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Abstract

Rotable spare parts are insurance-like assets that are kept available to maximise the utilisation of the supported production equipment. Financially, they are easily treated like regular production equipment even if their value preserving characteristics would require different treatment. In this study, the two functional roles of rotatable parts are identified and a distinction between the spare part role and the production asset role is made in the financial sense. This study also shows that the most suitable method for the valuation of rotatable spare parts is the annuity method, and that the values of rotatable spare parts are mainly dependent on the remaining service life of the supported production equipment. The effect of different valuation methods on the outsourcing decisions concerning rotatable spare parts is discussed.

Keywords:

Valuation; Cost of ownership; Rotable spare parts; Outsourcing; Aviation; Annuity

1. Introduction

Rotable spare parts are held to support critical production processes by ensuring that production equipment is available for use when needed. This activity is called here the rotatable spare part availability service. As it is basically balancing the spares inventory cost with the cost of production equipment downtime, the ownership cost of the rotatable spare parts is a key factor in managing this service.

The key area of decision-making that is affected by the cost of spare part ownership is outsourcing, which has become a focal issue in today's business environment in its various forms. In outsourcing decisions regarding rotatable spare part availability, it is necessary for the management to compare the ownership cost to the subcontracting cost. These decisions are not only made by the end customers of the availability service. At least in the aviation industry, practically every service provider in the value chain has the alternative of further subcontracting the availability service instead of providing the service using its own parts.

No empirical data of how companies value their rotatable spare parts were found when this study was prepared. Practical experience in the aircraft maintenance business indicates, however, that companies have been using and probably still use value data from the financial accounting in managerial decision-making regarding rotatable spare parts. As the financial accounting value is produced according to legislation for purposes very different from managerial decision-making, using it may well be misleading.

Rotatable spare parts are also easily treated like other assets as regards valuation and cost accounting. It will be shown in this study that rotatable spare parts form an asset category of their own, which behave unlike any other type of asset. Treating them like consumable spare parts or workshop machines may produce arbitrary results when outsourcing decisions on availability service are made.

The aim of this study is to provide tools for determining the total cost of owning rotatable spare parts. This will be accomplished by applying the concept of annuity to calculate the managerial accounting value of a rotatable spare part through its lifetime. It will also be shown that the value of a rotatable spare part is not primarily dependent on its own age or condition, but on the remaining service life of the fleet of equipment that it is supporting.

Valuation, service life and ownership cost of assets like production equipment have been widely discussed in the literature (e.g. Hotelling, 1925; Marston et al., 1953; Ijiri and Kaplan, 1969; Hall, 1971; Blades, 1983; Jorgenson, 1996). However, unproductive insurance-like assets such as rotatable spare parts have not been given the attention that their special characteristics would require. They also seem to be neglected in the practical business environment when it comes to ownership cost.

It is the purpose of this study to be applicable in all the industries where rotatable spare parts are involved. The air transport industry and aircraft spare components are used here as examples.

1.1 Financial and managerial accounting values

An important issue in valuation is that there is rarely a single figure that could be identified as the value of something. Almost every item in inventory has a historic value equal to its purchase price, a current value equal to its market value and a replacement

value equal to the sum needed to buy a new similar item. In addition to these real-world values, every item has accounting values i.e. agreed upon values that have been chosen to represent its value for various purposes. Most likely all these values differ from each other at any given moment, perhaps with an exception of the exact moment when the item was purchased.

The first type of accounting value is referred to here as the *financial accounting value*. It represents historical information suitable for periodical financial statements whose main audience consists of taxation authorities and other external stakeholders. The emphasis in providing this kind of information is to be complete and precise on the summary level. No additional benefit comes from providing this information quickly or in great detail.

Another type of accounting value is referred to here as the *managerial accounting value*. It represents topical information suitable for managerial control and swift decision-making. The managerial accounting value should preferably be as close to the actual market value of the item as economically viable. It is, however, better to produce a less precise value promptly than a very accurate value too slowly.

Johnson and Kaplan (1987, p.161) point out that organisations rarely distinguish between information needed promptly for managerial control and information provided periodically for summary financial statements, even if that would clearly make sense.

The financial accounting value mentioned above can also be referred to as the *traditional accounting value*, compared to the IFRS principles (Reinstein and Weirich, 2002, p.62) that direct the financial accounting value closer to the managerial accounting value. Brazell and Mackie (2000, p.541) report that the U.S. legislation governing fixed asset depreciation is being modified in the same direction.

1.2 Rotable spare parts

The term rotatable part is used here with the meaning of a complex module which has an important function in the production equipment and which can be replaced quickly by a spare unit. The rotatable nature of the part means that, in case of failure, it is generally less expensive to repair it than discard it and purchase a new unit as a replacement. After the repair has been completed, the unit is stored as a spare. The purpose of

keeping spare units at hand is to increase the utilisation of the production equipment by limiting the downtime to the time that it takes to replace the failed unit.

A rotatable spare part is identical in function to a unit installed in production equipment. The only difference between them is the insurance-like role of a spare part compared to the revenue generating role of its counterpart. In time, the installed unit fails and the roles change, so no individual rotatable part is a spare for long. If the rotation is working well, all the units take turns in being in revenue generating role and being a spare.

Depending on the part design, it is possible for units to have very long service lives. For example, many aircraft components can go through a practically unlimited number of repairs and overhauls without wearing out, thus having a service life equal to the economic life of the supported aircraft type. In real life, there are naturally rotatable spare parts that deteriorate with age regardless of the maintenance operations performed on them. Nevertheless, this study assumes that the only phenomenon affecting the service lives of the rotatable spare parts is the obsolescence caused by advancing technology and consequently the retirement of supported equipment. Blades (1983, p.18) identifies mortality and survival functions suitable to be applied to this distinct case which he calls 'simultaneous exit'.

1.3 Fleet of equipment

The term *fleet of equipment* is used here with the meaning of a group of similar pieces of production equipment or machinery which are supported by a number of rotatable spare parts. In the air transport industry, for example, a fleet of equipment is a fleet of aircraft operated by an airline representing the same aircraft type. A fleet of aircraft is supported by a number of spare components or line replaceable units (LRUs).

It is not necessary that the fleet is owned by a single company. If a group of companies have outsourced the spare part availability service to one service provider, all their production equipment belongs to the same fleet from the service provider's viewpoint.

1.4 Research on valuation, depreciation and service lives

Hotelling (1925) was one of the early researchers to discover how the value of production equipment and the cost of its output are interrelated. He was probably the first one to claim in an academic paper that depreciation is the decrease in the present value of the future returns of a production equipment. Marston et al. (1953) discuss

present value depreciation in their exhaustive volume on valuation and depreciation, and even introduce the possibility of calculating depreciation by setting the annual operation returns constant over the years. They, however, conclude that the present value method of depreciation is more suitable to be used in economy studies than in real life cost accounting.

Hall (1971) introduces an econometric model of estimating asset values by applying regression analysis to historical price data. A comprehensive selection of studies accomplished using Hall's model has been analysed by Jorgenson (1996).

Ijiri and Kaplan (1969) introduce the concept of probabilistic depreciation, which assumes that the service life of an asset is not known in advance. Ijiri and Kaplan (1970) further develop the concept to recalculate the probabilities sequentially each year of the service life. Friberg (1973) continues their work and extends the concept to be applicable with varying salvage value. Probabilistic depreciation in these variations could be used in the valuation of rotatable spare parts with age related mortality.

Blades (1983) has studied service lives of fixed assets from the perspective of national economy. From a viewpoint closer to this study, service lives have been studied by Goolsbee (1998), who finds a significant number of factors that influence the retirement of capital goods by studying the phase-out of Boeing 707 aircraft from the operation of the U.S. major carriers.

2. Determining the managerial accounting value

The purpose of this study is to provide a method for calculating the managerial accounting values of rotatable spare parts to determine the total cost of owning them. First it is necessary to understand the special characteristics of rotatable spare parts. After that it will be shown that the most suitable method to determine the managerial accounting value of rotatable spare parts is the use of equivalent annual annuity (EAA).

2.1 Rotable spare part as an asset

An intuitive way of valuing rotatable spare parts would be to bundle them together with the production equipment they are supporting and depreciate these two assets in a similar manner. This method has been used by some airlines in the past but it completely ignores today's trend towards specialisation, outsourcing and network

economy. It is getting more and more rare that an airline operator itself owns the spares; at least the owner is a different business unit in the airline company with its own income statement and balance sheet. According to Jackman (2006, p. 50) 65 per cent of the aircraft component business was outsourced in 2005 and the figure is estimated to increase to 75 per cent by 2010.

The value chains in the availability service can be long. In traditional airline companies the operations department commonly makes a full service contract with the in-house maintenance department. Then the maintenance department may contract out the component support of one fleet of aircraft to an external service provider like Lufthansa Technik or SR Technics. As these providers tend to work more and more as global service integrators (Burchell, 2006) they may further outsource the support of some components to other service providers. Every one of these parties has to decide whether to subcontract the availability service of a certain rotatable spare part or provide the service using its own parts.

It should be realised that in the network economy rotatable spare parts are production assets of the maintenance industry, instead of supporting assets of the actual production industry serving the end customers. They are, however, different from many other production assets. A rotatable spare part is like an insurance to be offered to customers for protection against the risk of extended production equipment downtime. This insurance-like nature of a rotatable spare part means that it is at work when it lies on the shelf collecting dust. Its role is to wait until the unexpected happens and it is needed for the supported equipment to continue working. When that happens, it is no longer a spare part, it is a part of that supported equipment in the functional as well as financial sense. The failed part will be repaired and in time takes the position of the spare part on that dusty shelf.

The value of production equipment includes the values of all the rotatable parts installed in it. When production equipment is depreciated, the installed units are also depreciated, but you cannot tell the share of the total value that belongs to a certain rotatable part. This uncertainty, together with the major difference in roles, leads to the fact that valuation of the rotatable spare parts has to be separated from valuation of the installed rotatable parts. It is like attaching the value tag to the shelf where the spare unit is stored, instead

of attaching it to the unit itself. Thus, the value of a rotatable part actually changes every time it is installed or removed.

In contrast, the value of the production equipment as well as the value of the rotatable spare part inventory remain unchanged after a replacement operation. It is assumed that in the revenue generating role, the installed and removed unit are equal in value. In the spare part role, the value of the removed unit equals the value of the installed unit after it has been repaired to serviceable condition. This logic leads to the fact that all rotatable spare parts that are interchangeable with each other must have the same value. To simplify the valuation, this study assumes that a rotatable spare part is always in serviceable condition and functionally as good as new when it is being valued.

There are basically two ways of treating rotatable spare part values in financial accounting. Seago (1996, p.347) has studied court cases in the U.S. and found out that at least under local legislation they can be treated as *inventory* or as *depreciable assets*. Holloway (1997, p.229) suggests that aircraft spare parts should preferably be treated as depreciable assets, still leaving the final decision to local accounting and tax regulations. As regards the managerial accounting value, the only plausible way of treating rotatable spare parts is as depreciable assets. The total value of an inventory item is generally written off at one time. Depending on the interpretation this may be when it is used for the first time or when it is scrapped. Both of these alternatives are unsuitable for expensive parts with long service lives.

The only way that a spare part generates income is by shortening the downtime of the supported production equipment. Instead of trying to estimate the amount of income, this study focuses on the fact that the savings in downtime are steady in the long run. This is because the downtime is initiated by a random phenomenon, system failure. As the number of random events increases in the long run, the law of large numbers reduces the variation. It is also assumed here that the nominal downtime cost of production equipment remains unchanged through its whole productive life. Consequently, the nominal income generated by a rotatable spare part will be uniformly distributed over its service life.

When the income approach of valuation is applied, it is evident that the value of a rotatable spare part is heavily dependent on the remaining service life of the supported equipment. There are also minor factors affecting the value like, for example, the

quality of maintenance operations and repairs performed on the spare part. Shallcross (1995) argues that high maintenance quality and good reputation of the maintenance service provider has a significant effect on the value of a second-hand aircraft. The same should apply to aircraft components as they are maintained by the same service providers as the aircraft.

The reasonably strong assumption of the nominal downtime cost of production equipment remaining unchanged is necessary for the simplicity of this study, and is somewhat relieved by the fact that the inflation rate is generally lower than the nominal discount rates used. Feldstein (1981, p.39) has studied the relationship of inflation and depreciation and concludes that real discount rates typically lie between 4 and 7 per cent.

2.2 EAA approach of valuation

The concept of net present value (NPV) is widely used in capital budgeting as well as in costing of assets and financial instruments (e.g. Horngren et al., 2000, p.751). NPV can also be applied to calculate depreciation of fixed assets, especially in managerial accounting. When the annual cash flows produced by the asset are constant, the NPV method of depreciation reduces to the annuity method (Kaplan, 1982, p.549), also referred to as equivalent annual annuity (EAA). By using EAA it is easy to calculate the constant annual payment needed to cover an investment if the discount rate and the payback period are known. In this study the EAA method is adapted to serve the needs of rotatable spare part valuation.

The income approach of valuation uses the logic of the EAA method in the opposite direction. It is based on an assumption that the value of the asset equals the present value of the future income generated by it (Marston et al., 1953, p.198). When the EAA method is used backwards, the investment means the value of the asset and it is calculated using the generated annual income, discount rate and the service life of the asset.

Since the income generated by a rotatable spare part is steady over the years, it is reasonable to pay a constant annual fee for the part being available. Considering all the possible valuation methods this fee, the total annual cost of ownership of a rotatable spare part, only remains constant with the EAA approach.

Spahr et al. (1999) extend the concept of annuity beyond the equivalent annual annuity. Based on their work, it seems possible to calculate annuities with any pattern of annual cash flows, as long as the annual cash flow is greater than or equal to the amount of annual interest. Actually, if the depreciation is allowed to be negative, there should be no restrictions to the pattern. From this perspective, the essential remaining characteristic of annuity is that it focuses on total annual cash flow instead of interest and depreciation separately. This would make it possible to calculate annuities with increasing nominal cash flows, and to let go of the assumption of nominal cost of production equipment downtime being uniform throughout the service life.

2.3 Financial accounting value

Financial accounting value represents the spare part value for external accounting purposes. From the viewpoint of this study, the most important alternative method of valuation is the use of the financial accounting value as the managerial accounting value. The importance is not due to the suitability of the method but to the unfortunate assumption that it is very much used. The popularity originates probably from the fact that taxation authorities require it for financial statements in any case. If no better values exist, it is tempting to use the one available regardless of how misleading results it may produce.

There are basically two different methods to determine the annual depreciation in financial accounting. With *accelerated depreciation* the residual value is decreased by a fixed percentage at the end of each year. The value never reaches zero but infinitely approaches it. *Straight-line depreciation* decreases the residual value by an even amount every year from its acquisition until the end of its life span when its value reaches zero. Estimation of the service life, which is not necessary with the accelerated depreciation, is the weakness of this method. Of the two methods, however, the straight-line depreciation is considerably more suitable for determining the managerial accounting value of rotatable spare parts. This is because the method assumes a uniform distribution of service for the depreciated asset through its life (e.g. Ijiri and Kaplan, 1969, p.743). It is naturally possible for a company to use straight-line depreciation in managerial accounting and accelerated depreciation in financial accounting.

In financial accounting it is generally most economical for the owner to depreciate the rotatable spare parts reasonably quickly. If the accelerated depreciation is in use, local

legislation sets the maximum percentage by which the residual value may be depreciated annually. When the part is sold or scrapped, its estimated share of the residual value is written off from the balance sheet.

3. Applying the EAA approach of valuation

This section introduces a simple method of calculating annuities. With the results of the calculations it is then possible to compare the EAA approach with its competitors. The final section deals with the allocation of the cost of ownership between different fleets of equipment.

3.1 Calculating annuities

The mathematics behind annuities are straightforward. A suitable formula for basic calculations can be found in any textbook on finance (e.g. Brealey and Myers, 1991, p.35):

$$PV = C \left[\frac{1}{r} - \frac{1}{r(1+r)^t} \right] \quad (1)$$

where C equals the Annual cash flow, i.e. annual cost of ownership, r equals the annual interest rate, t equals the remaining duration of the annuity in years and PV equals the present value of the annuity.

The expression in brackets is called the *annuity factor* and will be referred to here as A. The only factors affecting it are the annual interest rate r and the remaining duration of annuity in years t. Because the only thing affecting the service life of the rotatable spare part is assumed to be the retirement of the supported production equipment, and the age of the individual spare unit is mostly unknown, the annuity calculations are based on the remaining service life of the supported equipment.

If the annuity factor A and the present value of annuity PV are known, the annual cost of ownership C can be calculated as follows:

$$C = \frac{PV}{A} \quad (2)$$

If the annuity factor A and the annual cost of ownership C are known, the present value of annuity PV can be calculated as follows:

$$PV = C \cdot A \quad (3)$$

Theoretically, the present value of a rotatable spare part at the beginning of its service life is its purchase price. It is, however, already regarded as second-hand when it is received from the supplier. The new owner can only resell it under its original purchase price. Reasons for this devaluation include the risk of the seller trying to get rid of an unreliable or mistreated unit, and the lack of warranty in such second-hand agreements. Akerlof (1970) identified this phenomenon and calls it the market for lemons. In this study the term second-hand factor means a percentage of the original purchase price that is activated as a cost immediately when the spare part is purchased. When calculating annuities the initial present value is obtained by subtracting the second-hand factor from the purchase price.

The annual cost of ownership consists of two different types of cost: interest on invested capital and depreciation of that investment. With annuities, the sum of these two factors remains constant over time but their respective shares of the total do change. In the beginning the sum consists mainly of interest but towards the end the share of depreciation increases.

It is important to notice that the interest rate in the annuity calculations actually means the discount rate or the opportunity cost of capital instead of the cost of borrowing. What may cause confusion here is the fact that annuities are commonly used with loan calculations and in those cases the interest rate means the cost of borrowing.

An example illustrates the calculation of annuity. If the annual interest rate is 17 per cent and the duration of the annuity is 5 years, value 3.199 for the annuity factor A can be calculated using Equation (1). If the price of a new rotatable spare part is US\$3 000 and the second-hand factor is 10 per cent, it is easy to calculate the US\$300 depreciation of year 0 caused by the second-hand factor. The initial value of the spare part is thus US\$2 700. The annual cost of ownership of US\$844 is then calculated using Equation (2). From year 1 to 5 the interest is calculated by taking 17 per cent of the spare part value at the end of the previous year. Depreciation is calculated by subtracting the annual interest from the cost of ownership. Finally, the value at the end of the current year is calculated by subtracting the annual depreciation from the value at the end of the previous year. Alternatively, the value at the end of any year can be calculated using Equation (3) with the annuity factor A calculated for that year. The results of the example can be seen in Table 1.

Year	Cost of ownership	Interest	Depreciation	Value (end of year)
0	\$300		\$300	\$2 700
1	\$844	\$459	\$385	\$2 315
2	\$844	\$394	\$450	\$1 865
3	\$844	\$317	\$527	\$1 338
4	\$844	\$227	\$617	\$721
5	\$844	\$123	\$721	\$0
	\$4 520	\$1 520	\$3 000	

Table 1 Results of the annuity example

In this example the share of depreciation is quite high right from the beginning, which derives from the short duration of the annuity. Service lives of rotatable spare parts are commonly much longer but the duration of 5 years was chosen here to save space.

3.2 Comparison to other approaches

In this section the EAA approach is compared to two alternative approaches, accelerated depreciation and straight-line depreciation, both representing the financial accounting value.

It is rather easy to notice that accelerated depreciation is only suitable for assets with increasing risk of retirement and decreasing capability to generate income. Straight-line depreciation is usable with assets like rotatable spare parts, if the difference between the total future income and the net present value of all future income is not considered significant. This may be the case with short service lives or low rates of interest. Actually, straight-line depreciation is a special case of annuity with no interest.

In the middle third of the service life, where the difference between the straight-line depreciated value and the annuity value is greatest, there are two real life factors to support the preference of the annuity value. New unit prices are hardly lowering to compensate for the diminishing service life, which increases the demand for second-hand units in the middle of the service life. Furthermore, there is an intuitive logic to acquire low risk new units at the beginning of the service life but to be satisfied with higher risk second-hand units in the middle of the service life. This should also increase the demand for second-hand units during the middle third.

Figures 1, 2 and 3 show the annual interest and depreciation of a US\$10 000 investment recovered in 30 years using the annual interest rate of 10 per cent. An annual depreciation rate of 15 per cent of the residual value is used with accelerated depreciation.

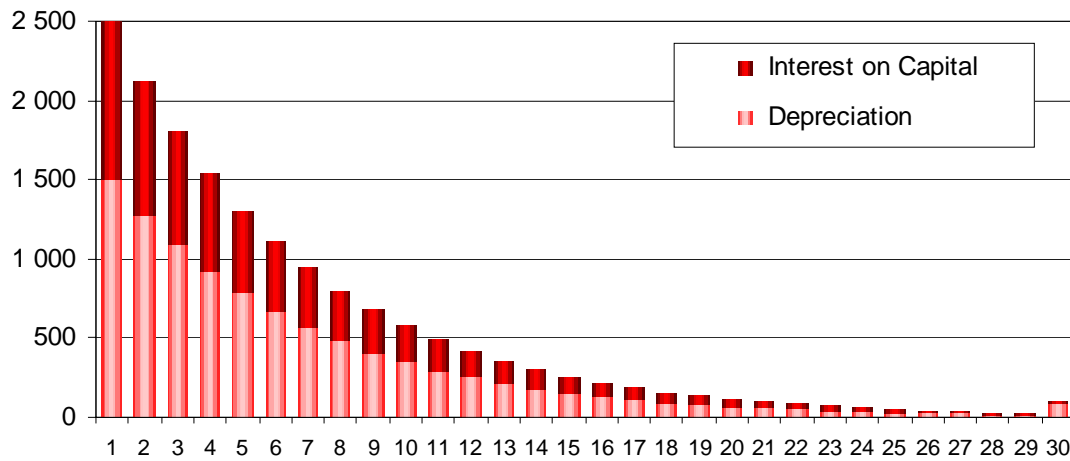


Figure 1 Annual cost of ownership using accelerated depreciation

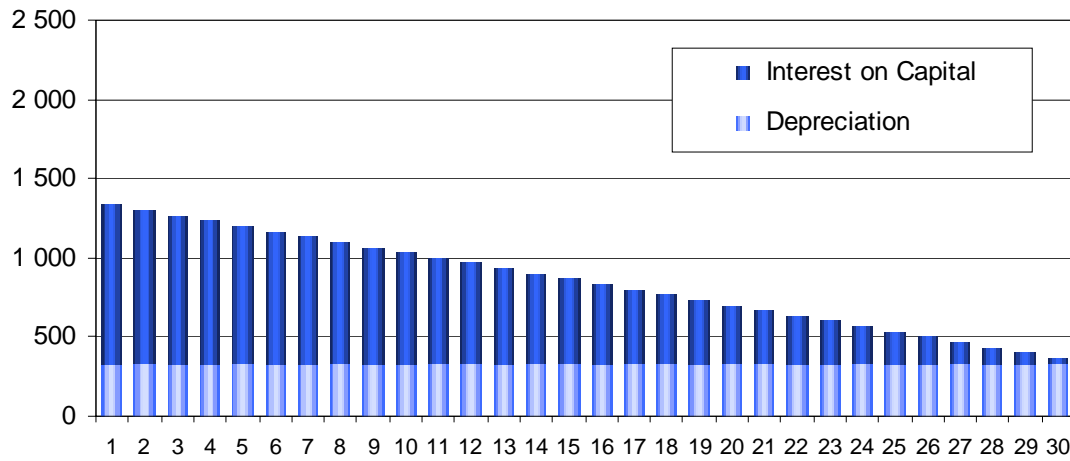


Figure 2 Annual cost of ownership using straight-line depreciation

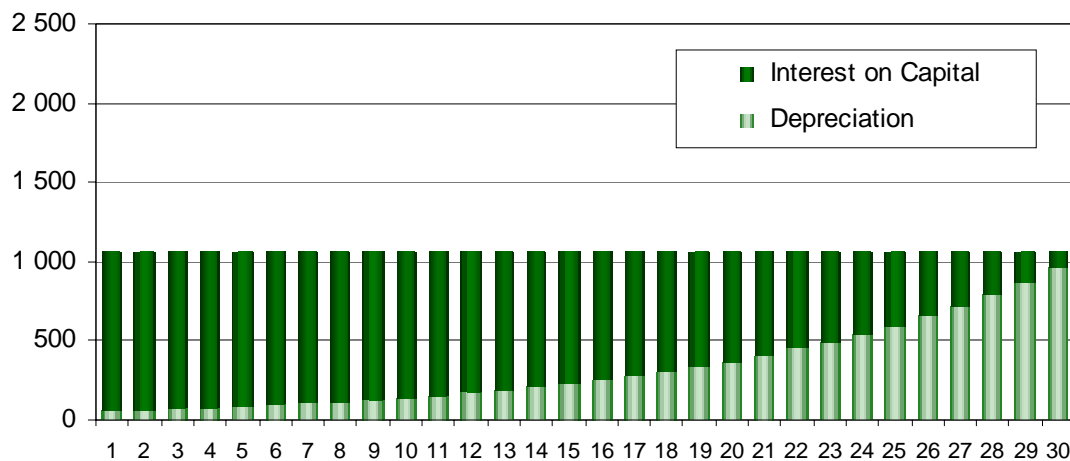


Figure 3 Annual cost of ownership using EAA approach

As can be seen in the figures, the distribution of the annual cash flows differs significantly between the methods. As they are in effect three different residual income schedules of the same investment, all of them have the same present value of US\$10 000 (e.g. Peasnell, 1982, p. 377). The differences become evident when looking, for example, at the first five years of the schedules. The present value of this early period is US\$7 245 using accelerated depreciation, US\$4 826 using straight-line depreciation and US\$4 021 with the annuity method. This means that accelerated depreciation shows 80 per cent higher cost and straight-line depreciation 20 per cent higher cost than the annuity method.

As a result, it is evident that the worst alternative for a company is to use accelerated depreciation in the valuation of rotatable spare parts. This makes the ownership costs during the first years of the service life appear significantly higher than they actually are. After that they appear lower, especially during the later half of the service life.

3.3 Allocating the cost of ownership

To have the desired effect on decision-making, the cost of ownership of a rotatable spare part has to be allocated to a correct cost object. The allocation of the ownership cost of a piece of production equipment is usually straightforward. Assuming that the asset is an aircraft, a typical cost object to allocate this cost to would be a fleet of aircraft. For the purposes of management decision-making, the average cost of available seat kilometre (ASK) of the aircraft fleet in question includes the cost of owning this particular aircraft.

If the rotatable spare part only supports one piece of equipment, its cost of ownership can be easily allocated. Commonly, when the spare part supports several pieces of equipment, it is necessary to find a cost driver to allocate the cost with. When a suitable cost driver has been identified, it can be used to divide the cost of ownership between the fleets of equipment supported by the spare part. For aircraft components, there are two suitable cost drivers, number of flight hours and number of landings accumulated by the supported aircraft. Depending on the function of the component, one of them can be chosen. For example, number of landings is clearly a more suitable driver for landing gears than number of flight hours would be. It is quite the opposite with an air conditioning unit.

An example illustrates the use of cost drivers in the cost allocation process. Let there be an airline with two fleets of aircraft, 14 Boeing 757 narrow-bodies and 8 Boeing 767 wide-bodies. The 757s operate short-haul with each aircraft accumulating 1200 cycles (landings) per year. The 767s operating long-haul accumulate half of that amount. Both aircraft types use the same type of fictional component to assist the pilots with instrument landings. The component is triplicated for safety reasons, which means that each aircraft has three units installed. 8 spare units are needed to support the 66 units installed in these aircraft. Among others, Kilpi and Vepsäläinen (2004, p.139) have presented a method of calculating the number of spare units needed to support a fleet of aircraft.

Let the original purchase price of the component be US\$28 000 with a second-hand factor of 15 per cent. If the annual interest rate is 9 per cent and the duration of the annuity is 30 years, the annual cost of ownership of US\$2 317 per unit can be calculated using Equations (1) and (2) above. For all 8 units together the annual cost of ownership is US\$18 533. This cost is then divided between the fleets with the same ratio as the total cycles accumulated. The results of the example can be seen in Table 2.

Fleet	# of A/C in Fleet	Average Cycles per Annum	Total Cycles per Annum	Share of the Spares Cost	Spares Cost per Annum
757	14	1 200	16 800	77.8%	\$14 414
767	8	600	4 800	22.2%	\$4 118
	22		21 600	100.0%	\$18 533

Table 2 Results of the cost allocation example

It is also possible to allocate *values* of rotatable spare parts to fleets of equipment to determine the distribution of capital tied up to support the fleets. The cost drivers can be used in exactly the same way in this calculation as they are used in allocating the cost of ownership. In contrast to the cost of ownership, the allocated value changes every year.

4. An illustrative example of rotatable spare part valuation

An example of rotatable spare part valuation is presented here to illustrate the effect of the ownership costs in decision-making. In the example the cost of ownership is calculated using both the annuity method and the accelerated depreciation method.

The decisions which the cost of ownership most substantially affects deal with outsourcing the rotatable spare part availability service. The question for the management

is basically whether to own the spares to support a fleet of production equipment or subcontract the availability service. In an outsourcing setting, the service provider owns the spare units and is responsible for providing sufficient availability to support the customer's fleet of equipment. It is also possible for the management to offer availability service to other companies in addition to supporting the company's own fleet.

4.1 A subcontracting decision of aircraft spare component availability

In this illustrative example there is an airline operator with a fleet of 12 aircraft and a service provider offering availability service to support the fleet with an inventory of a component Z. In each aircraft there are three units of component Z installed, and 7 spare units are needed to support the fleet. The aircraft in the fleet are 5 years old and will be operated by the airline for 5 more years. Regarding that five-year period the airline is making a decision of whether to own the spare components or subcontract the availability service to the service provider.

The airline purchased 4 spare units of component Z 5 years ago and is able to use them as spares in this setting. Two units are available in the second-hand market and the final unit has to be purchased new. If the airline decides to subcontract the service, the service provider is willing to purchase the 4 units for their fair market value.

This example shows how the outsourcing decision has a different result depending on the valuation method the airline uses. Two alternatives are presented, one with the annuity method and one with accelerated depreciation.

4.2 Results of the example

The original purchase price of component Z 5 years ago was US\$10 000 with a second-hand factor of 15 per cent. The current price of a new unit is US\$11 037. If the annual interest rate is 10 per cent and the duration of the annuity is 30 years, an annual cost of ownership of US\$902 per unit can be calculated using Equations (1) and (2) above. An annuity factor A of 9.077 can be calculated for year 5 using the expression in brackets in Equation (1). Using Equation (3) it is possible to see that the value and fair market price of one spare unit in year 5 is US\$8 187.

The service provider offers the availability service to the airline with a price of US\$29 500 to be paid upfront. As the total market price of the 4 units the airline sells to

the service provider is US\$32 748, the service provider actually pays US\$3 248 to the airline at the beginning of the service period.

If the airline uses the annuity method, its original 4 units are valued at the market price. These units and the 2 units the airline purchases from the second-hand market add up to a total value of US\$49 122. The airline also buys one new unit for a price of US\$11 037, of which US\$2 850 is immediately written off, as all the rotatable spare parts of the same type have the same value by definition. The total value of the 7 units is therefore 7 times US\$8 187 or US\$57 309. The resulting annual distribution of ownership costs can be seen in Table 3. The present value of the annual costs (equals the sum of discounted annual costs) is US\$26 785, which is well below the upfront cost of the subcontracted service.

Year	Value 1	Cost 1	Discounted cost 1	Value 2	Cost 2	Discounted cost 2
5	\$57 309	\$2 850	\$2 850	\$51 031	\$0	\$0
6	\$56 728	\$6 314	\$5 740	\$45 928	\$10 206	\$9 278
7	\$56 091	\$6 314	\$5 218	\$41 335	\$9 186	\$7 591
8	\$55 384	\$6 314	\$4 744	\$37 201	\$8 267	\$6 211
9	\$54 607	\$6 314	\$4 313	\$33 481	\$7 440	\$5 082
10	\$53 753	\$6 314	\$3 920	\$30 133	\$6 696	\$4 158
		\$34 420	\$26 785		\$41 795	\$32 320

Value 1: Value with Annuity method

Cost 1: Annual costs with Annuity method

Discounted cost 1: Present value of annual costs with Annuity method

Value 2: Value with Accelerated depreciation

Cost 2: Annual costs with Accelerated depreciation

Discounted cost 2: Present value of annual costs with Accelerated depreciation

Table 3 Results of the valuation example

If the airline uses accelerated depreciation instead, the figures are different. Using an annual depreciation rate of 10 per cent, each of the 4 units owned is worth US\$5 905 at the beginning of the contract period. The purchased units are valued at their purchase prices, US\$8 187 for the 2 second-hand units and US\$11 037 for the new unit. The total value of the 7 units of US\$51 031 is then depreciated for five years with the results showing in Table 3. The present value of the annual costs is now US\$32 320.

The ownership cost of US\$32 320 seems high enough to make the service provider's offer of US\$29 500 appear economical. Looking at these numbers the management would accept the offer satisfied with the savings of US\$2 820. Additionally, the

managers would perhaps congratulate each other for making a profit of US\$2 282 per unit by selling the 4 spare units for over their book value.

This example shows that using accelerated depreciation may lead to results significantly different from the annuity method. In an unlucky situation, as in this example, this difference would result in an uneconomical management decision. It is by no means so that the accelerated depreciation would always favour the subcontracted service. It may as well be the other way around.

When a large variety of different settings are constructed by altering the parameters of this example, certain conclusions can be drawn. If the age of the supported fleet is increased, the difference between the methods decreases and, at some point, accelerated depreciation begins to show lower costs than the annuity method. Increasing the depreciation rate causes the point of equal total cost to move backwards in time. If the spare units are all purchased second-hand, accelerated depreciation always shows higher cost.

4.3 Managerial implications

In this example, using the accelerated depreciation leads to an annual loss of only US\$543. Taking into account that there are easily 1000 different components in an aircraft to be supported by similar services and, that component Z with a list price of US\$11 037 is reasonably inexpensive, the magnitude of the problem becomes evident.

The benefits of subcontracting derive from the scale economies and will be realised if the service provider supports other similar fleets with the same pool of spare components. Similarly, the airline may utilise the scale economies by offering availability service or pooling its spare components with other operators (Kilpi and Vepsäläinen, 2004).

If the management decides to offer availability service of rotatable spare parts to other companies, the importance of the accurate valuation increases. Now the risk is not only about selecting higher cost alternatives, but it is about initiating loss making business activities.

Apart from subcontracting and service providing decisions, there are also other kinds of management decisions related to rotatable spare part values and their ownership costs. Service levels of spare part inventories are set to minimise the sum of production

equipment downtime cost and the cost of spare part ownership. Too high service level increases the cost of spare parts while too low service level increases the cost of downtime. If the management knows the actual cost of ownership, it will succeed in setting the service level correctly.

As the cost of rotatable spare part ownership is eventually allocated to fleets of production equipment, the method of calculation also affects the cost of the production process itself. Regarding an airline, the cost of rotatable spare part ownership appears as a small factor in the average cost of available seat kilometre (ASK) of an aircraft fleet. This way it has a minor effect on all the decisions based on the ASK cost of the fleet.

In 2002 the aviation supply chain was estimated to hold over US\$50 billion worth of spare part inventory (McDonald, 2002, p.48). Because of the easy availability of the information, it is most probable that this figure is based on the financial accounting values reported to taxation authorities by the industry. These values are usually calculated using accelerated depreciation. Bearing in mind that financial accounting typically accelerates the depreciation and makes the values on the average appear lower than they actually are, the figure could easily be over 30 per cent higher, ending up to over US\$65 billion. This example shows that a careless use of the financial accounting values seems to underestimate the problem of accumulating inventories.

5. Conclusions

In today's business life, there is an increasing trend towards outsourcing. Outsourcing even extends to functions like manufacturing or research and development previously considered as core competences. Following the trend is quite appropriate if there are foreseeable benefits available in doing so. In contrast, following the trend without really knowing the results is not recommended.

The purpose of this study was to provide help in making better judgements in outsourcing decisions concerning rotatable spare part availability. It has been shown here that taking into consideration the special characteristics of the rotatable spare parts and using the EAA approach in calculating their values as well as the costs of their ownership, actually results in more reliable estimates than other methods of valuation which might be considered.

It may not be just aircraft, trains, computer systems and paper mills that will be depending on rotatable spare parts in the future. It is possible and easily imaginable that advances in technology, increasing environmental awareness and higher requirements of availability will bring the rotatable spare part ideology to the consumer sector some day soon. The most complex consumer products like automobiles, personal computers, home entertainment centres as well as central heating and cooling systems could be fixed on-site or while-you-wait by replacing the faulty component with a spare unit.

As can be seen in the annuity calculations in the previous sections, the application of EAA is rather straightforward. It has not been the intention here to make any contribution by showing how it works, even if a lot of space is used to illustrate how it can be applied in the valuation of rotatable spare parts. The intended main contribution of this study can be found in section 2.1. It is to distinguish rotatable spare parts from other production assets in the financial sense based on the differences between their functional roles. This includes the rules of treating the rotatable part in its revenue generating role as a common production asset, in its insurance-like role as a spare part and while it is changing from one role to the other.

It would be interesting to study how volatile inflationary conditions could be taken into account in the annuity calculations. This study assumes low and stable inflation rates, which is a reasonable assumption regarding most of the Western economies. Globalisation and offshoring initiatives may lead to situations in which the rotatable spare parts are produced and owned by companies in the third world, where the inflation rates may not be so stable. As the payback periods of rotatable spare parts are long, high or volatile rate of inflation would definitely have an effect on their valuation.

One evident issue of utilising the EAA approach is the availability of necessary input data (e.g. discount rate, payback period, periodic cash flows). It would be interesting to study more thoroughly how the input data may be obtained.

The value of rotatable spare part is one factor affecting the outsourcing decision of its availability service. Another study would be needed to cover the other factors that have an effect on it.

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