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The Role of Companies in Accomplishing Environmental Sustainability Engineering

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Environmental problems deep-rooted in industrial activities have increased considerably, yet the role companies play in accomplishing environmental sustainability (ES) is disappointing. As a result, this paper disaggregates the components of sustainability into more dynamic formulations. For this reason, the study applies input–output life-cycle assessment (IO-LCA) in combination with a simulation of company-specific environmental performance. However, the resulting challenges in this study include integrating environmental, health, and safety concerns with green-product design, lean and green operations, and closed-loop supply chains. It presents a quantitative framework that can be used as a basis for designing sustainable production systems and monitoring existing ones. This includes reflection on how we can harness science and education for ES. This requires the companies to use the concepts of (a) total quality environmental management, (b) ecologically sustainable competitive strategies, (c) technology transfer through technology-for nature-swaps, and (d) reducing the impact of populations on ecosystems.

1. Introduction and literature review

A lot of corporations are taking up the challenge of reducing their impact on the environment. It is a multi-dimensional effort to achieve a balance between what is best for the planet and what is the best for industries. As client alertness and regulatory restrictions increase, it becomes the focus of not only "the right thing to do," but also "the best thing to do. It is clear that there are worldwide environment apprehensions because of the contemporary infrastructural development, which affect ecosystems and resources (Steffen and Tyson, 2011). As a result, the concept of sustainable development started to put in place outline procedures for addressing renewable resources, pollution control drive and improving marketplace failures (Turner, 2006).Sustainable development must be observed at all times, with the three guiding equally central principles; social, economical and environmental values for current and future generations(Garcıa et al., 2007) .This means that for the sustainability aims of engineering enterprises to be accomplished, applicable indexes and values of sustainability must be defined and modelled as a set of systems parameters (Al-dujaili, 2013).
Thus, the sustainability engineering stand point should promote a meticulous balance amongst the three themes of sustainability. As a consequence, professional industrial enterprises should form an essential platform for debate, knowledge sharing; dependability; to create awareness and shape public policy for ES. This requires that a lot of work on industrial projects be done in this area. It is very important to focus on product recovery (recycling, remanufacturing, or re-use) or the product design function (e.g. design for environment). In view of this, the relative decline in the value of key industrial production has not improved environmental impact on the resource base or environmental damage. Therefore, the case can be made that professional engineers have an ethical responsibility to consider the immediate and eventual environmental impacts of products and processes that they design and/or manage (Beamon, 2005).
Nevertheless, technology does not only swap materials with the environment but also with the industrial enterprises as a whole; so-called industrial metabolism. Moreover, it requires that there is a higher compatibility of a specific technology with the industrial enterprises systems, as studied in industrial ecology, which can result in lower resource extraction and reduced output of waste. Ultimately, this contributes to a better ES (Dewulf and Langenhove, 2005). On the other hand, these steps have been found to lead to more

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proactive sustainability aspirations. Sustainability itself, is addressing the needs of the present without negotiating the capability of future generations to meeting their own need and minimize health environmental hazards throughout the chemical production process (Mulvihill et al., 2011).

2. Methodology of research

The research was conducted using the maintenance and manufacturing systems to find out factors affecting the ES and the ability to recycle products within manufacturing enterprises. The aim of this was to identify the lapses within the manufacturing practices and the service delivery within the infrastructure systems. However, 18 a sample of the manufacturing system components was undertaken, including facilities for water supplies, the ability to recycle products, energy and maintenance of the entire system. As a result, the study sought to determine the infrastructure experts' views on the existing practices and better ways for environmental sustainable in the manufacturing enterprises. Accomplishing environmental sustainability engineering (ESE) requires green engineering in the design, commercialization, and use of processes and products, which must remain feasible and economic while minimizing 1) generation of pollution at the source and 2) danger to human health and the environment. Green engineering embraces the concept that decisions to protect human health and the environment can have the greatest impact and cost effectiveness when applied early to the design and development phase of a process or product. Figure1 explains the relationship between the three-dimensions of accomplishing ESE within any industrial enterprise.

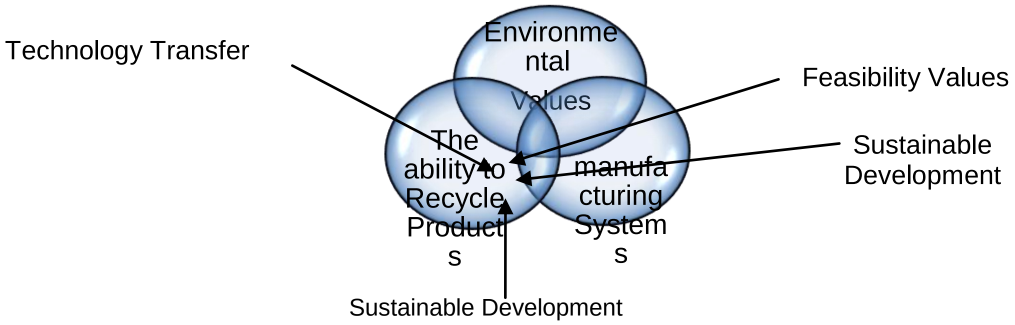

Figure 1: The three-dimensions of accomplishing environmental sustainability engineering

Fundamentally, the set of environmental values are; natural resources exploitation, environmental process drive, pollution prevention and controls- (air, solid waste and water resources). This is because, natural and environmental resources generally describe all the elements available in nature that are used or can be used in the economic system. In other words, natural and environmental resources can be further split into renewable and non-renewable, and non-renewable into recyclable and non-recyclable resources. On the other hand, manufacturing systems place focus on the standards of appropriate environmental indicators and are used for assessing and reducing the impact on the environment arising from manufacturing. At the same time, there are a number of environmental performance criteria, often they tend to be too complicated and there are also a large number of them to deal with. The ability to recycle product, is the reuse of partially processed components. The goal of recycling is to improve the percent yield of material elements during the manufacturing process.

3. Data collection and analysis

The major focus of data collection was be on the maintenance and manufacturing systems to find out factors affecting a suitable ES on the ability to recycle products within manufacturing enterprises in a study sample. Figure 2 explains the ability to recycle product during the manufacturing processes.

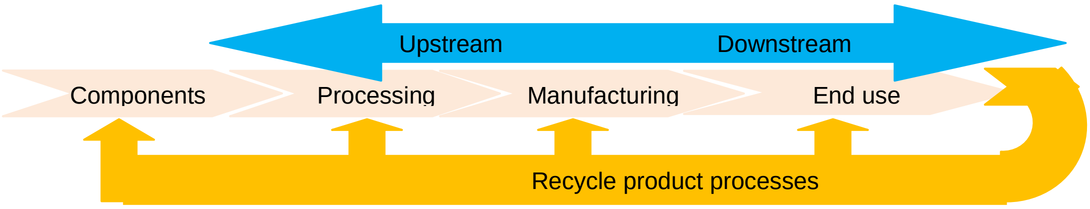

Figure 2 Recycling product during the manufacturing processes

In this case, we developed multiple-item measures of all constructs (variables). Multiple-item measures are commonly believed to improve confidence that the constructs of attentiveness are actuality accurately assessed and the measurement of the variable will be more consistent (George, 2003). According to the following equations; Standard deviation and normal distribution, are expressed as follows; (Devellis,1991)

$$\bar{y} = sample\,mean = estimate\,of\,\mu \tag{1}$$

S= sample standard deviation=estimate of σ (2) *V* = sample variance = estimate of σ^2 (3)

If we have a sample of size *n* and the characteristics are *y1*, *y2*, ..., *yn*, then μ, σ and σ^2 are estimated by, respectively;

$$\bar{y} = \frac{y_1 + y_2 + \dots + y_n}{n} \qquad \delta = \sqrt{v} \qquad v = \frac{\sum_{i-1}^{n} (y_1 - \bar{y})^2}{n-1} \tag{4}$$

The probability density function (PDF), f(x), of a normal distribution is

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left[\frac{x-\mu}{\sigma}\right]^2} \tag{5}$$

Where we usually denote $X \sim N(\mu, \sigma^2)$

When $X \sim N(\mu, \sigma^2)$ it can be converted into standard normal variable $Z \sim N(0,1)$ using the relationship of variable transformation,

$Z = \frac{X - \mu}{\sigma}$ (6), whose probability density function is $f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2}$ (7)

The Bartlett test statistic is designed to test for equality of variances across groups against the alternative that variances are unequal for at least two groups (Devellis 1991).

$$T = \frac{(N-k)Ins_p^2 - \sum_{i-1}^{k}(N_i - 1)Ins_i^2}{1 + (1/(3(k-1)))((\sum_{i=1}^{k} 1/(N_i - 1)) - 1/(N-k))} \tag{8}$$

$$X^2 = \frac{C_1}{C_2} = X^2{}_{(K-1)} \tag{9}$$

Where $H_0 \Rightarrow$ means that the subsamples drawn from the community is of variance σ^2, $H_1 \Rightarrow$ means that the subsamples drawn from communities are different from the variance. Consequently, the formula for the test, is as in Eq. (15, 16):

$$C_1 = \sum_{1-1}^{k} (n_i - 1) Log_e \frac{S_2}{S_i^{\,2}}, S_2 = \frac{\sum_{i-1}^{k} (n_i - 1) S_i^{\,2}}{\sum_{i-1}^{k} (n_i - 1)} \tag{10}$$

$$C_2 = 1 + \frac{1}{3(K-1)} \left[\sum_{i=1}^{k} \frac{1}{n_i - 1} - \frac{1}{\sum_{i=1}^{k} (n_i - 1)} \right] \tag{11}$$

Goodness of fit test: This test can calculate the cumulative distribution function to data that is binned. However, the value of the chi-square test statistic is dependent on how the data is binned. Another disadvantage of the chi-square test is that it requires a sufficient sample size in order for the chi-square approximation to be valid. And the steps to this test are as follows (Bartlett, 1937);

(1) The hypothesis determines what is required of test (H_0) and the alternative hypothesis as follows:

- The variable under study has a limited distribution (H_0);
- The variable under study has no specific distribution (H_1).

(2) Determine the level of moral (α) and then calculate the test, according to Eq. (12):

$$X^2 = \sum \frac{(O_i - E_i)^2}{E_i} \tag{12}$$

Where*E*E_i and O_i represent the frequency of the scenes in the sample, and the frequency distribution expected under the hypothesis specified in H_0. The Ei-npi depending on *n* represents the size of the sample (pi), which represents the relative frequency (probability) that we get it by using the specific distribution of the hypothesis (H_0) required in testing.

(3) Determine the rejection region on the basis of value (ά), and the use of the Chi-square distribution with degrees of freedom equal to K-1, where K represents variable values under the study.

(4) Decision-making with respect to the hypothesis where accepting H_0 when giving values of X^2extracted its tabular value at the amoral level ά.

In view of this, samples were restricted to the companies that embraced environmental values (EV) or held similar process innovation campaigns which adopted green engineering sustainable (GES) to limit the use of non-renewable resources, reduce environmental disasters, maintain natural habitats and biodiversity and control the use of renewable resources, and that for the purpose of controlling the process of products

Table 1: Regression values for a EV, GES and ARP

samples	EV	CP	PPR
1	0.81	1.0	0.88
2	0.84	3.0	0.81
3	0.68	2.0	0.75
4	0.79	2.0	0.75
5	0.77	1.9	0.89
6	0.75	1.5	0.91
7	0.86	2.0	0.91
8	0.91	3.0	0.68
9	0.83	1.9	0.85
10	0.78	1.8	0.87
11	0.89	1.6	0.72
12	089	1.4	0.65
13	0.97	1.4	0.77
14	0.76	2.0	0.79
15	0.82	1.9	0.59
16	0.84	2.3	0.87
17	0.93	1.9	0.88
18	0.91	2.0	0.89

recycle (PPR). Subsequently, we conducted the collection of data based samples which are taken directly from production lines. Before using the homogeneity test of the samples, we have calculated EV values and then used regression testing about the relationship among GES and ARP to measure constructs, as explained in Table 1 and Figure 3.

In accordance with these results, the application of EV and PPR methodology provides a reduction in variance and augmentation in the PC, the correlation value was 0.84 under a moral value 0.05, while R2 was 0.79 according to Eqs (1), (2), (3) and (4). This means, the CP index relates the scaled distance between the process mean and the nearest specification limit. As it is explained in the results above, a GES process can be interpreted in terms of process capability. This requires of the manufacturing companies within this study to produce a product with a specified CP value.

Furthermore, the use of life-cycle thinking in all engineering activities, makes sure that all material and energy inputs and outputs are as inherently safe and benign as possible. Additionally, this leads to prevention of waste, and creates engineering solutions beyond current or dominant technologies; improving, innovating, and inventing (technologies) to achieve sustainability. According to the Bartlett test Eq(10) and (11) clarifies the homogeneity test of the samples EV and compares the values with the tabular values. The results for this test clearly show that all of the values were less than tabular values. That means the acceptance of the hypothesis H_0. In other words, the 18 samples have been drawn of the community variances (σ^2), i.e., the variations were homogeneous, giving S^2. It is a good estimate of the variation of this community (σ^2) according to Eqs (5), (6) and (7).

This test also boosted by the goodness of fit Test according to Eq(12) to calculate the cumulative distribution function (CDF) to data that is binned. It was found that the value of a standard test with degree of freedom (K-1=18) and with moral level (0.05). They were less than the tabular value ($X^2_{0.05,\,18}$= 43.646).

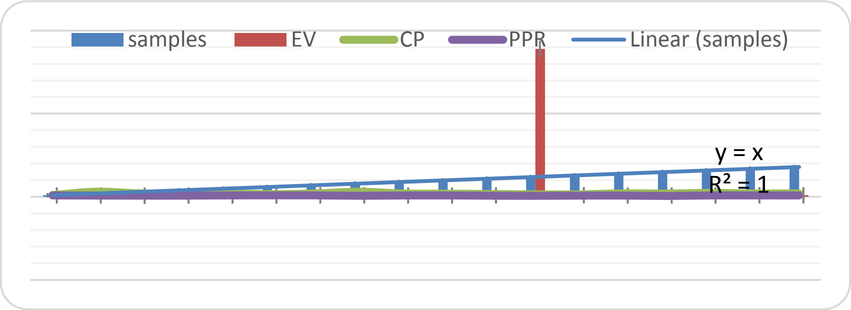

Figure 3 application of EV & PPR for augmentation in the PC (Source: Table 1)

Table 2: calculating the values among Bartlett test, Goodness of Fit and EV, CP, GES and PPR

Samples	Bartlett Test	Goodness of Fit	EV	CP	GES	PPR
1	32.61	2.67	0.81	1.0	0.83	0.88
2	30.34	2.99	0.84	3.0	0.78	0.81
3	28.52	2.77	0.68	2.0	0.98	0.75
4	27.42	1.88	0.79	2.0	0.87	0.75
5	31.24	2.08	0.77	1.9	0.77	0.89
6	28.52	3.09	0.75	1.5	0.88	0.91
7	29.17	2.98	0.86	2.0	0.67	0.91
8	31.66	3.22	0.91	3.0	0.94	0.68
9	33.88	2.65	0.83	1.9	0.65	0.85
10	28.89	3.12	0.78	1.8	0.83	0.87
11	31.56	2.88	0.89	1.6	0.76	0.72
12	30.91	2.00	089	1.4	0.75	0.65
13	29.78	1.89	0.97	1.4	0.91	0.77
14	37.23	2.89	0.76	2.0	0.71	0.79
15	33.32	2.06	0.82	1.9	0.69	0.59
16	26.96	3.55	0.84	2.3	0.86	0.87
17	34.77	3.66	0.93	1.9	0.79	0.88
18	32.86	2.77	0.91	2.0	0.97	0.89

This means acceptance of the hypothesis (H_0). These test values indicate that enterprises should develop a more sustainable relationship with the environment for purpose of limiting the use of non-renewable resources and maintaining natural habitats and biodiversity as well as control the use of renewable resources.For our places rated dataset, the study finds a significant Increase of fit. ($X^2 = 94.77$; d. f. = 18; $p < 0.01$). We conclude that the relationships among the variables are adequately described by the regression model. This suggests that we have the correct model for adoption among the Bartlett test, goodness of fit and EV according to Table 2 and Figure 4 and have explained that the correspondence between PPR and goodness of fit test has led to GES effect on the CP positively. The software PC/maturity models are storehouses of best practices for software processes, based on engineering processes and products holistically, and use systems analysis, and integrated environmental impact assessment tools, ensuring that all material and energy inputs and outputs are as inherently safe and benign as possible, which leads to minimized depletion of natural resources. However, GES has been applied in these firms of the study field to this specific aim as explained in Figure 4.

This indicates that the effort and resources could be reduced if the manufacturing variation could be forecast and managed through using process of products recycle during the design of the product, to conserve and improve natural ecosystems while protecting human health and well-being. Also, we see that design for GES, process engineering a framework to design materials, processes, systems, and devices with the objective of minimizing overall environmental impact (including energy utilization and waste production) throughout the entire life cycle of a product or process, from initial extraction of raw materials

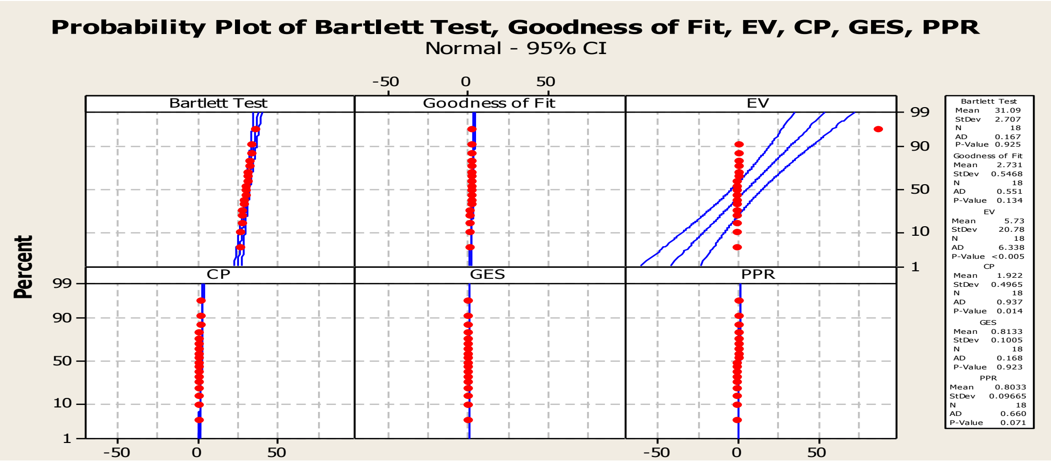

Figure 4 probability plot of Bartlett test,Goodness of fit, EV,CP,GES and PPR in the study (Source:Table 2)

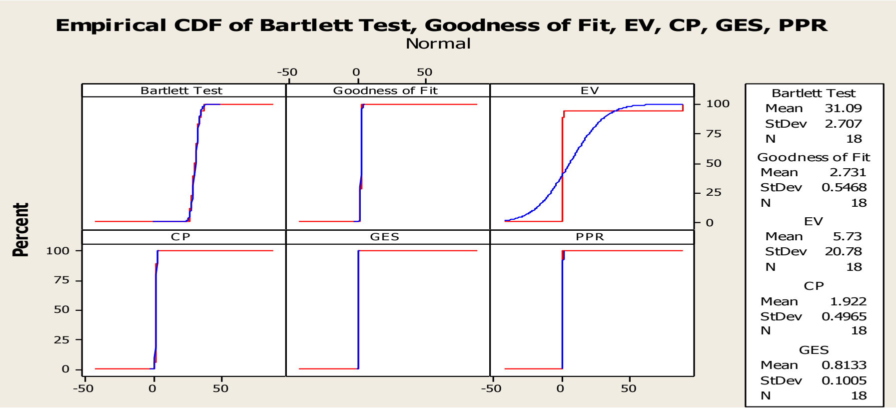

Figure 5: Empirical Cumulative distribution function for the study data (Source: Table2)

used in manufacture to ultimate disposal of materials that cannot be reused or recycled at the end of the useful life of a product as explained in Figure 4 a probability plot. The study data showed that it is normally distributed because it forms an approximate straight line. Additionally, CP is able to create designs that can be manufactured so that there are only 3.4 defects per million parts produced. CDF plot(X) in Figure 5 displayed a plot of the empirical CDF for the study data in the vector X.

The empirical CDF F(x) is defined as the proportion of X values less than or equal to x. This plot, displays the distribution of a sample of data a theoretical CDF on the same plot to compare the empirical distribution of the sample to the theoretical distribution. *h = CDF plot(X) returns a handle to the CDF curve.*

4. Conclusions

In this study, the contributions from manufacturing systems; the ability to recycle products and environmental values (in terms of system probability) yielded the correlation value of 0.84 under a moral value 0.05, while R^2 was 0.79. This is an acceptable sustainability for the industrial projects in the study. This is because, sustainable design" or green engineering includes a planned engineering design approach that meets the needs of the present without compromising the ability of future generations to meet their needs due to the reduction of consumption and waste of natural resources by increasing the resilience of relationships established between consumers and products.

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