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Assessing New Product Sustainability Index (NPSI) by Integrating Sustainability Aspects into the Early New Product Design Stages

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BSTRACT

Product design is one of the most important stages in the new product development process influencing global sustainability. However, the early design strategy offers the highest impact on sustainability, the need for using sustainable proactive approach in early design decisions could be the effective tool to achieve sustainability of new products. This paper presents a necessity of considering the sustainability aspects in pre-specification stages of new product design process, and introduces a modified methodology for establishing a single Index termed as New Product Sustainability Index (NPSI) which enables the designers to carry out a quick analysis of the alternatives of new product designs and make choices based on various criteria. The index aggregates (TBL) and R & D aspects of different types of quantitative and qualitative indicators and information objects from a product manufacturing point of view, into one single index. The sustainability matrix, aspects and criteria used in evaluating of (NPSI), is constructed in table form.

Keywords*:* Sustainability, Sustainable Manufacturing, Sustainability Index, Ecodesign, New Product Design, Triple Bottom Line (TBL), Aggregation Method.

تقدير مؤشر الاستدامة لمنتج جديد بدمج سمات الإستدامة مع المراحل المبكرة لتصميم المنتج

الخلاصــة

يعتبر تصميم المنتج من المراحل المهمة في عملية تطوير المنتج الجديد والتي تؤثر على الاستدامة الشاملة. وبينما تقدم استراتيجية التصميم المبكر التأثير الأعلى على الإستدامة، فإن الحاجة الى إستخدام اسلوب استباقي للاستدامة في قرارات التصميم المبكر قد تكون الاداة الفعالة لتحقيق الاستدامة للمنتجات الجديدة. ان هذا البحث يشير الى ضرورة الاخذ بنظر الاعتبار سمات الاستدامة في مراحل ما

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قبل المواصفة في عملية تصميم المنتج الجديد، ويقدم منهجية معدلة لتأسيس مؤشر منفرد يعبر عنه بمؤشر الاستدامة للمنتج الجديد (NPSI) والذي يمكّن المصممين من تنفيذ تحليلات سريعة لبدائل تصاميم المنتج الجديد والقيام بإختبارات قائمة على اساس معايير مختلفة. ويجمع المؤشر سمات خط الأساس الثلاثي (TBL) وسمات البحث والتطوير لمختلف انواع المؤشرات الكمية والنوعية والمعلومات المقصودة من وجهة نظر تصنيع المنتج بمؤشر منفرد واحد. تم صياغة مصفوفة الاستدامة والسمات والمعايير المستخدمة في تقدير (NPSI) على شكل جدول.

INTRODUCTION

The challenging Key for manufacturing companies is not only to manufacture products using sustainable approach, but designing products which are environmentally conscious, because the wrong choice of a concept in a given situation can rarely, if ever, be recouped by brilliant detail design [1].

Product design is one of the most important stages in new product development process, as almost all the products consumed by people are outputs of the product development process. Therefore, early design decisions can have very significant impacts on characteristics of the developed products, in particular, the sustainability of the materials, manufacturing processes choices, and then the entire product's life cycle, transportation, distribution, and end of life logistics [2].

The early stages of design can be defined as the stages prior to the specification being set. This is the stage when none of the decisions about the product have been finalized and things are usually very flexible.

Unfortunately the earlier stages suffer from a lack of tools and methods which can make it difficult for designers to see away forward [3]. The World Commission on Environment and Development (WCED) report in (1987) has put forth a definition of "sustainability" as: meeting the needs of the present without compromising the ability of future generations to meet their own needs [4,5,6].

According to the US National Research Council (1999), sustainability is defined as" the level of human consumption and activity, which can continue into the foreseeable future, so that the systems that provide goods and services to the humans, persists indefinitely [5,7].

According to the Lowell centre for sustainable production, sustainable production is defined as the creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people[8,9,10].

In terms of sustainable development (sustainable development, production, manufacturing), also Ecodesign, sustainable design, design for environment, are used interchangeably in this paper.

The concept of sustainable (production or manufacturing) emerged at the United Nation Conference on Environment and Development in (1992) and is closely related to the concept of sustainable development. The conference concluded that the major cause for continued deterioration of the global environment is the unsustainable pattern of consumption and production especially in industrialized countries [1,10,11,12]. While sustainable consumption targets consumers, sustainable production is related to production or services companies and organizations that make products or offer services [10,12]. Manufacturing industries are often cited as sources for environmental degradation and social problems, but they are the major sources of wealth generation [8].

The practical implications of this definition are diverse, ranging from the consumption of resources with respect to their rate of renewal, the efficiency of resource use, and the equity of their use across societies and generations, with different emphases according to discipline and political ideology.

However, recent sustainability research has become more quantitative and includes more dimensions of sustainability simultaneously which will allow for more targeted policies to be implemented and their success tracked more closely[7].

Achieving sustainable production will require changes in industrial processes, in the type and quantity of resources used, in the treatment of waste, in the control of emissions and in the products produced [6].

The UN Conference definition is consistent with current understanding of sustainable development, since it emphasizes environmental, social, and economical aspects of firms' activities.

At the same time it is more operational since it highlights six main aspects of sustainable production:

- Energy and material use (resources).
- Natural environment (sinks).
- Social justice & community development.
- Economic performance.
- Workers, and
- Products [8, 10].

Currently environmental impact is analyzed after all the important product decisions are made. Early design decisions account for 70% of the environmental impact [1]. Therefore it is crucial for manufacturing companies to improve environmental performance in order to reduce the real threat which leads to disturbance of ecological equilibrium. In the early days of industrial environmental consciousness focus was set on so called "end - of - pipe" solutions, i.e. solutions aimed at reducing the amount of hazardous emissions and substances after manufacturing. Recently focus has changed towards the environmental performance of the products and consequently product development has become of great importance because a product's environmental performance is mainly determined during the product development process [13], which is a proactive approach. Companies adopting this approach consider the environmental challenge as a competitive business opportunity rather than as an obstacle. They integrate environmental aspects in all functions of the business and the goal is zero waste [8].

Sustainable manufacturing aims for the future, where products are 100% recyclable and manufacturing processes minimizes the negative environmental impacts, conserve energy and natural resources [12], and the complete disassembly of products at its end of life is routine. This vision of the future needs to be a trusted system of measures to support the nations' ability to monitor energy consumption, hazardous materials usage and carbon output through the lifecycle of manufactured goods, from raw materials extraction, production of goods and use of products, including ultimate disposal, recycling, remanufacturing or reclamation [5].

SUSTAINABILITY INDICATORS & INDICES

Companies have long used standard financial indicators to determine their business success, only recently have a growing number of companies began to use environmental, health and safety (EHS), and social indicators. While the number of sustainability indicators in the literature is growing, none of them advances the understanding of corporate sustainability [10,12].

Human –Environmental systems are multi-dimensional influenced by many different economical, social and environmental characteristics. These characteristics interact in a complex network of feedbacks [7].

The indicators, concepts and measures used in sustainable manufacturing are both technical and process related quantifiable and qualitative. Therefore, technological changes, standards and metrics are necessary for a consistent, systematic, harmonized, comparable understanding, implementation and measurement of this new practice [9].

1- An ***"indicator"*** is a variable which describes one characteristic of the state of a system, usually through observed or estimated data. Some indicators may give information about the position of the system relative to particular sustainability boundaries or goals [7].

Indicators basically measure a single parameter of a system e.g. CO_2 emission, or energy use [5,14], and can be classified into various types such as descriptive, normalized, comparative, structural, intensity decomposition, causal, consequential, and physical[5, 15]. Indicators provide key information to a physical, social, and economical systems. They allow analysis of trends and cause- and- effect relationships and thus are a step beyond primary data. They have three key objectives:

- To raise awareness and understanding.
- To inform decision making, and
- To measure progress towards established goals [6,12].

Indicators then become the specific measurement of an individual aspect that can be used to demonstrate the status and performance of a system relative to a particular aspect and category. Aspects are defined as general type of data that is related to a specific category. Categories are broad areas of influence related to environment, economy and society referred to as the Triple Bottom Line (TBL) of sustainability [5].

Indicators have increasingly been used as a tool to measure progress toward sustainable development at different levels – national, regional, local and company [10].

It could be argued that it is not possible to have a set of sustainability indicators, applicable to any company or organization, since companies vary enormously in their business activities, and we still do not have the scientific knowledge and technology to implement such sustainability indicators,

- But it is possible to have a standard set of indicators (i.e. indicators applicable to any company); and
- As Vollmann points out, it is better to measure the right things approximately than the wrong ones with great accuracy and precision [10,16].

Indices are basically aggregates of several indicators, e.g. ecological footprint (a ratio of the amount of land and water required to sustain a population to the available land and water for the population) or environmental vulnerability index (consists of indicators of hazards, resistance and damage). Indices represent a single score by combining various indicators of different aspects of a system [5].

Indices can provide a simplified, coherent, multidimensional view of a system. To achieve and maintain sustainability, policy- makers require timely information which demonstrates whether a system is generally becoming more or less sustainable, and specific information on which characteristics need the most improvement.

Sustainability indices have been developed specifically to help policy -makers; they are usually giving a static overview of a system, but when calculated periodically, they can indicate the situation of the system if it is becoming more or less sustainable, and can highlight which factors are most responsible for driving the system [7, 14, and 17].

Indices will comprise a more holistic view of sustainability. Combining the indicators from the environmental, economic and social dimensions and evaluating those indicators will measure the sustainability on a much larger scale than individual indicators and, if interpretable, will create focus areas for improvement in regards to sustainability [14].

Interpretability with indices however, a key issue because the complexity of the interrelationships of indicator causes a number of contrary conclusions about the level of sustainability and what can be done to improve it [18].

Indices provide more straightforward conclusion on the level of sustainability because they rely on mathematical methods to aggregate many indicators into a single score. With a single score, a sustainability level can be set and used as a metric for performance, but still in regards to how to improve the sustainability contrary opinions can be drawn because of possible different interpretations of the indicators at a low level. Such difficulties with decision making have led to the introduction of a number of indicators, sets, and indices to attempt to match the varying level of evaluation. With current indicators, sets, and indices, sustainability is measured at different levels from low levels (process or product), high levels (organization or company), to macro-levels (region or nation) [14].

The strengths and weakness of several sustainability indices are compared by Mayer [7]. The authors identify several issues across sustainability indices: system boundaries, data inclusion, standardization and weighing methods, aggregation method, comparisons across indices.

Frameworks: A sustainability framework is not an index; they present large numbers of indicators in qualitative ways e.g. the vulnerability framework or the CRITING framework, which is a rather complex framework, with indicators split into three levels and grouped by dimension and type of ecosystem function represented [7].

Frameworks do not aggregate data in any manner. An advantage of them is that the values of all indicators can be easily observed and are not hidden behind an aggregated index; there is no loss of information. The disadvantage of using frameworks is that they are hard to compare overtime [5, 7].

RESEARCH CONTRIBUTION

The better performing and improving companies identified the significance of including Ecodesign in the pre-specification stages of design and are exploring ways to implement it. There is clearly a gap and an opportunity for the development of tools for use in this stage [3].

This paper will link between sustainable designs of new products & sustainable manufacturing by considering all of the sustainability aspects in addition to criteria related to R & D aspects, which will affect on the early design decisions. The main focus of this paper is developing and introducing a modified methodology for establishing a single Index termed as New Product Sustainability Index (NPSI).

The index aggregates different types of qualitative & quantitative sets of sustainability indicators into one single index. Thus the index has to work with both product and process standards, and inputs & outputs standards related to the manufacturing system.

The paper introduces functional descriptions and defines the goals of the criteria used in evaluating the index.

The NPSI will take the advantage of easy observation of values of all indicators which will help in re-evaluating and improving the solution i.e. there is no hidden or loss in information.

NPSI can be used in early design decisions in design or new product development stage, in addition to any later stages.

THE PROPOSED APPROACH

It is important to understand that even new designs are combination of existing ideas, concepts, parts and manufacturing processes. The environmental impact depends on material, manufacturing processes and the usage of the product over its lifecycle; which in turn depends on the structure of the product [1]. Using analogy from nature, a zero impact product is defined as one that can be remanufactured again with only the material and energies which is left behind after its actual usage [5].

ASSESSMENT OF SUSTAINABILITY PROCESS

The proposed method to assess sustainability of new product concepts and then products, manufacturing processes, is by using Triple Bottom Line (TBL) as the three main aspects of sustainability, and two additional aspects, which are technical advancement & performance management [9,10,12,14,19].

The primary approach is to define individual method to assess the impact of a product and manufacturing processes on environment, society and economy, and then to define a value based sustainability measurement method by considering all of the three basic and two additional dimensions of sustainability.

In early new product design stage, it is necessary to consider the following steps:

a. Exploring technological developments related to the manufacturing domain experts.
b. Defining the innovation systems objectives, boundaries, inputs, outputs, environmental, social and economical requirements, in addition to sustainability decision criteria covering all the system.
c. Assessing potential sustainability impacts of each sustainability decision criteria definitely.
d. Evaluating, weighing and aggregating these impacts.
e. Developing & improving the new product design according to the (NPSI) [adapted from 20].

MODELING OF SUSTAINABILITY INDEX IN AN EVALUATION MATRIX

It is important to consider that the fewer the number of metrics, the better and easier to implement, but should still indicate broader performance and should at least be comprehensive in terms of its treatment of all the main and additional aspects of sustainability [21].

For better understanding of sustainable production, the Lowell Center for Sustainable Production (LCSP) has formulated nine guiding principles of sustainable production (Table 1).

To establish the evaluation matrix, the following steps should be performed:

a. Establishment of a list of sustainability main criteria and sub-criteria for (NPSI) matrix that is used as a tool for assessing and judging values of new product concepts alternatives. The higher level criterion takes into account all viewpoints formalized by a set of sub-criteria which is assumed to be operational, coherent and exhaustive [20]. (Table 2) shows the five main aspects (TBL + Two additional aspects) and criteria and sub-criteria under each main criterion.

b. Development of weights which represent the relative importance of any main criterion in relation to others in the list of main criteria. The higher weights are assigned for more important criteria. All sub-criteria under any main criterion share the weight assigned to their parent main criterion.

For this purpose, a questionnaire based on paired- comparison techniques, can be used for assigning a numerical relative importance weight to each main criterion. The same technique can be used for sub-criteria.

CALCULATION METHOD OF SUSTAINABILITY MATRIX

Once the considered sustainability matrix is organized as in Table 3, the (NPSI) can be conduct to evaluate each concept alternative with respect to the sustainability criteria.

The evaluation can be performed by using aggregation method (geometric aggregation i.e. the product of weighted criteria, or Non compensatory multi-criteria analysis, compensability refers to the existence of trade-offs i.e. possibility of offsetting a disadvantage on some criteria by a sufficiently large advantage on other criteria). With this method, qualitative and quantitative information can be jointly treated [23].

The aggregation method was designed based on:

a. *Suitability* of new product design concept with each sub-criterion. The suitability of a concept can be rated (1-10) from worst to best; at its best this method would appear to satisfy the target sustainability.
b. The *compatibility* value for each criterion, which is the degree of fit of the design concept with any criterion, is determined by multiplying the suitability value by the corresponding criterion weight.
c. *New Product Sustainability Index* (**NPSI**) can be calculated by aggregating the indices of the five sustainability aspects $\boldsymbol{NPSI_i^{(k)}}$, i.e.:
   1. New Product Sustainability Index (**NSPI**) for Environment ($_{En}$) for the concept ***(k);***$(\boldsymbol{NPSI_{En}^{(k)}})$ **.**
   2. **NSPI** for Society ($_{So}$); $(\boldsymbol{NPSI_{So}^{(k)}})$.
   3. **NPSI** for Economics ($_{Ec}$); $(\boldsymbol{NPSI_{Ec}^{(k)}})$.
   4. **NPSI** for Technical Advancement ($_{TA}$); $(\boldsymbol{NPSI_{TA}^{(k)}})$.
   5. NPSI for Performance Management ($_{PM}$); $(\boldsymbol{NPSI_{PM}^{(k)}})$.

The calculation steps excerpted and adapted from ref. [20,22].

- To calculate **NPSI** for any aspect; use the equation (1),

- To calculate **NPSI** for all sustainability aspects; i.e. for the concept, use the equation (2).

$$NPSI_i^{(k)} = \sum_{j=1}^{J} W_{ij} S_{ij}^{(k)} \Big/ \sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)} \qquad \textit{for any aspect } \boldsymbol{i}. \ldots(1)$$

$$NPSI^{(k)} = \sum_{i=1}^{I} \sum_{j=1}^{J} W_{ij} S_{ij}^{(k)} \Big/ \sum_{i=1}^{I} \sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)} \qquad \textit{for all aspects } \boldsymbol{i}. \ldots(2)$$

Where:

$NPSI^{(k)}$: Represents the New Product Sustainability Index for the concept ***k*** according to all the five aspects.

i = 1, 2, ….I; I is the number of sustainability aspect.

j=1, 2, …J; J denotes the number of sub-criteria under any aspect.

k=1, 2, ….K; K represents the total number of design concepts being assessed.

W_{ij}**:** Relative importance weight assigned to the sub-criterion ***j*** under the aspect ***i***.

$S_{ij}^{(k)}$: Suitability of concept ***k*** with the sub-criterion *j* under the aspect ***i***.

As shown above, $NPSI_i^{(k)}$ and $NPSI^{(k)}$ were normalized into a common scale, by using:

$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$ and, $\sum_{i=1}^{I} \sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$

The final assessment of the New Product Sustainability Index (**NPSI**) of any concept (**k**) from the evaluation matrix is the aggregation of all the normalized weighted sum of (all the sub-criteria evaluations).

d. The index may take any value between (**0 & 1**), the recommendations can be done by using cutoff values and choosing the higher values.

Excel – based computer application can be used to execute the task. According to the (**NPSI**) values, the decision makers need to ask how a concept can help to move forward or how the concept can modified to make it more attractive and sustainable, rather than how to determine which concept to eliminate[13].

The re-evaluation can be performed for some attractive concepts, by improving values of low suitability scores of some sub-criteria. Having decided which concepts are worth further attention, the next step is to prioritize the attractive concepts and select the best ones.

Table (3) was constructed to illustrate the sustainability matrix, aspects and criteria used in evaluation of (**NPSI**).

CONCLUSIONS

The paper highlighted the importance for successful sustainable design of having structured approach to integrating sustainability decisions at these very early stages. One particular problem in this stage was the lack of tools available for designers to use for sustainable designs. These tools as indices can be very powerful for sustainability policy but only if they are used appropriately and the information objects are available. Indices such as NPSI will enable them to carry out a very quick analysis of the alternatives they have for new product. Another problem in this stage was the lack of accurate and precise information about the criteria or indicators used in the index.

The indicators or sub-criteria used in this paper could be classified into two sets; with one set of obligatory baseline criteria and another set of optional, self- determined criteria. It is very hard to determine which criteria are effective since the same criteria may be effective at one company and ineffective at another. Therefore, this classification has to be considered on an individual basis to reflect specific characteristics of different manufacturing companies and products to be produced.

The limitation of the proposed index includes the information about uncertain manufacturing processes handling and the weighting method enhancement. It is necessary to incorporate uncertainty analysis into the index assessment, and further improve the sustainability weighting calculations in the matrix evaluation model.

For such system to interoperate, it is necessary to understand metrics standards and business and information objects from a product manufacturing point of view. Sustainability standards have to work with product and process standards. It is also necessary to see standards related to outputs and inputs that are related to the manufacturing system.

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Table 1: Principles of sustainable production (adapted from the Lowell Center for Sustainable Production) [9, 14].

1- Products and packaging are designed to be safe and ecologically sound throughout their life cycles; services are designed to be safe and ecologically sound.
2- Wastes and ecologically incompatible byproducts are continuously reduced, eliminated, or recycled.
3- Energy and materials are conserved, and the forms of energy and materials used are most appropriate for the desired ends.
4- Chemical substances, physical agents, technologies, and work practices that present hazards to human health or the environment are continuously reduced or eliminated.
5- Workplaces are designed to minimize or eliminate physical, chemical, biological, and ergonomic hazards.
6- Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm.
7- Work is organized to conserve and enhance the efficiency and creativity of employees.
8- The security and well-being of all employees is a priority, as is the continuous development of their talents and capacities.
9- The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.

Table (2) shows the five main aspects (ABL & Two additional measures) and sub-criteria under each main criterion [excerpted & adapted from references 10,11,14,15,19,21,24].

Sustainability Aspects (1)	*Criteria, Sub-criteria(2)*	*Functional Description of metric (3)*	*LCSP Principle according to Table 1 (4)*	*Generic Goal (5)*	*Metric (6)*
1- Environmental	**a- Emission to the Environment**				
	1-Water emission	An indicator that measures organizational water use relative to an allocated share of locally available renewable supplies.	Principle #3	Reduce the use of fresh water.	liters
	2- Solid waste assimilation	An indicator that measures organizational emissions of solid wastes relative to an allocated share of the earth's assimilative capacity to safely absorb them (e.g., landfill capacities).	Principle #2	Reduce the amount of waste	kg
	3-Air emission	An indicator that measures organizational impacts on air quality, relative to standards for what such impacts ought to be in order to ensure human well-being.	Principle #4	Reduce greenhouse gas emissions	kg

	4-Weight of hazardous waste	An indicator that measures organizational impacts of hazardous waste, relative to standards for what such impacts ought to be in order to ensure human well-being.	Principle #4	Reduce the amount of waste generated before recycling (air, water, and land).	kg
	b- Resource (energy & material usage)				
	1-Materials used: - Total &per unit product	An indicator that measures organizational use of, and/or impacts on, non-water natural material resources, including space, relative to standards for what such usages or impacts ought to be.	Principle #3	Reduce material use.	kg
	- % of recycled input materials			Increase the use of recycled materials.	%
	2-Energy consumption - Energy use (total & per unit of prod.	An indicator that measures organizational energy use relative to an allocated share of locally available renewable supplies.	Principle #3	Reduce energy use.	kWh
	- % energy from renewable			Increase the use of energy from renewable sources.	%
	-Energy saved due to conservation & efficiency improvements			Reduce energy use.	kWh
	3-Water use (total water consumption)	An indicator that measures organizational water use relative to an allocated share of locally available renewable supplies.	Principle #3	Reduce the use of fresh water.	liters
	c- Ambient Ecosystem				
	1-acidification potential	An indicator that measures organizational impacts on flora, fauna, and biodiversity, relative to standards for what such impacts ought to be in order to ensure human and non-human well-being. PBT: Persistent, Bio-accumulative and Toxic.	Principle #4	Reduce emissions of acid gasses	Tons of CO_2 equivalent
	2-kg of (PBT) chemicals used			Phase out all (PBT) chemicals	kg
	3-Global warming potential			Reduce greenhouse gas emissions.	Tons of CO_2 equivalent

Table (2) (continued)

(1)	*(2)*	*(3)(*	*(4)*	*(5)*	*(6)*
2- Economical	**a- Financial Performance**				
	1-Costs associated with EHS compliance (e.g. fines, liabilities, worker compensation, waste treatment & disposal, remediation)	An indicator that measures organizational impacts on flora, fauna, and biodiversity, relative to standards for what such impacts ought to be in order to ensure human and non-human well-being.	Principle #6	Reduce EHS compliance costs	$
	2- Operational costs: - Material acquisition - Manufacturing: -Production costs	An indicator that used to establish cost & profit guidelines and decisions.	Principle #6	Reduce Operational Costs	$

5- Social well-being (community development & socialization)	**a- Employee:**				
	1- Health & safety.	An indicator that measures organizational impacts on human heath, relative to standards for what such impacts ought to be in order to ensure human well-being.	Principles #4, 5	Achieve zero lost workdays as result of work-related injuries and illnesses.	Rate
	2- Average hours of employee training per year.	An indicator that considers the skill development of workers per given	Principles #7, 8	Increase employee training.	hrs
	3- Employee job			Increase employee	

	- Management costs				
	3- Profits		Principle #6	Increase profits	$
	b- Productivity	An indicator that used to measure the overall financial efficiency of an organization and its processes.	Principle #6	Increase personnel & labor efficiency	%
	c- Investment:				
	- In local suppliers - In Environmental protections	An indicator that used to establish the growth of a product and/or company and to measure the overall financial growth and sustainability of an organization.	Principle #9	Increase community spending & charitable contributions	$
	d- Products:				
	1-Percent of components designed for disassembly	An indicator that measures organizational impacts on ecosystem health and habitats relative to an allocated share of related carrying capacities and/or impacts on non-human well-being.	Principle #1	Design all products so that they can be disassembled, reused or recycled.	%
	2- Percent of biodegradable packaging			Use 100% biodegradable packaging.	
	3- Percent of components with take-back policies in place			Increase percent of products with take-back policies.	

	satisfaction rate.	programs, and their satisfaction within an organization, the rights of workers and indirectly their effectiveness in regards to quality and performance.		well-being and job satisfaction.	%
	4- Employee turnover rate.			Reduce turnover rate	Rate (years)

4- Technical Advancement	**a-** R & D staff.	R&D staff considers the experience of personnel within the R&D departments of an organization or company for the benefit of innovation in product and process development.	Principles #1, 2, 3, 4, 5, 7, 8, 9.	Increase personnel & labor efficiency	Rates (1- 10)
	b- R&D expenditure.	R&D expenditure concerns the monetary and time investments for R&D projects within an organization.		Raise the ability for the organiz-ation to promote technological advancement for society through education and research & develo pment and in the contributions made through patents and publications.	
	c- Technology imports.	Technology imports are the technologies or products imported from out of the country of residence for an organization and specifically establish a technology level for an organization based on the availability to certain technologies and products.			

(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
3- Social well-being (community development & social justice) (continued)	5- Gender Ratio.	Same as above.	Principles #7, 8	Increase employment opportunities for the local community.	%
	6- Livable wages compared to local minimum wage.	An indicator that measures the extent to which an organization pays its workers a livable wage, relative to local standards.	Principle #1	Perform equity in wages.	$
	b- Customer:				
	1- Health & Safety	An indicator that measures organizational impacts on human heath, relative to standards for what such impacts ought to be in order to ensure human well-being.	Principles #4,5	Reduce EHS compliance costs.	$
	2- Customer Rights. 3- Customer satisfaction.	An indicator that considers the satisfaction and the rights of customers and indirectly their effectiveness in regards to quality and performance.	Principle #9	Zero customer complaints or returns.	No. of complaints /returns per product sale
	c- community:				
	1- health	An indicator that measures organizational impacts on human heath, relative to standards for what such impacts ought to be in order to ensure human well-being.	Principles #4, 5	Reduce EHS compliance costs.	$
	2- Justice 3- development	These indicators are directly related to an organization's actions per its philanthropy, social amenities, development, and human rights works. All such works maintain the organization's standing amongst the surrounding community and its overall relation with the community without which operation would be difficult if not impossible.	Principle #9	Increase community spending & charitable contributions.	%
	4- Number of community-company partnerships.			Increase community-company partnerships.	Number.
	5-Percent of product consumed locally			Increase sales locally	%

Table (3) illustrates the sustainability matrix sheet, aspects and criteria used in evaluation of (NPSI).
[*10 points scale, strongly disagree (1), strongly agree (10)*].

Sust. Aspect. i	*No. j*	*Criteria, sub-criteria*	*Wei-ght Wj*	*Suitability score S_i j(1…10)*				*Compatibility score C_{ij}*			
				New product Concept k				*New product Concept k*			
				1	*2*	*…..*	*k*	*1*	*2*	*…..*	*k*
1- Environmental		**a- Emission to the Environment**									
	1	Water emission									
	2	Solid waste assimilation									
	3	Air emission									
	4	Weight of hazardous waste									
		b- Resource (energy & material usage)									
	5	Materials used: - Total &per unit product									
	6	- % of recycled input materials									
	7	Energy consumption - Energy use (total & per unit of prod.									
	8	- % energy from renewable									
	9	- Energy saved due to conservation & efficiency improvements									
	10	Water use (total water consumption)									
		c- Ambient Ecosystem									
	11	acidification potential									
	12	kg of (PBT) chemicals used									
	13	Global warming potential									
		$\sum_{j=1}^{J} W_j$									
							$\sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$				
							$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$				
							$NPSI_{En}^{(k)}$				

Table (3) (continued)

	8	-In Environmental protections								
		d- Products:								
	9	Percent of components designed for disassembly								
	10	Percent of biodegradable packaging								
	11	Percent of components with take- back policies in place								
$\sum_{j=1}^{J} W_j$										
$\sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$										
$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$										
$NPSI_{Ec}^{(k)}$										
3- Social well-being (community development & social justice)		**a- Employee:**								
	1	Health & safety.								
	2	Average hours of employee training per year.								
	3	Employee job satisfaction rate.								
	4	Employee turnover rate.								
	5	Gender Ratio.								
	6	Livable wages compared to local minimum wage.								
		b- Customer:								
	7	Health & Safety								
	8	Customer Rights.								
	9	Customer satisfaction.								
		c- community:								
	10	health								
	11	Justice								
	12	development								
	13	Number of community- company partnerships.								
	14	Percent of product consumed locally								
$\sum_{j=1}^{J} W_j$										
$\sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$										
$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$										

4- Technical Advancement	1	R & D staff.									
	2	R&D expenditure.									
	3	Technology imports.									
	4	Scientific papers (Technology maturity).									
	5	Patents.									
	6	Technology exports.									
	7	High technology products.									
$\sum_{j=1}^{J} W_j$											
$\sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$											
$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$											
$NPSI_{TA}^{(k)}$											

5- Performance Management	1	Policy & Program									
	2	Conformance.									
	3	Financial performance.									
	4	Community involvement.									
$\sum_{j=1}^{J} W_j$											
$\sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$											
$\sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$											
$NPSI_{PM}^{(k)}$											

$\sum_{i=1}^{I} \sum_{j=1}^{J} W_{ij}$					
$\sum_{i=1}^{I} \sum_{j=1}^{J} W_{ij} S_{ij}^{(k)}$					
$\sum_{i=1}^{I} \sum_{j=1}^{J} max\, W_{ij} S_{ij}^{(k)}$					
$NPSI^{(k)}$					