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A MEASURE OF PRODUCT SUSTAINABILITY BASED ON TRIPLE BOTTOM LINE

Prabir Sarkar **Sudarsan Rachuri**
Hyo Won Suh **Kevin Lyons** **Ram D. Sriram**
National Institute of Standards and Technology, Gaithersburg, Maryland, USA

ABSTRACT

Sustainable societies require the use of sustainable products. Sustainability is generally expressed in terms of Triple Bottom Line (TBL) - people, planet, and profit. Products that are sustainable have positive effects and value for all the stakeholders. In this work, we propose different measures to assess sustainability of manufactured products with respect to TBL. The proposed measures should help designers to assess sustainability of design alternatives during the initial phase of design and point out ways to reduce the impact.

Keywords: sustainability, sustainability assessment, environmental impact, design for sustainability

1 INTRODUCTION

We are witnessing an increased interest in ensuring that future generations have adequate resources to maintain a high standard of living. Sustainable development is defined by the World Commission on Environment and Development as "S*ustainable development is development that meets the needs of the present without compromising the needs of future generations to meet their own needs"* [1]. As society's ability to remain sustainable depends upon the availability of natural resources [2] and since natural resources are limited, responsible use of these resources is important for a sustainable future [3, 4].

Continuous use of raw materials without any replenishment is leading to resource depletion, biological diversity loss, and global climate change [5, 6]. This is underscored by Sikdar [7] in the following statement: "*qualitatively, the concept of sustainable development is simple enough: the natural resources of the Earth are limited; they are being used disproportionately by a minority of people living in the wealthy nations, thus creating intra-generational inequity. The rate of use of these resources is ever-increasing, thus depriving the future generations of a living standard comparable to that of the present, and creating inter-generational inequity*."

Measurement of sustainability has been expressed by researchers in different ways [8, 9] but most definitions are based on the Triple Bottom Line (TBL) approach, e.g., with economic (profit), environmental (planet), and social welfare (people) objectives [10, 11] (see Figure 1). Hecht [12] expressed that the three pillars of sustainability are economic, environmental, and social and that there is need for the system as a whole to be sustainable. Sikdar [7] pointed out that many researchers have attempted to measure improvements in terms of three groups of metrics (indicators) corresponding to the three aspects of sustainability: ecological metrics, economic metrics, and sociological metrics. He classified the indicators into 1-D (one-dimensional) that measures only one aspect of the system such as economical or social, or 2-D (two-dimensional) such as eco-efficiency metrics or socio-ecological metrics, and 3-D (three-dimensional) which are true sustainability metrics. Sikdar [7] also stated that no consensus exists on a reasonable taxonomy of sustainability related metrics. We found that most of these are generic indicators. One can ask the following questions regarding sustainability metrics:

1. What are the measures for these three pillars of sustainability - people, planet, and profit?
2. How to determine what attributes of these indicators have a positive or a negative effect on the indicator?
3. Is it practically possible to design a product that does not have any impact on environment, adds value to the people, and still generates profit? How tradeoffs among these indicators could be developed?

These questions and many others are still unanswered and extensive research is required to answer each of these questions. Most of the methods available to design engineers to assess sustainability are environmental-centric or are too generic. What designers need is a method to quantitatively assess sustainability of products. A method that would help them assess, compare, and select the most sustainable product alternative will be of considerable use during initial design stages. We have not found any method or tool would provide quantitative values for impact of a product on planet, people, and profit. In this paper, we make an initial attempt to develop measures to assess a product in terms of its impact on people, profit, and planet. Our future research will involve finding out interactions among these measures. We are also interested to find out how to develop strategies for designers to help them develop sustainable products.

To measure the impact of products on sustainability we believe (also see Hecht [12]) that the impact should be measured in terms of the TBL, considering all the three indicators (e.g. planet, people, and profit). Researchers proposed many methods and tools that are related to measurement of sustainability of products (e.g., GaBi, Eco-indicator 99 [13]). However, most of these are only environmental impact assessment methods or tools. For instance, Eco-indicator 99 methodology, with Life Cycle Assessment or LCA as the base method, uses damage indictors for human health, eco system quality, and resources to assess the impact of a product on the environment. This method has been implemented as a piece of software tool called Simapro [14].

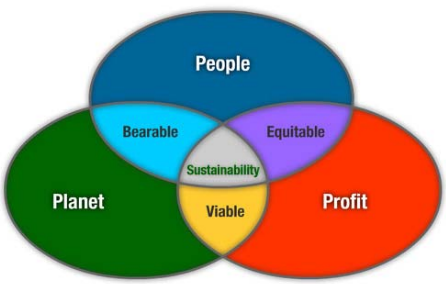

Figure 1. Triple bottom line [11]

Most of the available methods related to the measurement of sustainability of products do not consider TBL for assessing sustainability. These methods tend to be computationally expense and are difficult to use during the initial phases of design, as underscored by Bevilacquas [15] comment: *"if the number of components or materials constituting the product is too large, calculations cannot be executed in a practically feasible time, because the number of possible combinations of life cycle options increases exponentially."* During the initial design phase, the kind of data that the designers work with are not always detailed, yet they would like to make informed decisions on the sustainability of product concepts instead of conducting extensive computation to assess the sustainability of each product concept. We believe that designers require a simple and less data intensive method that would help them visualize the effect of each change made on the product on sustainability. This would help them to make informed decisions, and the results would be intuitive and close to that of using other data intensive methods.

In this work, we try to address the question: What are the measures for sustainability- people, planet, and profit, as applied to manufactured products? Alternatively how could we develop a product that has minimal impact on the environment, generates profit, and adds value to the society? For this, we need to answer the following questions.

1. How can we measure the environmental impact of products during the initial stage of products or what is the condition for it minimal impact on sustainability?
2. How can we measure the impact of a product on the companies' profit?
3. How can we measure the impact of a product on people or the value that a product adds to the society?

Once we have defined the individual metrics, we also attempt to define the 3-D metric as defined by Sikdar [7]. In particular, we are interested helping designers find a simple way to alter product characteristics to make it more sustainable. We are also interested in finding out why some of products are not sustainable and how to make them sustainable.

2 PROPOSED MEASURES

The main aspect of measuring the impact of a product with respect to the TBL is based on the assumption that the product should add value and have a positive impact on people, planet, and profit. During comparison of product alternatives, designers could select the product that adds more value to each of these indicators.

In this work, we outline a method to assess sustainability of a product using TBL. This method uses individual measures to assess sustainability of products.

2.1 Developing measure for impact of a product on planet or environment

What exactly do we mean by "sustainable environment?" For this, we quote Hecht [12], who points out that: *"an environment is considered to be sustainable if at some level the species within it continues to exist and interact with each other, with only gradual evolution of species."*

Environmentally conscious design (Eco-Design) or Design for Environment (DfE) plays an important role in achieving product sustainability [15, 16]. Environment impact is expressed in terms of change that significantly affects the quality of the human environment [17].

McAloone [18] and Bevilacqua [15] state that little effort has been made to understand how DfE methods could be integrated into design process, and most approaches fall short with respect to the requirements of any product design team [19]. Also, most of these methods require great amount of detailed information, making them inapplicable for early phases of design [15].

Environmental impacts of products are generally determined using Environmental Impact Assessment (EIA) methods and tools. These EIA methods are commonly used in eco-design, a design approach with special consideration for environmental impacts of the product during its whole lifecycle [18]. These EIA methods and tools use criteria or indicators with associated factors to find the effect of products on environment.

Criteria are parameters that are used in practice to evaluate the contribution of a product to meet the required objectives [20]. Selecting the right criteria is often difficult, allocating a weighting factor to these criteria is challenging, subjective, and in many cases empirical validation is missing [3]. There are also issues such as data uncertainties and data specificity (geographic) of these measures [21] associated with these criteria.

There are many environmental impact assessment methods currently available. Many of these environmental methods are incorporated into Life Cycle Assessment (LCA) tools such as Eco–indicator 99 (in SimaPro), GaBi, or carbon footprint[1] [17,22]. These techniques assess the impact on the environment based on the changes on some preselected measuring criteria – such as land use, depletion of fossil fuel, etc.

2.1.1 Learning from nature

During the process of evolution, nature has learnt to use the two vital ingredients – material and energy wisely. Nature uses recyclable material and renewable energies. It has learnt how to develop static systems (such as trees) and moving systems (such as animals and birds) whose material and energy are completely reusable and recyclable. Natural systems such as animals, plants, a lake or a particular area of cultivatable land are self-sustainable, provided there is no human intervention. Ideally, nature could create the same set of living systems repeatedly using the same amount of materials and energy as resources. The wastes generated by natural systems are converted into resources in the consecutive cycle. As, natural systems are considered to be self-sustainable; understanding natural systems could help in developing a method for assessing environmental impact of products, as pointed out by many researchers [24, 25]. Unlike natural systems, artificial systems such as product manufacturing systems are not self-sustainable. Generally, products designed and used by humans cannot be manufactured again with the amount of material and energy left from its previous life cycle. Bio-mimicry as defined in [26] as *"(from* bios, *meaning life, and* mimesis, *meaning to imitate) is a design discipline that seeks sustainable solutions by emulating natures time-tested patterns and strategies, e.g., a solar cell inspired by a leaf. The core idea is that Nature, imaginative by necessity, has already solved many of the problems we are grappling with: energy, food production, climate control, non-toxic chemistry, transportation, packaging, and a whole lot more"*.

Natural systems do produce some harmful side effects, for example, animals release carbon dioxide (CO_2) gas in the atmosphere thus increasing the green house gases. Yet, we see that nature is sustainable in the long run. This is because, nature can create the same set of systems with the same material and energy repeatedly that makes nature 100% sustainable. Therefore, an ideal sustainable product is one that mimics the cycle of natural systems and, thus, has no harmful impact on the environment in the end. If one could create the same product with the materials (recycled, reused) and energy utilized in the previous product, then the effect of the first product on the environment is minimum. Therefore, a "minimal impact product" is that product which can be developed again with the same resources (material and energies) utilized in the previous product. Hence, for an ideal product, either the waste generated by the product during its life cycle is zero or the waste is converted into reusable resources.

Deviation from this ideal "minimal" impact condition of a product is the measure for the environmental impact of the product. The impact of the first set of products on the environment is the amount of different kinds of materials and energies that have been added while developing the second set of products, and the initial impact of the first set of products caused by the use of material and energy (also called as permanent impact, see Section 2.1.3).

2.1.2 Representation of natural and artificial systems

Figure 2 shows that in a closed predefined natural system such as an animal or a plant, nature is able to produce Natural System 2, which is same as Natural System 1 (as both systems contain the same number and kind of living systems) without significant input and output of material and energy from external sources. Figure 2 also shows that in case we need to recreate the same artificial system with the usable material and energy of natural after its usage, generally it requires addition of fresh materials and energies. For example, let us say that artificial system 1 is a car and after its usage, we want to make another car that is system 2, exactly the same as the first car using the material and energies (if any) left from the first car. This is not a possible scenario, as we need to add more new material and energy to make another new system 2. Some waste -- mainly in the form of material or energy -- would be added to the nature from the first car which cannot be reused or recycled in manufacturing the second car.

[1] A carbon footprint is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced. The footprint calculates the direct and indirect level of CO_2 emissions.

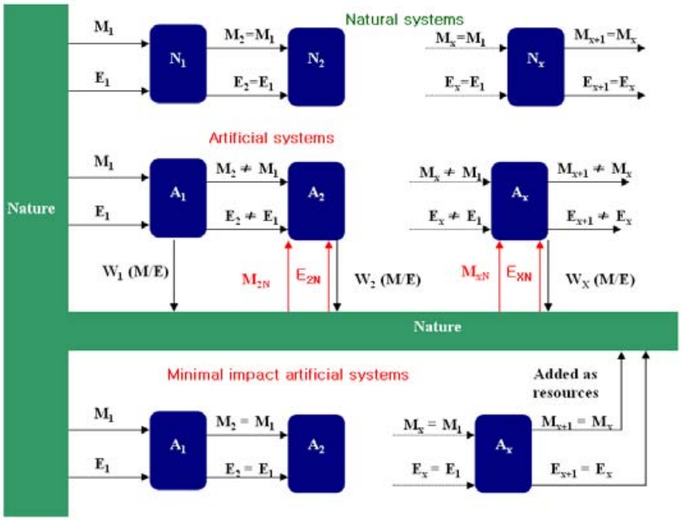

Figure 2. Material-Energy representation of natural and artificial systems

Note: M- material, E-energy, W-waste, N_1, N_2 and A_1, A_2-new 1,2 are the first and the second life cycle of the same product.

2.1.3 Assessing environmental impact of an artificial system (a manufactured product)

We consider the environmental impact of an artificial system 1 (A_1) (see Figure 2) as the amount and kind of new material and energies added to artificial system 2 (A_2), while simulating life cycle of artificial system 2.

Generic representation: Let us assume that a designer of a product A_1, would like to find the impact of that product on the environment. The designer first identifies the material and energy that are required to manufacture the product. Next, the designer approximately calculates material and energy that is added to the product during its entire life cycle. The designer also calculates the amount of material that will be reused and recycled from the product.

Let, the amount of material required to produce A_1 be M_1. Since A_1 and A_2 are same in design and have a similar life cycle, A_2 uses the same amount of material as A_1. Let, the amount of material required to produce the product A_2 be M_2. There are materials that could be recycled and reused from A_1. Let, $M_{1recycled}$ be the amount of material that we are able to recycle from A_1 and add to A_2. Also, let $M_{1reused}$ be the amount of material that we are able to reuse from A_1 and add to A_2. Let the amount of waste materials from M_1 be M_{1waste}. This indicates that we need to add additional material to M_2, apart from $M_{1recycled}$ and $M_{1reused}$ to make M_2 equal to M_1. Let, this amount of new material be M_{2new}. From the above discussion, we can formulate the following equations:

$$M_2 = M_{1recycled} + M_{1reused} + M_{2new} \quad (1)$$

$$M_1 = M_{1recycled} + M_{1reused} + M_{1waste} \quad (2)$$

M_{2new} consists of material resources such as metals, plastics, alloys, etc. M_{1waste} consists of emissions, landfills, etc. Note that when $M_1 = M_{1recycled} + M_{1reused}$ then $M_{1waste} = 0$ which implies $M_{2new} = 0$. Because there is no wastage of material M_1 ($M_{1waste} = 0$) there is no need to add any new material (hence $M_{2new} = 0$). This is what we call *minimal impact product condition*. However, there is always an initial impact of any product on the environment, as explained below.

To produce any product for the first time some amount of new material and energy are always required. This new material and energy forms the permanent impact. Part of M_1 constitutes permanent material impact of the product A_1 ($M_{permanent}$).

Energy that went in to produce A_1 can be expressed in similar terms as discussed for material. Let, the amount of energy required to produce product A_1 be E_1 and the amount of energy required to produce product A_2 be E_2. Let, $E_{1recycled}$ be the amount of energy required to recycle material ($M_{1recycled}$). Let, $E_{1reused}$ be the amount of energy required to reuse material (M_{1reuse}). E_{2a} is the amount of energy added to E_2 apart from $E_{1recycled}$ and $E_{1reused}$.

Let, $E_{1produced}$ be the amount of energy generated by burning waste from M_{1waste} (in case it is made of combustible materials such as paper or plastics). Also, let E_{1saved} be the amount of energy that we are able to save by reusing material (M_{1reuse}). Thus, we get the following equations:

$$E_2 = E_{1recycled} + E_{1reused} + E_{2a} + E_{1produced} + E_{1saved} \quad (3)$$

Let E_{2new} be all the new energies that are added to E_2, then

$$E_2 = E_{2new} + E_{1produced} + E_{1saved} \quad (4)$$

For *minimal impact product condition*, E_{2new} (that is, $E_{1recycled} + E_{1reused} + E_{2a}) = 0$, also $E_{1produced} = 0$ as $M_{1waste} = 0$, thus $E_2 = E_{1saved}$.

Similar to permanent material impact, part of E_1 forms permanent energy impact of the product A_1 ($E_{permanent}$). Hence, the permanent environmental impact EI_P of product A_1 is expressed as follows:

$$EI_P = f(M_{permanent}, E_{permanent}) \quad (5)$$

Where f stands for 'function of'.

Thus, the environmental impact of a product (*EI*) which is not a minimal impact product is:

$$EI = f((M_{permanent} + M_{2new}), (E_{permanent} + E_{2new})) \quad (6)$$

Since we are not controlling the permanent impact (depends on the system boundary), we remove EI_p from equation ***(6).*** Also, let N represent the similar products of the kind A_1. We also drop the subscript 2, so equation ***(6)*** becomes equations (7), that represent the environmental impact ***(EI)*** of all products that are similar to A_1.

$$EI = N\,(f(M_{new}, E_{new})) \quad (7)$$

Note 1. It should be noted here that as shown in equation (7), both M_{new} and E_{new} could consist of several kinds of material and energies.

$$EI=N(f(M_{Inew}, E_{Inew})) \text{ where, } M_{Inew}=\sum_{I=1}^{TM} M_{Inew} \text{ and } E_{Inew}=\sum_{I=1}^{TE} E_{Inew} \quad (8)$$

Where, M_{Inew} = different new materials added and E_{Inew} = different new energies added, TM is the total number of different kinds of materials added and TE is the total number of different kind of energies added.

Note 2. To reduce environmental impact of a product, designers should try to reduce the value of M_{new} and E_{new} by redesigning the product. For instance, by reducing the amount of material M_1, E_1 would also reduce. Thus the impact of this product on environment would reduce.

The environmental impact as found by the proposed measure could also be expressed in other terms such as carbon foot print, ecological footprint, land usage, or depletion of fossil fuel by expressing these in terms of materials or energies. For example, one can find carbon footprint of a product by assessing the amount of CO_2 emitted - while new materials and energy are added starting from ore extraction to actual input to the product. The amount of new material and energies added during simulated manufacturing is directly proportional to the emissions, wastes, and other harmful effects. Hence there is a relationship between our proposed measure (based on inputs) and the existing measures (based on output) that are currently used as criteria of evaluating environmental impact of products by various methods [13,27] (see Figure 3).

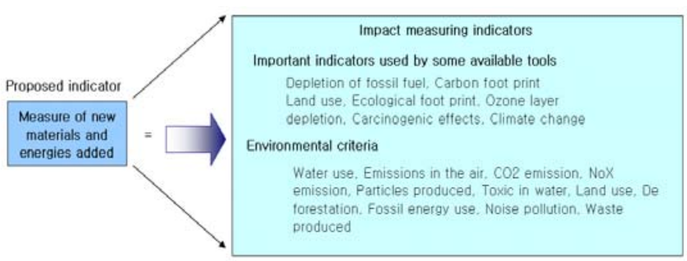

Figure 3. Relationship of the indicators (measures) with other indicators

2.2 DEVELOPING MEASURE FOR IMPACT OF A PRODUCT ON PROFIT OR ECONOMY

Companies which emphasize sustainable practices will not be able to survive in the long run if they are not able to make a profit. Hence, it is important for any analysis of sustainability to include metrics for economic viability.

As design is a crucial part for product development - majority of a products cost, typically about 80%, is determined early in the design stage [28] - designers should assess the potential profit generating ability of each design concept, while addressing various environmental concerns, to decide which product concept should be selected for manufacturing. As noted by Sikdhar [7] engineers should create products and systems which are economically valuable and environmentally preferable.

A company could increase profit in various ways: either by increasing the price of the product or by reducing the expenses incurred on the product or by increasing the sales of the product. Profit is a function of price, expenses, and sales: i.e., profit = number of products sold * (Price of each product – Cost incurred for each product) [29]. In other words,

$$Profit = N\,(P - C) \qquad (10)$$

Where, N is the number of products sold by the company, P is the price of the product. C is the cost incurred on the product by the company, which includes cost of manufacturing, labor, transportation and other fixed and variable costs.

Both price of a product and sales are influenced by many factors and this paper does not attempt to address these. For simplicity we could assume that the price and sales of a product constant, and focus on reducing various costs associated with the design, manufacture, and sales of the product.

2.3 DEVELOPING MEASURE FOR IMPACT OF A PRODUCT ON PEOPLE OR SOCIETY

"A sustainable society is one that will continue to exist in its current form [12]."

Products are developed to satisfy the needs of people of a society. People have various kinds of needs and they try to satisfy these needs by using products and services. Products must add value to the society. Thus, a sustainable product is that, which 'adds value' or is 'useful' to the people of the society. Usefulness of products in a society could be measured in terms of level of importance, rate of popularity of use, and rate of use [30]. These terminologies are explained below.

Importance of use or level of importance: In a society, importance of a product depends on its impact on users lives. Some products are indispensable to use, while others are not. Thus, products that are more important to the society should have a higher value for their usefulness. Five levels of usefulness of a product were identified (see Table 1) [30].

Table 1. Level of importance of different products [30]

Level of importance	**Points in a scale of 5**	**Type of importance**
Extremely important	5 (4.1 to 5)	life saving drugs, life supporting systems

Very highly important	4 (3.1 to 4)	compulsory daily activities
Highly important	3 (2.1 to 3)	shelter, social interaction
Medium important	2 (1.1 to 2)	machines for daily needs
Low importance	1 (0.1 to 1)	Entertainment systems, recreation systems

Rate of popularity of usage: If all other parameters are same, the products that are used by a larger number of people should be more useful to the society. Thus, the number of people using a product within a given period represents the rate of popularity [30].

Rate of use / rate of duration of benefit: Products that are used more frequently are likely to have been more useful to the society. Assuming that the level of importance and the rate of popularity for a certain set of product are same, the rate of usage increases the value for usefulness of such products. Where rate of usage is unknown, rate of duration of benefit could be used. Therefore, the rate of duration of benefit per person per unit of time could be expressed as the product of the frequency of usage and duration of benefit per usage person, at a given unit of time.

Survey in a given community is required to be carried out in order to identify the values for these parameters, namely, L, F, D, and T, for subsequent assessment of usefulness of the product in that community. Where, L stands for level of importance, F stands for frequency of usage, D stands for duration of benefit per usage, and T stands for total number of people using the same kind of products (which is equivalent to popularity of use) (Note that the unit of time for T, F and D should be same i.e. day, month or year). When designing a new product, a designer could use the values of these parameters which may be extrapolated from data of other similar products available in the market and predict the usefulness of the new product. Taking the above discussion into consideration we can construct a formula, as shown below, for assessing the usefulness [30] of a product.

$$\textit{Usefulness} = L\ F\ DT \qquad (11)$$

The unit of time in the terms used in the equation ***(11)*** should be selected carefully. For those products whose usage changes over a period, say over a month, it is better to take a larger unit like a year to calculate the usefulness. For instance, the usage of a fan fluctuates over seasons (so, year may be the preferred unit), while usage of tooth brushes practically does not change over days (so day could be chosen as the preferred unit). Therefore, in order to find the frequency of use, the rate of use and popularity of use, should have the same unit for the time.

We would like to modify this equation to add N that represents total number of products sold during a specific period. Then, $T = \alpha * N$ where α is the average number of people using the same kind of product. Also, usefulness could be considered as the value of the product in the society. Thus,

Value added by a product to the people of a society,

$$\textit{Social value } (S) = N\,(LFD\alpha) \qquad (12)$$

3 SUSTAINABILITY MEASUREMENT METHOD

Sustainability is a function of value added to people, planet, and profit. In addition, as discussed in Section 2, sustainability of a product depends on length of the life cycle of products or in other terms number of products used during a particular period. Thus, if N is the number of products sold during a given time period, 'the value subtracted from the planet by the products' or in other terms 'the effect of these products on environment (Environmental impact, ***EI***) is calculated using equation ***(7).*** Value added by a product A_1 to the profit of a company is found using equation (***10***), and value added by the product A to the people is found using equation (***12***).

To select among product alternatives the difference between these values for each product could be assessed. For example, let the values for ***EI, Profit*** and S for product A and B are EI_A, $Profit_A$, S_A and EI_B, $Profit_B$, S_B respectively. Then product alternative B is more sustainable compared to A if two or more of these differences are positive: $(EI_A - EI_B)$, $(Profit_B - Profit_A)$ and $(S_B - S_A)$.

It could also be noted that the individual terms used in these three equations influence one other as discussed in the following examples.

Effect of reduction of materials and energy: Reducing usage of material and energy would make products more sustainable. If the value for M_{new} is reduced, the cost incurred on the product (C) would reduce; which either would increase profit or reduce cost (C). This in turn would enable more number of people use this product (T).

Effect of sharing a product: Sharing products would make products more sustainable. If many people use a single product, then the value of N would reduce. Hence, the environmental impact would reduce. This would decrease the cost incurred on products (C) which would in turn bring down the price (P). As people share a product they may be willing to pay more for such a product, thus the amount of profit (***Profit***) would increase. Again, sharing could reduce the value for N, which has a negative effect on profit. Here, the company needs to make a tradeoff between the price of the product, environmental impact, and profit gained. Government policies could help in deciding a suitable number for N.

Effect of manufacturing and selling effective products: If a company replaces products with low level of importance with that of high level of importance, then the people would be interested to pay more, and the company could make more profit.

4 Example

Let us assume that a Maryland-based company[2] in USA is interested to manufacture and sell packaged drinking water. Apart from selling prefilled mineral water bottles made from Polyethylene terephthalate (PET), the company would like to consider two more alternative solutions- selling reusable bottles (so that users could refill them and use it many times) and selling repackaged water (i.e., the company would collect used bottles, clean them, and repack them with drinking water). Assume that the company employs a team consisting of designers and marketing professionals to select a suitable alternative among them.

The options are:
1. *A one-liter mineral water bottle* (use and throw out for recycling): The team estimated that the company has market penetration potential of 30 Million bottles sales per month. Other data that the team has collected is shown in Figure 4.
2. *Reusable metal bottles*: These are reusable bottles made of aluminum. One could reuse it several times a day.
3. *Repackaged water bottles*: The company gives a $1 incentive for returning each used bottle. The company believes that a very high incentive would encourage more people to recycle an used bottle. The company wants to collect these used bottles, clean them and refill them with water. In this way the company could save money for purchasing new empty bottles. Using data from other states of America, the team found that not all the bottles would be reused; some bottles are still thrown away. The team forecasts that the company needs to procure 8 million new bottles each month. Using equations (7,10 and 12) the team found that the last option (that is selling repackaged water bottles) is more sustainable (see Figure 4).

5 Conclusions

Green manufacturing and sustainability initiatives are promising areas of research. Traditional product development generally aims for minimum capital and maximum return that is products which add values to the society and generates profit only. As resources are getting depleted and harmful effects of the wastes added to the environment are causing measurable ill effects on human life, companies and governments are getting actively involved in the development of products that are not only profitable and adds value to the society but also causes less damage to the environment. Sustainability is generally expressed in terms of Triple Bottom Line (TBL). Products that are sustainable have positive effects on people, planet and profit and add value to each of them. In this work, we propose a method to assess sustainability of manufactured products using TBL. A method to assess the impact of a product on planet, profit and people is proposed. The proposed method should help designers to assess sustainability of design alternatives during the initial design phases, which will result in more environmentally friendly and economically profitable designs.

[2] *Note:* Data shown here are not real and used for illustrative purposes only.

	Environment	Economic	Social
	N f(M_{new} , E_{new})	**N (P – C)**	**N (LFDα)**
	N= 30 Million M_{new} = 90% of the original amount E_{new} = 100 % of the original amount	P = $ 1.0, C= $ 0.4 Total profit is= $ 30 (1.0-0.4) million = $ 18 million	L= 4, α =1 FD= 20 min /day* 30 days= 600 min S= 30* 4* 600= 72000 Million min.
	N= 1.2 Million M_{new} = 30% of the original amount E_{new} = 100 % of the original amount **Improve**	P = $ 12.0, C= $ 4 Total profit = $ 1.2(12-4) Million = $9.6 Million **Decline**	L= 4, α =1 FD= 8 hours * 30 = 14400 min S= 1.2* 4* 14400= 69120 Million min. **Decline**
	Total N= 30 Million (sales). But New N = 8 Million, remaining 22 million is reused M_{new} = 90% of the original amount E_{new} = 100 % of the original amount **Improve**	P = $ 2.0 , C= $ 0.1 for reused, E= 0.4 +1 (incentive) for new Total profit = $ 22 (2.0-0.1) + 8 (2.0-1.4) Million= $46.6 Million **Improve**	L= 4, α =1 FD= 1 hour /day* 30 days= 1800 min (including carrying time) and FD= 20 min /day* 30 days= 600 min for new bottles S= (22*4*1800) +(8*4*600)= 177600 Million min. **Improve**

Figure 4. Comparison

Note: $\boldsymbol{M_{new}}$ is the new material added, $\boldsymbol{E_{new}}$ is new energies added, ***P*** is the price of the product, ***C*** is the expenses incurred for the product by the company, ***L*** stands for Level of importance, ***F*** stands for Frequency of usage, ***D*** stands for Duration of benefit per usage, $\boldsymbol{\alpha}$ is the average number of people using the same kind of product, and N is the total number of products.

Disclaimer

Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. This use does not imply approval or endorsement by NIST, not does it imply that these products are necessarily the best for the purpose.

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