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Optimal channel coordination in use-based product-service system contracts

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Nowadays, service economy efficiencies are key to keep competitiveness and increase market advantages. The development of Product-Service Systems (PSS) can be an interesting strategy as they seek to improve the business performance of all the participants in the value chain. This paper proposes a novel reliability-based reward scheme for use-oriented PSS contracts. In a PSS instead of paying for the product, the client pays a fee for its performance. The contribution of this work to the existing literature is to provide a quantitative tool for the development of a use-oriented PSS contract based on non-repairable component reliability and risk sharing. It can be extended to other performance metrics such as availability and reliability. A well designed PSS achieves a mutual growth agreement for the client and the supplier if it aligns their interests through channel coordination. This is achieved by balancing the improvement in the expected cost and profit for the client and the supplier, respectively. The improvement is measured with respect to a baseline scenario where no PSS contract exists. The methodology is tested using a case study that analyses mining haul truck tires. The results show a significant overall improvement in the main key performance indicators and environmental impact of the value chain.

**Keywords:** product-service systems; physical asset management; service contracts; channel coordination

1. Introduction

A Product-Service System (PSS) is an agreement between a client and a supplier in which a traditional product-oriented business strategy shifts to a service-oriented one (Vasantha et al. 2011). This means that the client pays for the performance of the product instead of paying for the product itself. A PSS usually adds value to the value chain, provides an optimal answer to the customers’ needs and increased the sustainability of the business models of both the client and the supplier (Baines et al. 2007). A PSS business model can be: (i) product-oriented, (ii) use-oriented or (iii) result-oriented (Reim et al. 2015). In a product-oriented PSS, the client buys the product as usual but it also includes an additional service such as maintenance, spare parts provisioning and/or training. In a use-oriented PSS, the client pays for the use or availability of the product. Finally, in a result-oriented PSS the client pays for the performance or capability of the product. The decision of which kind of PSS to adopt depends on the specific characteristics of the business chain (Tukker 2004).

The PSS concept was developed in response to the increasingly complex business environment. It is a way in which suppliers can enhance their competitiveness and reduce risks associated to market volatility (Song 2017; Mahut et al. 2017). PSS can align the interests of the client and the supplier to create an overall improvement in the business value chain. Moreover, PSS can create value to the client through a better response to the needs that are related to the use of the product. It eliminates the responsibilities of owning the product so that the client can focus on its core business. For the supplier the PSS creates value as it increases its profits through the sale of additional services (Baines et al. 2007) and gives a competitive advantage that is difficult to imitate by the competition. PSS can also create value for the environment since a PSS leads to a more responsible relationship within the value chain (Tukker 2004).

To effectively establish a PSS relationship there are several barriers that must be overcome by the client and the product supplier. Some of them are: (i) the need for reciprocal trust between the client and the supplier, (ii) the lack of enthusiasm of clients about an unowned consumption and (iii) the suppliers concern with the risk of a new pricing policy. Therefore, firms must undergo a transition in their organisational structure to effectively overcome these barriers. The transition is difficult and requires collaboration between the client and the supplier to be successfully done. In this context, channel coordination arises as an attractive solution to align interests in the value chain as it can provide flexibility, create new value and generate extra profit (Pascual et al. 2016).

To the authors’ knowledge, while an interesting body of knowledge has been published on the PSS as a concept (Baines et al. 2007; Song 2017; Mahut et al. 2017), no work has been published to optimise the design of a PSS contract subjected to

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non-repairable components reliability. In the following sections it is shown that components' reliability may have a strong impact on the contract performance. Therefore, a structured methodology is proposed for the design of a use-oriented PSS contract based on this concept and risk sharing. It can be easily implemented to different operational conditions that results in optimal solutions for the client’s requirements. In this contract, the supplier has the ownership of the component and is responsible for its performance. On the other hand, the client pays a fee for its use and usually has individual and unlimited access to it.

This paper is structured as follows. Section 2 presents a general literature review of PSS and channel coordination to provide a context for the problem formulation. Section 3 develops the formulation of the proposed methodology for the design of the PSS contract based on component reliability and channel coordination. Section 4 presents the case study of mining haul truck tires, the results and a sensitivity analysis. Finally, Section 5 presents the conclusions and future lines of work.

2. Literature review

PSS studies have increased in the recent last few years due to the potential benefits that they can create to the value chain. Casadesus and Ricart established that a PSS is conformed by three main components: (i) a strategy, (ii) a business model and (iii) tactics (Casadesus and Ricart 2010). These components may be organised in a hierarchical relationship in which the strategy leads to a business model while the selected business model creates tactics for its optimal implementation. Maussang et al. propose that for many suppliers their strategy is to achieve a competitive advantage with respect to other companies in order to increase their market share (Maussang et al. 2009). Nonetheless, Cavalieri and Pezzotta suggest that the existing literature lacks quantitative tools for the design of PSS that aligns the strategy of a firm with its business model and tactics (Cavalieri and Pezzotta 2012).

There are some works on the design of maintenance outsourcing contracts using analytical models that can be extended to PSS contracts, but no one has addressed these contracts directly. Tarakci et al. present several incentive policies to achieve channel coordination in maintenance outsourcing contracts. They also study the effect that backup machines have in the risk mitigation of machine failure (Tarakci et al. 2014). Wang presents different contract designs based on the level that the maintenance activities are outsourced (Wang 2010). Pascual et al. consider imperfect maintenance and contracts negotiation under a finite time horizon (Jackson and Pascual 2008; Pascual et al. 2013). They also consider in more recent work a mechanism to reach channel coordination over a finite time period (Pascual et al. 2016).

Channel coordination is a concept that can be used for the development of a PSS as it can align interests. Several studies have addressed the problem of developing contracts with channel coordination. Arshinder et al. develop a detailed review of channel coordination in the supply chain which includes different coordination mechanism and gaps in the literature (Arshinder et al. 2008). They also link coordination mechanism with the supply chain performance (Arshinder 2004). Hill and Omar establish that the supply chain can reach coordination when the members effectively minimise the global cost and share the profits obtained (Hill and Omar 2006). Barrat considers the implementation issues that arise with the development of coordination and designs a mechanism to overcome them (Barrat 2004). Pan and Nguyen conclude that a PSS considers channel coordination to enhance client satisfaction and loyalty which are the most important indicators for manufacturing companies (Pan and Nguyen 2015).

3. Model formulation

The contract developed is a use-oriented PSS for a non-repairable component. The client must pay the supplier a fee that depends on the time that the component is effectively used until it needs to be replaced. The improvement that the contract creates for the client and the supplier is measured with respect to a baseline scenario, where the component is sold at a fixed price per unit.

The model considers the following assumptions,

(1) System usage is known for both parties. It is basic in the context of a use-based PSS,
(2) The risk of early failures in the component is shared with an appropriate fee structure that seeks to mitigate the risk aversion of both parties involved in the contract,
(3) The reliability of the component can be modelled with a known distribution. In our case, we use Weibull and Mixed-Weibull. Both distributions are commonly used in the literature because they have the advantage of being flexible and can be used to represent a great variety of hazard rate functions.

The first assumption avoids the moral hazard issue that may arise with respect to the usage of the components. It also facilitates building a trust relationship between the parties. We may, then, focus on building incentive schemes and avoid...
more complex decision-aid models. Example of use of game theory and information asymmetry can be found in Jackson and Pascual (2008), Kim et al. (2007, 2017).

3.1 Baseline scenario

In the baseline scenario the client buys a non-repairable component from a supplier for a unit price of $C_0$ (mu, monetary units) while the supplier has a unit cost of $C_f$ (mu). The component is expected to last $t_e$ (tu, time units) until it has to be replaced. Therefore, the expected cost for the client ($c_b$) (mu/tu) and profit for the supplier ($\pi_b$) (mu/tu) can be written as,

$$c_b = \frac{C_0}{t_e}$$  \hspace{1cm} (1)

$$\pi_b = \frac{C_0 - C_f}{t_e}$$  \hspace{1cm} (2)

We have preferred to keep direct costs per unit time as the key performance indicator for the customer. There are three main reasons: (i) in complex production systems (such as the mine load and haul system of the case study) it is very difficult to estimate the downtime cost due to failures. The main reasons are: equipment redundancy, work-in-progress buffers and the existence of several sequential processes in the production line (processing plants, smelters, port for the case study); (ii) in many systems (such as mining), performance is measured in terms of throughput and direct operational and maintenance costs; (iii) accountability: the PSS contract is limited to a single component of a piece of equipment, it may be very difficult to control every stoppage to check the reason and charge the contractor for it.

In the baseline scenario, preventive maintenance expenditure is negligible. Interests of both parties are not aligned. The client benefits if the component passes its expected life while the supplier benefits if the opposite happens. In response, there is an opportunity to develop a contract that leads to a greater expected life of the component, reducing cost rates for the client and improving supplier’s profits. Given this conditions, a use-oriented PSS contract arises as a good option.

3.2 PSS contract

The PSS contract is use-oriented so the client pays a fee ($C$ mu) for the effective time ($t$) that the components is used until it fails. Equation (3) and Figure 1 shows the proposed fee as a function of the usage.

$$C(t) = \begin{cases} 
C_0 & \text{if } t \leq t_e \\
C_0(1 + (1 - \alpha)\frac{t-t_e}{t_e}) & \text{if } t > t_e 
\end{cases}$$  \hspace{1cm} (3)

For durations below $t_e$, the fee includes a pro-rata cost and a usage cost that decreases as the component life increases (see Figure 1). For $t \geq t_e$, there is an extended-life sharing factor $\alpha$ that affects $C$. The extended-life sharing factor creates an incentive for the client to optimise his/her maintenance effort (expenditure) so that the component lasts longer. The objective of the
pro-rata cost is to guarantee that the supplier will not reduce its profit if \( t \) falls below \( t_e \). Therefore, the supplier will be attracted to develop a PSS agreement. This structure assures that the contract risks will be shared among the client and the supplier, as the expected improvement for both depends on the actual duration of the component. The client can extend the expected life of the component by increasing a preventive maintenance cost rate (\( c_m \text{ m} \text{tu} \)). The reliability function of the component depends on the operational conditions and the time that the component is used, as it is shown in Figure 2.

The expected improvement that the PSS contract creates for the client (\( \gamma_c \)) and the supplier (\( \gamma_s \)) are calculated with respect to the baseline scenario. The improvement is normalised with respect to the baseline, rather than in absolute terms. It allows for considering the relative sizes of both businesses. In absolute terms, the customer usually has a larger business than the supplier does. If that is the case, the user will observe larger absolute advantages with the PSS.

\[
\gamma_c = \frac{\overline{c}_b - \overline{c}_{PSS}}{\overline{c}_b} \\
\gamma_s = \frac{\overline{\pi}_{PSS} - \overline{\pi}_b}{\overline{\pi}_b}
\]

The PSS contract must satisfy the following conditions under the assumptions described above and that the client and the supplier will share the improvement achieved,

\[
\begin{align}
\max_{c_m, \alpha} & \quad \gamma_c (c_m, \alpha) + \gamma_s (c_m, \alpha) \\
\text{s.t.} & \quad \gamma_c (c_m, \alpha) = \gamma_s (c_m, \alpha) \\
& \quad \overline{c}_{PSS} \leq \overline{c}_b \\
& \quad \overline{\pi}_{PSS} \geq \overline{\pi}_b \\
& \quad 0 \leq \alpha \leq 1 \\
& \quad 0 \leq c_m
\end{align}
\]

The constraint allows a fair solution for both parties as the gains will be equal, considering the relative sizes of both businesses. The decision variables \( c_m \) and \( \alpha \) are agreed between both parties after optimisation.

This work presents two different models for the design of the PSS. In the first model, the component fails only by the use that the client gives to it. In the second one, it can also present manufacturing failures in early stages of its life. If the component fails due to manufacture failures the client does not have to pay the pro-rata cost.

### 3.3 Model 1

The reliability function for the component in this model is a two-parameter Weibull distribution, where \( \beta_c \) is the shape parameter and \( \eta_c (c_m) \) is the characteristic life of the component, that depends on the road maintenance cost rate \( c_m \). We consider a known dependency between the cost spent in maintenance and the expected reliability of the tires.

\[
R_c (t, c_m) = e^{-\left( \frac{t}{\eta_c (c_m)} \right)^{\beta_c}}
\]
Using Equations (3) and (7), the expected cost ($\overline{C}_1$) that the client pays until the component is replaced may be written as,

$$\overline{C}_1 = \int_0^{\infty} C(t) f_1(t, c_m) \, dt$$  \hspace{1cm} (8)

$$\overline{C}_1 = C_0 \int_0^{t_e} f_1(t, c_m) \, dt + (1 - \alpha) \frac{C_0}{t_e} \int_{t_e}^{\infty} (t - t_e) f_1(t, c_m) \, dt$$  \hspace{1cm} (9)

where $f_1(t, c_m)$ is the associated probability density function. By adding the maintenance cost to Equation (9), the expected cost of the client ($\overline{C}_{c1}$) is obtained. Similarly, the expected profit of the supplier ($\overline{\pi}_{s1}$) may be obtained by adding its unit cost to Equation (9).

$$\overline{C}_{c1} = C_0 \int_0^{t_e} f_1(t, c_m) \, dt + (1 - \alpha) \frac{C_0}{t_e} \int_{t_e}^{\infty} (t - t_e) f_1(t, c_m) \, dt + c_m \int_0^{\infty} t f_1(t, c_m) \, dt$$ \hspace{1cm} (10)

$$\overline{\pi}_{s1} = C_0 \int_0^{t_e} f_1(t, c_m) \, dt + (1 - \alpha) \frac{C_0}{t_e} \int_{t_e}^{\infty} (t - t_e) f_1(t, c_m) \, dt - C_f$$ \hspace{1cm} (11)

The expected cost of the client and the expected profit of the supplier may be written as closed form equations using the following expressions,

$$F_1(t_e, c_m) = \int_0^{t_e} f(t, c_m) \, dt = 1 - R_1(t_e, c_m)$$ \hspace{1cm} (12)

$$\overline{t}_{f1}(c_m) = \int_0^{\infty} R_1(t, c_m) \, dt$$ \hspace{1cm} (13)

$$\overline{t}_{1}(t_e, c_m) = \int_0^{t_e} R_1(t, c_m) \, dt$$ \hspace{1cm} (14)

$$\int t f_1(t, c_m) \, dt = \int R_1(t, c_m) \, dt - t R_1(t, c_m)$$ \hspace{1cm} (15)

where $F_1(t_e, c_m)$ is the failure cumulative density function, $\overline{t}_{f1}(c_m)$ is the expected life of the component and $\overline{t}_{1}(t_e, c_m)$ is the expected time to intervene. Then, the expected cost of the client and the expected profit of the supplier are,

$$\overline{C}_{c1} = C_0 F_1(t_e, c_m) + (1 - \alpha) \frac{C_0}{t_e} [\overline{t}_{f1}(c_m) - \overline{t}_{1}(t_e, c_m)] + c_m \overline{t}_{f1}(c_m)$$ \hspace{1cm} (16)

$$\overline{\pi}_{s1} = \overline{C}_c - c_m \overline{t}_{f1}(c_m) - C_f$$ \hspace{1cm} (17)

Equations (16) and (17) may be divided by the expected life of the component ($\overline{t}_{f1}$) in order to obtain the expected cost and profit per time units.

$$\overline{\pi}_{pss1} = \frac{C_0}{\overline{t}_{f1}(c_m)} F_1(t_e, c_m) + (1 - \alpha) \frac{C_0}{t_e} \left[ 1 - \frac{\overline{t}_{1}(t_e, c_m)}{\overline{t}_{f1}(c_m)} \right] + c_m$$ \hspace{1cm} (18)

$$\overline{\pi}_{pss1} = \overline{C}_{pss1} - c_m = \frac{C_f}{\overline{t}_{f1}(c_m)}$$ \hspace{1cm} (19)

Equations (18) and (19) have an intuitive interpretation. The client pays to the supplier the list price of the component independent if it passes its base expected life. Nevertheless, once the component passes its base expected life the client pays a reduced fee until it has to be replaced for a new one. Therefore, now the client also benefits if the expected life of the component is extended with respect to the one of the baseline scenario.

### 3.4 Model 2

The reliability function for the component in this model is a Mixed Weibull distribution represented by Equation (20). This is a linear combination of the reliability function of the client and the supplier, where the relative weight of the client and the supplier are $p_c$ and $p_s$, respectively. The objective of this model is to include the manufacture failures that the component
may present in early stages of its life.

\[ R_2(t,c_m) = p_c e^{-\left(\frac{t}{t_{f2}(c_m)}\right)^{1/\alpha}} + p_s e^{-\left(\frac{t}{t_{f3}(c_m)}\right)^{1/\alpha}} \]

\[ = p_c R_c(t,c_m) + p_s R_s(t) \]  

(20)

The client must pay the pro-rata cost only if the component fails before \( t_e \) and is not due to manufacturing problems. Therefore, it is necessary to calculate both costs separately. The expected usage cost \( \left( C_{use} \right) \) that the client pays to the supplier under this model may be written as,

\[ C_{use} = \frac{C_0}{t_e} \int_0^{t_e} t [ p_c f_c(t,c_m) + p_s f_s(t)] dt + \left(1 - \alpha\right) \frac{C_0}{t_e} \int_{t_e}^{\infty} t [ p_c f_c(t,c_m) + p_s f_s(t)] dt \]  

(21)

Similarly, the expected pro-rata cost \( \left( C_{pro} \right) \) that the client pays under this model is,

\[ C_{pro} = C_0 \int_0^{t_e} \left(1 - \frac{t}{t_e}\right) p_c f_c(t,c_m) dt \]  

(22)

Analogously to Model 1, the expected cost of the client \( \left( C_{PSS_2} \right) \) and the expected profit of the supplier \( \left( \pi_{PSS_2} \right) \) may be written as closed form equations.

\[ C_{PSS_2} = \frac{C_0}{t_{f2}(c_m)} \left[ p_c f_c(t_e,c_m) + p_s \tilde{t}_{i_s}(t_e) \right] + \left(1 - \alpha\right) \frac{C_0}{t_e} \left[ 1 - \frac{\tilde{t}_{f2}(t_e,c_m)}{t_{f2}(c_m)} \right] + c_m \]  

(23)

\[ \pi_{PSS_2} = C_{PSS_2} - c_m = \frac{C_f}{t_{f2}} \]  

(24)

where,

\[ \tilde{t}_{f2}(c_m) = p_c \tilde{t}_{f_c}(c_m) + p_s \tilde{t}_{f_s} \]  

(25)

\[ \tilde{t}_{i_s}(t_e,c_m) = p_c \tilde{t}_{i_s}(t_e,c_m) + p_s \tilde{t}_{i_s}(t_e) \]  

(26)

\[ F_{2}(t_e,c_m) = p_c F_c(t_e,c_m) + p_s F_s(t_e) \]  

(27)

Equations (26) and (27) are similar to Equations (18) and (19) of the first model. The main difference is that now the client does not always pay the list price of the component. This is because if the component has an early failure, the pro-rata cost is not considered. Therefore, under this model the expected cost of the client is at least as good as in the first model.

4. Case study

In an open-pit mine, haul truck tires are a considerable proportion of the operational expenses. They also represent a problem for the mines as the practice to stockpile the used tires affects the environment and requires considerable amount of space inside the mine. To solve this issue some mining companies have developed programs to recycle them. For example, there are companies that have used tires as a derived fuel or insulating material for the construction industry. Nevertheless, due to the remote locations where these companies operate there are still no alternatives to deal effectively with this problem. Therefore, the development of a PSS contract that extends the expected life of the tires arises as a solution that could lead to economical and environmental benefits for the business chain (Cavalieri and Pezzotta 2012; Diallo et al. 2017). Figure 3 shows a size reference for the mining haul-truck tires.

Mining haul truck tires are usually bought by the mining companies through a contract with a specific supplier that establishes a list price per unit. Under this policy, companies try to increase the expected life of the tires by increasing preventive maintenance of the haul roads (Caterpillar Global Mining 2007; Chen et al. 2017). Mining haul truck tires receive minimal maintenance policies and their expected life can change drastically depending on the mine’s characteristics. For the case study, the characteristic life of the reliability function of the tires is modelled as follows:

\[ \eta_c(c_m) = \eta_0 \left(1 + k \left(1 - e^{-\left(c_m - \eta_0\right) / \beta_m}\right)\right) \]  

(28)

Equation (28) models tire reliability and impose reasonable bounds on expected durations for different values of preventive maintenance expenditures \( (c_m \text{ mu/ut}) \). A close example of this kind of reliability model in equipment components may be found in Townson et al. (2003) and Pascual et al. (2011). For the case study, if the road preventive maintenance expenditure is negligible \( (c_m \approx 0) \), then \( \eta_c \) may attain a minimum value of 3.5 ut, and consequently, \( t_e \) may reach its lowest value at 3.1
Table 1. Parameters of the case study.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>$C_0$</td>
<td>50</td>
<td>μu</td>
</tr>
<tr>
<td>$C_f$</td>
<td>35</td>
<td>μu</td>
</tr>
<tr>
<td>$t_e$</td>
<td>3.1</td>
<td>tu</td>
</tr>
<tr>
<td>$\eta_0$</td>
<td>3.5</td>
<td>tu</td>
</tr>
<tr>
<td>$c_0$</td>
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<td>tu</td>
</tr>
<tr>
<td>$\eta_s$</td>
<td>20</td>
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<tr>
<td>$\beta_m$</td>
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<td>–</td>
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<td>0.7</td>
<td>–</td>
</tr>
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<td>$p_c$</td>
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<td>–</td>
</tr>
<tr>
<td>$p_s$</td>
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<td>–</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>1.5</td>
<td>–</td>
</tr>
</tbody>
</table>

The parameters used for each model and the baseline scenario are presented in Table 1. For confidentiality reasons, monetary and time units were used. The parameters for the reliability function of both models were obtained by adjusting the Weibull and Mixed Weibull distribution from historical data of the mine.

4.1 Results

The problem presented in Equation (6) can be solved graphically by analysing the curve resulting from the intersection of the surfaces created by Equations (4) and (5). Figure 4 illustrates this analysis for model 1.

The intersection curve of both surfaces is presented in Figure 5 for model 1 and in Figure 6 for model 2. The resulting curves show that there is a unique optimal configuration in the contract that maximises the improvement for the client and the supplier.

4.2 Sensitivity analysis

The results show that the proposed methodology creates a considerable improvement for both parties under both models. Nevertheless, it is important to study how changes in the list price of the tires affect the improvement as the market price of many components is subject to uncertainty. Figures 7 and 8 illustrate the optimal PSS configuration for both models when the list price of the tires ($C_0$) increases and decreases by 20%.
Figure 4. Improvement of the client and the supplier with PSS under model 1.

Figure 5. Intersection curve for model 1.

(a) $c_m$ axis view

(b) $\alpha$ axis view

Figure 6. Intersection curve for model 2.

(a) $c_m$ axis view

(b) $\alpha$ axis view
Figures 7 and 8 show that only the extended life sharing factor changes, while the maintenance costs remain constant for both models. However, it is important to study the difference between the improvement under the first PSS contract configuration ($C_0 = 50$) and the proposed variations as the market price of the component may change over time.

According to the results of model 1, the client obtains an improvement of 17% and the supplier of 101% over the baseline scenario when the price decreases 20%. On the contrary, when the price increases 20%, the client obtains an improvement of 20% and the supplier of 1% over the baseline scenario. The results are analogous for model 2. The client obtains an improvement of 22% and the supplier of 128% over the baseline scenario when the price decreases 20%. When the price increases 20%, the client obtains an improvement of 24% and the supplier of 2% with respect to the baseline.

4.3 Discussion

The results obtained for the case study show that the proposed PSS methodology creates a significant improvement in the expected cost for the client and profit of the supplier. This is achieved by developing effective channel coordination within the business chain so that the client and the supplier align their interests. Another important improvement that the PSS contract creates is that it increases the expected life of the tires in both models as the maintenance cost increases. Nowadays, an important feature of a PSS is that it may reduce the environmental impact of the business chain.

The sensitivity analysis shows that for both models the improvement that the PSS contract creates for the client and the supplier is sensitive to changes in the list price of the tires. However, only the discount over the usage fee changes while the
maintenance cost remains constant for each optimal configuration. This result raises the question of how much value does the flexibility in the design of the PSS contract creates when there is uncertainty over the market price of the component. Based on the results, it is recommended to create a mechanism to adjust the extended life sharing factor at specific periods of time during the contract depending on the market price of the tires.

5. Conclusions

This paper develops a quantitative methodology for the design of use-oriented PSS contracts. It is based on non-repairable components reliability and risk sharing. The objective is that the client and the supplier follow a simple and straightforward formulation to reach an optimal configuration for the contract, based on the extended life sharing factor and the maintenance cost that the client pays. In order to align both interests, channel coordination is achieved by improving equally the client cost and the supplier profit with respect to a baseline scenario without the PSS contract.

The contribution of this work to the existing PSS literature is to provide a quantitative tool for the design of contracts and show its results in a case study. The methodology can be applied to many kinds of components due to the flexibility of parametric distributions to model the components’ reliability. Moreover, the proposed approach helps to deal with information asymmetry, a common difficulty in contract design, by encouraging mutual trust. Mutual trust is needed as the proposed methodology requires that the supplier reveals its unit cost per component to estimate his improvement. Accordingly, the PSS contract is designed to overcome these difficulties.

Some possible future lines of work are: (i) the current work can be extended to the case of repairable components subjected to perfect and imperfect maintenance services. It can be achieved by modifying the fee structure so that the maintenance cost is paid by the supplier; (ii) study the effects of uncertainty over the list price of the components to enhance the design of the PSS contract and adapt it to different market scenarios; (iii) study the effects of investments and the contract duration over the optimal fee through a net present value analysis; (iv) consider information asymmetry in certain variables to study the optimal contract configuration with a game theory approach; (v) consider net present value/cost.

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