Evaluation of asset replacement strategies considering economic cycles: lessons from the machinery rental business

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Abstract: In businesses with heavy capital investments, the effective management of assets is crucial, in particular in the fleet rental business where assets are the major source of revenues. One important question in this regard concerns the replacement of used assets and the purchase of new assets. Thus, the objective of this study is to evaluate performance effects of asset replacement strategies. In order to maximise net cash flow of a rental company for construction machinery, a range of scenarios investigating the timing and nature of policies for replacing the fleet are analysed. Simulation findings are then discussed to generalise results beyond the insights for the case study company.

Keywords: asset management; replacement strategy; policy; system dynamics; simulation model; rental industry; economic cycle.

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1 Introduction

The effective management of assets is crucial in many industries that employ high-value machinery. This is true in particular in the fleet rental business, where assets are the major source of revenues and, thus, companies' success depends primarily on these assets. One important decision in asset management is about the replacement of used assets and the purchase of new assets. Therefore, in this study, we evaluate performance effects of a variety of asset replacement policies. In order to maximise net cash flow of a rental company for construction machinery, a range of scenarios investigating the timing and nature of policies for replacing fleet units are analysed. In particular, we take into account effects of a macro-economic cycle that determines prices and demand for used machinery.

1.1 Research background and purpose

Effective asset management has always been crucial in business with heavy capital investments, including the fleet rental business (Mardiasmo and Tywoniak, 2008). Asset management has been defined as: "a strategic, integrated set of comprehensive processes (financial, management, engineering, operating and maintenance) to gain greatest lifetime effectiveness, utilization and return from physical assets (production and operating equipment and structures)" [Mitchell and Carlson, 2001, cited after Schuman and Brent, (2005), p.567]. Incorrect decisions regarding equipment replacement can often cost far more than all the savings and cost reductions achieved in other areas of production and planning (Mathew and Kennedy, 2003).

A large number of studies deals with asset management issues in asset-intensive industries such as manufacturing, process or transportation. For example, Rajagopalan (1998) proposed an integrated approach taking into account both capacity expansion and equipment replacement. Ierapetritou and Li (2009) addressed uncertainties in process scheduling and planning. Schuman and Brent (2005) discussed a comprehensive asset life cycle management framework for the process industry. Finally, Weissmann et al. (2003) described an information system prototype for automatic selection of units for replacement.

This research addresses the vehicle rental industry, which is distinct from the industries investigated in those studies [and is also not concerned with asset management of rental housing like Gruis et al. (2004), or the management of knowledge assets like Schiuma et al. (2012), or the discussion of abstract strategic assets like Dierickx and Cool (1989)]. In industries covered by previous researches, the assets are mainly used to support continuous and effective production processes. Therefore, the linkage towards revenue generation is indirect. In the rental industry, fleet assets are the major, if not the sole, source of revenue generation, which is directly influenced by customers' choices. Due to this characteristic, asset management in rental businesses is closely related to revenue management with a focus on understanding market conditions and customer demands.

This article is based on a project with a leading fleet equipment provider in Europe (referred to as the case study company below), which specialises in rental and sales of access equipment, such as hydraulic lifts and telescopic handlers. In total, the fleet consists of 13,000 units and the company employs 800 staff worldwide. The objective of this research is to obtain a systematic understanding of the causal structure underlying asset management decisions and to explore potential strategic options for answering the following research question:

- What replacement strategy could be implemented to achieve the best financial performance (relative to other potential strategies) of the fleet considering macro-economic cycles?

In this study, we develop a system dynamics model that allows evaluating simulation scenarios that represent long-term behaviour of the financial performance of fleet assets. The scenarios are used to explore and to gain deeper insights in effective fleet management policies. As a side effect, the modelling process facilitates a better understanding of the causal relationships between financial outcomes, strategic considerations and external factors such as macro-economic conditions.

2 Methodology

2.1 Principles of system dynamics

The issue of effective asset management is a dynamically complex problem. Specifically, asset management decisions involve the consideration of lagged, nonlinear and trade-off phenomena. These three phenomena are among the sources of dynamic complexity in systems (Sterman, 2000). First, such decisions are always made and executed on a continuous basis with a delayed feedback of earlier decision on the current state of the system, which results in variations of the relevant financial outcomes over time. Second, replacement decisions of assets are affected by multiple factors such as prices and demand, which are further subject to conditions like the macro-economic situation. The relationships between these factors are rarely linear. For example, a change in price does not cause a company to change its purchase of assets proportionally. The nonlinear relationships between causal factors make the system more complex. Thirdly, asset management decisions, like most other decisions in business management, involve trade-offs between different business goals. With limited resources in the organisation, the achievement of certain goals may compromise others. For example, while fleet units with a longer economic life cycle would be financially more beneficial for the company, the long time span between replacements might damage technology leadership in the market. System dynamics (SD), as a modelling methodology, is a suitable tool to explore dynamically complex asset management issues, since it "is a powerful method to gain useful insights into situations of dynamic complexity" [Sterman, (2000), p.39; Größler et al., 2008].

The existing literature on asset management calls for an integrated approach to look at engineering and governance factors (Tywoniak et al., 2008). For fleet management in the rental industry, comprehensive approaches taking into account considerations from strategic, tactical and operational decisions are lacking (Wu et al., 2003). This research aims to provide a systematic understanding of causal relationships between strategic factors, available resources, and financial outcomes when forming an asset management strategy. SD methodology, with its focus on causal structures, feedback mechanisms, time delays and nonlinearities, serves as an effective tool in achieving the research goal. System dynamics is considered to be a useful method when simulating asset management scenarios (Schneider et al., 2006).

It is worth noting that limited research has been found within the existing SD literature on physical asset management issues in rental business. A number of studies have indirectly touched on the topic while focusing on maintenance problems. The strategic importance of maintenance management was demonstrated based on causal relations and feedback thinking (Zuashkiani et al., 2011). SD modelling was applied to illustrate the nature of a reactive maintenance culture in an asset maintenance system, identify the vicious reinforcing loops that drag the system into failure, and formulate a policy portfolio that transforms vicious into virtuous cycles (Sterman, 2000). Model simulations indicated that the implementation of total productive maintenance in a production system has a positive impact on its overall performance and a switch from preventive maintenance to maintenance prevention should be considered as maintenance strategy (Thun, 2006).

Another SD-based study depicts the network of cause and effect relationships between asset maintenance and business subsystems including production, finance, assets management and human resources, in order to analyse the long-terms and short-term implications of different strategies (Bivona and Montemaggiore, 2010). With an attempt to determine the optimal replacement time for capital assets, model simulations indicated that overhaul action can extend the economic life of capital assets and reduce the net present value (NPV) of total costs during the planning horizon (Mardin and Arai, 2011). Wenzler (2005) describes a modelling and simulation approach to support decision making for durable assets of energy companies (e.g. transmission networks and power plants). Besides the last reference, some more studies deal with asset management in 'network organisations' in the broadest sense (Volker et al., 2014), like energy transmission (Ilic et al., 2013), water systems (Sahin et al., 2014), and wastewater disposal systems (Rehan et al., 2014).

Another source of SD research relevant to asset management lies in the literature focusing on supply chain decisions in the aircraft industry. Alfred et al. (1997)

represented feedback structures of aircraft fleet aging processes, identifying three factors that affect the normal aging rate: work quality, mission stress and deferred maintenance. Malloy (2004) illustrated the complex interaction between mission requirements, failure rates and spares ordering policies, providing insight into the impact of system redundancy on life cycle costs in aerospace supply chain. More recently, Caicedo and Diaz (2009) explored the impact of renewal policies of aircraft fleets with a focus on cash constraints and delay effects arising from purchase decisions, aircraft production, and fleet delivery processes.

2.2 Research approach and scope

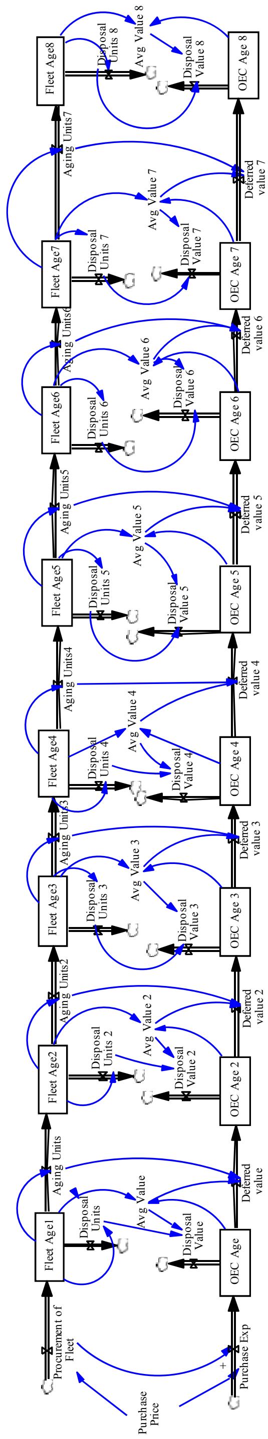
As first step in the research process, the authors built a preliminary model based on a literature analysis and preliminary discussions with the case study company. This preliminary model was used during group model building (Vennix, 1996) and interview sessions to elicit managers' mental models of the cause-and-effect relationships prevalent in the strategic decision making process related to the fleet asset management of the case study company. Using a participatory approach allowed eliciting enhanced information from company stakeholders. Insights about strategic issues and decision structures were obtained by this approach. Subsequently, periodical meetings with the project team were carried out to transform the conceptual model into a formal model.

Construction of the formal model and simulations followed a two-phase approach. In the first phase, the model was constructed with a focus to address the question of brand choice. Each potential brand option was treated as an alternative strategy in these simulations. This analysis provided insights of how brand choice affects the financial performance of the fleet base, in terms of effects on cash flow and its NPV. We do not report on the details and results of this phase but concentrate on the next phase of the research project. In this second phase, the best performing brand identified in the first project phase was selected to provide the starting point for replacement strategy analysis. Thus, the model was extended to facilitate the testing of more sophisticated replacement policy options based on the previously identified brand choice. Different policy combinations are evaluated through simulation results. The scope of the model presented in this article focuses on the fleet mix for one sample product type, chosen by the case company in the Netherlands.

2.3 Model description and validity

The model used in our analysis follows standard system dynamics practice and is based on examples published in the classical texts in the field (Forrester, 1961; Sterman, 2000). Thus, in the following description, we concentrate on peculiarities of the model used in this study. The cause-and-effect relationships concerning the replacement decision consist of both financial and non-financial factors. Financial factors could be further categorised into revenue related factors, cost related factors and fleet mix related factors, which affect revenue generation, total cost and fleet investment cash flows respectively. Specifically, revenue generation and total costs will contribute to operating cash flow while replacement of fleet mix affects investing cash flow.

Figure 1 Stock/flow diagram of fleet aging chain with OEC as a co-flow (see online version for colours)



2.3.1 Fleet mix

The term 'fleet mix' is used by the case company to refer to its fleet asset base, which consists of fleet units of various product types, brands and ages. In this research, the term 'fleet mix' represents the total fleet units of one sample product type of one brand. In the SD model (as shown in Figure 1), an aging chain structure is adopted to keep track of the units of fleet in each age class through the typical life cycle of this product type. A co-flow keeping record of the original equipment cost (OEC) of the fleet units is also developed.

The fleet mix is disaggregated into specific age groups for mainly two reasons. First, when fleet units get older, their physical condition changes. The fleet units in different age classes require a different level of maintenance needs and posses a different residual value. As a result, financial performance will vary with age. Second and more importantly, purchase price varies every year, giving rise to a different OEC for fleet units purchased in different years. In addition, these original costs need to be tracked when the fleet is disposed in future years. An aging chain with yearly compartments serves well for tracking historical equipment costs in a dynamic simulation.

2.3.2 Revenue generation

In the case company, the fleet rental revenue is calculated on a daily basis from the rental contract specifying the number of fleet units rented, rental days, and average daily price (ADP). From the perspective of the whole fleet mix of one brand, ADP will be considered identical. In addition, available days for rent and utilisation percentage of that brand determine the rental days per fleet unit.

2.3.3 Total cost of ownership

Total cost of ownership is the term used by the case company to refer to the total of all directly relevant operating cost items for fleet management operation; it is the sum of maintenance cost, repair cost and transport cost. Again as in the revenue calculation, the total cost of ownership calculation is extended to the whole fleet mix by replicating the structure for each fleet age group.

2.3.4 Financial performance

The case company uses NPV of accumulated cash as the indicator to measure the financial performance of the fleet rental operation. The cash flow calculation takes into account cash generated from operating activities, including rental revenue and total cost, and investment activities, including purchase expenditure and disposal income of the fleet operation. The discounting factor used in the calculation of NPV incorporates both interest rate and inflation rate.

2.3.5 Age distribution and disposal decisions

The fleet units could be disposed at any age in their life cycles, depending on management's perceptions of their financial prospects. Since maintenance needs increase with the aging of fleets, management is required to evaluate the benefit and cost for keeping the fleet units of a specific age group. From the perspective of the overall fleet mix, management wants to have a healthy age distribution to deliver sustainable financial performance and maintain positive reputation in the market.

In the model, stocks of fleet units have an outflow representing the units being disposed calculated as a percentage from the existing fleet units. When a fleet unit is disposed, its OEC needs to be removed from the pool of overall OECs correspondingly.

The disposal percentage is a subscripted variable with a set of values corresponding to each age group. The combination of different percentages for different age groups represents the company's policy of disposal decisions to control the age distribution of the fleet mix. The management team of the case company uses various value sets of this policy parameter to explore the result of different replacement strategies.

2.3.6 Influence of macro-economic cycle

Replacement decisions are greatly influenced by macro-economic conditions of the region where the business operates. Specifically, economic conditions affect the average rental price, the utilisation of the fleet, prices of disposal, and the purchase of fleet units.

In the model, an economic cycle index has been added to represent the dynamics of the macro-economic cycle. The management team of the case company provided this customised index to reflect the overall performance of the heavy construction industry in Europe from 2001 to 2015, combining historical trends and forecasts from the management team's experience. The economic cycle affects ADP, expected sales price, purchase price and utilisation nonlinearly.

The purpose of modelling in this research is to conduct quantitative scenario analysis to explore potential future developments of replacement strategies for the case study company. To support this aim, model validation in this research served the purpose to increase confidence of policy makers in the soundness and usefulness of the model (Forrester and Senge, 1980). Accordingly, the model was validated through structural and behavioural tests (Forrester and Senge, 1980; Barlas, 1996). In particular, together with the fleet management team in the case study company, the structures and the results of simulations of the SD model were scrutinised in terms of coherence and reliability. Furthermore, extreme condition tests and sensitivity tests demonstrated the model's robustness.

3 Simulation analysis of replacement strategies: results and discussion

The simulation of the model intends to explore how different replacement strategies influence financial performance of the fleet mix. The result regarding the optimal brand (identified in previous simulations) is used to provide brand specific information.

A replacement strategy is essentially a combination of decision rules for both disposal and procurement decisions. This research has identified a series of replacement strategies according to different settings of two factors:

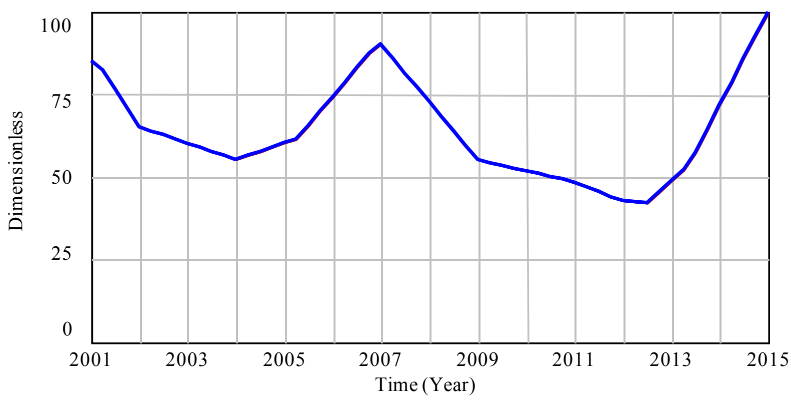
- Fleet size

  Fleet size refers to the total number of equipment units in the fleet mix. The assumption of constant fleet size enables the scales of rental operation to be comparable under different replacement policies, eliminating the differences in cash generation due to different numbers of units available for rent. With the constant fleet size assumption, procurement decisions are dependent on disposal decisions. In the model, the procurement of new fleet units (the inflow in the fleet mix) is calculated so that disposed units are immediately replaced.

- Linkage between disposal decisions and macro-economic cycle (see Figure 2)

  In different phases of the economic cycle, the company has different sales possibilities for the disposal of fleet units. Fleet units that are between six to eight years old could always be disposed at a low price, no matter in which phase the economic cycle currently is. The younger units, however, are sold with the intention to earn profit. As the demand drops in an economic downturn, sales possibilities for young fleet units decline. During the 'bottom' of the economic cycle, it would be impossible to dispose any units younger than six years. Accordingly, the replacement strategy could specify whether the disposal of fleet units is in line with the sales possibilities in different phases of the economic cycle.

Figure 2 Economic cycle index as assumed by management team of case company (see online version for colours)



The replacement strategies in the simulation could thus be divided into three subsets as depicted in Table 1.

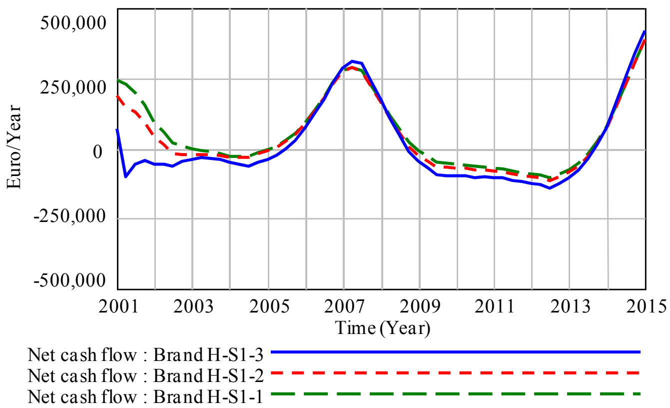
Table 1 Replacement strategies investigated in this article

Replacement strategies		*Content*	*Maintaining constant fleet size*	*Consideration of economic cycle*
Subset 1			Yes	No
S1-1	Natural retirement	All units are disposed at the end of their life cycle at age 8		
S1-2	Dispose old units	Dispose 50% of all fleet units in each age class from 6 to 8		
S1-3	Dispose before refurbishment	Dispose all units before they enter age 5		
Subset 2			Yes	Yes
S2-1	Disposal with cycle	Disposal according to sales capacities under different economic conditions		
S2-2	Disposal with cycle and capacity control	Partial utilisation of sales capacities with less replacement in upturn		
Subset 3			No	Yes
S3-1	Counter-cycle procurement strategy	Less procurement during economic upturn, recover fleet size during downturn		

3.1 Simulation of Subset 1

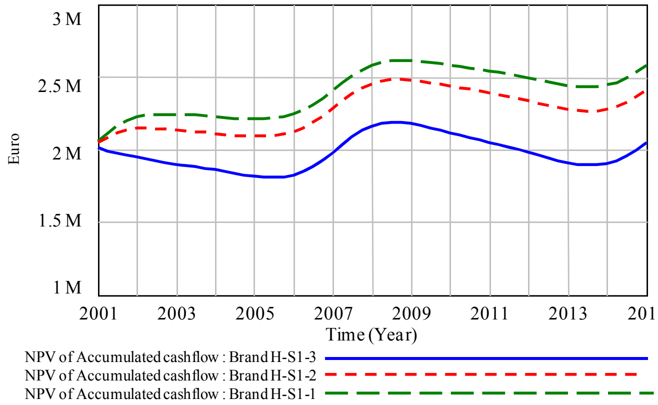
The settings of the three strategies in Subset 1 have been designed to explore how the age distribution of the fleet mix affects financial performance of the fleet under the influence of macro-economic cycle (shown in Figure 2).

Figure 3 Simulation results Subset 1, cash performance, (a) net cash flow (b) NPV of accumulated cashflow (see online version for colours)



(a)

Figure 3 Simulation results Subset 1, cash performance, (a) net cash flow (b) NPV of accumulated cashflow (continued) (see online version for colours)

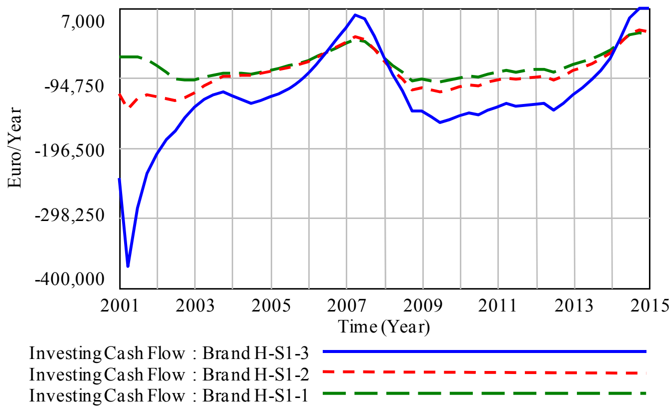


(b)

The outputs of the simulation in NPV of accumulated cash and net cash generated in Figure 3 show fluctuations over the years. It is worth noticing that Net cash flow is closely corresponding to the external economic cycle index (Figure 2), while the accumulation of cash flow shows a delayed adaptation.

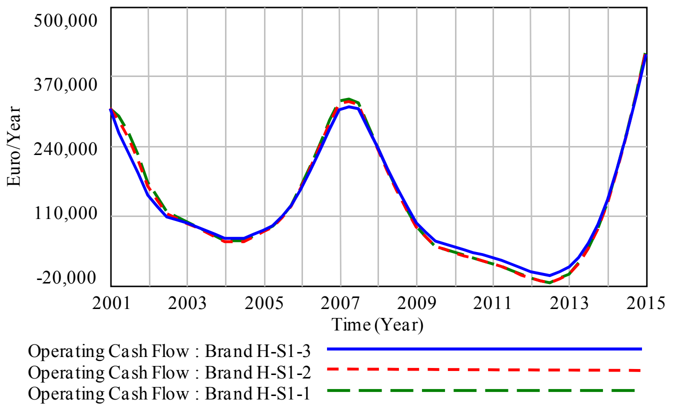
Net cash flow is generated through operating activities (rental operation) and investing activities (replacement of fleet units). A further look at these components in Figure 4 exposes that operating cash flow drives the behavioural pattern of net cash flow (shown in Figure 3) since it constitutes a larger part of the cash generation. Meanwhile, investing cash flow appears to be the cause of differences between these three strategies according to simulation results.

Figure 4 Simulation results Subset 1, cash flow generation, (a) investing cash flow (b) operating cash flow (see online version for colours)



(a)

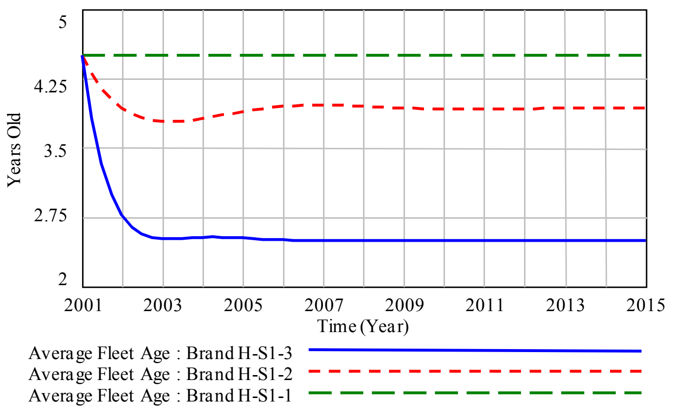
Figure 4 Simulation results Subset 1, cash flow generation, (a) investing cash flow (b) operating cash flow (continued) (see online version for colours)



(b)

The difference in operating cash among the three strategies is insignificant. Since operating cash flow in the model is calculated as the difference between rental revenue and total cost of ownership, it is worthwhile looking at these two aspects one by one. Since in the strategies of Subset 1, the fleet size remains constant, rental revenue is mainly influenced by ADP and utilisation, which are strongly driven by the economic cycle. As a result, rental revenue is almost identical among the three strategies. Total cost of ownership mainly depends on the age distribution of the fleet mix. The younger average fleet age, the lower total cost.

Figure 5 Simulation results Subset 1, fleet age distribution (see online version for colours)



Age distribution of the fleet in itself is an important indicator of operational performance independent of financial performance. A young fleet creates a positive reputation for the company in the market. While we do not include the effects of such positive reputation on financial performance directly into our model, we report on fleet age as being an indicator of success. As such, average fleet age shown in Figure 5 gives a clear picture of age distribution in the three scenarios, with younger age distributions being preferable.

Strategy S1-1 holds a constant average fleet age based on the constant fleet size and the stable natural disposal at life end of fleet units. Both Strategy 1-2 and 1-3 have a drop of average age in the first two years due to more replacements of old fleet units and even out in later years with the age distribution stabilised.

The comparison of the overall performance among the three strategies illustrates that the additional capital expenditure for keeping a younger fleet mix cannot be compensated by its cost advantages and investment benefits in economic upturns with a constant disposal policy (disposal rules remain constant in the whole simulation period). Thus, in the simulations of Subset 2 strategies, more flexible disposal policies will be adopted.

3.2 Simulation of Subset 2

In the strategies of Subset 2, the disposal decisions no longer stay constant through the simulation period. Instead, disposal units are dependent on the sales capacities of the company in different phases of the economic cycle. Sales capacity indicates the potential percentages of fleet units of specific age groups that the company can dispose or re-sell. In the model and in accordance to the situation in the case study company, sales capacity is assumed as indicated in Table 2.

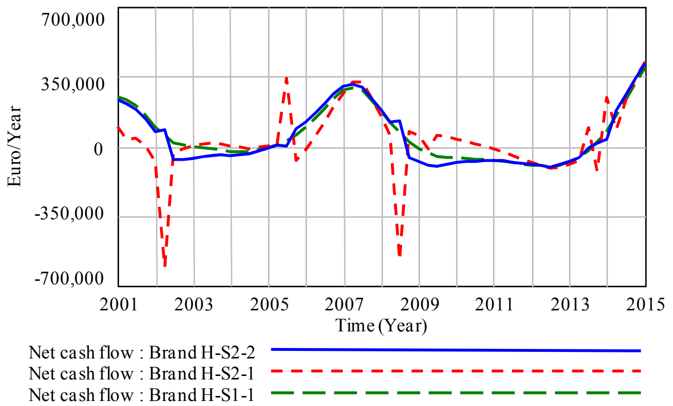
Table 2 Sales capacity assumed in Subset 2 strategies, depending on economic cycle

Economic cycle phases	*Sales capacity of young fleet units (age 1 to age 3)*	*Sales capacity of middle age fleet units (age 4 to age 5)*	*Sales capacity of old fleet units (age 6 to age 8)*
Boom	50%	50%	100%
Downturn	0%	30%	100%
Bottom	0%	0%	50%

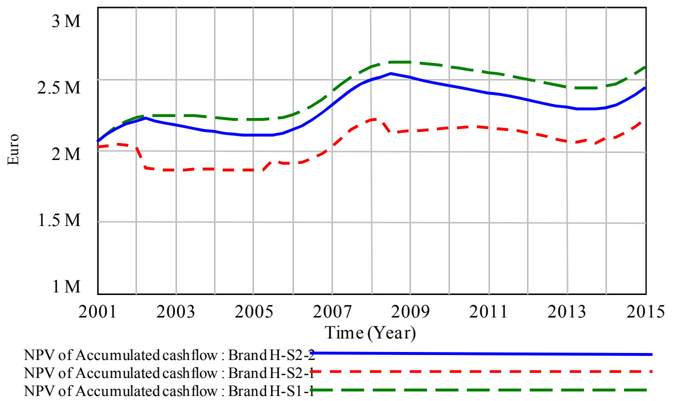
The purpose of using the strategies in Subset 2 is to explore whether the financial performance of the fleet mix will improve if the company adjusts its disposal decisions according to macro-economic conditions, given the constant fleet size assumption like in Subset 1. In Strategy S2-1, the company fully utilises the sales capacity as indicated in Table 2 and disposes all the units within this capacity. In Strategy S2-2, the company adopts a counter-cycle control policy which prescribes that only a certain (small) fraction of its actual sales capacity is used in economic booms while in downturns and bottoms the sales capacity is used to a larger degree or even fully. In order to allow for an easier comparison of results between strategies, the best performing strategy of Subset 1 (Strategy S1-1) is kept to be shown in the following graphs.

Simulation results of Subset 2 strategies in Figure 6 show similar behaviour patterns as those of Subset 1 (shown in Figure 3), yet the difference in disposal policies causes the difference in cash performances. The NPV of accumulated cash flow demonstrates that Strategy S2-2 outperforms Strategy S2-1, while both are not able to achieve the same level of accumulated cash as Strategy S1-1. Net cash flow generation indicates that strategies from Subset 2 are more volatile in cash generation. Although they perform slightly better during economic upturns, they suffer from significant drops in cash during economic downturns, which leads to less favourable accumulated cash over the years.

Figure 6 Simulation results Subset 2, cash performance, (a) net cash flow (b) NPV of accumulated cashflow (see online version for colours)



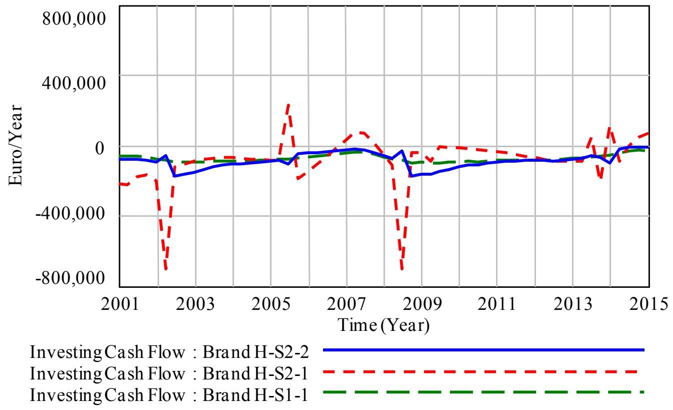
(a)



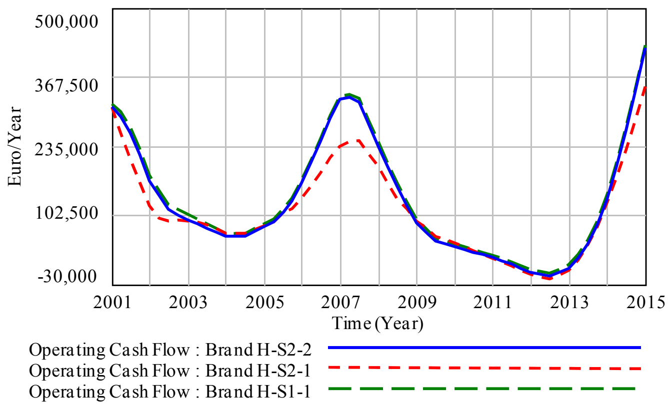
(b)

The dramatic fluctuation of cash generation of Strategy S2-1 mainly attributes to its volatile investing cash flow, which is caused by an aggressive disposal policy across different economic cycle phases (see Figure 7). In particular, more than half of the fleet is replaced according to sales capacity in economic booms, resulting in significant increase in both disposal income and purchase payments, while disposal incomes from sales of fleet units of various ages cannot compensate the expenditure of purchasing new units. For Strategy S2-2, the counter-cycle control policy requires less percentage of capacity be utilised during economic upturns and higher percentage in downturns. This policy has resulted in more replacements during downturns than during upturns, producing a smoother investing cash flow.

Figure 7 Simulation results Subset 2, cash flow generation, (a) investing cash flow (b) operating cash flow (see online version for colours)



(a)



(b)

This analysis illustrates the following insights:

- Replacing middle age or old fleet units with newly purchased units always results in negative cash flows due to the significant price difference between re-sales and purchasing. Thus, all replacement activities according to sales capacity during economic downturns and bottoms (when only old and middle age fleet units can be disposed) cause negative cash flows. The more radical the replacement activities are during these two phases, the more loss is made.
- Only re-sales of young units will potentially create profitable cash flow. However, according to the simulation, the investment surplus generated by disposing young units during economic upturns could not compensate the negative cash flows from the replacement of middle age and old units over the whole simulation period.
- As a result of the above two points, linking disposal decisions to economic conditions with the effort to maintain constant fleet size results in a worse financial performance of the fleet mix than adopting the natural retirement disposal policy.

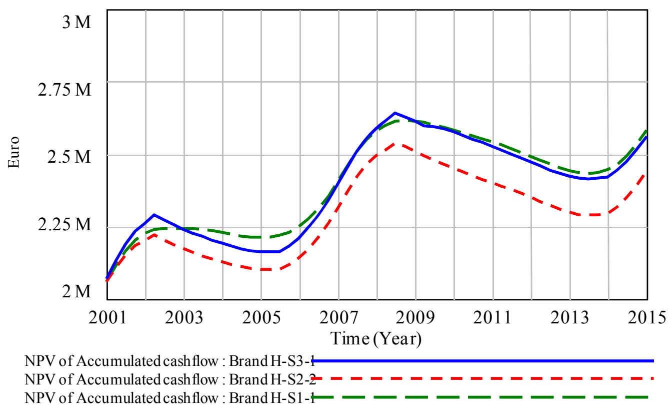
3.3 Simulation of Subset 3

Simulation of Subset 2 strategies fails to generate better financial performance than Strategy S1-1 of constant natural retirement, which was an unexpected result for the management team of the case-study company. The analysis of this result in the discussion above indicates that the constant fleet size assumption plays an important role. Since the procurement of new fleet units always takes place at the same time when the units are disposed, the company essentially loses the chance of exploiting the dynamic price difference of procurement and disposal. Disposal prices react to changes of economic condition faster than procurement prices do. In addition, the re-sell price could jump if demand is strong. Based on this understanding, it is worth exploring the situation when the constant fleet size assumption is discarded and procurement decisions are specified independent from disposal decisions.

In Strategy S3-1, the disposal decision rule remains the same as in Strategy S2-2, where fleet units are disposed according to the sales capacity in economic cycle and the counter-cycle control policy. However, the units disposed are not refilled through procurement instantaneously. The procurement is scheduled in a way that fewer replacements take place during economic booms and more in economic downturns to recover original fleet size.

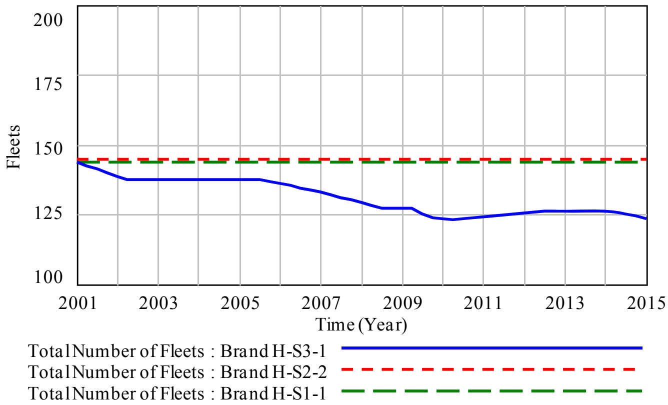
Simulation results shown in Figure 8 indicate that Strategy S3-1 has generated similar accumulated cash with a smaller fleet size. During economic booms when most disposals take place, the company holds back its procurement so that the total number of fleet units drops. When the economy slows down, the gap between current fleet size and original fleet size drives more procurement, leading to a slower decrease in total number of units. Before the fleet size recovers, another economic cycle starts and fleet size drops again. However, even with a decreasing asset scale, the fleet is generating comparable cash performance with the best performing strategy so far.

Figure 8 Simulation results Subset 3, cash performance and fleet size, (a) NPV of accumulated cashflow (b) total number of fleets (see online version for colours)



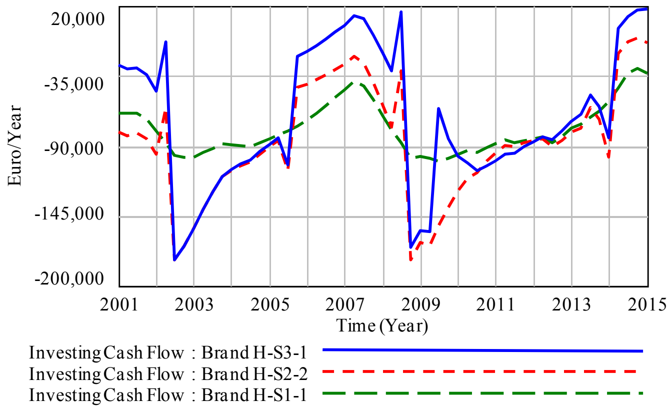
(a)

Figure 8 Simulation results Subset 3, cash performance and fleet size, (a) NPV of accumulated cashflow (b) total number of fleets (continued) (see online version for colours)

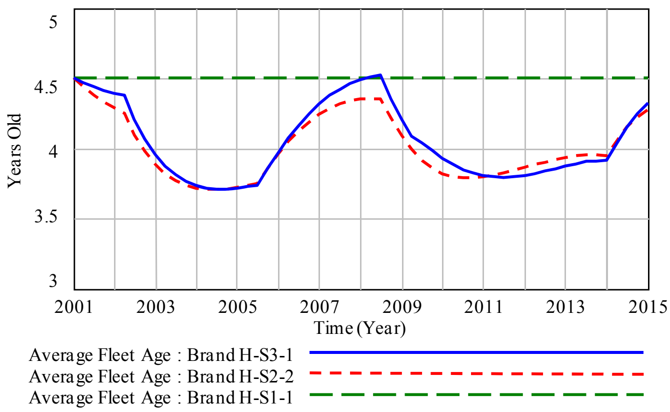


(b)

Figure 9 Simulation results Subset 3, cash flow and fleet age, (a) investing cash flow (b) average fleet age (see online version for colours)



(a)



(b)

An analysis of the components of cash generation shows that Strategy S3-1 is able to improve cash performances compared to Strategy S2-2 because of significant cost advantages and satisfactory investing cash flow [see Figure 9(a)].

With a smaller fleet size, both revenue and cost of running the fleet decrease. The reduction in unit costs due to a younger fleet contribute to the fact that cost savings outweigh revenue loss in this case (due to less renting opportunities), resulting in a comparable operating cash of Strategy S3-1 with Strategy S2-2 and Strategy S1-1.

Investing cash flow of Strategy S3-1 fluctuates dramatically in parallel to the economic cycle index as was the case in other strategies. During economic booms, the company enjoys a significant increase in investing cash flow since disposal is active while procurement is holding back. When the economy slows down, the company firstly decreases procurement in line with fewer disposals with reduced sales capacity. When the economic conditions continue to deteriorate, the company increases procurement to take advantage of stagnant purchase prices of new units. Since procurement activities contribute adversely to the investing cash flow, this for instance explains the jump and drop of investing cash flow between 2009 and 2011.

With replacements linked to macro-economic conditions, Strategy S3-1 provides a younger fleet as Strategy S2-2 [see Figure 9(b)]. Also due to smaller asset scale, fleet mix in Strategy S3-1 presents the highest cash generation ability among all strategies in the simulations.

4 Conclusions

For the research question concerning replacement strategies improving fleet asset performance, the simulation of various strategies indicates that a natural retirement strategy generates surprisingly good financial performance by fully utilising the cash generation capability of fleet units within their working lives. In addition, a replacement strategy that takes advantage of lower purchase prices in economic downturns and higher disposal prices in upturns also proves to perform better than other strategies simulated. With this strategy, the simulation results in a smaller fleet size which generates less rental revenue due to fewer units available for rent. However, the overall financial performance is similar or even better than with bigger fleets since the replacement decisions take into account the different dynamics of purchase and disposal prices across economic cycle phases.

The practical implications of this study for companies in the fleet rental industry are two-fold. First, given the difficulty the economic cycle poses on the planning of companies, a rather straight-forward policy of disposing fleet units at the end of their life-cycle might be a beneficial way to act. Policies that are more complicated and (seemingly) superior, can fail because of the uncertainties and dynamics in the environment and system of fleet units. Second, basic financial measures might not capture all performance effects of disposal policies. For instance, potential benefits of having a smaller fleet are not incorporated in the NPV of rental and disposal incomes. Considering operational performance measures could lead to better decisions in this regard.

The implications for research focus on how system dynamics modelling could better support asset management decisions. In particular, the following aspects are deemed to be relevant:

- Extend the model to represent operations of multiple geographic locations so that various disposal options could be incorporated in the model. This will enable more complicated policy scenarios for consistent asset management decisions for de-centralised international operations. Insights from simulations as such would help companies with international asset bases to develop more robust and financially beneficial policies.
- Gain more understanding of how financial performance influences asset management decisions and establish feedback loops in the model to explore if endogenous system structures could better explain the dynamic behaviour of fleet performance.
- Link the model to other decision areas and relevant processes of asset management, such as revenue management, maintenance processes and asset governance to gain a more comprehensive and systematic understanding of how asset management decisions affect financial performance of the overall business.

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