LEASING STRATEGY REVISITED: ECONOMIC AND ENVIRONMENTAL VALUES

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Abstract: *The debate on selling and leasing has been in the spot recently. This paper revisits the leasing strategy and develops a new evaluation model to capture economic value and environmental impacts of different leasing strategies. A case study employed shows that a high-cost product is more favourable than its low-cost counterparts in attaining economic value through its higher recovery value and that the level of reusability improvement from maintenance and upgrade services can determine whether leasing with services is cost effective. These findings provide useful suggestions for business managers to design eco-efficient leasing strategies and have policy implications for government and environmental strategists to encourage mainstreaming sustainability in key business decisions.*

Key words: *leasing, product life cycle, economic value, depreciation, environmental value*

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1. Introduction

The debate on "selling or leasing" has recently been in the spot again. The proponents argue that leasing enhances product life-cycle management, particularly end-of-life product recycling and remanufacturing, resulting in lower environmental impacts (Fishbein et al., 2000; Lifset and Lindhqvist, 2000). The opponents claim that leasing encourages premature disposal of used products as producers do not want these 'old' products to cannibalize the sales of new products, leading to higher volume of disposal and greater environmental impacts (Agrawal et al., 2009; Lawn, 2001; Ruth, 1998).

While the debate continues and both sides have their merits, several issues are noticed in previous discussions. For example, researchers in different fields have taken different perspectives in examining close-loop supply chains. In industrial ecology, closed-loop supply chain management means "design, control and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time" (Guide and Van Wassenhove, 2009, p.10). In business and economics research, the examination of product life cycle is simplified with focus primarily on taking back post-consumption products and recovering remaining value of the products or components through reusing, remarketing or recycling. Services such as maintenance, repair and upgrade during product consumption are not built in their assessment models and dynamic recovery of value from returned products is not considered (e.g. Chalkley et al., 2003; Agrawal et al., 2009; Intlekofer et al., 2010). Also, the relationship between product use and disposal, in particular, the impact of product use on product disposal, is overlooked in previous studies. For example, regular inspection and maintenance can increase a product's functioning lifetime, reducing the frequency of disposal (Roy, 2000; Mont, 2002; Sundin and Bras, 2005). Furthermore, previous studies of product life span skipped the link between product life and its economic value changes (e.g. Sundin and Bras, 2005; Geyer et al., 2007; Intlekofer et al., 2010). The missed link between product life and its economic value changes may lead to ignoring several important factors in making leasing or selling decisions, e.g. product depreciation (Mitchell, 1970; Myers et al., 1976), the effect of depreciation on product residual value (Desai and Purohit, 1998), tax effects accompanied by depreciation (Chasteen, 1973), etc.

While this paper does not claim to solve all issues in current debates, it has put several critical issues in such debates in the spotlight. The purpose of this paper is to develop a new evaluation model to capture economic value and environmental impacts of leasing strategies. This examination allows for design and control of value changes over the entire life cycle of a product. A case study is employed to identify significant parameters in such examination. The results of this research will provide useful suggestions for business managers to design eco-efficient leasing strategies and have policy implications for government to encourage mainstreaming sustainability in key business decisions.

The remaining of the paper is organised as follows. In Section 2, economic value over a product life is discussed. Section 3 analyses environmental impacts over a product life cycle and links environmental implications with leasing strategies. In Section 4, a case study is presented to compare different business scenarios for product life-cycle management, which is followed by conclusions in Section 5.

2. Economic Value over a Product Life

Regardless of the transaction mode, a capital product is an asset that depreciates. From the environmental perspective, if the asset can be used longer, less waste will be generated and less natural resources needed. From the economic rationality, as leasing allows the producer to retain ownership of the asset, it will be in the producer’s best interest to keep the product operating at peak condition, extending the asset life and thus lowering the deprecation rate while maximising the residual (i.e. take-back) value. Therefore, the key to an economic “win” is the relationship between depreciation, residual value and cost of leasing.

2.1 Depreciation and Cost of Leasing

Desai and Purohit (1998) contend that the relative profitability of leasing and selling hinges on the *depreciation rate* of the asset. A lower depreciation rate in leasing produces financial benefits as it prevents a product from losing significant reuse or remanufacturing value at the end of its life. This means an *increased residual value*, resulting in an increased recovery value or resell/release value for the product. For example, in Figure 1, assume that the straight line depreciation method is applied. Line P_1 represents the asset‘s depreciation under the traditional sell/purchase mode, with the original value being V_{O1}, its depreciable life as L_D, and the estimated residual value for depreciation as V_{R1}. In contrast, line P_2 represents the asset depreciation under a leasing and services mode, with present value of the asset increased to V_{O2} because of gains from additional services provided, and an increase in that estimated residual value as a result net gains from the additional preventative services such as inspection, maintenance, repair, etc.. The asset value increases to V_{R2}. In economic terms, the producer will have incentives to ensure the increase in residual value is substantial and exceeds the additional service costs involved. Once this is not achievable, the producer may upgrade or replace the product earlier before the product loses its reuse and reprocessing value.

Lease rates are normally set based on expected residual value (Desai and Purohit, 1998). Measured in terms of cash flow the *cost of leasing* (COL) is the present value (PV) of lease payments over the lease term, which is the difference between the asset’s original value (V_O) at the inception of the lease and the PV of the residual value (V_R). The relationship can be expressed as follows:

$$COL = V_O - PV(V_R) \quad (1)$$

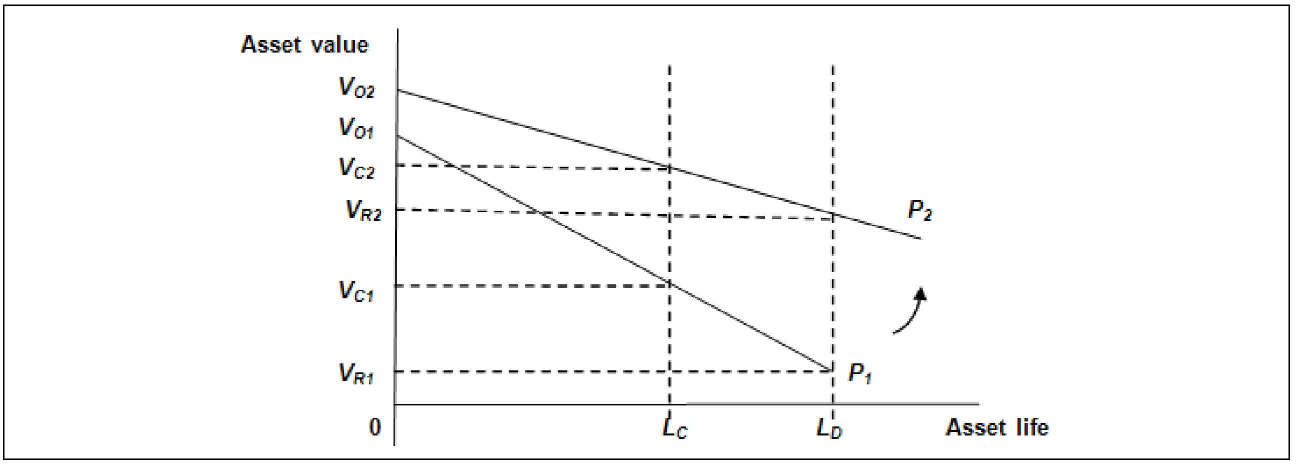


Fig. 1. Changes of value over asset's life

A higher residual value means a *lower cost of leasing*, which is likely to create higher customer values by lowering lease rates, i.e. the capitalised cost for customers. Although service provision may involve additional costs, the changes in the nature of the relationship between the producer and the customer in the proposed leasing mode will align their incentives to reduce the total cost of product functionality. The lease payment is the payment for consumption of product functions, not the acquisition of functions through ownership (Schaltegger et al., 2003; Fishbein et al., 2000). Therefore, the *reduced cost of leasing* (*RCOL*) will be the difference between the increase in residual value and the increase in the original asset value. That is:

$$RCOL = PV(V_{R2} - V_{R1}) - (V_{O2} - V_{O1}) \qquad (2)$$

Producers that can achieve the lowest cost of product functionality and the highest recovery value of the product will be favoured by customers because of the potentially lower costs of leasing. Producers can also extend the useful life beyond the product's normal depreciable life (L_D). However, when a product reaches its 'end-of-life', it often happens at the time when the product's performance, functionality, or/and exterior fails to satisfy its user. This means the product may be used longer, or much shorter, than its depreciable life. More often, it will be the latter because of technological innovations and changes of consumer preferences, especially for consumer products such as computers, cars, etc.. With a traditional selling mode, if the customer stops using a product at point L_C, and the product has not deteriorated markedly, the recovery value for the customer will normally be between 0 and V_{C1}. If there is an active second-hand market, the product could be traded in the market at or below its carrying value. If no such market exists, the product has to be discarded with no economic value being recoverable (disposal costs may also be incurred, see further discussion in the next section). The leasing strategy facilitates the management of such product and maximizes its value in use, reuse and recycling. The producer can achieve the higher recovery value V_{C2} by re-selling/re-leasing the product to a new customer after simple refurbishment and cleaning, re-leasing the product to new customer after disassembling the product and restoring it to "as new" condition with replacement parts and cleaning, upgrading the product with technologically advanced components for the existing customer, or reprocessing materials from the product and using them as feedstock in the production of new products. Thus, the reduced cost of leasing in the case of early retirement of the product will be:

$$RCOL = PV(V_{C2} - V_{C1}) - (V_{O2} - V_{O1}) \tag{3}$$

The benefit achieved (see Equation (3)) may be significantly less than that in Equation (2) if the product is retired by the first user at a very early stage of its useful life, or if there is a well established second-hand market. However, the life-cycle services provided in the leasing mode will help producers recognize the impact of fast changing fashions and consumer preferences on product retirement time, which will then facilitate innovations in product design and technology development.

2.2 Residual Value and Cost of Leasing

Closer attention also needs to be paid to residual value of the leased asset. Residual value V_D is often assigned as positive or zero, as indicated in Figure 2. Sometimes, disposal costs may account for a significant part of realised value at the end of the asset life, or may exceed the residual value of the asset if there is limited second hand market, or if it is necessary for materials in the asset to be recovered or sold for scrap. With increasing community concern about the environment and the shortage of land space, product disposal costs can be much higher than normally expected due to increased landfill levies, removal of hazardous substances, or lost opportunities for recovering/conserving non-renewable resources. From both economic and environmental perspectives, residual value is more likely to be negative instead of positive. Taking negative residual value into consideration, the estimated residual value V_{R1} will fall below zero as V_{R1}', which moves the original asset depreciation line P_1 downward to line P_1' in the traditional selling mode (see Figure 2). Such a move will essentially shorten an asset's useful life because the business would prefer to dispose of the asset when disposal costs are equal to the benefits the asset could generate, when its real residual value is zero. Therefore, the asset's useful life will change from L_D to L_D'.

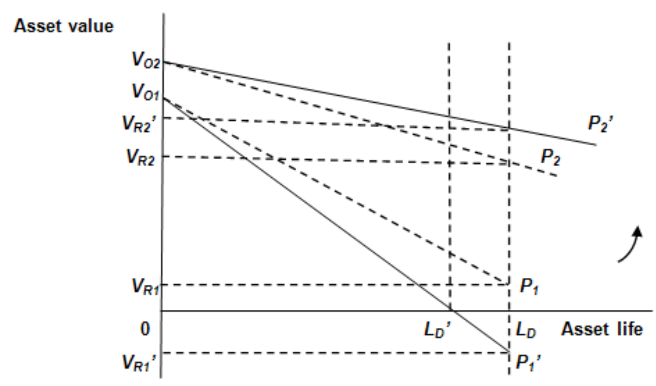


Fig. 2. Changes of asset residual value at its end of life

In contrast, leasing saves disposal costs and creates the most environmental value from its service processes. These service processes not only reduce the need for landfill space but also reduce the need to use depletable natural resources because the material value of products is recovered through reuse, remanufacturing and recycling, thereby reducing the environmental impacts of extraction, materials processing, and production, as well as conserving natural resources (Fishbein et al., 2000). Therefore, in the leasing mode, the estimated residual value V_{R2} will continue to move upwards to V_{R2}', which moves the original asset depreciation line P_2 to line P_2' and essentially further extends the asset's useful life. The reduced cost of leasing will then be:

$$RCOL = PV(V_{R2'} - V_{R1'}) - (V_{O2} - V_{O1}) \tag{4}$$

As the difference between the residual value estimates widens (as shown in Figure 2), the RCOL value becomes higher.

2.3 Tax Credit and Cost of Leasing

Tax shield is an additional, but crucial, consideration in business decision-making (Chasteen, 1973). Tax benefits reinforce the benefits of leasing over selling. For the lessee, lease payments are tax deductible, reducing the cost of leasing. For the lessor, tax deductions have two effects. First, as ownership of the product is retained by the lessor instead of being transferred to the lessee, the lessor will capitalise the product and then periodically expense deprecation. Such deprecation will reduce income taxes by the amount of depreciation times the income tax rate. For tax purposes, the lessor may also take advantage of accelerated depreciation (e.g. by using the reducing balance depreciation method). By doing so, the lessor can benefit significantly from the tax deduction from depreciation in the early life of a product, generating higher early cash inflows for the business.

Assume D represents the depreciation expense and T is the income tax rate, the adjusted RCOL after tax credits will be the present value of the tax deduction of asset depreciation plus the present value of increased residual value to realisable market value of the asset, which can be expressed as follows:

$$RCOL = PV(V_{R2'} - V_{R1'}) - (V_{O2} - V_{O1}) + PV(D_2 - D_1)\, T \tag{5}$$

In theory, the reduced cost of leasing through product life cycle service provision should also include environmental costs such as natural resources and landfill space saved. The conventional accounting system, however, places hurdles on the recognition and measurement of these costs and impacts. So, as trade off, cost savings and/or revenues generated from product life extension and reutilisation can be used as the proxy to monetise the benefits of leasing.

While the arguments and the RCOL model presented above are conceptual, it is considered as useful to demonstrate the applicability and conditions/contexts for realising the benefits of leasing through a study on a real-life system and the comparison of business modes applied to it. These will be presented through a case study in the next section.

3. Environmental Impacts over a Product Life

Environmental impacts of a product are associated with the life stages where they are incurred, and can be categorised as either material-related or energy-related. For some products, such as furniture, packaging, and mobile phones, their impacts on the environment are mainly caused by the production and/or end-of-life disposal due to the environmental loads and recyclability of the material contents. Other products, such as refrigerators, washing machines, photocopiers, and vehicles, however, exert most impact due to resources consumed (e.g. energy and water) for, and waste generated from, performing their functions during the use phase. To identify whether a leasing mode is effective for achieving an 'environmental win', the following model is proposed to assess its environmental implications.

3.1 Measuring Environmental Loads

During the life of a product, environmental loads are related to and often represented by consumption of resources (e.g. raw materials, fossil fuels, land) and generation of by-products and waste emissions (to air, to land, and to water), such as CO_2, NO_x, SO_x, solid waste, etc.. For a multi-component, durable product, the environmental load (EL) of each of the components can be assessed as the combination of followings:

- the ELs of its material contents related to production and disposal, i.e. EL^{P} and EL^{EOL},
- the ELs of the material and/or energy inputs, i.e. EL^{UI}, from external sources (rather than from other components) to the component for its functions, and
- ELs of the outputs released to the environmental in forms of solid, liquid, and/or gaseous emissions from its use, i.e. EL^{UO}.

Meanwhile, when the usage and reusability (pr) of a component are considered after being used for a period of time, the environmental load of a component at a particular point of time t will be measured by using the following equation:

$$EL_i(t) = \sum_{j=1}^{J} EL_{ji}^{P} + \sum_{j=1}^{J}\left\{\left(EL_{ji}^{P} + EL_{ji}^{EOL}\right)[1 - pr_i(t)]\right\} + \sum_{k=1}^{K} EL_{ki}^{UI}(t) + \sum_{l=1}^{L} EL_{li}^{UO}(t) \qquad (6)$$

i: i-th component in the product, where $i = 1, \dots, N$
j: j-th material of the i-th component, where $j = 1, \dots, J$
k: k-th external input for the i-th component to function, where $k = 1, \dots, K$
l: l-th output from the function of the i-th component, where $l = 1, \dots, L$

By incorporating additional services, some components may be replaced by new ones during maintenance or upgrade at certain stages while the product is in use. Therefore, the total environmental load of the product, i.e. EL_{sys}, at the time t can be calculated as

$$EL_{sys} = \sum_{i=1}^{m-1} EL_i(t) + \sum_{j=m}^{N} EL_j\left(t_j^{'}\right) + \sum_{j=m}^{N} EL_j^{'}\left(t_j^{''}\right) \qquad (7)$$

$EL_i(t)$: the environmental load of an original component remaining in use at time t, where $i = 1, 2, \ldots, (m-1)$
$EL_j(t_j^{'})$: the environmental load of the j-th component replaced after serving its life $t_j^{'}$, where $j = m,\ (m+1), \ldots, N$
$EL_j^{'}(t_j^{''})$: the environmental load of the new j-th component after serving its life $t_j^{''}$, where $t_j^{'} + t_j^{''} = t$

Some operations and activities (e.g. transportation, installation/de-installation using powered tools, cleaning/refurbishing, etc.) involved in delivering services during leasing also have environmental impact through consumptions of materials and energy. However, their environmental loads are often negligible relative to those of production, use, and disposal of the product and its components due to the small duration or quantity of their deployment. Therefore, for simplification, the environmental loads of service operations are not included in this assessment model.

3.2 Environmental Implications of Leasing Strategies

By using the EL model presented in the previous section, it is possible to examining the impact of leasing on the environment based on which life-cycle phase of a product attracts the most environmental load and whether service options, if provided, can mitigate the impact. According to the model, three main product life-cycle phases are considered in the assessment, i.e. Production phase, Use phase, and End-of-Life phase.

- If EL_{sys} of a product is predominantly determined by the EL^P and production of its components (e.g. photovoltaic panels, furniture, bicycles, etc.), providing maintenance during leasing can reduce the impact on the environmental by improving the reusability (pr) and extending the life of components, indicated in Eq.6. However, incorporating upgrade is not necessarily positive for the environment under this circumstance, depending on which components are replaced. Upgrade can even increase the environmental impact of leasing if both the replacing and the replaced components are major contributors to EL_{sys} and have their ELs mainly related to the fabrication of their material contents.

- If EL_{sys} of a product is mainly related to its material and energy consumptions during the Use phase (e.g. washing machines, gas stoves, refrigerator, automotives, etc.), leasing with maintenance will have no or very little effect on the environmental impact of the product, if the environmental loads of maintenance operations are neglected. In contrast, upgrade options can lead to the improvement of EL_{sys} by replacing those obsolete energy/material-using components with newer, better ones for higher efficiency and less waste generation, i.e. $EL_j^{'} < EL_j$ in Eq.7.

- If EL_{sys} of a product is primarily incurred during the disposal at the End-of-Life stage (e.g. mobile phones, CRT monitors, computers, etc.), both maintenance and upgrade options are capable of achieving the 'environmental win' by reducing/postponing waste disposal and resource consumption through life extension and reuse of the product as suggested by Eq.6.

The discussions on the environmental implications of normal leasing, leasing with maintenance, and leasing with upgrade options are summarised in the table (Table 1) below. Although the categorisations presented in the table are qualitative, it is useful for a quick decision making when detailed life-cycle information is not accessible. A quantitative assessment by using the EL model can be conducted to compare different leasing scenarios if data of particular environmental loads (e.g. amount of coal (in ground), fresh water, CO_2, SO_x, or NO_x consumed/generated for per unit of material/energy used) is available for the product and its components.

Option / Stage of Impact	Lease without service	Lease with Maintenance	Lease with Upgrade
Production	—	↑	↓
Use	—	—	↑
End of Life	—	↑	↑

—: Neutral ↑: Positive ↓: Negative

Tab. 1. Environmental effects of different leasing modes

4. Case Study

The product selected for this study is a heating system using renewable source of energy. While the price of the system is around AUD 10,000, leasing is considered as a possible alternative to make it more affordable for ordinary households by alleviating the cost of ownership. In this case study, the investigation will be focused on comparing estimated costs associated with the activities and arrangements under various leasing modes. The system and scenarios for the case study are defined in the following section.

4.1 System and Case Scenarios

The selected heating system consists of 6 main functional components (names and main technical information are listed in Table 2). It is understood that functional changes or improvements introduced to the system and its components are generally evolutionary and incremental between different generations of models, providing a good technological basis for adopting progressive upgrade if needed. Within the system, each component has a different reliability feature and level of complexity for repair and replacement. A mixed use of corrective and preventive maintenance strategies may be applied for keeping the physical conditions of the components. The details of the system's technical and life-cycle characteristics can be found in (Xing and Luong 2009; Xing and Belusko 2008).

No.	Part	Engineering Attribute (EA)	Mass (kg)	Current Value	Annual Operation Time (AOT) (hrs/year)
C1	Ventilation Unit	Fan efficiency	40	0.40	2360
C2	Controls	control function factor	0.5	1.05	2360
C3	Ducting	duct diameter	52	0.30 m	2360
C4	TSU	heat storage capacity	334	80.0MJ	1458
C5	Collector	collector area	6.41	40.0 m^2	1180
C6	Aux. Heater	heater efficiency	64	0.80	695

Tab. 2. Technical information of the heating system

The study on the system will be based on three basic modes as described below. For each scenario, the same timeframe is applied while the contractual relationship and arrangements between the supplier and the customer remain unchanged during the period. The system will be taken back by the supplier for disposal, reprocessing to reuse, or reselling.

- Scenario 1: the system is *leased* to the customer without any addition services provided during its contract period, i.e. lease-without-service or simple lease.
- Scenario 2: the system is *leased* to the customer with *maintenance* applied to its parts. The same system will be continuously used and retrieved at the end of the contract period.
- Scenario 3: the system is *leased with maintenance* provided by the supplier throughout its use phase. *Upgrade* is applied to three components (C1, C2 and C4) of the system a half way through the contract period. The same system will be used during the entire lease term.

4.2 Cost Items and Assumptions

For each scenario in this case study, the cost studies and comparisons will be focused on the following items from the system supplier's perspective:

- System/asset cost ($Cost_{SYS}$) – total cost of developing the product. The cost of the system is assumed to be the sum of the costs of all its components. It is assumed that the cost of a component is dependent of its key engineering attribute (EA) and reliability characteristics (Xing and Abhary 2010). Introducing a new, better component through upgrade will increase the value of the system and lead to $Cost_A^{'}$
- Maintenance cost ($Cost_M$) – a combination of cost corrective maintenance (or repair), i.e.$Cost_{CM}$, and cost of preventive maintenance (or service), i.e. $Cost_{PM}$, of system components. For each component, a fixed rate is applied for each event of maintenance, i.e. cost per maintenance (cpm), to cover estimated labour work and minor part changes involved, while $Cost_{CM}$ and $Cost_{PM}$ are assumed to be the

function of annual operation time (AOT) and frequency of failure (λ) and frequency of service (fpt), respectively. The following equation can be used to determine the annual $Cost_M$ of the system:

$$Cost_M = \sum_{i=1}^{m}\{cpm_i \times AOT_i \times [\alpha\lambda_i + (1-\alpha)fpt_i]\} \quad (8)$$

m: the number of components
α: indicator of maintenance option: 1 for corrective and 0 for preventive

- Upgrade cost ($Cost_{UP}$) – this cost occurs when the system is improved with changes introduced to one or several of its components. It is assumed that the cost of each occurrence of upgrade consists of a fixed fee, which can be the same as cost per maintenance, and the difference in the costs of new and existing components affected.
- Disposal cost ($Cost_{DIS}$) – the cost to discard end-of-life system as solid waste in landfill, including expenditures incurred for take-back, treatment, and disposal. For simplification, this cost item is set as a fixed value.
- Residual/remaining value (V_R) – the estimated carrying value. In this instance, this value is assumed to be dependent on the system cost and the chance of the system being fit for further use (p_r) at the end of the contract period. The coefficient is affected by the time in use, technological changes, system functional and physical characteristics, and services applied to the system (e.g. maintenance and upgrade). The models of fitness for extended use (FEU) presented in (Xing and Belusko 2008) can be used to determine the value of p_r .

Also, for simplification, the internal rate of return (IRR), i%, and tax rate, T%, are both assumed to be constant over the entire contract period. Meanwhile, costs of other operations and activities (such as delivery, installation, retrieval, and reprocessing) are omitted from this case study based on an assumption that their occurrence and values remain the same under all the scenarios and therefore will not contribute to relative differences in the comparisons of costs.

Based on the NPV approach, the cost items listed are categorised as current, annual, and future costs. The following equations are applied to express the correlation between these cost items and measures of V_R and V_O in forms of their present values. Meanwhile, the asset depreciation (D) is expressed as a straight-line depreciation based on the difference between V_R and V_O.

$$PV(V_O) = Cost_{SYS} + Cost_M\left[\frac{(1+i)^n-1}{n(1+i)^n}\right] + Cost_{UPG}\left[\frac{1-T}{(1+i)^{n/2}}\right] \quad (9)$$

$$PV(V_R) = \left[Cost_{SYS} + \frac{Cost_{UPG}}{(1+i)^{n/2}}\right]p_r - Cost_{DIS}\left[\frac{1}{(1+i)^n}\right](1-p_r) \quad (10)$$

$$PV(D) = \left[\frac{Cost_{SYS}-(Cost_{SYS}+Cost_{UPG})p_r+Cost_{DIS}(1-p_r)}{n}\right]\left[\frac{(1+i)^n-1}{n(1+i)^n}\right] \quad (11)$$

n: the total number of years, or the contract period, applied for the study.

4.3 Cost Analysis and Scenario Comparisons

The values of the costs and related factors defined above for each of the three scenarios are listed in Table 3 below. The timeframe for the study is set as 6 years, and system upgrade (in Scenario 3) will occur at the end of 3th year. Also, the reusability coefficient p_r differs under the three scenarios, with the value of p_r at the end of 6th year is assessed as 0.59 when no maintenance and upgrade are applied to the system (Xing and Belusko, 2008), i.e. Scenario 1. On this basis, 10% improvement of p_r from maintenance services and 30% improvement of p_r through the combination of maintenance and functional upgrade are estimated. Based on this information and Equations (5~9), the comparisons between the three scenarios in terms of RCOL are presented in Table 4.

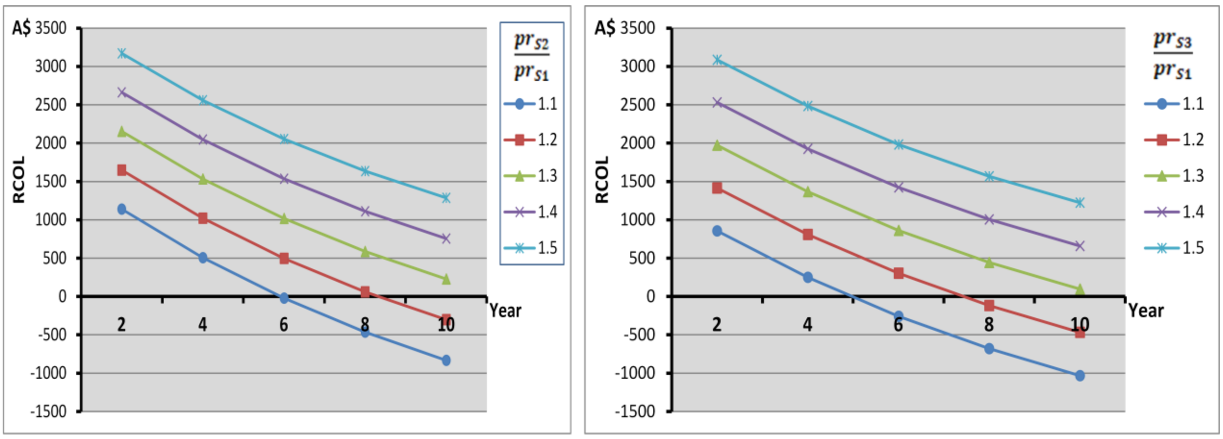
Length of period (*n*)	**6 years**			
IRR (*i%*)	**10%**			
Tax rate (*T%*)	**30%**			
Reusability (*pr*)	**{S1:0.59, S2:0.69, S3: 0.83}**			
Cost Item	**Scenario 1 (in AUD)**	**Scenario 2 (in AUD)**	**Scenario 3 (in AUD)**	
C1	1553.0	1553.0	1553.0	
C2	529.4	529.4	529.4	
C3	1037.7	1037.7	1037.7	
C4	1483.9	1483.9	1483.9	
C5	5114.2	5114.2	5114.2	
C6	991.5	991.5	991.5	
PRODUCT	**10709.5**	**10709.5**	**10709.5**	
cpm	0	300	300	
CM	0	313.5	313.5	
PM	0	212.4	212.4	
MAINTENANCE	**0**	**525.9**	**525.9**	
			Affected	Increment
			C1	601.3
			C2	78.7
			C4	333.4
UPGRADE	**0**	**0**		**1313.4**
DISPOSAL	**1200**	**1200**	**1200**	

Tab. 3. Cost information of leasing scenarios

Comparison	**ΔDT(A\$)**	**ΔV_R(A\$)**	**ΔV_O(A\$)**	**$RCOL$(A\$)**	**Favourable**
S2 vs. S1	910.3031	671.8272	1603.3	**-21.1718**	**S1**
S3 vs. S1	384.9094	2772.327	2294.0	**863.2019**	**S3**
S3 vs. S2	-525.394	2100.499	690.732	**884.3736**	**S3**

Tab. 4. Cost comparisons

According to the results, it appears that simple leasing (S1) is slightly more cost-effective than leasing with maintenance (S2) due to the limited influence of maintenance on the improvement (i.e. only 10%) of system reusability and residual value in this particular instance. On the other hand, the inclusion of system upgrade (S3) has a more substantial contribution to the fitness of the system, which leads to sizeable increase in the system's residual values in comparison with the other two scenarios. This highlights the positive correlation between p_r and RCOL, which is supported by the parametrical analysis on the trends of RCOL for S2-S1 and S3-S1 comparisons demonstrated in Figure 3 (a-b). By varying the length of lease period (n) and the ratio between the p_r values of 'with service' and 'without service' scenarios (representing reusability improvement), it is shown that RCOL increases when the ratio of reusability improvement is higher or the lease term becomes shorter. When RCOL becomes negative, it is considered more favourable to lease the system without introducing maintenance or upgrade.



(a) S2 vs. S1 (b) S3 vs. S1

Fig. 3. Correlations between reusability and RCOL

This case study is focused on a specific system. However, the results of the analysis on the scenarios and their comparisons can be applied to other similar cases. In general, this study supports the argument that leasing coupled with services can deliver the 'economic win' for the lessor, but to avoid a combination of a low-cost system, a long lease term, and a low effect of services on system reusability improvement.

4.4 Analysis from the Environmental Perspective

The case study presented in the previous sections is mainly focused on the use of RCOL model for comparing three leasing scenarios from the economic perspective. Based on the proposed EL assessment model and Table 1, the potential of the leasing scenarios for delivering environmental benefits can also be evaluated and compared. In this section, a focus on carbon dioxide emissions (CO_2) during the life-cycle of the system is used as an example of measuring and comparing the environmental performance of the three scenarios. The three main life-cycle stages considered include production, use, and end-of-life disposal. The estimates of CO_2 emission associated with producing and disposing of the system components are presented in Table 5 below.

			Estimated CO_2 Emission (kg)	
		Mass (kg)	Production	EOL Disposal
C1	Ventilation Unit	40	223.17	37.46
C2	Controls	5.25	122.85	15.01
C3	Ducting	47	122.34	35.11
C4	TSU	332	318.82	77.92
C5	Collector	6.41	28.34	14.37
C6	Aux. Heater	64	163.79	20.81
	Total	494.66	979.31	200.68

Tab. 5. Estimated CO_2 emissions of production and disposal

During the use stage, electricity and natural gas are consumed by ventilation fan, control units, and auxiliary gas heater to enable the circulation of air and heat flows and to provide the backup heating. For measuring the system's energy consumption, the size of under-roof heating area is assumed as 120m^2. Accordingly, the average annual energy consumption from space heating and ventilation is approximately 7580.14MJ/year, of which about 11% from electricity use and 89% from the use of gas heater. This leads to CO_2 emission estimated as 264.38kg per year based on the current settings of the system components. When the upgrade plan is implemented to modify and improve the components C1, C2, and C4, the CO_2 emission from the system use is reduced to 5435.15MJ per year and 169.68kg of CO_2 emission per annum. Meanwhile, the changes of TSU and ventilation unit lead to the increase of mass and consequently CO_2 emissions at production and end of life stages.

Table 6 presents the estimated life-cycle EL, i.e. CO_2 emissions under the three scenarios. It is assumed that the energy consumptions of maintenance and upgrade operations are negligible due to their infrequency and short duration. Also, for the purpose of simplification, the vehicle use for goods and personnel transportation is also not considered in this particular case due to lack of information. Accordingly, the total CO_2 emissions over the life cycle of the system under S1 and S2 are measured based on Equation(12-a), while Equation(12-b) is applied for the total CO_2 emission under S3. In Equation(12-b), ΔEL^P is the difference in EL values o before and after the upgrade. Meanwhile, $EL^{P'}$, $EL^{EOL'}$, and $EL^{UI'}$ are based on the data after the upgrade.

Length of period (*n*): 6 years Reusability (*pr*): {S1:0.59, S2:0.69, S3: 0.83}									
System	Scenario 1 (S1)			Scenario 2 (S2)			Scenario 3 (S3)		
	Production Kg	EOL Kg	Use Kg/yr	Production Kg	EOL Kg	Use Kg/yr	Production Kg	EOL Kg	Use Kg/yr
C1	223.17	37.46		223.17	37.46		223.17 (334.76)*	56.18 (37.46)*	
C2	122.85	15.01		122.85	15.01		122.85	15.01	
C3	122.34	35.11		122.34	35.11		122.34	35.11	
C4	318.82	77.92	264.38	318.82	77.92	264.38	318.82 (398.38)*	77.92 (97.43)*	264.38 (169.68) *
C5	28.34	14.37		28.34	14.37		28.34	14.37	
C6	163.79	20.81		163.79	20.81		163.79	20.81	

*: the value after upgrade

Tab. 6. System's life cycle EL(CO_2) under different leasing scenarios

$$Total\ EL = EL^P + (EL^P + EL^{EOL})(1 - pr) + EL^{UI} \quad (12\text{-a})$$

$$Total\ EL = \left(EL^P + \Delta EL^P\right) + \left(EL^{P'} + EL^{EOL'}\right)(1 - pr) + \left(EL^{UI} + EL^{UI'}\right) \quad (12\text{-b})$$

Based on the scenarios described in Section 4.1, the total CO_2 emissions under S1, S2, and S3 over the designated period (i.e. 6 years) are *3049.39kg, 2941.39kg,* and *2712.23kg*, respectively. According to the results, the difference between S1 and S2 is relatively small. If transportation and use of power tools for maintenance are taken into consideration, it is likely that the environmental performance of S2 may be the same as, or even worse than, that of S1. Clearly, S3 leads to a more significant emission reduction and an 'environmental win' in comparison with the other two scenarios, which is benefited by the combination of maintenance and upgrade that leads to improvement of both system reusability and system efficiency.

5. Discussion and Conclusion

This paper revisits the leasing strategy and develops new evaluation models to capture economic value and environmental impacts of different leasing strategies. Based on the analysis of the case system, it can be seen that incorporating service options into leasing does have better potential to achieve both economic and environmental benefits, although these cannot be automatically assumed and are highly dependent on what and how service options are offered. The following observations are made from the case study regarding the applications of RCOL and EL models, and whether leasing with services is capable of delivering the 'economic-and-environmental win' result:

- It is shown that recovery value is pivotal to the RCOL comparison between leasing options. Therefore, a *high-cost product* is more favourable than its low-cost counterparts in attaining economic benefits through its higher recovery value. Meanwhile, it appears that RCOL is relatively sensitive to the system cost and tax credit, but less so with regard to the interest rate and cost of disposal.
- The level of reusability improvement from maintenance and upgrade services can determine whether leasing with service is cost effective. A moderate improvement may make the leasing with service options economically less beneficial, or even worse, in comparison with leasing without service.
- The length of lease term also has critical effect on which lease scenario is economically superior. As shown in Figure 4, the longer the lease term, the less value-adding the incorporation of service options is. The ageing effect of the system becomes less curable by maintenance or partial upgrade when it serves for a prolonged use life.
- From the environmental perspective, the lease-without-service mode is very much the same as normal sell-purchase approaches and has little effect in actively reducing the life-cycle environmental impact of a product, apart from having a better position for implementing the take-back exercise.
- The lease-with-maintenance mode can have a positive effect on improving reusability, leading to economic and environmental benefits. But, in comparison with normal leasing, the mode is mainly effective for alleviating the environmental impact caused during production and disposal by reducing/postponing the demand on materials and resources. The upkeep of components which have most of its EL during the use phase (such as the ventilation fan and the heater) will not notably reduce its environmental impact, unless this can lead to less or more efficient energy consumption of the components.
- The lease-with-upgrade can have better potential to achieve the economic and environmental benefits. But, it needs to ensure that the increase of costs and ELs, due to fabrication of new components and/or disposal of the old ones, can be effectively offset by significant improvements of resource efficiency and reusability of the product over its use life. Lease-with-upgrade will not be more effective in achieving the 'environmental win' than lease-with-maintenance if the product produces most of its life-cycle ELs over the production and/or disposal.

These findings can provide useful suggestions for business managers to design eco-efficient leasing strategies and have policy implications for government and environmental strategists to encourage mainstreaming sustainability in key business decisions. But, the study does not take into consideration the impacts of stochastic feature of system failure, technology breakthrough, and uncertainties in logistics and supply chains on the planning of leasing strategies. Meanwhile, it is only focused on different lease modes and does not include competitions between leasing and selling as well as between new and renewed/reused products regarding revenue generation and environmental implications. Further research will be needed to overcome these limitations. Also, as part of a future study, the evaluation models can be incorporated with value engineering to provide decision support for product-service system design.

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