Environmental Performance of the Product Shared System
By Modified Life Cycle Assessment

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The characteristics of Product Shared System (PSS) are analyzed in this paper. We present a Modified Life Cycle Assessment (LCA) approach to evaluate the environmental performance of PSS in order to take the usage efficiency into consideration. In the case study, we calculate the environmental impact of the car rental and lease system. From the simulation results, it can be found that the usage efficiency can affect the environmental impact of products.

1. Introduction
With the increasing crisis of the global environmental issue and the limitation of resource, the total product life cycle had to be required to consider during the life cycle management. The key aim of the life cycle management is the environmental protecting and improving.

Therefore a more sustainable product life cycle requires rethinking the whole value chain of the product system and envisioning how to create a new service with minimized environmental impact. For the most of energy consumption products, such as car and home appliances, the amount of environmental impact in the usage process is the largest one. Now the research on consumer’s behavior, usage mode, and environmental evaluation in the usage process are being paid more attention. The main purpose of this research focuses on the environmental performance evaluation in the Product Shared System (PSS).

2. Review of previous works
From the analysis of the consumer’s behavior, Kimura (2002) states that the major resources of inefficiency of closed product life consist: 1. Unexpected early disposal of products; 2. Non-use or idle products in user’s hands; 3. Long-term use of old and inefficient product; 4. Life cycle management overdone, particularly maintenance, multiple life cycle (reuse) and take-back cycles. All such inefficiencies can be understood to occur due to the incompatibility of the planned product life cycle and actual product usage style of customers.

In this paper, we present a mathematical model, modified Life Cycle Assessment (LCA) approach, to evaluate the environmental performance of the PSS by taking the usage efficiency into considered.

3. Product Shared System
From the perspective of ownership to the product in the usage process, the customer’s consumption can be divided into two main different usage modes: purchasing with the ownership and shared without ownership through renting or leasing.

Either purchasing or shared usage mode, the main objective of product consumption is to utilize functions to satisfy requirements of consumers. Therefore, on the context of sustainable development and considering the objective of achieving more efficiently use with fewer resources, the concept of Product Shared System (PSS) is presented. The Product Shared System (such as car rental and lease, laundry store and so on) means that the product is no longer to be purchased by the customer but rented or leased over a certain period, it also means that selling use instead of selling products. In the PSS, the products should be easy to access, easy to clean, and easy to maintenance and update in order to provide satisfied services to customers.

Generally, a product in user’s hand has two different statuses: using or idle. If the costs of idle capacity are higher than extra costs to be paid in the service management during product renting or leasing. Then the product shared system (PSS), a user oriented paradigm, becomes more popular and competitive.

Due to the shared attribute, the different users can use the same product. Therefore the key characteristic and merit of the PSS is that it improves the usage efficiency of the product than the traditional purchasing mode.

4. Modified Life Cycle Assessment and case study
During the usage process, the products have two status: usage and idle. In the usage status the energy consumption directly causes the environmental impact. The idle status leads to the resource (materials and energy) used in the manufacture process can not be utilized efficiently, which also causes the environmental impact indirectly. Therefore the usage efficiency of the product is an important factor, which heavily affects the environmental impact of product

Improving the usage efficiency of the product through the shared method in the PSS is one of the key characteristics. In order to take the above two issues into considered during the evaluation of environmental impact in the PSS, the modified LCA approach is presented by refining the traditional LCA. Figure 1 shows the principle of this approach, in which the internal transportation process is ignored in order to simplify the model. The output (environmental impact) in the production process is translated into input factor (usage efficiency, Eu) in the usage process in order to calculate the usage efficiency of product. The expression of usage efficiency, Eu of the product is given as

\[ Eu = \frac{\text{Usage time}}{\text{Usage time} + \text{Idle time}}, Eu \in [0, 1] \] (1)
From the definition, we can know that if the idle time is infinite big or the usage time is zero, the $E_u$ will be zero (i.e. the product is never used). However, if the idle time is zero or the usage time is infinite big, then the $E_u$ will be 1. (i.e. the product is always used without any failures).

![Fig. 1 Principle of Modified LCA in the PSS](image)

The evaluating model of environmental impact of the PSS in the usage process can be expressed as the following two equations

$$EI_1 = k_1 \times Ef$$

and

$$EI_2 = k_2 / Eu$$

where equation (2) represents the direct environmental impact (CO2 emission) caused by energy consumption, $k_1$ the transmit coefficient of the fuel consumption, $Ef$ the energy consumption (As for the car, $Ef$ is the driving distance $Ef = v \times t \times Eu$, where $v$ denotes the velocity of the car, $t$ denotes the product life time), equation (3) represents the indirect environmental impact (resource inefficiency) caused by usage efficiency of product, $k_2$ the transmit coefficient of the usage efficiency (CO2 emission in the production process), $Eu$ the usage efficiency.

In order to summarize these two different environmental impacts during the usage process, the results of $EI_1$ and $EI_2$ are normalized by the following two expressions

$$EI_1' = EI_1 / (EI_1|_{Ref usage time})$$

and

$$EI_2' = EI_2 / (EI_2|_{Eu=1.0})$$

Then the total environmental impact of PSS in the usage process consists two parts: direct and indirect effect. Then we can get the following expression

$$EI = EI_1' + EI_2'$$

In a case study, we evaluate the environmental performance of car rental and lease system, which is becoming a more popular PSS. Table 1 provides the specified input values for a specified type of passenger car. Figure 2 shows the result of simulation by the presented Modified Life Cycle Assessment approach.

**5. Conclusion**

Improving the usage efficiency is one of the key characteristics in the Product Shared System. With the analysis and simulation the environmental performance of PSS, the user’s behavior has more effects to the environmental performance. Modified LCA approach provides a tool to calculate the environmental performance, $EI$ of the PSS taken the usage efficiency into considered.

The total environmental impact the Product Shared System in the usage process consists two parts: one is the direct effect, which is caused by the usage time; another one is the indirect effect, which is caused by the idle time (it can lead to lower usage efficiency of the product).

It is shown in the Figure 2 that the total environmental impact of Product Shared System decreases firstly. It is also shown that with the increasing of usage efficiency of product, the indirect environmental impact ($EI_2$) will be decrease.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. usage time</td>
<td>0.5 year</td>
</tr>
<tr>
<td>Life time (t)</td>
<td>3 years</td>
</tr>
<tr>
<td>Velocity (v)</td>
<td>80 Km/h</td>
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<tr>
<td>CO2 emission ($k_2$)</td>
<td>4700 Kg</td>
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<tr>
<td>Fuel consumption</td>
<td>8.9 L/100Km</td>
</tr>
<tr>
<td>CO2 emission</td>
<td>0.289 Kg-CO2/Km</td>
</tr>
</tbody>
</table>

![Fig. 2 Environmental impact of car rental and lease](image)

**References**


