Research Journal of Applied Sciences, Engineering and Technology 11(10): 1124-1138, 2015
DOI: 10.19026/rjaset.11.2127
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 2, 2015 Accepted: August 2, 2015 Published: December 05, 2015

Research Article

Enhancing Economical, Environmental and Social Objectives through Leasing Services

[1]Alireza Noorbakhsh, [2]Sajjad Shokohyar and [3]Armin Aalirezaei
[1]Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy
[2]Department of Information Management, Shahid Beheshti University, G.C., Tehran, Iran
[3]Department of Industrial Engineering, Semnan University, Semnan, Iran

Abstract: What human has been doing on earth natural system till now is competitively unfair consuming of limited resources, continuing this trend without thinking of sustainable development caused irreparable destruction. Sustainable leasing is an effective tool for fulfilling consumer's demands with attaining high level of resources productivity. Current researches are just focused on economical and environmental consideration. Hence in this study; a model is developed to help leasing companies to achieve sustainable development. The objective of this model is to design a sustainable leasing system, in which economical, environmental and social impacts are balanced during leasing and its EOL phase from customers and leasing company point of views. To solve the problem, Multi-Objective Genetic Algorithm (MOGA) has been applied to find the Pareto-optimal solutions. These Pareto-optimal solutions will give some trade off information about the three mentioned objectives. So decision makers can analysis the variability of economical impact in compare to environmental and social improvements. Finally, a company of electronic leasing has been considered for a case study to validate the method and potential applications of the developed model.

Keywords: End of life, genetic algorithm, leasing, sustainability

INTRODUCTION

Limited resources have been being consumed by unsustainable use of human (Giljum *et al*., 2008). Resources consumption gains vital importance once it accounts for up to one-third of the product cost. Hence we can consider energy consumption as a strategic input for the establishment of any economic and social development policy (Melo *et al*., 2013). Sustainable development strategy is essential for making balance between demand and fair consumption in competitive situation (Bringezu *et al*., 2014). 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" (United Nations, 1987). 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 simultaneously fulfills three pillars in product development; environment, social and economy, is entirely sustainable.

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 (Quirke, 1996). By leasing, the organization retain the ownership of the product throughout its life cycle (Stahel, 1997) 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 leasingcompany. At the end of leasing period, the consumer returns the product to the leasing company which becomes responsible for product EOL recovery (Shokohyar *et al*., 2013). The leasingcompany must consider economical, environmental and social impact of their products during the use and EOL phases in order to achieve sustainability (Mont, 2002; Robert *et al*., 2002; Fishbein *et al*., 2000).

Actually, sustainable leasing company's activities and decision making 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 (Mont, 2004).

Corresponding Author: Armin Aalirezaei, Department of Industrial Engineering, Semnan University, Unit 12, No. 7(Gandi Building), Gandi St, Tehran, Iran, Postal Code: 1517613337, Tel.: (+9821)88195679, Ph: (+98)9124607284, (+98)9356062146

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 (Mont, 2002; Robert *et al*., 2002; Fishbein *et al*., 2000). 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) (Wei and Roger, 2011). 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" (Fishbein *et al*., 2000; Stahel, 1997).

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 deprecation rate while maximizing take-back value (Wei and Roger, 2011). A lease is less risky for consumer and positively affects the consumer's tax situation (Bierman, 2003). Therefore, the key to an economic "win" is the relationship between depreciation, take-back value and cost of leasing (Wei and Roger, 2011). According to learning curve Leasing can reduces maintenance costs over time (Wang and Lee, 2001). 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.) (Chien, 2005). 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 (Erkoyuncu *et al*., 2011).

Small and medium enterprises support a balanced local economy by providing job opportunities and industry diversity (Chong *et al*., 2013). From the social perspective, social impact in sustainable leasing system positively increases by employment inside and outside of the leasing company, for instance products such as electronics characterizing disposition practices for end-of-life is a key step in developing policies that prevent negative environmental and health impacts while maximizing potential for positive social and economic benefits though reuse. Reuse of end-of-first-life electronics can positively impact society. The lower price of second hand electronics, compared to new devices and increasingly prevalent electronics donation programs are escalating computer accessibility in low income communities around the world. Increased accessibility is lauded for helping reduce the digital divide and improve contemporary education settings. Moreover, small and medium businesses in developing countries view the used computer trade as an opportunity to redefine traditional business (Babbitt *et al*., 2011). Postconsumer electronics disposition industry, particularly through asset management, refurbishment, manufacturing, materials and parts recovery and material processing. This young and growing economic activity creates employment in developed and developing countries. In 2006, the electronics disposition industry in the United States created more than 19 000 jobs, more than 100% increase compared with reported 2003 values (IAER, 2006).

The main objectives of sustainable leasing system are:

- The performances of leasing company during leasing period and in EOL decisions result in minimizing effects of producing the product in environment. This process is held by using its core competency which is repairing during leasing period and optimized using of product at the end of its useful life.
- In the vision of consumer, the leasing of product provides more economical benefits in comparison with buying since they pay as much as they use and they are exempt from maintenance cost because leasing organization is in charge of such cost, on the other hand leasing organization minimizes the total cost during leasing periods and the product recovery costs at the end of useful life.
- Achieving social benefits such as safety, consumer satisfaction, local development, employment, reliability, product risk and so forth.

In this study, a mathematical model is developed for optimized balancing between sustainability's pillars and then we try to fit our model in case study which is about laptop leasing company in Iran,. To solve the problem, Multi-Objective Genetic Algorithm (MOGA) has been applied to find the Pareto-optimal solutions. These Pareto-optimal solutions will give some trade off information about the three mentioned objectives.

LITERATURE REVIEW

Recently leasing has been found as a strategy towards sustainability (Clark, 1978). Fishbein *et al.* (2000) compared leasing to selling process in a practical way, the established result proves leasing increases productivity, avoiding waste generation and using primary materials as much as possible. Some companies have been exampled as leasing company which gain benefits when leasing period is finished. Mangun and Thurston (2002) worked on their case study about eco-leasing of personal computer and incorporating component reusing, remanufacturing along several life cycles and recycling into product portfolio design. What comes out from their research

Table 1: Summarized sustainable leasing literature review

Publication	Lease period	EOL phase	Environmental	Economical	Social	Consumer/leasing Company view point	Modeling tool	Outputs
Fishbein *et al*. (2000)	✓	✓		✓		Leasing company	Mixed integer linear Program	Lease period
Mangun and Thurston (2002)		✓	✓	✓		Leasing company	Mathematical utility Function	EOL options
Thurston and De La Torre (2007)		✓	✓	✓		Leasing company	Mathematical utility Function	EOL options
Zhao *et al*. (2010)		✓	✓	✓		Leasing company	Mathematical utility Function	EOL options/lease period
Sharma (2004)		✓		✓		Leasing company	Mixed integer linear Program	EOL options/lease period
Kuo (2011)	✓			✓		Leasing company	Simulation modeling	Lease period
Shokohyar and Mansour (2014)	✓	✓	✓	✓		Consumer/leasing company	Simulation modeling	EOL options/lease period
Subramanian *et al*. (2005)	✓	✓		✓		Consumer/leasing company	Linear programming	Lease period
Intlekofer *et al*. (2010)	✓		✓	✓		Leasing company	Linear programming	Lease period

was the importance of modeling product's environmental impact at the end of life cycle, but they have not measured environmental and economic effects during leasing period. Thurston and De La Torre (2007) remarked Leasing and extended producer responsibility for personal computer component reuse and have also demonstrated many advantages of leasing with respect to extended producer responsibility and sustainable production. Economical and environmental impacts of leasing were optimized as a multi-attribute utility function. They presented a model which determines the optimal mixture of decisions for end of life among various market segment over different product life cycles. They recommended thinking about service contracts during leasing period as an effective factor for future engineering design of leasing model (Zhao *et al*., 2010).

Introduced varying lifecycle lengths within a product take-back portfolio and developed a leasing model which focused to take-back portfolio. The main objective of their model is economical and environmental impact at products EOL phase, but the product impact during leasing period was not considered. In addition the probabilistic nature of product quality was not included. Sharma (2004) developed a mixed integer linear program in a leasing system to model relationships between product transportation and disposal costs. Kuo (2011) simulated repair, replacement and remanufacturing cost during leasing based on product service system and compared these costs with.

Purchase cost. Shokohyar *et al*. (2013) developed a model which enables leasing Companies to select the best leasing duration and EOL options based on environmental and economical objectives. A simulation-based optimization method was applied to solve the model. A case study of a notebook computer with 30 components was used to illustrate the application of the developed model. Furthermore Shokohyar and Mansour (2014) designed a model which assist leasing companies to select the best leasing period and number of leased product based on sustainability objectives. However, EOL options were not included in their research. A simulation-based optimization method was applied to solve the model (Subramanian *et al*., 2005). Find the optimal leasing period and their presented model minimizes all costs in both, company and customer during leasing and EOL phases. Intlekofer *et al*. (2010) tried to find an optimal leasing period regarding the energy consumption during leasing and product EOL phases. However, Optimization of number of leasing periods and EOL options were not involved in mentioned researches.

Table 1 summarizes and compares the relevant literature on sustainable-leasing concept. In Table 1, there are few studies on developing a connection between consumption period and EOL phase in leasing systems. Accomplished gap analysis on Table 1 illustrates social aspect in all models were not included. Regarding sustainability concept, social impact during leasing period and after each EOL decision could be quantified and tradeoff between objectives should be defined (Shokohyar *et al*., 2013).

Contribution and objectives of this study are as follow:

- This research has explored leasing company's social achievements such as employment.
- For demonstrating the purposed problem, Multi-Objectives Genetic Algorithm is applied for modeling the uncertain conditions in the leasing process.

- A case study for laptop in Iranian computer market will be applied and the results will be discussed. The proposed model will be examined through an example by using a real data representing leasing situation for laptops in Iran. Also environmental parameters will be quantified by SimaPro software. Then the relation between leasing periods and EOL decision will be discussed. The main goal of this study is to propose a model considering all three aspects of sustainability, leasing periods and EOL phase.

MATHEMATHICAL MODEL AND OPTIMIZATION ALGORITHM

The objectives of the developed model are to optimize economical, environmental and social impacts during leasing periods and the EOL phase. Figure 1 gives schematic illustration for better understanding of this concept.

Three aspects of sustainability come in the left side of the leasing company. Two issues have to be considered for environment which are Life Cycle Assessment (LCA) and End of Life (EOL). This research considers only employment perspective in Social aspect. From economic point of view we have five kinds of costs included Employment Cost, EOL cost, Transportation cost, leasing period cost and buying cost and one gaining which is leasing gain. In the right side of the leasing company, the main activities that company is doing are hiring employees, transporting the goods, maintenance services and finally activities which have been considered when the products reach end of it's life.

According to conceptual model, the objective functions and constraints can be explained as follows:

Mathematical model: In this section proposed model is presented. The index set parameters of the model and decision variables are summarized as follows:

Indices and parameters:

n = Number of parts
i = Index set of product parts where i = 1... n
K = Number of products
k = Index set of product where k = 1… K
J = Index set of EOL options where j = 1… 4
T_P = Number of Leasing Period
h = Leasing period where h = 1…T_p
t_h = Duration of leasing period
$\alpha_{k,h}$ = Rate of employment for product k during leasing period h
F1 (t) = The cumulative distribution function for repairing part i
F2 (t) = The cumulative distribution function for replacing part i
β = The shape parameter of the Weibull distribution
$\lambda_{i,k,h}$ = Failure rate in Weibull distribution function for part i in product k during leasing period h

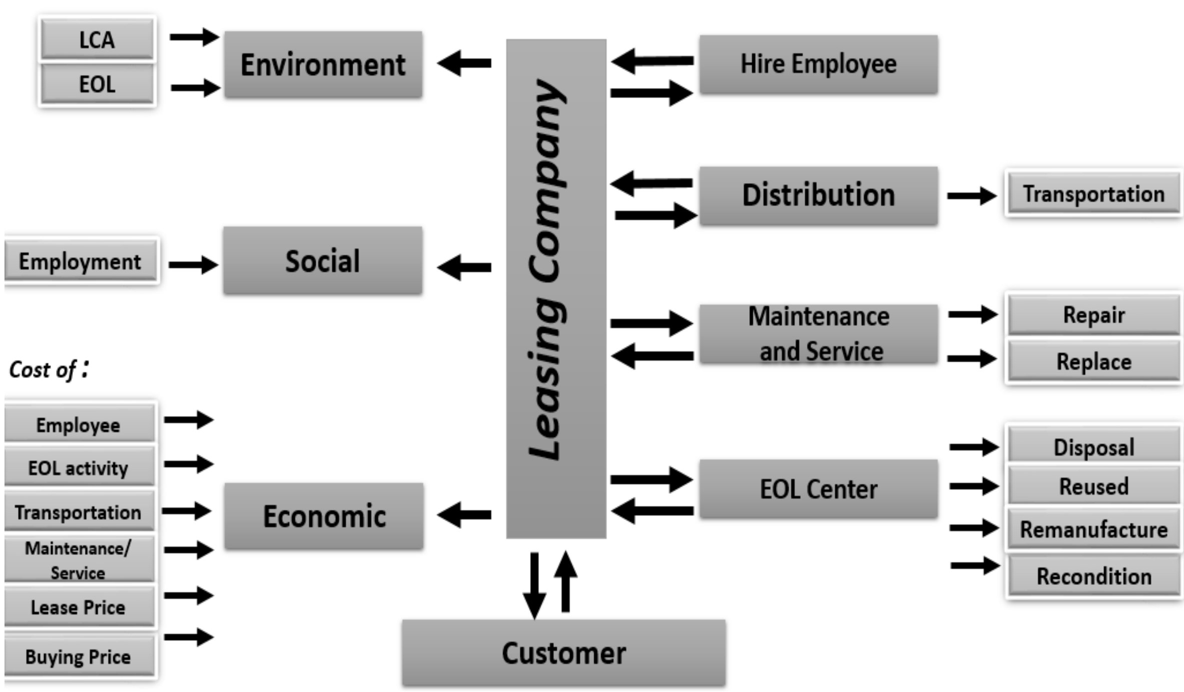

Fig. 1: Conceptual model of a sustainable leasing company

$\lambda_{1,i,k,h}$ = Failure rate due to repairing in Weibull distribution function for part i in product k during leasing period h

$\lambda_{2,i,k,h}$ = Failure rate due to replacing in Weibull distribution function for part i in product k during leasing period h

M (t) = Expected number of product failure during time t

$Q_{j,i,k}$ = Degree of quality of the part i after the treatment for EOL option j for product k

Q_k = Minimum quality level of a product required for reuse

B_k = Buying price of product k

n = Number of parts

i = Index set of product parts where i = 1... n

K = Number of products

k = Index set of product where k = 1… K

J = Index set of EOL options where j = 1… 4

T_P = Number of Leasing Period

h = Leasing period where h = 1…T_p

t_h = Duration of leasing period

$\alpha_{k,h}$ = Rate of employment for product k during leasing period h

F1 (t) = The cumulative distribution function for repairing part i

F2 (t) = The cumulative distribution function for replacing part i

β = The shape parameter of the Weibull distribution

$\lambda_{i,k,h}$ = Failure rate in Weibull distribution function for part i in product k during leasing period h

$\lambda_{1,i,k,h}$ = Failure rate due to repairing in Weibull distribution function for part i in product k during leasing period h

$\lambda_{2,i,k,h}$ = Failure rate due to replacing in Weibull distribution function for part i in product k during leasing period h

M (t) = Expected number of product failure during time t

$Q_{j,i,k}$ = Degree of quality of the part i after the treatment for EOL option j for product k

Q_k = Minimum quality level of a product required for reuse

B_k = Buying price of product k

$L_{p,k}$ = Lease price for product k

$C_{P_{i,k,h}}$ = New material purchase cost of part i in product k during leasing period h

$C_{RE_{i,k,h}}$ = Remanufacturing cost of the part i in product k at the end of leasing period h

$C_{RC_{i,k,h}}$ = Reconditioning cost of the part i in product k at the end of leasing period h

$C_{A_{k,h}}$ = Assembly cost for product k associated leasing period h

$C_{D_{k,h}}$ = Disassembly cost for product k associated leasing period h

$C_{S_{i,k,h}}$ = Disposal cost of the part i for product k at the end of leasing period h

$C_{TK_{i,k,h}}$ = Take-back cost which is caused by transportation cost of part i in product k at the end of leasing period h associated with EOL phase

$CO_{i,k,h}$ = Consumer cost due to part i failure for product k during leasing period h

$C_{l,1,i,k,h}$ = Manufacturer's cost due to repairing part i for product k during leasing period h

$C_{l,2,i,k,h}$ = Manufacturer's cost due to replace part i for product k during leasing period h

$C_{\ EM_{k,h}}$ = Cost of employment of product k associated leasing period h

$C_{\ N_{k,h}}$ = Cost of transportation of product k associated leasing period h

$C_{j,i,k,h}$ = EOL recovery cost for part i at EOL option j for product k at the end of leasing period h

$E_{\ P_{i,k,h}}$ = Environmental impact of purchasing part i for product k at the end of leasing period h

$E_{\ RE_{i,k,h}}$ = Environmental impact of remanufacturing part i for product k at the end of leasing period h

$E_{\ RC_{i,k,h}}$ = Environmental impact of reconditioning part *i* for product k at the end of leasing period h

$E_{A_{k,h}}$ = Assembly Environmental impact of product k associated leasing period h

$E_{S_{i,k,h}}$ = Environmental impact of part i disposal for product k at the end of leasing period h

$E_{TK_{i,k,h}}$ = Environmental impact of product take- back which is caused by transportation of part i in product k at the end of leasing period h associated with EOL phase

$E_{l,1,i,k,h}$ = Environmental impact of repairing part i for product k during leasing period h

$E_{l,2,i,k,h}$ = Environmental impact of replacing part i period for product k during leasing period h

$E_{j,i,k,h}$ = Environmental impact of selecting EOL option j for part i for product k at the end of leasing period h

$EO_{k,h}$ = Environmental impact due to product transportation to the leasing company for product k associated leasing period h

W_{EM} = Normalized weight of employment involved in distribution

$EM_{D,k,h}$ = Employment score of distributing product k or any part of it associated leasing h

$EM_{s,1,k,h}$ = Employment score of repairing product k or any part of it during period leasing h

Decision variables:

$Y_{j,k,h}$ = If each maintenance service option is selected for product k during leasing period h then $Y_{j,k,h}$ equals to"1," otherwise equals to "0.

$X_{1,i,k,h}$ = If part i of product k is disposed at the end of leasing period h then $X_{1,k,i,h}$ equals to "1", otherwise 0

$X_{2,i,k,h}$ = If part i of product k is reused at the end of leasing period h then $X_{2,k,i,h}$ equals to "1", otherwise 0

$X_{3,i,k,h}$ = If part i of product k is remanufactured at the end of leasing period h then $X_{3,k,i,h}$ equals to "1", otherwise 0

$X_{4,i,k,h}$ = If part i of product k is reconditioned at the end of leasing period h then $X_{4,k,i,h}$ equals to "1", otherwise

S_1 = If product or any part of it need to be repaired then S_1 equals to "1", otherwise

S_2 = If product or any part of it need to be replaced then S_2 equals to "1", otherwise 0

The objective functions can be explained as follows:

Economical objective function: The economical objective function includes leasing period costs, product EOL costs, employee cost, transportation costs, buying cost and leasing price. The mathematical formulations of these costs are explained as follows:

Leasing period costs: Total repair and replacement cost depends on the product failure rate. The general failure time distribution in reliability is the exponential distribution, which is appropriate as long as the products fail at a constant rate (Blischke and Murthy, 1996). However, many products do not have a constant failure rate. The Weibull distributions can be used to model in the situations of increasing or decreasing failure by appropriate selection of parameter values. Therefore, in the present study we consider that F (t) follows a Weibull distribution with failure rate λ and shape parameter β which is given by Eq. (1) (Ahluwalia and Nema, 2007):

$$F(t) = 1 - e^{-(\lambda t)^{\beta}} \tag{1}$$

Then, the expected number of product failures during time *t* can be obtained by Eq. (2):

$$M(t) = (\lambda t)^{\beta} \tag{2}$$

The cost of product failure during leasing period depends on expected number of product failure and relevant costs of product's repair or replacement. Repair and replacement costs are in charge of maintenance and service's responsibility during leasing period. Therefore the expected value of total cost during leasing periods is obtained by Eq. (3):

$$\sum_{h=1}^{T_P}\sum_{k=1}^{K}[[\sum_{i=1}^{n}[C_{l,1,i,k,h} \times (\lambda_{1,i,k,h}t_h)^{\beta} + Cl,2,i,k,h \times (\lambda 2,i,k,hth)\beta]]] \tag{3}$$

As far as customer is concerned, apart from the cost of product failure and its resultant inconveniences' costs, he/she should also pay for the transportation cost to leasing company. The consumer cost is calculated based on the expected number of failures shown in Eq. (4):

$$\sum_{h=1}^{T_P}\sum_{k=1}^{K}\sum_{i=1}^{n} \lambda_{i,k,h} \times CO_{i,k,h} \tag{4}$$

The expected number of repairs and replacements were determined based on simulation results and then were multiplied by manufacture's cost due to repairing and replacing parts.

EOL cost: At EOL phase, one of these options should implemented: Reuse, Recondition, Remanufacture or dispose. Each of these mentioned options has its own cost, so the EOL cost is written as fallow:

$$\sum_{h=1}^{T_P}\sum_{k=1}^{K}\sum_{i=1}^{n}\sum_{j=1}^{4}[X_{j,i,k,h} \times C_{j,i,k,h}] \tag{5}$$

where,

$$C_{1,i,k,h} = C_{D_{k,h}} + C_{P_{i,k,h}} + C_{A_{k,h}} + C_{S_{i,k,h}} + C_{TK_{i,k,h}}$$
$$C_{2,i,k,h} = C_{TK_{i,k,h}}$$
$$C_{3,i,k,h} = C_{D_{k,h}} + C_{RE_{i,k,h}} + C_{A_{k,h}} + C_{TK_{i,k,h}}$$
$$C_{4,i,k,h} = C_{D_{k,h}} + C_{RC_{i,k,h}} + C_{A_{k,h}} + + C_{TK_{i,k,h}}$$

Employment cost: The expected number of associated employees to a certain product (α) multiply by average paid to these employee presented employment cost. The employment cost is written as follow:

$$\sum_{h=1}^{T_p}\sum_{k=1}^{K}\alpha_{k,h}\,\bar{C}_{EM,k,h} \tag{6}$$

Transportation cost: Transportation cost occur between customer and service center. Therefore transportation cost is given as follow:

$$\sum_{h=1}^{T_p}\sum_{k=1}^{K}\sum_{j=1}^{4}[Y_{j,k,h} \times C_{N,k,h}] \tag{7}$$

Buying cost: Apart from above mentioned costs, leasing company has another cost which named "buying cost"(B_k). Leasing company pays for buying products from it's earlier chain, these buying prices are calculated as follow:

$$\sum_{k=1}^{K} B_k \tag{8}$$

Leasing gain: Leasing gain includes all received account from customers to leasing company. Leasing price is determined by marketing and finance professionals through pricing analysis, then the total amount gained by leasing company is sum of the leased product prices according to their number of leased periods.

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} L_{P,k} \times h \times t_h \tag{9}$$

$$\text{Min } Z_1 = \sum_{h=1}^{T_P} \sum_{k=1}^{K} [[\sum_{i=1}^{n} [C_{l,1,i,k,h} \times (\lambda_{1,i,k,h} t_h)^{\beta} + C_{l,2,i,k,h} \times (\lambda_{2,i,k,h} t_h)^{\beta}]]] + \sum_{h=1}^{TP} \sum_{k=1}^{K} \sum_{i=1}^{n} \lambda_{i,k,h} \times CO_{i,k,h} + \sum_{h=1}^{TP} \sum_{k=1}^{K} \sum_{i=1}^{n} \sum_{j=1}^{4} [X_{j,i,k,h} \times C_{j,i,k,h}] + \sum_{h=1}^{Tp} \sum_{k=1}^{K} \alpha_{k,h} C_{EM,k,h} + \sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{j=1}^{4} [Y_{j,k,h} \times C_{N,k,h}] + \sum_{k=1}^{K} B_k - \sum_{h=1}^{T_p} \sum_{k=1}^{K} L_{P,k} \times h \times t_h \tag{10}$$

Environmental objective function:

Environmental impacts during leasing period: Environmental impacts occurring during leased periods, can be calculated based on the expected number of repair and replacement operations shown in Eq. (10). Therefore, similar to the cost objective function, environmental impacts during leased periods are as follow:

$$\sum_{h=1}^{T_p} \sum_{i=1}^{n} \sum_{k=1}^{K} [E_{l,1,i,k,h} \times (\lambda_{1,i,k,h} t_h)^{\beta} + E_{l,2,i,k,h} \times (\lambda_{2,i,k,h} t_h)^{\beta}] \tag{11}$$

EOL environmental impacts: Depending on the EOL decision for each part, the EOL environmental impacts is estimated as fallow:

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} \sum_{j=1}^{4} X_{j,i,k,h} \times E_{j,i,k,h} \tag{12}$$

Each EOL option has environmental impact ($E_{j,i,k,h}$) which is calculated as follows:

$$E_{1,i,k,h} = ED_{k,h} + E_{P_{i,k,h}} + EA_{k,h} + E_{S_{i,k,h}} + E_{TK_{i,k,h}}$$
$$E_{2,i,k,h} = E_{TK_{i,k,h}}$$
$$E_{3,i,k,h} = ED_{k,h} + E_{RE_{i,k,h}} + EA_{k,h} + E_{TK_{i,k,h}}$$
$$E_{4,i,k,h} = ED_{k,h} + E_{RC_{i,k,h}} + EA_{k,h} + E_{TK_{i,k,h}}$$

Product transportation environment impact: Consumer environmental impact due to product transportation is shown in Eq. (13).

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} EO_{k,h} \times (\lambda_{i,k,h} t_h)^{\beta} \tag{13}$$

According to Eq. (11), (12) and (13), the environmental objective function is given as follow:

$$\text{Min } Z_2 = \sum_{h=1}^{T_p} \sum_{i=1}^{n} \sum_{k=1}^{K} [E_{l,1,i,k,h} \times (\lambda_{1,i,k,h} t_h)^{\beta} + E_{l,2,i,k,h} \times (\lambda_{2,i,k,h} t_h)^{\beta}] + \sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} \sum_{j=1}^{4} X_{j,i,k,h} \times E_{j,i,k,h} + \sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} EO_{k,h} \times (\lambda_{i,k,h})^{\beta} \tag{14}$$

Social objective function: Social Objectives should contain every activities which help to improve social justice. However, in this study, Just employment has been focused as social objective. Involved people in leasing company as employee, gain economic benefits and these economic benefits improve their's lifestyle by providing stronger socialinfra structure. Employment impact from leasing company occurred in these three situations: Transportation, leasing periods and EOL.W_{EM} Indicates the weight of employment, which is defined by decision makers and is related to the importance of the hiring employees.

Social impact of transportation: Product Transportation requires workers. The mathematical formula for employment in transportation is given as follow:

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} W_{EM} \times EM_{Tr_{k,h}} \tag{15}$$

Social impact during leasing periods: Failure products require some service man, therefore leasing company have to hire professionals at service and maintenance center. Employment in this section is calculated as follow:

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} [S_1 \left(W_{EM} \times EM_{s_{1,k,h}}\right) + S_2 \left(W_{EM} \times EM_{s2,k,h}\right)] \tag{16}$$

EOL social impact: Different EOL options may provide different number of employment opportunities. The EOL social impact objective function is as follow:

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} [X_{1,i,k,h} \left(W_{EM} \times EM_{T_{1,k,h}}\right) + X_{2,i,k,h} W_{EM} \times EM_{T2,k,h} + X_{3,i,k,h} W_{EM} \times EM_{T3,k,h} + X_{4,i,k,h} W_{EM} \times EM_{T4,k,h}] \tag{17}$$

So at the end:

$$\text{Max} Z_3 = \sum_{h=1}^{T_p} \sum_{k=1}^{K} W_{EM} \times EM_{Tr_{k,h}} + \sum_{h=1}^{T_p} \sum_{k=1}^{K} [S_1 \left(W_{EM} \times EM_{s_{1,k,h}}\right) + S_2 \left(W_{EM} \times EM_{s_{2,k,h}}\right)] + \sum_{h=1}^{T_p} \sum_{k=1}^{K} \sum_{i=1}^{n} [X_{1,i,k,h} \left(W_{EM} \times EM_{T_{1,k,h}}\right) + X_{2,i,k,h} \left(W_{EM} \times EM_{T_{2,k,h}}\right) + X_{3,i,k,h} \left(W_{EM} \times EM_{T_{3,k,h}}\right) + X_{4,i,k,h} \left(W_{EM} \times EM_{T_{4,k,h}}\right)] \tag{18}$$

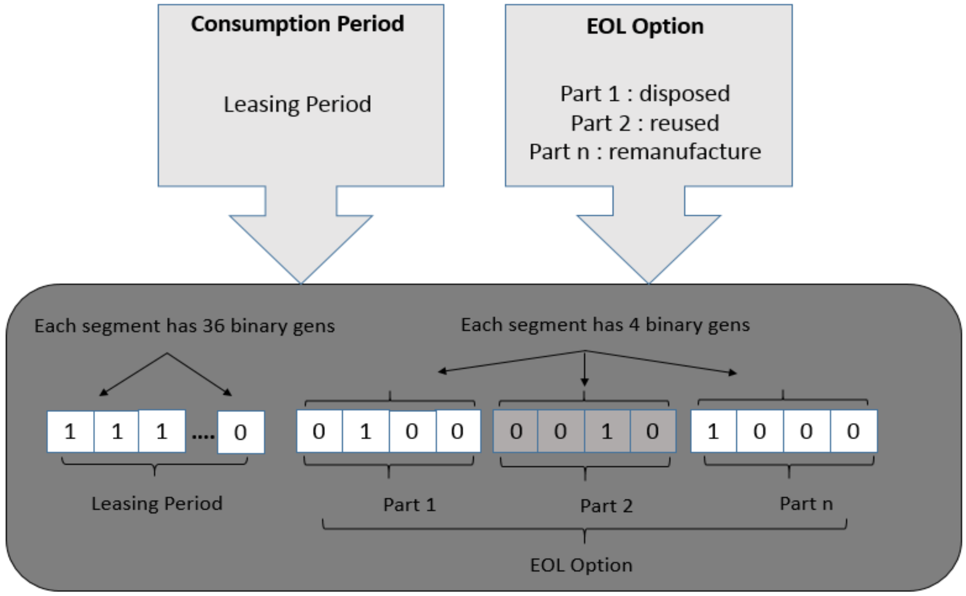

Fig. 2: Chromosome representation of the problem

Constraints: In order to build the mathematical model, the following constraints have been considered:

- In Fig. 2, a product could go through T_p leasing periods; therefore, the total leasing duration is the summation of these periods:

$$\sum_{h=1}^{T_p} t_h = T \tag{19}$$

- Only one EOL option among disposal, reuse, remanufacturing or reconditioning can be selected for each component:

$$X_{1,i,k,h} + X_{2,i,k,h} + X_{3,i,k,h} + X_{4,i,k,h} = 1 \tag{20}$$

- Only one maintenance option among repair and replace can be selected for each product:

$$S_1 + S_2 = 1 \tag{21}$$

- The quality level of a component depends on the selected EOL option. The quality level is defined as threshold for product rejection at the EOL phase. Therefore, the total quality level of all parts of a product should be greater than or equal to a predefined quality level (Jun *et al.*, 2007).

$$\sum_{k=1}^{K} \sum_{i=1}^{n} \sum_{j=1}^{4} X_{j,i,k,h} \times Q_{i,j,k,h} \geq Q_k \tag{22}$$

- If each EOL option is selected then $X_{j,i,k,h}$ equals to"1," otherwise equals to "0."

$$X_{j,i,k,h} : 0,1 \tag{23}$$

- The leasing periods should be greater than zero:

$$t_h > 0 \tag{24}$$

- The expected number of associated employees to a certain product (α) is equal to blew expression:

$$\sum_{h=1}^{T_p} \sum_{k=1}^{K} \alpha_{k,h} = Z_3 \tag{25}$$

- Leasing gain should not be lower than total cost:

$$Z_1 = Total\ cost - Leasing\ gain \leq 0 \tag{26}$$

Optimization algorithm: In this section, as described earlier, MOGA is used to find different Pareto-optimal solution for the developed mathematical model. The research problem is a multi-objective mixed integer nonlinear programming model. Evaluating a product with 30 components and 4 possible EOL decisions, leasing period within 1-36 months requires consideration of $4^{30} \times 36$ possible solution values. Comparing all of those configurations would not be possible in a reasonable time.

To obtain the corresponding Pareto-set, the NSGA-II algorithm (Deb *et al.*, 2002) is adapted similarly A multi-objective genetic algorithm has been applied to simultaneously optimize service period and product EOL decisions (Shokohyar *et al.*, 2012). The following sections describe in details how the MOGA has been implemented.

Step 1: Representation: The segment based method is applied for representation of the problem. Each segment can have a number of binary genes. Figure 2 shows the corresponding chromosome representation of the problem.

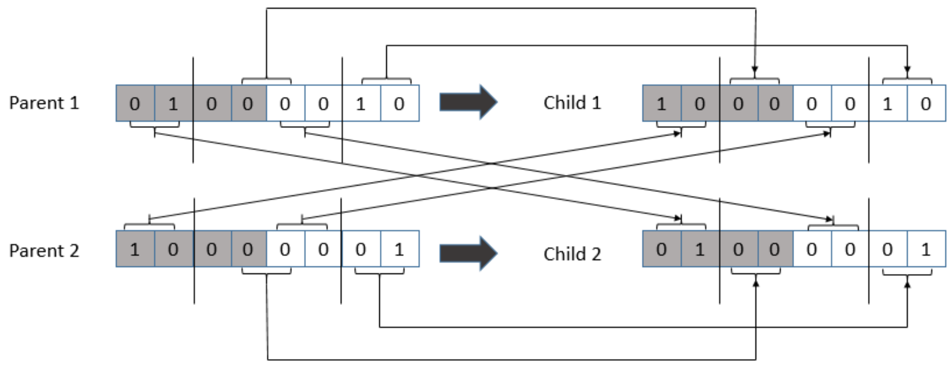

Fig. 3: Illustration of the crossover operator

Fig. 4: Mutation operation

EOL options for each part are represented with four binary genes where "1" denotes the selected EOL option and "0" addresses otherwise. Similarly, one segment is considered for representation of leasing period. Each segment includes array with 36 gens for representing maximum 36 months leasing period. For example, 36 months leasing period is represented with 36 binary gens with value "1" and other genes with value "0". In the developed model, one segment is considered for leasing period and 30×4 segments represents the EOL options for 30 parts.

Step 2: Crossover and mutation: The segment-based crossover operator of Altiparmak *et al.* (2006) is applied which is based on uniform crossover. In this operator, each segment of offspring is randomly selected with equal chance among the corresponding segments of parents. Crossover operator utilizes a binary mask (Altiparmak *et al.*, 2006). Its length is equal to the number of segments of a chromosome. '0' means that corresponding segments of parents will not transfer their genetic materials to each other while '1' means otherwise (Fig. 3). The operator creates two off springs. Similar to crossover operator, segment-based mutation has been applied based on the binary mask. Selected segment is mutated using swap operator. This operator selects two genes from the corresponding segment and exchanges their places. Figure 4 shows the applied mutation operation.

Step 3: Fitness functions: An important issue in multi-objective optimization is how to determine the fitness value of the chromosome for survival. The fitness value of each individual reflects how good it is based upon its achievement of objectives. Each chromosome has three fitness values with respect to economical, environmental and social objective functions. Each chromosome specifies the EOL options, leasing period which can be transformed to cost, environmental and social objective functions with Eq. (10), (14) and (18).

Step 4: Selection mechanism: In the proposed GA, initial population is randomly generated and Pareto-optimal set is created by non-dominated sorting on the initial population. Non-dominated sorting creates a number of fronts of non-dominated solutions in which first front include solutions that cannot be dominated by other solutions. Excluding first front solutions, second one contains solutions that cannot be dominated by other remaining solutions and so on. To build new population, the algorithm start from first front and select solutions until the number of selected solutions equals to the population size. If the number of solutions in first front be less than the population size the algorithm go through the other fronts, respectively, to choose new solutions. Crowding distance measure (Deb *et al.*, 2002) will be applied in case that there are more than one alternative to choose for new population. Pareto-optimal set is updated by new individuals obtained with genetic operators in each iteration (Fig. 5).

Step 5: Terminating the algorithm: Termination condition limits the total number of generations. In this study, the algorithm is terminated if the total number of generations reaches to a certain predefined number.

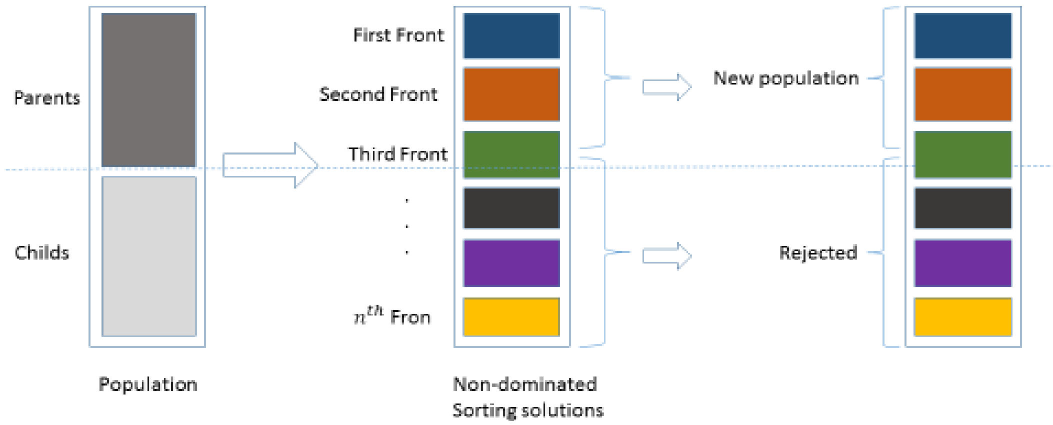

Fig. 5: Chromosome selection for the proposed problem

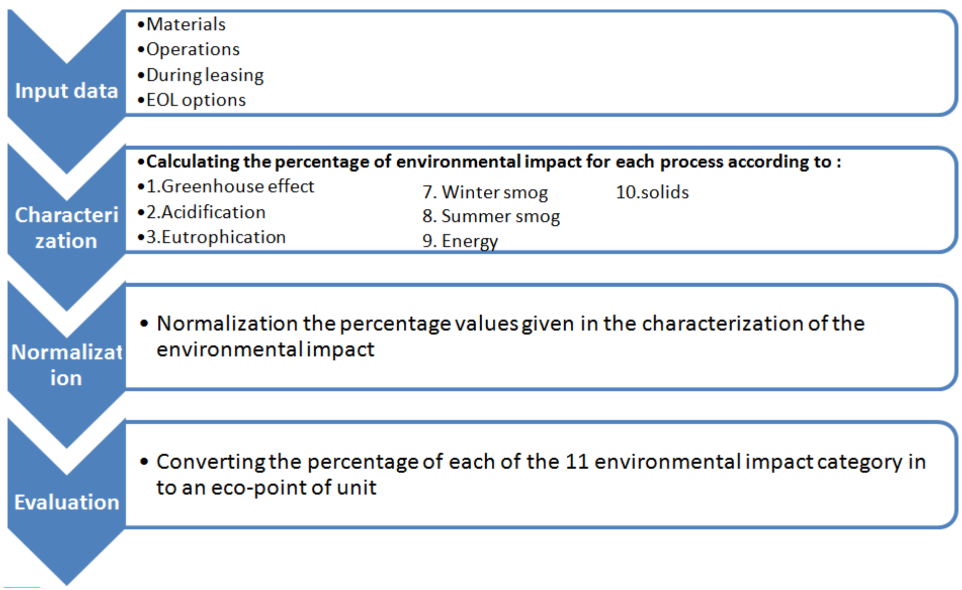

Fig. 6: Environmental impacts calculation in SimaPro software (2011)

CASE STUDY

In recent years, sales of the notebook computers in Iran have increased drastically and well over 500,000 notebooks are sold every year (Itiran, 2011). On the other hand, computer manufacturers in the world, because of the customer environmental awareness and introduced legislations, are addressing sustainability considerations (APPLE, 2014; SONY, 2013).

The laptops considered here consist of 30 components. Average price for buying each laptop is 1,093 US dollars. The product useful life is assumed to be 48 months (Choi *et al*., 2006). Also the maximum number of leasing periods is set to 6. According to sales force management, leasing price depends on duration leasing period. Leasing period is varied from 1 to 36 months. The required data have been provided by Iran Rahjoo Company which is the official service provider of Sony notebooks in Iran (Iranrahjoo, 2011). A sample set of data for the keyboard of a laptop is shown in Table 2.

The environmental impact of individual components is calculated by applying SimaPro software (SimaPro, 2011). This software is based on Life Cycle Assessment (LCA) method (Thurston and De La Torre, 2007; Lu *et al*., 2006). LCA is a tool for quantitative assessment of materials, energy flows and environmental impacts of products, services and technologies and presented for environmental product management (Krozer and Vis, 1998). LCA has been applied to investigate the environmental impact of different End-Of-Life (EOL) options (Dehghanian and Mansour, 2009). According to recent LCA software survey (Jönbrink *et al*., 2000), SimaPro is suitable for environmental analysis and other partial LCA studies. In this study SimaPro v6.0 is used which is available in the “Compact”, “Analyst” and “Developer” versions and in the “Classroom”, “Faculty” and “PhD” educational versions. For this study the “PhD” version have been used.

The input data required by the software for calculating the environmental impact are as follows:

- The weight and type of material for each component.
- The processes required for repairing or replacing during leasing periods. The environmental impact of these processes is quantified by applying the software’s global database.
- The processes required for performing each EOL option such as reusing, reconditioning, remanufacturing and disposal.

The environmental impact is calculated through three basic steps shown in Fig. 6 and by applying the input data and the SimaPro global databases. After these steps, environmental impact is calculated in millipoint by SimaPro software. Table 3 summarizes the sample results for the keyboard components (Shokohyar *et al*., 2013). Iranrahjo hire 4 employees for one laptop with average salary 4$ per h, working in these departments: Distribution, maintenance and service and take back center.

RESULTS AND DISCUSSION

MOGA (as described earlier) was applied to solve this example problem. The algorithm has been coded in MATLAB 8.3 (The Mathworks Inc., R2014A). We set crossover rate, mutation rate and population size as 0.6, 0.2 and 90, respectively. These parameters had been determined after preliminary experiments. The algorithm was stopped after 150 generations. Pareto-optimal solutions of given example for leasing four laptops are depicted in Table 4. It needs to be mentioned that the environmental objective function should be minimized at the same time profit and social objective function should be maximized. The leasing companies can select their best solution based on their acceptable environmental, economical and social impact.

In Table 4, company can determine leasing periods considering the company costs, consumer costs, environmental impacts and number of hired employees. Also the best EOL options for each component can be

Table 2: Cost parameters for keyboard parts (in US dollars)

	Lease Period		EOL Option			
Component name	Replacing	Repairing	Reconditioned	Remanufactured	Reused	Disposed
Electric function unit	7.56	3.30	4.92	6.12	0.30	6.96
Base	2.70	1.02	1.62	1.92	0.30	2.34
Key foil	7.62	4.08	5.22	6.06	0.30	6.42
Keys	14.70	5.82	7.92	8.28	0.30	11.58

Table 3: Environmental impacts of EOL options and repairing or replacing for keyboard parts (in millipoints)

		Lease period		EOL Option			
Component name	Material	Replacing	Repairing	Reconditioned	Remanufactured	Reused	Disposed
Electric function unit	Cu/Epxy/Si2O3	0.92	4.62	7.02	8.76	0.18	9.90
Base	Steel	3.54	1.38	2.16	2.64	0.18	3.06
Key foil	ABS/Cu	9.66	5.04	6.66	7.68	0.18	8.22
Keys	ABS	20.82	8.76	12.18	12.90	0.18	17.58

Table 4: Pareto-optimal solutions of the example

Solution #	New	Reused	Remanufactured	Reconditioned	Leasing duration (years)	Environmental (mpt)	Economical ($)	Social (person-hour)
1	64	12	28	12	3	18252	24528	151
2	36	40	8	28	2	17568	25536	133
3	32	40	52	4	2	16236	26736	162
4	28	44	36	8	2.08	18540	23856	145
5	68	32	12	24	3.5	17640	25488	167
6	28	32	20	32	1.75	18396	24480	140
7	72	20	12	16	2.75	17928	25056	145
8	60	32	28	12	3.33	18468	24048	166
9	56	20	32	20	2.91	16452	25920	166
10	56	16	16	36	2.83	18036	24588	159
11	28	40	44	20	2.42	16596	25680	171
12	60	24	28	12	3.08	16668	25584	158
13	52	16	28	24	2.92	18612	23568	158
14	64	20	20	28	2.58	17136	25104	163
15	48	16	16	52	2.17	18269	24144	168

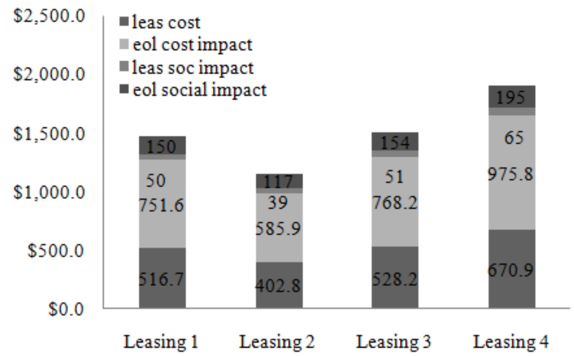

Fig. 7: Comparison of economical and social impact of leasing and EOL phase (Person-hour multiplied by 4$ per hour)

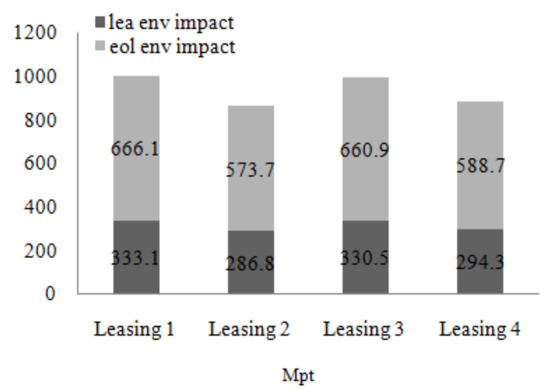

Fig. 8: Comparison of environmental impact of leasing and EOL phase

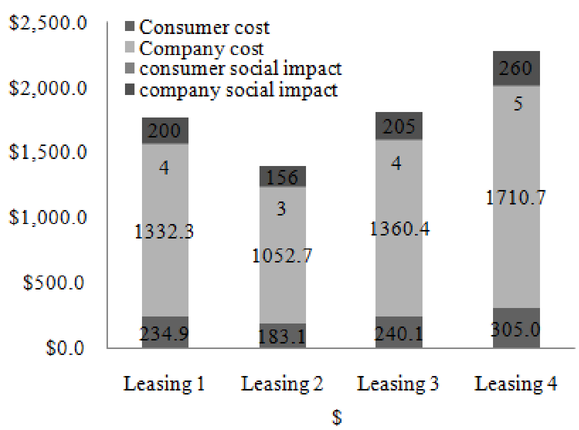

Fig. 9: Comparison of economical and social impact from both consumer and company perspective

selected. Each row in Table 4 corresponds to the best EOL options and leasing periods. For example, solution number 3 shows that the optimal leasing period is 2 year, respectively. Also, the best EOL options for four laptops is to have 32 new components, 40 reused components and 52 remanufactured components as well as 4 reconditioned components.

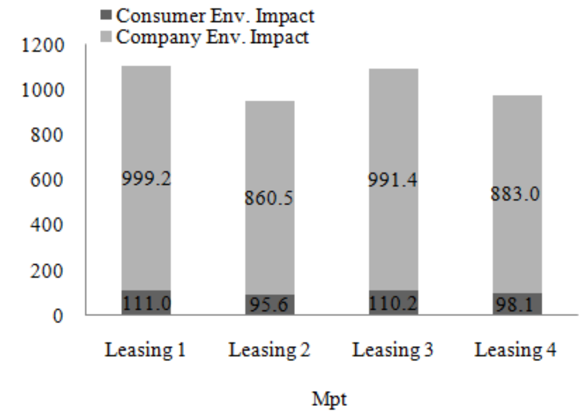

Fig. 10: Comparison of environmental impact from both consumer and company perspective

The corresponding environmental, economical and social impacts for these four leasing periods in Table 4 are compared in Fig. 7 and 8. The impact during leasing and EOL phases are represented by different colors. Therefore, the leasing company can figure out the amount of economical, environmental and social impact for each phase. As shown in Fig. 7, the leasing period 4 has the highest cost and social impact while period 2 has the lowest one.

According to the developed model, decision makers can analyze the total cost, the environmental and social impact from both the company and consumer point of view. Equations (3), (5) and (8) are used to calculate the total cost which is incurred by the company, Eq. (4) and (7) is used to calculate consumer's costs during leasing period. Equations (11) and (12) calculate the company's environmental impact during leasing periods and EOL phase. Equation (13) calculates the environmental impact due to product failure. Equations (16) and (17) are used to calculate the total social impact which is incurred by the company and Eq. (15) is used to calculate consumer's social impact. These analyses are shown in Fig. 9 and 10.

In order to show how the achieved solutions correspond to decision makers' preferences, the following steps are introduced:

- **Ideal point has been calculated:** To find ideal point, the single objective programming model was solved by considering each objective function individually. The optimum objective value of each single optimization model constructs the elements of the Ideal point vector. For instance social objective tends to hire the higher number of employees with respect to other objective functions without considering their optimal value.
- Weighted Percent of Deviation (WPD) was defined for solution *i* as Equation. (27):

$$WPD_i = \sum_{j=1}^{3}(W_j \times \frac{\left|f_j^{(i)}-f_j^*\right|}{f_j^*}) \qquad (27)$$

Table 5: Fifteen different pareto-optimal solutions and their calculated WPDs

Solution #	Environmental	Economical	Social	W_{env} = 0.3 W_{soc} = 0.2 W_{eco} = 0.5 WPD %	W_{env} = 0.$\overline{3}$ W_{soc} = 0.$\overline{3}$ W_{eco} = 0.$\overline{3}$ WPD %
1	18252	24528	151	8.2	8.6
2	17568	25536	133	11.0	11.6
3	16236	26736	162	7.7	5.6
4	18540	23856	145	7.9	9.2
5	17640	25488	167	7.2	5.8
6	18396	24480	140	9.6	10.6
7	17928	25056	145	9.4	9.7
8	18468	24048	166	5.7	5.6
9	16452	25920	166	6.0	4.4
10	18036	24588	159	6.9	6.7
11	16596	25680	171	5.1	3.4
12	16668	25584	158	6.6	5.7
13	18612	23568	158	5.9	6.7
14	17136	25104	163	5.8	5.0
15	18269	24144	168	5.4	4.7

W_j indicates the weight of each objective function (j = 1-3), that is defined by the decision makers and represents the importance of each objective function. $f_j^{(i)}$is the jth objective function value for solution i and $f_j^*$is the jth objective function value for optimal single objective problem. Since objective functions have different units (the environmental impact unit is mPt, the cost unit is US dollars and social unit assumed number of person-hour), to normalize the distance, it was divided by the optimal single objective value. Three sets of $W_j$for environmental, economical and social objective functions were recommended to and approved by Iranrahjoo company (W_{env} = 0.3,W_{soc}=0.2 W_{eco}= 0.5 and W_{env} = W_{soc}= W_{eco}= 0.$\overline{3}$).

The calculated WPDs for the solutions are listed in Table 5. WPD gives a good approximation of the quality of the Pareto-optimal solution. The lower value of WPD shows more agreement between decision maker's preferences. For example, solution number 11 has lowest WPD and seems to be the best solution in the Pareto-optimal set. Solution can be selected based on company's preferences about the importance of each objective function defined by WPD.

CONCLUSION AND FUTURE RESARCH

Regarding to multi-dimensional concept of sustainability, the objectives of leasing companies, should be balance in order to achieving the best leasing policy which:

- Minimize the total cost in both company and consumer point of view
- Minimize total environmental impact of all activities during leasing period and EOL treatments
- Maximize social benefits by improving employees' population in different parts of leasing company and trade of second-hand market between developed and developing countries.

In developing countries such as Iran which have weak technological production oppose to the high electrics demand, customers will enjoy from leasing laptop rather than buying, because prices increased by importing tariffs and transportation cost. Therefore, it is more economical for customers, especially organizations to benefit by leasing which is the best decision also from environmental and social points of view. A case study of a laptop with 30 components was used to illustrate the application customers of the developed model.

In this study, presented model will support leasing companies by choosing the best leasing duration, EOL options and number of hired employees based on environmental, economical and social objectives. The output of developed model are optimal number of leasing periods in the planning horizon, the optimal duration of each leasing period, the optimal person-hour requires for leasing company and the optimal EOL options for different components of the returned used product at the end of the leasing period.

The model is a multi-objective mixed integer nonlinear problem. The high complexity of the established model does not permit for developing polynomial time exact algorithm; so a search methodology based on the MOGA algorithm was adapted to reach Pareto-optimal solutions. The suitable representation of NSGA-II algorithm and the relevant operators (the segment based crossover and mutation) is applied to simultaneously optimize leasing period length, product EOL decisions and number of hired person-hour. This method allowed consideration of the uncertainties associated with number of person-hour involved during the leasing periods and EOL phase.

The developed model creates a win-win situation for both leasing company and customer. Leasing company's costs are minimized, furthermore from consumer point of view, it is economical to lease instead of buying. In addition entire society benefits from maximizing environmental and social impact.

Some of the future research directions that can be derived from this study are presented here:

- Social dimension is considered only for employment point of view, however future research can analysis local development, social justice, damaged to workers and product risk.
- Leasing company can ask design development for product with special features for the purpose of leasing (Integrated supply chain), such as asking for user friendly design.
- Future research can use other type of method for solution like simulation with arena software, game theory or other heuristic method.

REFERENCES

Ahluwalia, P.K. and A.K. Nema, 2007. A life cycle based multi objective optimization model for the management of computer waste. Resour. Conserv. Recy., 51: 792-826.

Altiparmak, F., M. Gen, L. Lin and T. Paksoy, 2006. A genetic algorithm approach for multiobjective optimization of supply chain networks. Comput. Ind. Eng., 51: 197-216.

APPLE, 2014. Supplier Responsibility 2014 Progress Report. Retrieved from: http://www.apple.com/supplier-responsibility/pdf/Apple_SR_2014_Progress_Report.pdf.

Babbitt, C.W., E. Williams and R. Kahhat, 2011. Institutional disposition and management of end-of-life electronics. Environ. Sci. Technol., 45(12): 5366-5372.

Bierman, H., 2003. The Capital Structure Decision. Springer, US, 6: 227.

Blischke, W.R. and D.N.P. Murthy, 1996. Product Warranty Handbook. Marcel Dekker, New York.

Bringezu, S., H. Schütz, W. Pengue, M. O´Brien, F. Garcia, R. Sims, R. Howarth, L. Kauppi, M. Swilling and J. Herrick, 2014. Assessing global land use: Balancing consumption with sustainable supply. A Report of the Working Group on Land and Soils of the International Resource Panel, UNEP.

Chien, Y.H., 2005. Determining optimal warranty periods from the seller’s perspective and optimal out-of-warranty replacement age from the buyer's perspective. Int. J. Syst. Sci., 36: 631-637.

Choi, B.C., H.S. Shin and T. Hur, 2006. Life cycle assessment of a personal computer and its effective recycling rate. Int. J. Life Cycle Ass., 11(2): 122-128.

Chong, M.Y., J.F. Chin and W.P. Loh, 2013. Lean incipience spiral model for small and medium enterprises. Int. J. Ind. Eng-Theory, 20(7-8).

Clark, T.M., 1978. Leasing. McGraw-Hill, London.

Deb, K., A. Pratap, S. Agarwal and T. Meyarivan, 2002. A fast and elitist multi-objective genetic algorithm: NSGA-II. IEEE T. Evolut. Comput., 6: 182-197.

Dehghanian, F. and S. Mansour, 2009. Designing sustainable recovery network of end-of-life products using genetic algorithm. Resour. Conserv. Recy., 53(10): 559-570

Erkoyuncu, J.A., R. Roy, E. Shehab and K. Cheruvu, 2011. Understanding service uncertainties in industrial product-service system cost estimation. Int. J. Adv. Manuf. Tech., 52(9-12): 1223-1238.

Fishbein, B.K., L.S. McGarry and P.S. Dillon, 2000. Leasing: A step toward producer responsibility. INFORM, New York, pp: 55.

Giljum, S., C. Lutz, A. Jungnitz, M. Bruckner and F. Hinterberger, 2008. Global dimensions of European natural resource use. First Results from the Global Resource Accounting Model (GRAM), Sustainable Europe Research Institute, Vienna.

IAER, 2006. IAER Electronics Recycling Industry Report. International Association of Electronics Recyclers (IAER), Albany, NY.

Intlekofer, K., B. Bras and M. Ferguson, 2010. Energy implications of product leasing. Environ. Sci. Technol., 44(12): 4409-4415.

Iranrahjoo, 2011. Service Provider for Sony Notebook. Retrieved from: www.iranrahjoo.com. (Accessed on: September 1, 2013)

Itiran, 2011. Iran Information Technology Data. Retrieved from: http://www.itiran.com/?type0article&id013822. (Accessed on: September 1, 2013)

Jönbrink, A.K., C. Wolf-Wats, M. Erixon, P. Olsson and E. Wallén, 2000. LCA software survey. IVL Report No B1390, Swedish Environmental Research Institute Ltd., IVL, Stockholm.

Jun, H.B., M. Cusin, D. Kiritsis and P. Xirouchakis, 2007. A multi-objective evolutionary algorithm for EOL product recovery optimization: Turbocharger case study. Int. J. Prod. Res., 45(18-19): 4573-4594.

Krozer, J. and J.C. Vis, 1998. How to get LCA in the right direction. J. Clean. Prod., 6: 41-53.

Kuo, T.C., 2011. Simulation of purchase or rental decision-making based on product service system. Int. J. Adv. Manuf. Tech., 52(9-12): 1239-1249.

Lu, L.T., I.K. Wernick, T.Y. Hsiao, Y.H. Yu, Y.M. Yang and H.W. Ma, 2006. Balancing the life cycle impacts of notebook computers: Taiwan's experience. Resour. Conserv. Recy., 48(1): 13-25

Mangun, D. and D.J. Thurston, 2002. Incorporating component reuse, remanufacture and recycle into product portfolio design. IEEE T. Eng. Manage., 49(4): 479-490.

Melo, M., L. Bueno and S. Campello, 2013. Industry energy efficiency analysis in Northeast Brazil: Proposal of methodology and case studies. Int. J. Ind. Eng-Theory, 19(11).

Mont, O.K., 2002. Clarifying the concept of product-service system. J. Clean. Prod., 10(3): 237-245.

Mont, O., 2004. Product-service systems: Panacea or myth? Ph.D. Thesis, Lund University.

Quirke, B., 1996. Leasing the environment. Sustain. Dev., 4: 98-102.

Robert, K.H., B. Schmidt-Bleek, J. Aloisi de Larderel, G. Basile, J.L. Jansen, R. Kuehr and M. Wackernagel, 2002. Strategic sustainable development-selection, design and synergies of applied tools. J. Clean. Prod., 10(3): 197-214.

Sharma, M., 2004. Reverse logistics and environmental considerations in equipment leasing and asset management. Ph.D. Thesis, Georgia Institute of Technology, Atlanta, GA 30332, United States.

Shokohyar, S. and S. Mansour, 2014. Environmental services through leasing process: A simulation optimization approach. Adv. Environ. Biol., 8(17): 1103-1115.

Shokohyar, S., S. Mansour and B. Karimi, 2012. A model for integrating services and product EOL management in Sustainable Product Service System (S-PSS). J. Intell. Manuf., 25(3): 427-440.

Shokohyar, S., S. Mansour and B. Karimi, 2013. Simulation-based optimization of ecological leasing: A step toward Extended Producer Responsibility (EPR). Int. J. Adv. Manuf. Tech., 66(1-4): 159-169.

SimaPro, 2011. Software for Environmental Assessment. Retrieved from: www.pre.nl/simapro. (Accessed on: September 1, 2013)

SONY, 2013. Annual Report 2013: Business and CSR Review. Retrieved from: http://www.sony.net/SonyInfo/IR/financial/ar/2013/.

Stahel, W.R., 1997. The Function Economy: Cultural and Organizational Change. In: Richards, D.J. (Ed.), the Industrial Green Game, Implications for Environmental Design and Management. National Academy Press, Washington.

Subramanian, R., S. Guptay and B. Talbot, 2005. Remanufacturable Product Design and Contracts under Extended Producer Responsibility. Working Paper.

Thurston, D.L. and J.P. De La Torre, 2007. Leasing and extended producer responsibility for personal computer component reuse. Int. J. Environ. Pollut., 29(1): 104-126.

United Nations, 1987. Report of the World Commission on Environment and Development: Our Common Future. United Nations, New York.

Wang, F.K. and W. Lee, 2001. Learning curve analysis in total productive maintenance. Omega, 29(6): 491-499.

Wei, Q. and B. Roger, 2011. Lease and service for product life-cycle management: an accounting perspective. Int. J. Account. Inform. Manage., 19(3): 214-230.

Zhao, Y., V. Pandey, H. Kim and D. Thurston, 2010. Varying lifecycle lengths within a product take-back portfolio. J. Des., 132(9): 091012.