every 24 hrs
V check	100 FH		
K check	250 FH		
Weekly check		85 FH	
A check	600 FH	500 FH	500 FH
C check	5,000 FH/ 12 months	5,000 FH	Annual 'PSV' check
SC check	4,000 FC/ 48 months		

Base maintenance programmes

The MD-11's base maintenance programme comprises C and D checks. C check intervals are 6,000FH and 15 or 18 months for most operators. Varig, for example, has an interval of 6,000FH or 15 months, whichever occurs first; since it operates about 4,400FH per year it reaches its 15 month interval first. This is an escalated interval compared to the MPD interval of 4,200FH, which would be an annual check in the case of most operators.

The D1 check interval is 30,000FH and 72 months, but reduced to 22,400FH and 60 months for subsequent D checks. Some operators have gained extensions for their D2 checks. The D1 interval allows a utilisation of up to 5,000FH per year, while the D2 interval allows only about 4,500FH per year.

KLM combined either its C5 or C6 check with its D1 check. It has since had its C check interval escalated, and so will have a reduced number between subsequent D checks. Most MD-11s will have had their D1 check, and will have a D check interval of 60 months; they will therefore perform the fourth C check with the D check, with a C check interval of 12-15 months. This will raise MH per FH for the D check cycle because the interval is shorter than the D1 interval. Varig has a 24,000FH and 60 month D check interval.

The A330 and A340 have a system of C checks, up to the C8 check, an intermediate structural inspection (IL check) at five years, and structural inspection at 10 years (D check). The C check's MPD interval is 15 months, although some operators have extended it to 18 months.

Access and repetition mean most airlines try to combine the C4 with the IL check and the C8 with the 10-year check. To utilise these five- and 10-year intervals, and combine them with the C4 and C8 checks, airlines have to achieve the C check's full 15 month interval. In many cases, however, the C check has to be scheduled as an annual event. "Aer Lingus has to have C check every winter because of operational requirements," explains O'Sullivan. "Interval utilisation is typically 85%, and this means the C4/IL check is actually done at four years and the C8/D check at eight years; meaning two years are lost off the D check interval."

The same occurs for some A340 operators which cannot schedule C or D checks in the summer months. "We do a C check every 12 months,"says de Oliveira. "The C8 and D check could be done separately, but this incurs additional downtime and MH." Only operators with larger fleets and a more even operating schedule could make use of the C check's 15-month interval. Air France, for example, has been able to use the D check's full 10-year interval.

The 777 has two main group of job cards, which are system and structural related. These can be grouped into 'C' checks.

Most system items have limits and multiples of 6,000FH and 750 days, and so can be grouped into a C check. Many structural items have limits or multiples of 4,000FC and 750 days, and are grouped into SC checks. Annual utilisation and average FC time will influence if the C and SC checks are performed separately or combined.

Air China achieves about 2,900FH and 1,100FC per year. This makes it optimal to combine the C and SC tasks into a single bi-annual check, with the fourth being the heaviest check at eight years because of 4SC items.

SC checks get steadily larger because of multiple items and more items are introduced and then repeated. Multiples of 2, 4, 6 and 8 SC checks are heaviest.

An airline operating the 777 on long-haul routes and generating about 4,500FH and 600FC per year would have to perform the C items every 12-15 months, and the SC items up to every two years. The C and SC checks could be performed separately, but this increases downtime and MH expenditure. Many airlines have an annual C check and perform SC items every second year. This results in alternating light and heavy checks. This is a system used by Cathay Pacific, United and Delta.

Air France has separate C and SC checks, with the SC check interval four times longer than the C check.

Despite older generation technology, the MD-11 still has competitive maintenance costs due to low cost of components. The aircraft also has a durable airframe, and the increases in MH consumed in base checks should be low.

Line check inputs

Line check inputs will be for routine inspections and subsequent rectifications, minor service bulletins (SBs), deferred defects and cabin work. The majority of cabin work will be cleaning, but some replacement of worn items occurs. Line checks also use MH for the removal and replacement of line replaceable rotables and heavy components, such as brake units. Modifications, engineering orders, heavy SBs, airworthiness directives (ADs) and interior refurbishment are not normally included in these checks.

Besides labour, additional cost will be incurred for materials and consumables.

KLM records MH inputs of about 11MH for its transit/daily checks, 31MH and 65MH for the intermediate and hangar checks, and an average of 475MH for A checks. Varig records a similar input of 500MH for its A checks.

KLM has 12 A checks in its A check cycle, with an interval of 8,400FH. The total MH consumption over this cycle is about 12,600. Actual MH used per FH will depend on the interval achieved. A utilisation of 85% will be about 7,100FH for the full A check cycle, and MH consumption will be about 1.8MH per FH. At a labour rate of $70 for line maintenance this is equal to $124 per FH *(see table, page 29)*.

Material and consumable costs are in the region of $150 for transit/daily checks, $950 for intermediate and $3,000 for hangar checks and an average of $18,000 for A checks. Total material consumption for the A check cycle will be about $336,000. This is equal to about $50 per FH, depending on utilisation of the A check interval *(see table, page 29)*.

Two operations will have to be considered for the A330. The first is a medium-haul operation of about 3FH per FC, with the aircraft generating about 3,000FH per year. The second is a long-haul operation of about 7FH per FC, with the aircraft generating 4,000FH.

An aircraft in the medium-haul operation will complete its A check cycle over a longer calendar period than the aircraft in a long-haul operation, which means that the medium-haul aircraft will have a larger number of daily and weekly checks. The aircraft in the medium-haul operation will also have a larger number of transit/pre-flight checks per year in the A check cycle. Both aircraft will complete the A check cycle in the same number of FH. Aircraft on a medium-haul operation, generating about 1,000FCs each year, will require about 340 daily checks and 660 transit checks. Long-haul aircraft will require a similar number of daily and transit checks.

O'Sullivan gives 2MH as a typical labour requirement for transit checks, 12 MH for a daily check and about 18MH for a weekly check. A check consumption varies with A check multiples, but averages about 270MH. Gerrit Van Humbeeck, structures, systems and interiors engineering manager at Sabena Technics agrees with the average A check input, saying it is in the region of 220-230MH, and totals about 1,840MH for the eight A checks. MH consumptions will be the same for A330-200 and -300 models.

The aircraft with a medium-haul operation will consume about 9,300MH over its A check cycle, compared to about 6,800MH for the aircraft in the long-haul operation. If both aircraft achieve 85% of the 4,000FH interval of the A8 check cycle then the medium-haul aircraft will use about 2.7MH per FH, while the long-haul aircraft will use in the region of 1.7MH per FH. At a labour rate of $70 per MH this is equal to $191 and $121 *(see table, page 29)*.

The cost of materials and consumables is in the region of $150 for transit, $500 for daily and $1,000 for weekly checks. A check material cost is $7,500-9,000. Material cost for the A check cycle will be about $420,000 for the medium-haul aircraft, and $276,000 for the long-haul aircraft. This is equal to $125/FH and $81/FH for the two aircraft *(see table, page 29)*.

Most A340s will have a usage similar to an A330 operating a long-haul mission. A340s have flight lengths of 7.5-9.0FH, and accumulate about 550-660FC per year. In most cases the aircraft require about half this number of daily checks each year (275-330) and a similar number of transit checks.

Most operators also have an A check cycle of eight checks and A check interval of 500FH, and cycle interval of 4,000FH. A utilisation of 85%of this interval (or 3,400FH) is normally achieved. This will be less than a year for most airlines. Operators with extended A check intervals of 700FH will complete an A check cycle in about 4,800FH.

MH inputs vary between line checks, since operators put different items in different checks. Typical consumption for a transit check is 2MH, and 12-15 MH for a daily check. Weekly checks consume about 18-20MH, although they are sometimes lighter. A checks vary in size, depending on A check multiple performed, between 200MH for light multiples and 350MH for heavy checks. Total consumption for the A check cycle will be in the region of 6,000MH; about 1.7MH per FH, equal to $121 per FH at a $70/MH labour rate *(see table, page 29)*.

Expenditure for materials and consumables will be about $150 for transit checks, $500 for a daily check, $1,200 for a weekly check and $9,000-10,000 for an average A check. This takes total material cost to the region of $260,000 for the A check cycle; $77 per FH *(see table, page 29)*.

The 777 is like the A330/340 in that it will be operated on medium- and long-haul flights. Aircraft with lower utilisations and shorter cycles will have a

The A340's heavy check interval of 10 years may be compromised by the need to schedule C checks as an annual event. This will reduce the utilised heavy check interval to eight years. This is more likely for airlines with smaller fleets that cannot afford maintenance downtime in the summer months. MH and material consumption will be similar for A330s and A340s.

higher number of daily and weekly checks per A check cycle, and will have a higher ratio of transit checks to daily checks than aircraft on long-haul operations.

Airlines with 777s operating medium-haul operations, with a 3FH cycle and 1,000-1,200FCs per year, will have about 750 transit checks each year. A/B check cycles vary in interval from 1,400FH to 6,000FH, depending on maintenance programme. Labour inputs are in the region of 5MH for a transit check, 12MH for a daily check and 15MH for a weekly check. The transit check inputs are high compared to the A330, putting the 777 at a disadvantage.

Inputs for A checks are low compared to the A330/340, with averages of about 150MH. Although some airlines have B checks, the consumption for A and B checks averages at about 0.75-0.80MH per FH. Overall consumption is high at about 3.55-3.75MH per FH, at $255 per FH *(see table, page 29)*. This compares to about 2.7MH per FH for the A330.

The 777 on long-haul operations tends to have lower line check inputs, with weekly checks at 12-20MH, but similar inputs to the A340 for transit and daily checks. Overall this equates to a consumption of about 1.8MH per FH over the A check/line maintenance cycle, equal to $125/FH *(see table, page 29)*.

Costs for materials and consumables are low for the 777 compared to the A330/340. The 777 uses $200 for transit checks, $300 for daily checks, $500 for weekly checks and an average of only $2,300 for A checks. A checks consume more for aircraft on short cycles, using up to $7,000. Expenditure is $115/FH for medium-haul aircraft, and about $60/FH for long-haul aircraft *(see table, page 29)*.

Base maintenance inputs

Most MD-11s will now have had their first D check, and will perform subsequent heavy maintenance visits with the fourth C check. This implies the C check will be performed every 15 months by most operators. This will equate to 4,700-5,600FH for airlines generating 3,800-4,500FH per year. The D check cycle interval will thus be 22,500-27,000FH.

KLM records inputs of 3,600MH and 38,000MH for its equalised C and D checks. "This includes routine inspections and rectifications, SBs, ADs, modifications, component changes, strip and paint and interior cabin refurbishment," says Vincent Fokkinga, project engineer at KLM Engineering & Maintenance. This totals about 49,000MH for the base maintenance cycle. In comparison Varig consumes about 9,000MH for C checks and 33,000MH for D checks.

The base maintenance cycle consumption of about 55,000MH is equal to 2.6MH per FH; $130 per FH *(see table, page 29)*.

Material costs are about $85,000 for a C check and $800,000 for the D check, including materials for cabin refurbishment. This totals about $1.0 million for the cycle, equal to about $40-55 per FH *(see table, page 29)*.

A330s with medium-haul operations generate less FH within C and heavy check intervals than aircraft on long-haul operations. Some A330 and A340 operators are also forced to have their C checks at annual intervals. An A330 generating 3,000FH per year completing its D check at eight years will have an interval of 24,000FH. An aircraft able to have its full 10-year interval will have 30,000FH between D checks.

A330s operating on longer cycles and achieving 4,000FH per year will have D check intervals of 32,000-40,000FH.

Intervals will be even longer for A340s that typically generate 4,600-5,000FH annually. The full heavy maintenance cycle will be 37,000-40,000FH for aircraft that have an eight-year D check interval, and up to 46,000-50,000FH for aircraft with a 10-year interval.

These wide variations in base maintenance cycle lengths are the main determinant of MH expenditure per FH, rather than the scale of MH inputs.

MH inputs into C and heavy (C4/IL and C8/10-year) checks are either low for the C checks and subsequently high for the heavy checks, or higher for C checks with corresponding lower inputs on the heavy visits. Lighter C checks can have MH inputs only about only 1,500MH, while C checks under heavier programmes use 3,500-9,000MH. Most operators have experience with C4/IL checks, and most inputs have consumed about 25,000MH. The first 10-year checks were performed by Air France in 2001, while more airlines are now putting their first aircraft through these checks. Most operators are reporting 40,000-45,000MH. This includes routine inspections and rectifications, modifications and SBs, engineering orders, interior refurbishment and strip and paint. MH expenditure for the base maintenance cycle will be similar for A330s and A340s, and total 84,000-88,000. "Actual MH expenditure for C checks will vary according to content and non-routine ratio and operating environment," says Humbeeck.

A330s on medium-haul operations will use up to 3.5MH per FH, and 2.6MH per FH for long-haul aircraft. This is equal to $175 per FH and $131 per FH *(see table, page 29)*. The longer intervals for A340s will reduce this to about 1.9MH per FH; $95 per FH *(see table, page 29)*.

Total material costs are in the region of $90,000 for C checks, $750,000 for C4/IL checks and $950,000 for C8/D checks; totalling about $2.5 million for the D check cycle. This is equal to $104 per FH A330s on medium-haul operations, $78 per FH for A330s on

long-haul cycles and $54 per FH for A340s *(see table, this page)*.

A 777 operating on medium-haul routes and with a combined C and SC check uses varying MHs, because of the variance in check requirements. Some C check cycles are four checks, with an interval of eight years; about 24,000FH. MH for the C checks vary between 2,500 and 6,200. Additional MH are used for strip and paint and interior refurbishment. Each may occur about every five years. Interior refurbishment on 777s is expected to consume about 4,500MH, strip and paint 2,500MH. Total MHs used over the C check cycle will be about 28,000MH; equal to 1.4MH per FH; $58 PER FH *(see table, this page)*.

Materials used in C checks will be $10,000 for lighter checks, $50,000 for heavier visits and $450,000 for the 4C check. Material cost for interior refurbishment is expected to be in the region of $450,000, and $16,000 for strip and paint. Total material expenditure over the base maintenance cycle will be about $1.2 million, equal to $60 per FH *(see table, this page)*.

Base maintenance programmes for 777s used on long-haul operations vary, and multiples of C and SC items means that cycles of annual C checks can be as long as the 16C check. C check MH consumption will vary from 1,000MH for the C1 check up to 10,500MH for the 16C check. This will be added to by interior refurbishment every five years, using 4,800MH, and 2,500MH for strip and paint with a similar interval. Total MH consumption will be about 80,000MH over 16 years, a FH interval of 72,000-80,000MH. MH use is therefore about 1MH per FH, of $50 per FH *(see table, this page)*.

Material costs are similar to the 777's on medium-haul operations, and are also similar for the interior refurbishment and strip and paint. Total cost will be about $5 million over the full cycle, equal to about $60 per FH *(see table, this page)*.

MD-11, A330, A340 & 777 FLIGHT HOUR AIRFRAME AND COMPONENT MAINTENANCE COSTS

Aircraft	A330	777	MD-11	A330	A340	777
FH/Year	3,000	3,300	3,750	4,000	5,000	5,000
FC/Year	1,000	1,100	610	570	550	600
FH:FC	3.0	3.0	6.1	7.0	9.0	8.3
Line & light maintenance MH/FH @ $70/MH	191	255	124	121	121	125
Line & light maintenance material costs-$	125	115	47	81	77	60
Base maintenance MH/FH @ $50/MH	175	58	128	131	96	50
Base maintenance material costs-$	104	60	55	78	54	60
Total line & base maintenance-$/FH	**594**	**488**	**353**	**412**	**347**	**294**
Heavy components-$/FH						
Tyres remould/replace	4	6	3	2	2	2
Wheel inspection	5	7	3	2	2	3
Brake repair	64	96	39	27	26	34
Landing gear overhaul	31	33	22	23	20	22
Thrust reverser repair	23	29	17	10	16	9
APU shop visit	46	43	49	26	20	20
LRU and rotables-S/FH						
Rotable home base capital cost	31	30	25	23	19	20
Pooling fee	65	75	70	65	65	75
Maintenance & repair	230	275	180	230	240	275
TOTAL AIRFRAME & COMPONENT-$/FH	**1,116**	**1,110**	**778**	**830**	**773**	**763**

Heavy components

This category of components includes wheels, tyres, brakes, landing gears, thrust reversers and auxiliary power units (APUs). The maintenance or repair intervals of these are all FC-related. Aircraft FH:FC ratio therefore affects the costs per FH of these components.

There is little variation in the average removal interval for the wheels of these aircraft types for tyre remoulding and wheel inspection. Tino Honore, product manager at SAS Component says main and nose wheels have an average interval of 450FC and 350FC. Tyres can also typically be remoulded three times before being replaced after a fourth removal.

Honore makes the point that although regarded as small items, costs of tyre remoulding can be reduced by digitally tracking tyres, which allows a high number of remoulds. With the average cost for mainwheel and nosewheel remoulds at $370 and $230, and new mainwheel and nosewheel tyres costing $1,350 and $760, the cost per FC for tyre remoulds and replacement are $18 per FC for the 777, $13 per FC for the A330, $16 per FC for the A340 and MD-11. The costs per FH depend on the FH:FC ratio these aircraft operate *(see table, this page)*.

Wheel inspections are performed following wheel removal for tyre remoulds, and cost about $700 for mainwheels and $650 for nosewheels. These translate into costs per FC of $22 for the 777, $16 for the A330, $19 for the A340 and MD-11. Costs per FH depend on the FH:FC ratio these aircraft operate in service *(see table, this page)*. Wheel replacements rates are generally low and occur later in life. New wheel rims cost about $16,000-20,000.

Brake units for all types have carbon disks. The repair intervals for all four types average about 1,800FC. Repair cost for a brake is $40,000-45,000. This equates to a repair cost per FC of $290 for the 777, $190 for the A330, $240 for the A340 and MD-11, with costs per FH shown according to FH:FC ratio *(see table, this page)*. Brake unit replacement rates are low, and new units cost $60,000-70,000 for these aircraft types.

Landing gear overhaul intervals are FC and calendar limited. FC limits are as high as 20,000FCs in the case of the A330/340. Aircraft operating 550-

The 777 has light inputs for base checks, and this is attributed to its low non-routine ratio. Other elements of maintenance increase costs compared to other types, however. The aircraft has more brake units than other types, for example, and its LRU components are expensive. The 777 is overall more efficient that its competitors, however, and this efficiency gap should widen.

1,000FCs per year will thus only accumulate a maximum of 10,000FCs between removals. Workscopes are lighter for landing gears removed at eight years, and generally result in better costs per FC and FH. Exchange and repair costs are in the region of $860,000 for a 777 gear set, $740,000 for an A330 gear set, $780,000 for an A340 and $700,000 for a MD-11. The resulting costs per FH are shown *(see table, page 29)*.

Thrust reversers for these aircraft types have soft time repair intervals in the region of 6,000FCs, with corresponding intermediate workscopes. Costs for shop visit and exchange fee are similar, but vary between types. The cost of a reverser set for a 777 is about $320,000, $200,000 for an A330 and MD-11, and $190,000 for an A340, and is most affected by engine numbers. Resulting cost per FH are shown *(see table, page 29)*.

Cost per FH for APU repair is mainly affected by aircraft FH:FC ratio, APU shop visit interval, APU hours to aircraft FC ratio and shop visit cost. The GTCP 331-500 on the 777 has an average shop visit interval of 3,500 hours, the GTCP 331-350 on the A330/340 about 3,300 hours, while the GTCP 700-4E on the MD-11 is poorer at about 1,700 hours. The typical shop visit cost in each case is in the region of $350,000, with resulting costs per FH shown *(see table, page 29)*.

Rotables & LRUs

All four aircraft types have been designed to make most other rotable and repairable components line replaceable, rather than requiring repair scheduling with a base check.

Airlines are required to keep an inventory of minimum equipment list items (MEL) at their home base. They will also keep a stock of parts with high failure rates, or ones with high transport times. Airlines with large fleets normally hold inventories for other items, since cost per aircraft will low.

Torge Meyer, section manager product management aircraft component services at Lufthansa Technik explains that airlines with smaller fleets will have higher costs per aircraft for these parts, but can minimise the cost related to these components by using a third-party specialist to provide access to these parts via a pooling arrangement. The same agency often also provides a fixed rate per FH for the management and repair of these parts, as well as those held in an airline's inventory. The parts provided in the pool are LRUs not held by the airline, deep access rotables and engine rotables.

Lufthansa Technik provides pooling arrangements for the A330/340, 777 and MD-11, and can also provide line maintenance assistance for airlines.

While the airline customer airline bears the capital cost of its home consignment, it pays the pool provider an access fee for the other parts. The third cost element is then the management and repair fee for parts.

Meyer estimates the capital cost of home stock will be about $10 million for a fleet of 10 777s. This will be a little lower, at about $9 million, for the same number of A330/340s and MD-11s. The annual depreciation charge for this stock over 15 years at 6% interest is about $1 million for the 777 stock and $925,000 for the A330/340s and MD-11s. This translates to a varying cost per FH for each type, depending on annual utilisation *(see table, page 29)*.

The pooling access fee will be about $75/FH for the 777, $65/FH for the A330/340 and $70/FH for the MD-11 *(see table, page 29)*.

The third element the maintenance, repair and overhaul will be in the region of $275/FH for the 777, $230/FH for the A330, $240/FH for the A340 and $180/FH for the MD-11 *(see table, page 29)*.

Summary

The total airframe and component maintenance costs for the MD-11, A330, A340 and 777 are summarised *(see table, page 29)*. This shows the A330 and 777 in both medium-haul operations of about 3,000FH per year and long-haul operations. The 777 in long-haul operations has utilisations and FC lengths closer to the A340, while the A330 tends to have shorter average FC times.

With the elements of maintenance described, the A330 and 777 have almost equal costs per FH for all maintenance elements in their medium-haul capacities, despite the A330 having higher line and base maintenance costs. The A330 makes up for this disadvantage with lower LRU and brake related costs *(see table, page 29)*. The 777's main disadvantage is its high LRU costs, since components are expensive. The 777, however, has a higher seat capacity than the A330.

The MD-11's older technology is clearly illustrated against the A330, A340 and 777. This is particularly the case in base maintenance expenditure. The MD-11 overcomes this disadvantage through lower LRU-related costs, which is explained by its components being cheaper than the A330/340 and 777.

The 777 outperforms all the other types through its efficiency of low line and base inputs. This is mainly accounted for by low ratios of non-routine maintenance. This will be the most important factor with age, since other costs will not increase as much.

The 777 is therefore likely to widen the gap with its competitors as aircraft age and non-routine ratios rise. The 777's line and base maintenance inputs are expected to increase as fast as the three other aircraft. AC