Environmental Services through Leasing Process: A Simulation Optimization Approach

Sajjad Shokohyar and Saeed Mansour

**ABSTRACT**

In recent years, the concept of sustainable product service system has been emerged as a solution for achieving our production and consumption more sustainable by emphasizing product function, the usage efficiency and services. The objective of this paper is to design a leasing company process in which economical, environmental and social impacts are balanced. Analytical hierarchy process (AHP) has been utilized to calculate social impacts. Life cycle analysis (LCA) has been applied to investigate the environmental impact of leasing process. Also economical impacts calculated during the leasing period and product EOL phase. For achieving these goals, indicators for each sustainability objectives are modeled with simulation modeling and results are discussed. Also simulation-based optimization approach is investigated and the integrated mathematical and simulation optimization model is developed for optimizing leasing services with respective of three mentioned sustainability objectives. Finally, a case study of a leasing notebook company is provided to show the applications of the model.

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**INTRODUCTION**

Limited resources have been being consumed by unsustainable use of human [1]. Sustainable development strategy is essential for making balance between demand and fair consumption in competitive situation [2]. The concept of sustainability was first formulated in 1987 with Brundland report stating that the goal of sustainability is to “meet the needs of present generation without compromising the ability of future generation to meet their own needs” [3]. What pushes organizations in competitive market to set strategy for achieving sustainability is more and more demanding for economical and green products. Leasing can be considered as a strategy for achieving sustainability. Therefore, leasing which is entirely sustainable fulfills simultaneously these three pillars in product development: Environment, Social and Economy.

A lease is a method by which a customer acquires the use of a product from a lessor for a period of time in exchange for a regular lease payment [4]. By leasing, the organization retain the ownership of the product throughout its life cycle and the product has a closed loop life cycle in which the product is used by consumer during the leasing period, after that it will be taken back to the leasing company. During leasing period, repair and replacement costs are paid by the leasing company [5]. At the end of leasing period, the consumer returns the product to the leasing company which becomes responsible for product EOL recovery [6]. The leasing company must consider economical, environmental and social impact of their products during the use and EOL phases in order to achieve sustainability [7].

Actually, sustainable leasing company’s activities and decisions are based on pull supply chain framework. Pull supply chain is focusing on optimized using resources to serve flexible demands and high customer service. If the focus is shifted from products sold to services rendered, it becomes advantageous to have reliable and long-lasting product, especially where maintenance and repair costs are high [8].

A growing number of researchers have argued that leasing has environmental benefits as well, claiming that the practice of leasing products, rather than selling them, increases resource productivity by moving to a pattern of closed-loop material use by manufacturers. To address growing problems of waste, governments around the world have established or proposed stricter legislation to prevent the open loop “sell and forget”
mode of transacting for a producer. That is, producers are required to take responsibility for their products at the end-of-life (i.e. sell and take-back). A primary argument for the environmental benefit of leasing focuses on the leasing firm’s ability to promote extended producer responsibility (EPR). EPR motivates manufacturers to “take back their products when consumers discard them, manage them at their own expense, and meet specified recycling targets”.

From an economical perspective, leasing allows the leasing company to retain ownership of the product. It will therefore be in the leasing company’s best interest to keep the product operating at peak condition, extending the product life and thus lowering the depreciation rate while maximizing take-back value. A lease is less risky for consumer and positively affects the consumer’s tax situation. Therefore, the key to an economic “win” is the relationship between depreciation, take-back value and cost of leasing. According to leasing curve Leasing can reduces maintenance costs over time [10]. Any product failure within the leasing period imposes costs both on the leasing company and the consumer (Handling cost, shortage cost, system down cost, waiting cost, etc.) [11,12]. Therefore, the terms of lease should be carefully determined to minimize the maintenance and repair costs during the leasing period as well as the product recovery costs at the end of the period. Also the leasing period and EOL options should be defined such that the overall environmental impact of the product to be minimized [16].

Computer leasing companies, car renting services and home appliances leasing are some of the most popular types of these services [8]. Some examples of successful computer leasing companies were summarized in Table 1.

<table>
<thead>
<tr>
<th>Company</th>
<th>Leasing program Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell</td>
<td>Customer can lease the Notebook and take-back or own at the EOL phase.</td>
</tr>
<tr>
<td>IBM</td>
<td>Customer can extend the leasing length, purchase the equipment outright, or returning leased assets to IBM Global Financing.</td>
</tr>
<tr>
<td>Toshiba</td>
<td>With Toshiba financial services, the lessee can choose to return or purchase the assets, or renew the lease for a shorter term.</td>
</tr>
</tbody>
</table>

Also many rental organizations offer a wide variety of leasing services to a large number of major business industries such as Banking & Investment, High Tech Companies, Small to Medium Business (SMB) and etc [13].

Therefore, leasing services has been viewed as a strategy for increasing resource productivity and minimizing waste generation for many companies [8,7,14]. In a leasing system, product life cycle loop is fully closed and product ownership is resided with the manufacturer. In the lease period, the product is used by consumer and after this period product is taken-back to the leasing company. During the lease period, repair and replacement cost is paid by the leasing company. At the end of leasing period consumer takes back the product to leasing company and the ownership of that product is remained by him whom is now responsible to recover the end-of-life value from its products. Leasing is environmentally advantageous, as it increases the probability of a product being reused, remanufactured, or recycled at the EOL phase and minimizes waste generation. Also it has social and economical impact. In Figure 1 the proposed sustainable leasing system is depicted.

![Fig. 1: The proposed sustainable leasing system.](image-url)
to recover as much value from his/her products as possible. In this phase, remanufactured product is leased to a new consumer with repaired, replaced or remanufactured parts for a new leasing period.

Besides the benefits of leasing for the manufacturer, consumers also have advantages when they lease a product instead of buying them. As such, they pay for the services provided by the product rather than for the product itself. Moreover, leasing products like computers makes it easier for customers to sooner upgrade to the newest technology. Certainly, product characteristics affect the viability of a leasing [15]. But during leasing period, because of repair and replacement, consumer has feel inconvenience and operational cost is increased because of product failure, handling cost, shortage cost, system down cost, waiting cost, etc. On the other hand by increasing the number of lease products, leasing company’s cost is increased due to buying product, increment employees and increasing EOL cost. Therefore considering all of sustainability objectives collectively and analyzing the trade-off between these objectives can help the leasing company to achieve sustainability through leasing services. Also consideration of uncertainty during services and EOL phase (such as product failure, repair and replacement distribution functions) is lacking in literature [16].

According to proposed problem, our model gives a better understanding of sustainable leasing services concept by considering tradeoffs between environmental, social and economical objectives.

The final goal of this paper will be to provide a model for sustainable leasing services and determining the number of leased products and leasing period with respect to environmental, economical and social impact of this process. However due to the fact that any product failure during consumption period has a very uncertain and probabilistic nature therefore the developed model should be able to accommodate all these uncertain conditions.

Contribution and objectives of this paper are as follow:

- We model the impacts of three objectives of sustainability, named: environmental, economical and social for leasing services.
- For evaluation of each objective, indicators are determined and quantified by mathematical model. For quantifying social indicator, Analytical hierarchy process (AHP) has been utilized to calculate social impacts. Also life cycle analysis (LCA) has been applied to investigate the environmental impact of leasing process.
- For demonstrating proposed problem, simulation modeling and optimization technique will be applied. Real situations of leasing operations such as product failure rate or repair and replacement probability functions can model due to flexibility of this tool.
- At last, a case study for leasing computer notebooks in Iranian market will be applied and results will be discussed.

This paper is organized as follows. At first related literature survey on sustainable leasing services is reviewed. Then the methodology for modeling of sustainable leasing is proposed. In next section we demonstrate applying simulation modeling in sustainable leasing. The case study relating to the proposed problem is described and results are discussed. Finally, conclusions and suggestions for future studies are explained.

**Literature Review:**

In this section, a brief literature review on the role of leasing process in sustainable service-production development is presented. The main reason of our literature review is to ascertain the major achievements of previous researches in order to clearly differentiate our work from those studies.

Halme et al. [17] present a methodology for evaluation of over 200 European household services in seven different areas related to household consumption. Services were chosen that contribute to at least two of the three dimensions of sustainable development: environment, social aspects, and economy. The analyzed services are called sustainable home services indicating that they are provided to the customers directly at home or on the premises, and that they enhance sustainable development. It appears that the social effects of the assessed services are larger than their environmental and economic benefits. Kuo [18] investigated the options of purchasing or leasing by developing a simulation model. He used the office copy machines as an example to propose a maintenance service model on sell and leasing process. The service included maintenance, recycling, reverse logistics, and final waste disposal. Watanabe et al. [10] suggested the service process model to describe the influence of a service to multiple stakeholders. A bike rental company was analyzed as a case study and a simulation framework was developed for modeling a complicated service structure for the evaluation of company's leasing process. Mont et al. [19] propose a business model that integrates leasing services and remanufacturing strategies for baby pram manufacturers. They argued that, with appropriate design changes that enable easy and cheaper remanufacturing, utilizing the leasing option is expected to generate long-term sustainable profits, which otherwise would be lost to the second-hand market. Mangun and Thurston [20] presented a case study on personal computer to demonstrate eco-leasing advantage. The model developed in their paper applied constrained optimization modeling to help decision making regarding component reuse across multiple product lifecycles. This approach highlights the importance of leasing services on environmental product design. Thurston and Delatorre [21] have addressed many advantages of leasing with respect to
extended producer responsibility and sustainable production. Economical and Environmental aspects of leasing were optimized as a multi-attribute utility function. To better meet the needs of various customers, they introduced a product portfolio model. The model identified the optimal combination of decisions for remanufacturing, recycling or disposing of 88 components of personal computer among three different market segments over three product lifecycles. They also recommended that service contracts could be considered as engineering design decision variables at future works. Zhao et al [22] introduced a methodology to establish more efficient closed-loop, multiple life cycle product stewardship. A multiple life cycle design decision model was created to help manufacturers identify component level decisions to accommodate flexibility in the number of lifecycles according to different customer needs. The objectives of the model are environmental and economical impact of product at EOL phase. But the impact of product during leasing period was not modeled. Also the probabilistic factors such as product quality at the EOL phase or product failure rate during leasing period were not modeled. The model proposed by Sharma [23] described how leasing services for product with short life cycles, such as computers, can still be economical and environmentally beneficial. He developed a mixed integer linear program (MILP) to model relationships between transportation and disposal cost of product in leasing system. The model developed by Intlekofer et al. [24] considered energy consumption during leasing and EOL phase of a product and determined the optimum leasing period with respect to total energy consumption. But optimization of EOL options and number of leasing periods was not modeled. Also product was used for one lease period. In Table 2 the reviewed literature review on eco-leasing is summarized and compared.

### Table 2: Literature review on modeling sustainable services.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Sustainability objectives</th>
<th>Modeling Tool</th>
<th>Case study</th>
<th>Research output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halme et al. (2006)</td>
<td>✓</td>
<td>Questionnaire method</td>
<td>Home household</td>
<td>Sustainability indicators for sustainable services</td>
</tr>
<tr>
<td>Watanabe et al. (2011)</td>
<td>✓</td>
<td>Future research</td>
<td>Simulation</td>
<td>Bike</td>
</tr>
<tr>
<td>Mont et al. (2006)</td>
<td>✓</td>
<td>Linear programming</td>
<td>Baby pram</td>
<td>Number of bike</td>
</tr>
<tr>
<td>Kuo (2011)</td>
<td>✓</td>
<td>Simulation</td>
<td>the office copy</td>
<td>Maintenance time/service rule</td>
</tr>
<tr>
<td>Mangu and Thurston (2002)</td>
<td>✓</td>
<td>Reliability indicator</td>
<td>Utility function</td>
<td>Computer EOL options/Leasing period</td>
</tr>
<tr>
<td>Thurston and Torre (2007)</td>
<td>✓</td>
<td>Reliability indicator</td>
<td>Utility function</td>
<td>Computer EOL options/Leasing period</td>
</tr>
<tr>
<td>Zhao et al. (2010)</td>
<td>✓</td>
<td>Reliability indicator</td>
<td>Utility function</td>
<td>Computer EOL options/Leasing period</td>
</tr>
<tr>
<td>Intlekofer et al. (2010)</td>
<td>✓</td>
<td>Linear programming</td>
<td>Computer</td>
<td>Leasing period</td>
</tr>
</tbody>
</table>

As we can see in the literature, leasing services as a means for achieving sustainability is a relatively new concept. The final goal of this paper will be to provide a model for sustainable leasing services and determining the number of leased products and leasing period with respect to environmental, economical and social impact of this process. However due to the fact that any product failure during consumption period has a very uncertain and probabilistic nature therefore the developed model should be able to accommodate all these uncertain conditions.

Contribution and objectives of this paper are as follow:

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**Methodology for Modeling:**

For demonstrating the proposed model, we apply a simulation modeling tool which is presented in Section 3.1. Then the mathematical formulation of sustainability objectives for incorporating into the simulation model is presented in section 3.2.
a) Developing simulation model:

In this study, a simulation model is constructed to determine the number of leased notebooks and also the leasing period length with respect to economical, environmental and social objectives. The main reason for applying simulation modeling for the proposed model is to consider uncertainties and the risks associated with leasing process. The uncertainties which are created with repair, replacement and reuse strategy are quite obvious. For instance, product failure, disposal rate at EOL phase and recyclable parts carries a great deal of uncertainties. Furthermore, uncertainties are also involved in consumer arrival for getting leased product. Methods to deal with uncertainties vary from the group decision making to the use of multi-attribute indices and statistical tools. Among various existing statistical tools, Monte Carlo simulation is the classic approach to handle uncertainties [25]. Hence simulation approach is selected for the proposed problem. In this research, simulation is carried out by using ARENA simulation software [26]. The model is developed based on the problem described above, and the uncertainties are defined using relevant probability distributions from past practical experiences for consumer arrival rate, product failure, recycling, repairing and disposal rate of product. The developed model in ARENA software is shown in Figure 2.

![Simulation model](image)

**Fig. 2: Simulation model for proposed problem.**

As we can see in Figure 2, three sustainability criteria were calculated within leasing services and EOL phase. When consumer enter in system, receives lease product or wait for coming leased product. After leasing period, the product is taken back to the leasing company and then EOL decision is made and product is leased for new leasing period.

In next sub section, we describe mathematical formulation of each sustainability objectives which are incorporated in the simulation model.

b) Mathematical formulation:

At first, decision variables and parameters are listed and then the three objective functions are as follow.

**Input parameters:**

- $T$: Number of leased products during leasing period
- $T_r$: Product useful life
- $T_w$: Planning time
- $n_i$: Customer average waiting time for receiving product
- $A$: Customer arrival distribution function
- $r_d$: Disposal rate of a product at each EOL phase
- $r_r$: Recycling rate of a product at each EOL phase
- $r_p$: Repairing rate of a product at each EOL phase
- $p_l$: Price of a leased product per month
- $p_n$: Price of a new product
- $p_r$: Price of a remanufactured product
- $F_r$: Failure rate of each leased product
In order to estimate the environmental impact of products, SimaPro software [27] was used in many researches. This software is based on lifecycle assessment (LCA) method and classifies environmental impact into eleven categories and provides environmental impacts in terms of millipoints (mPt). Data on the weight of each component was taken from the SimaPro database and then Eco-indicator score was calculated, by establishing an inventory of all emissions to air and water as well as the necessary resource extraction for product manufacture [28]. However calculation the exact effect of environmental impact is not the purpose of this paper and relative environmental impact is sufficient in our model, so the Mangun and Thurston [29] results is used for quantifying environmental impacts.
(3) Estimation of social objective:

Social responsibility (SR) is defined as “the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large” [30]. Halme [17] have mentioned that the social indicators for services can be classified into six categories: Equity, Health, Safety and security, Comfort, Social contacts and empowerment information and awareness. Thurston and Delatorre [31] consider product reliability as one of the social sustainability objectives.

For incorporating social impact into the developed model, social indicators are selected with respect to the criteria which are determined by the panel of experts in computer industry in Iran. However, other social indicator simply can be added to developed model. Also the coefficient is quantified by these experts. These criteria are briefly described in Table 3.

<table>
<thead>
<tr>
<th>Issues</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer comfort</td>
<td>It means duration of lease period effect on consumer upset such as handling and waiting for repairing product. Therefore consumer comfort is related to product reliability. If product reliability is increased number of product failure and all mentioned consumer upset is decreased (Thurston and Torre; 2007).</td>
</tr>
<tr>
<td>Employment</td>
<td>Total number of notebooks being leased creates different number of job opportunities in leasing company.</td>
</tr>
<tr>
<td>Consumer satisfaction level</td>
<td>It depends on product availability when consumer requests a product.</td>
</tr>
</tbody>
</table>

Each indicator in Table 3 has its own unit. Also these indicators should be merged to create the total social objective. Therefore, for computing the total social objective, the AHP model was applied [32]. Through applying AHP approach, the problem sets as a hierarchy, where the topmost node is the overall social indicator, while subsequent nodes at lower levels consist of the criteria which are used for building overall social indicator. The developed AHP is shown in Figure 3.

![Fig. 3: Hierarchy of decision making for social impact of given number of leased product and lease length.](image)

The important factors for overall social indicator are the number of leasing product and the leasing length. So, different number of products and leasing length can have different social impacts. The final normalized weight for different proposed variables can be included in mathematical representation of social objective function. The mathematical formulation of social objective is presented in Eq. (3).

$$\text{Max} Z_s = w_1 \times (e^{-\lambda p(l)}) + w_2 \times (\lambda \times n) + w_3 \times (T_w)$$ (3)

The first part of Eq. (3) is related to consumer comfort. As mentioned before, this part is modeled through reliability of leased product. The reliability is defined as the probability that a product will not fail within its leasing period. Therefore we apply Eq. (4) for modeling product reliability [33].

$$R_p(l) = e^{-\frac{l}{\theta}p}$$ (4)

Where $R_p(l)$ is product reliability which is leased for life of $l$, $\theta$ is characteristic life of product and $b$ is slope of the Weibull distribution. These two last parameters are defined by analyzing historical data from leased product.

The second part of Eq. (4) models the number of employment which is needed to handle leasing process. The last of Eq. (4) part formulate consumer satisfaction factor by customer average waiting time for receiving product. Also $w_i$ is the importance factor of indicators. The final normalized weight of these social indicators
Numerical Example:

In recent years sales of notebooks have increased drastically in Iran and well over 500,000 notebooks are sold per year [34]. Also environmental impacts of computers are more serious than other electrical products and could pose severe impacts on human health and the eco-system when they are not well managed during consumption and EOL phase [35].

Therefore in this study we consider a leasing company which leases notebooks. Data for analysis have been provided by the field engineers of the service centers that carry out repairs, replacement and upgrading of the notebook during leasing and product EOL phase. Probability function of consumer arrival and product failures is fitted by input analyzer software [26]. The data on the failure rates of parts have been provided by Iranrahjoo company service centers which is the official service provider of Sony notebooks in Iran market [36]. Table 4 shows input parameters for the proposed model.

### Table 4: Summarized input parameters.

<table>
<thead>
<tr>
<th>Input parameter</th>
<th>Value</th>
<th>Input parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_l$</td>
<td>$30</td>
<td>$C_{EOL}$</td>
<td>$50</td>
</tr>
<tr>
<td>$p_c$</td>
<td>$950</td>
<td>$c_{r_0}$</td>
<td>$2</td>
</tr>
<tr>
<td>$p_r$</td>
<td>$500</td>
<td>$c_r$</td>
<td>$4</td>
</tr>
<tr>
<td>$F_r$</td>
<td>Triangular (.06,0.1,0.18)</td>
<td>$c_s$</td>
<td>$500</td>
</tr>
<tr>
<td>$r_a$</td>
<td>0.1 $F_r$</td>
<td>$\lambda$</td>
<td>0.02</td>
</tr>
<tr>
<td>$r_c$</td>
<td>0.1 $F_r$</td>
<td>$E_c$</td>
<td>1027</td>
</tr>
<tr>
<td>$r_e$</td>
<td>0.6 $F_r$</td>
<td>$E_e$</td>
<td>654</td>
</tr>
<tr>
<td>$b$</td>
<td>1</td>
<td>$E_r$</td>
<td>231</td>
</tr>
<tr>
<td>$A_r$</td>
<td>Expo(0.08) month</td>
<td>$\theta$</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Also comparison of the relative importance of social criteria is presented in Table 5. As mentioned before, importance of social criteria quantified by the panel of experts in the field of leasing notebooks in Iran.

### Table 5: Comparisons of the relative importance of social criteria.

<table>
<thead>
<tr>
<th>Social criterion</th>
<th>Consumer comfort</th>
<th>Employment</th>
<th>Consumer satisfaction level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer comfort</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Employment</td>
<td>0.25</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Consumer satisfaction level</td>
<td>0.33</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Total weight</td>
<td>0.53</td>
<td>0.29</td>
<td>0.16</td>
</tr>
</tbody>
</table>

The model was simulated for 5 years. During this five years, leasing company decide on number of leased product and leasing length with respect to environmental, economical and social objectives. The number of simulation replication is calculated by Kuo [18]. This formula is shown in Eq. (5).

$$n^*_{i}(\gamma) = \min \left\{ i \geq n: \frac{t_{1-\alpha(i)}s(n)/i}{X(n)} \leq \gamma \right\}$$

According to this formula, for calculating number of simulation replication ($n^*_{i}(\gamma)$), the model runs for number of test run ($n$). Then mean ($X(n)$) and variance ($s^2(n)$) of the customer average waiting time for test runs were substituted in the above equation to calculate the number of simulation runs. For applying this formula, the developed simulation model run for fifteen times ($n=15$). Other parameters are defined as follow:

$$n^*_{i}(0.05) = \min \left\{ i \geq 15: \frac{t_{1-\alpha(i)}0.0071/0.02}{0.05} \leq 0.05 \right\}$$

According to Eq. (6), Number of replication ($i$) should be 15 for achieving 5% error ($\gamma = 0.05$).

RESULTS AND DISCUSSION

According to the developed model, nine scenarios are suggested. The model is solved for 600, 700 and 1000 notebooks with varying leasing length from 1 to 3 years. Results are summarized in Table 6.

As we can see in Table 6, the economical and social objective is increased by means of increasing number of products or leased length. Also the negative environmental impact is increased. The leasing company can arrange the number of notebooks and leasing period according to this evaluation result. For more analysis, leasing company can compare results with respect to each objective function by applying AHP model [32].
These comparisons are made between each indicator with respect to the top node (Figure 4). For example, The AHP model constructed for the 600, 700 and 1000 leased notebooks with fixed 1 year leasing period.

**Table 6: Summarized results for the proposed model.**

<table>
<thead>
<tr>
<th>Number of notebooks</th>
<th>Leasing length (month)</th>
<th>Environmental (mPt)</th>
<th>Economical ($)</th>
<th>Social (× 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>12</td>
<td>12,970</td>
<td>68,747</td>
<td>239</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>24,643</td>
<td>124,432</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>32,425</td>
<td>151,243</td>
<td>96</td>
</tr>
<tr>
<td>700</td>
<td>12</td>
<td>15,879</td>
<td>120,461</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>30,170</td>
<td>218,034</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>39,698</td>
<td>265,014</td>
<td>118</td>
</tr>
<tr>
<td>1000</td>
<td>12</td>
<td>22,951</td>
<td>186,465</td>
<td>455</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>43,607</td>
<td>337,502</td>
<td>285</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>57,378</td>
<td>410,223</td>
<td>182</td>
</tr>
</tbody>
</table>

**Fig. 4: Hierarchy of decision making for sustainable services through leasing process.**

According to Figure 4, for calculating the sustainable services, the weight of each criteria is assumed to be same (environmental= economical= social= 33.33%). The pair-wise comparisons with respect to each objective are calculated in Table 7.

**Table 7: The pair-wise comparisons of each objective.**

<table>
<thead>
<tr>
<th>Environmental comparisons</th>
<th>Economical comparisons</th>
<th>Social comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Note books</td>
<td>Number of Note books</td>
<td>Number of Note books</td>
</tr>
<tr>
<td>600 700 1000</td>
<td>600 700 1000</td>
<td>600 700 1000</td>
</tr>
<tr>
<td>Number of Note books</td>
<td>1.00 0.57 0.37</td>
<td>1.00 0.81 0.53</td>
</tr>
<tr>
<td>700 1.75 1.00 0.65</td>
<td>1.22 1.77</td>
<td>1.23 1.00 0.65</td>
</tr>
<tr>
<td>1000 2.71 1.55 1.00</td>
<td>0.82 1.00 1.45</td>
<td>1.90 1.55 1.00</td>
</tr>
</tbody>
</table>

Figure 5 shows the final results of each objective for the 600, 700 and 1000 leased notebooks with fixed 1 year leasing period.

According to Figure 5, by comparing various given decisions, if all objective has same weight factor, then the decision with 1000 notebooks seems more sustainable than other decisions. But this decision has less environmental friendly impact than decisions with 600 or 700 notebooks. Same as this analysis, Fig 6 shows the comparison of nine scenarios with respect to environmental, economical and social objectives. These analyses perform with equal weights for objectives (ie: environmental weight= economical weight = social weight = 33.33%).

According to Figure 6 and Table 6, the social and economical objectives are increased by means of increasing the number of notebooks in the same leasing period. But the impact of environmental objective is decreased as the environmental impact has increased due to increase in number of notebooks. Also the social objective has more impact than economical and environmental objectives by means of increasing the number of
notebooks. For example with 1000 notebooks and 12 month leasing, social objective has more impact than economical and environmental due to increasing customer satisfaction and increased number of employment.

Fig. 5: Comparing sustainability of each decision for leasing services.

For determining the optimal solution of the proposed problem, simulation-based optimization method was applied through OptQuest software [37]. This software combines the meta-heuristics of Tabu Search, Neural networks and Scatter Search algorithm into simulation model and optimizes the combination of simulation and mathematical model. Figure 7 shows the main parts of the developed simulation optimization model.

With this technique, the leasing period and the number of leased notebooks is optimized without evaluating all possible setting of variables. Variables (the leasing period and number of leased notebooks) are changed after any replication of the model with respect to total objective function. The weight of each criteria is environmental= economical= social= 33.33%. The model runs for 700 replications. Results are shown in Figure 8.

According to Figure 8, optimized results of the proposed model with different weight of each objective are depicted in Table 8.

With applying the developed model, decision makers can analyze the impacts of number of leased products and leasing length on sustainability objective. With respect to leasing company preferences and importance of each objective, optimal solution can be determined. For example, if environmental impact is more important than other objectives, so the optimal leasing length and the number of leased product are 26 month and 921 notebooks, respectively.
Fig. 7: The main parts of the developed leasing model.

**Objective 1:** To maximize the total profit during leasing and product EOL phase

**Objective 2:** To minimize the total Environmental impacts during leasing and product EOL phase

**Objective 3:** To maximize the total Social impacts during leasing and product EOL phase

The developed model

<table>
<thead>
<tr>
<th>Simulation optimization model for sustainable services</th>
</tr>
</thead>
</table>

Fig. 8: Optimal solution for developed model.

Table 8: Optimal results for the proposed model.

<table>
<thead>
<tr>
<th>weight of each criteria</th>
<th>Optimized solution</th>
<th>Optimized criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leased length (month)</td>
<td>Number of Notebooks</td>
</tr>
<tr>
<td>Ecological</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Economical</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Social</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Conclusions and Future Research Directions:

In this paper, we dealt with Enhancing sustainable product-service system through leasing process. Regarding multi-dimensional concept of sustainability, we considered all sustainability objectives named: environmental, social and economical.

It is important to solve such problems, as in many developing and consumable countries, such as Iran, because of governmental structure of many organizations; they prefer to lease rather than buy the notebook computers. Therefore, if leasing systems are provided for these organizations, they can decide on best economical and environmental and social impact of their decisions. So the developed model which is considering all sustainability objectives is becoming very important for leasing companies.

Our model will enable these companies to select the best leasing period and number of leased product based on sustainability objectives. For solving the developed model, a simulation modeling was applied for the
problem. Also for optimizing the proposed model, a simulation optimization technique was applied and results
were analyzed. The proposed model was examined through an example by using industrial data in Iran.

Some of the future research directions that can be derived from the work presented here are as follow:
1. Regarding to sustainability concept, in the proposed model, social impacts of each decision is quantified.
Also other social issues such as security and consumer awareness can be incorporated in to the future model.
2. In this paper, sustainable-leasing was modeled and advantage of this was illustrated by simulation modeling.
In recent years comparison of leasing versus selling for achieving sustainable development is growing [38]. But
comparing leasing and selling model in uncertain environment is an unexplored area and is suggested for future
researches.
3. Simulation optimization was developed for modeling the proposed problem. Also game theory model can be
applied for modeling both consumer and leasing company preferences as players in leasing problem.

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