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Optimization of Economic and Environmental Perspectives for sustainable Product Design and Manufacturing

Abstract-Growing environmental concerns, coupled with public pressure and stricter regulations, are fundamentally impacting the way companies design and launch new products across markets. Companies are recognizing that implementing design and manufacturing for the environment in their product development process, provides opportunities for both improving the environmental aspects of a product and for enhancing the product competitiveness. Therefore, considering concurrently economic and environmental perspectives for decision-making during early stages of design and manufacturing are considered crucial to the product design process. In this paper, taking into account these perspectives, a framework in design and manufacturing of a new product is presented, using genetic algorithm to obtain the optimal values of performance measures. The combined sustainability index (CSI) is used as an informal measure for identifying the decision variables of a maximally sustainable design and manufacturing method for a new product. The proposed framework has been applied to a case study on a bottle opener design and its manufacturing processes. As a result of this case study, the product sustainability index can be used in order to assist product designers to judge their product at the early development stages.

Keywords-Sustainable Manufacturing and Design; Combined Sustainability Index (CSI); model, multi-objective.

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1. Introduction

The manufacturing industry in recently need for sustainable growth and development to keep the challenges faced resulting from global competition, increasing market demand, and limited resource availability. As a result, manufacturers have expanded their emphasis on the three pillars of sustainability, economic, social and environmental as in Figure 1, also referred as "the triple bottom line or the "3P" planet, people, and profit [1]. Manufacturers need to follow activities of production internalize negative environmental externalities while profits maximize and social economic benefits. Most of the manufacturing organizations spend large quantities of resources at that generates wastes and pollution. However, with recent increase in sustainability issues, organizations should consider taking suitable measures to enhance their sustainability aspects. It has thus become the need of the time for manufacturers to pursue manufacturing activities, which helps in minimizing environmental impacts while maintaining social and economic benefits [2]. Sustainable products are those that provide environmental, social, and economic benefits while

protecting public health, welfare, and the environment over their full commercial cycle (SPC 2011). Therefore, the design and manufacturing of sustainable products must follow a comprehensive approach that simultaneously considers the economic, environmental, and societal aspects of the TBL. This paper aim to achieve sustainable product and to set main parameters to maximize a suggested manufacturing sustainability.

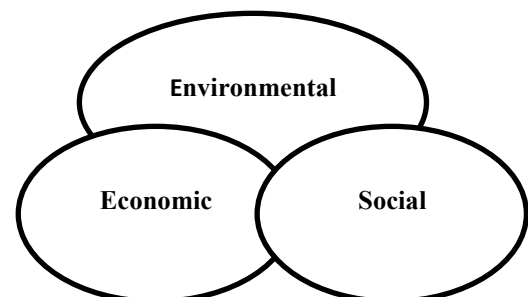


Figure 1: Interaction of three parts of sustainability [3]

2. Literature Review

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In the present time this engineering specially include lowering consumption of energy, minimising impact of environment, and greater focus on decreasing cost. lowering consumption of energy significant to every type of business and almost every individual as the costs of energy continue to rise. Industrial engineers seek for ways to allow systems to decrease the waste of energy by operating at certain times of the day. Minimising impact of environment, while decreasing energy can also be considered a way of decreasing impact of environmental , this is such an important trend that it deserves attention in its own right. Lastly, decreasing cost of manufacturing.

These trends toward “greener” living and decreasing our footprint of environment can be seen in many areas of our lives today, and industrial engineering is no different. one thing we should sure about it that the future will continue to usher in changes and engineers will looke for better ways to adapt. So there are many reaserachers prospsed methodolgy for acheiving sustainable product “green product” .

Kushwaha et al. proposed index term as “A Comprehensive Sustainability Index (CSI) Balanced Social, Economic and Environmental Approach” to measure sustainability of countries based on the triangular tradeoff among environment, economy and society. Collected hierarchal clustering method is used to group 101 countries with their peers into two groups :(1) More Sustainable Nations (63 countries) and (2) Less Sustainable Nations (38 countries).The low standard deviation in CSI represents the clustering of nations about mean CSI value. The clustering is an indicator of mediocre sustainability of nations. Hence severe measures are needed to be taken by governments, policy makers, industry and residents to increase the sustainable environment [4].

Schmidt and Butt et al developed method baed on life cycle assessment term as Product Sustainability Index (PSI), It consists of 8 key environmental indictors toward 3 main portion of product sustainability. The indicators of economic are from Life-cycle Costing assessment method. The indicators of socail are aimed at assement the mobile capability ad safety of the product [5].

de Silva et al sustainability scoring method developed as a quantitatively assess of the potential benefits of Aluminum alloys for manufacturing of an auto body. This method consists of six main components of the Design for Sustainability (DfS): , recyclability and re-manufacturability environmental impact, manufacturability, functionality, utilization/economy of the resource and societal impact. Each one of these components was divided into sub-components. various levels of influencing factors categorized based on their imprtance to the product. The level of significance of each sub-component was appointed with low, medium, or high

weights. At last sustainability scores of the two different materials (Aluminum alloy and Steel alloy) were calculated and their levels of sustainability performance were compared [6].

Zhang et al. introducing methodology use the total life-cycle approach, involving the life-cycle assessment (LCA) method, for improving the sustainability performance of the product of metallic automotive components sustainability aspects [7].

Vilaa et al. proposed framework developed the key stages for a sustainable product lifecycle strategy. The Proposed model establish all the processes carried out through the product lifecycle and indicates the application and interaction of specific methodologies, tools and knowledge at each stage that will help to achieve sustainability. The processes applied are controlled by means of the ecodesign and sustainable manufacturing approach throughout the lifecycle of the product.This makes it possible to increase the efficiency in product development and sustainable lifecycle management [8].

Chen et al., attitude literature review to appreciate asset of 12 sustainability tool used at factory level. The evaluated of the tool addressed against 4 criteria: application at the factory level, generic applicability and holistic view of sustainability. The results call the existing tool defeat to satisfy all 4 criteria, and tool efficiently help decision makers of facility in developing sustainable factories [9].

Joung et al. attitude literature review on sustainable manufacturing indictors comprising 11 indicators. They existed a classification sketch of the National Institute of Science and Technology (NIST) covering 5 dimensions of sustainability: economic, environmental, social, technological advancement and management of performance [10].

Samuel et al. used the developed framework approach by the Global Reporting Initiative (GRI) and the Lowell Center for Sustainable Production (LASP) to appreciate the sustainability of petrochemical industry in Malaysia [11].

Dobrovolskii et al. proposed a tool term as composite sustainability index of a project (CSIP) which to measure the sustainability of a business project in the construction industry, take 15 criteria (four economic, six environmental and five social criteria) of construction sustainability selected, then group of professionals had to rank the importance of each criterion from 1 to 15, where the highest score was 15 points and the lowest 1 point. The next step is normalization by applying a distance to a reference method, the normalized value is calculated as the ratio between the indicator and an external benchmark (or target value). The final step is aggregation. At this stage, an aggregate index, called a composite sustainability index of a project is developed. The most common form of aggregation is

the summing-up of the weighted and normalized individual indicators [12].

Li et al. develop a mathematical model term as Comprehensive Sustainability Index (CSI) that can be used to comprehensively evaluate and clearly define a country's sustainability based on factor analysis. Sustainability index was determined by a linear combination of a set of indicators. They selected 10 representative indicators coming from three aspects: social development, economic development and environmental protection. They used factor analysis to convert observations of correlated variables into values of linearly uncorrelated variables called factors thus determining the weights of indicators. In the evaluation section, they select 15 countries to form the sample, 5 least developed countries, 5 developing countries and 5 developed countries. By calculating the value of CSI of each country, they found out that there are clear differences among the CSIs of the three kinds of countries. And based on such differences, they reached classification of CSI [13].

The current work offers a mathematical model considering the environment and economic aspects of sustainability to help systematically plan and improve sustainable manufacturing activities.

3. Methodology

This section details the proposed framework for considering the overall product sustainability in design and manufacturing development stages taking into account the trade-off between the two perspectives; economic and environmental in terms of the total manufacturing cost and CO₂ emission respectively.

3.1 Theoretical Background of the Framework

Manufacturing companies aims to increase profits by reducing manufacturing cost of product, but given to the increase in taxes paid versus each amount of CO₂ emitted through manufacturing of product. Therefore the world towards to manufacture "green product". Consider a manufacturing system, such as that described in Figure 2, launching a variety of products. The system transforms a set of natural resources with the help of worker, technical methods and processes, and financial resources to outputs. These outputs are the final products to be sold in the market also scrap producing from inefficiencies in the processes of transformation and some of recyclable material. The operation of this manufacturing system has environmental, social, and economic influence on its surrounding environment. Most of researchers introducing approaches to reduce manufacturing cost and others introducing approaches reducing

CO₂ emission, often include limitations such as the lack of integration between the design and manufacturing stages of the product and the key parts of sustainability; economic and environmental. Quantity and variety decisions have to be made that form the efficiency of the manufacturing operation. These decisions are production process method, skill level of workers, number of workers, number of machines, and type of materials. These decisions heavily affect the economic and environmental aspects of the facility, thus, determine the manufacturing sustainability. The target is to arrive at decisions concerning the sustainable product and the aforementioned operating parameters, to maximize system sustainability.

3.2 Mathematical Model

The process and also as a tool that enables decision makers to setting up optimum This paper present mathematical model as a comprehensive evaluation metric for alternative scenarios of al vital decision variables, so as to maximize manufacturing sustainability. The objective function should represent sustainability, while the constraints represent the limited resources. Sustainability consists of 2 pillars, environmental and economic; the objective function will include these elements. The challenge is to integrate these incommensurable aspects. Each of these pillars is evaluated by a set of sub-indicators; economic evaluated by total manufacturing cost of product (C_{TM}); and environment evaluated by Carbon Dioxide Emission from machines during manufacturing process (C_E).

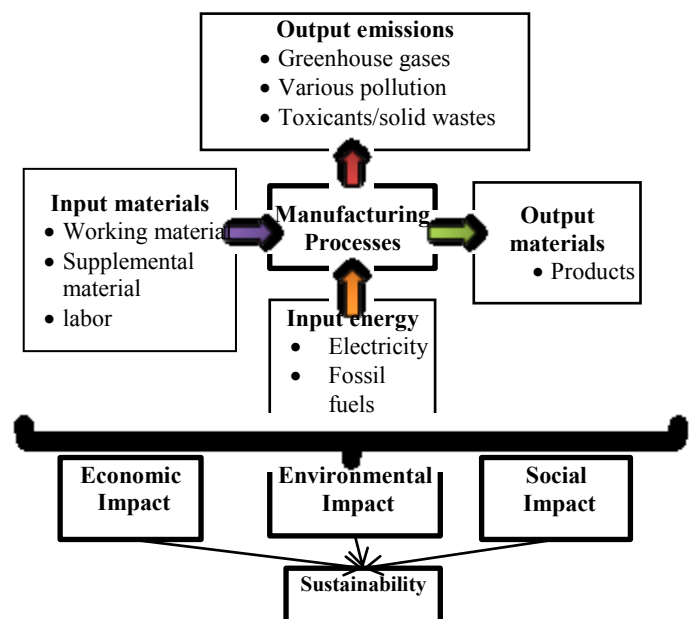


Figure 2: components of a manufacturing system influencing its sustainability [14]

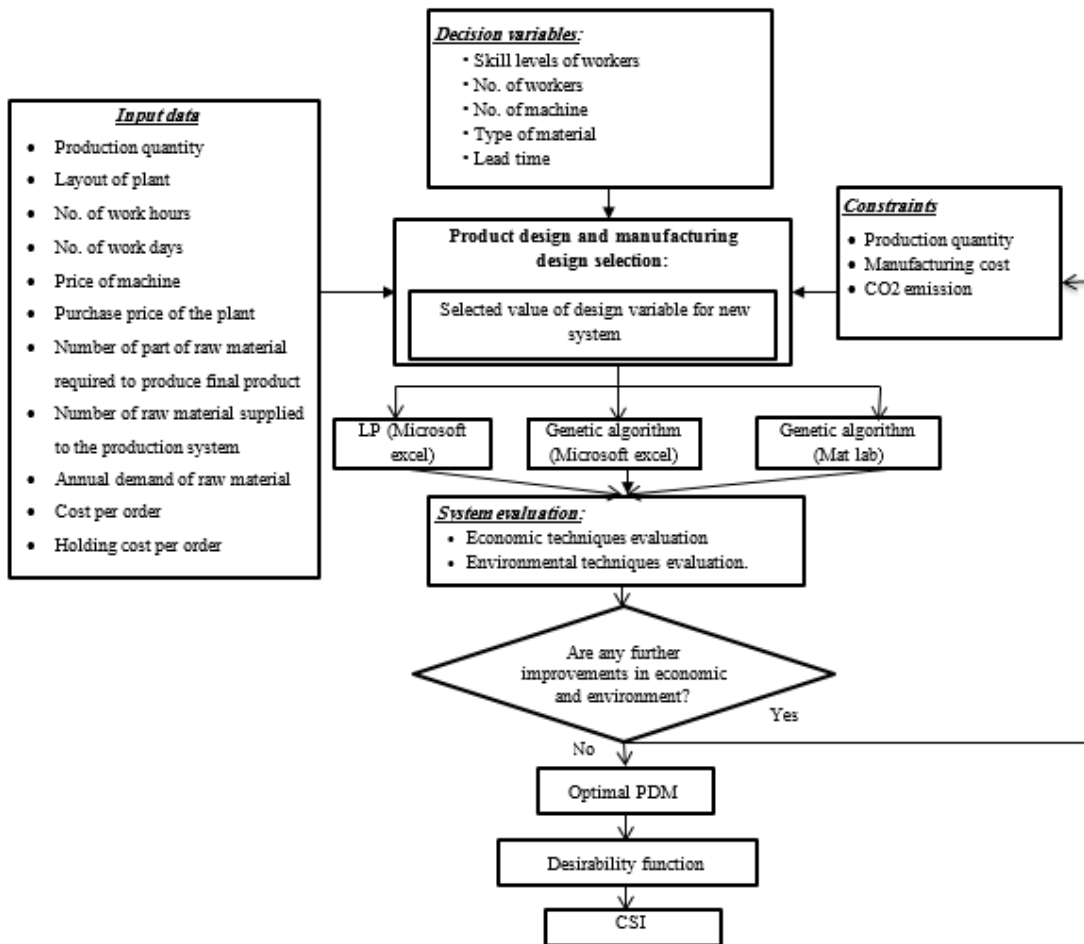


Figure 3: Systematic Approach to Achieve CSI Scoring

All these indicators are devised that they have value ranging from zero to one. The two performance measures discussed in this paper C_{TM} and C_E belong to the smaller-the-better characteristic. In order to find the best decision variable set values satisfying the two performance measures applying genetic algorithm (GA), it is a requirement that these multiple measures are converted into a single measure. This single measure is referred to as comprehensive sustainability index (CSI). The CSI is an overall representative measure and needs to be finally optimised. The desirability function approach is used to convert from multiple measures to a single measure as described in the following Figure 3.

3.2.1 Assumptions of the Model

The following assumptions

- Co2 is considered as one type of
- Constant and deterministic amount of demand.
- Producing each product by exact amount of raw material
- Ability of machine to produce exact amount of product each day.

3.2.2 Model Nomenclature

Parameters

- C_{TM} : Total manufacturing cost required to produce specified production quantity each year.
- C_E : Carbon Dioxide Emission from machines during manufacturing process.
- C_o : Ordering cost of raw materials monetary unit (MU).
- C_H : Holding cost of raw materials within the production.
- C_{tr} : Cost of transportation raw material to production system (MU).
- C_P : Cost of purchasing raw material to produce one product (MU).
- C_U : Cost of utilities of the final product (MU).
- C_D : Cost of duties emerging from producing acquiring raw material from an external supplier (MU).
- T_{P_i} : Price of transfer raw material from an external supplier (MU).
- h: Hourly operation time required to produce the product (hr.)
- AU: Annual use of power (kwh) per year.
- E_C : Energy consumption of power (Kwh/hr.) used per day.

v : Required raw materials destination.
 m_i : Mode of transportation required to transport raw Materail.to its customer.
 N_T : Number of mode transportation used for freighting raw materail to the production system (unit).
 M_i : Raw material types required in producing one unit of product i .
 N_P : The requiried number of parts to produce one product (unit).
 C_{Uo} : Cost of ordering raw materail to produce final product (MU).
 C_{UH} : Cost of holding raw materail required to produce final product in production system (MU/day).
 C_{UMi} : Unit cost of the raw material i at the beginning of each cycle (MU).
 d_{RM} : The everyday demand of raw materail required to meet customer order (unit).
 $\%d_{RM}$: The everyday demand percentage of raw materials required to meet customer order(unit).
 C_{TOMang} : the total managerial cost of ordering per order (MU).
 C_{THmang} : The total managerial cost of holding raw material required to produce final product during specific duration time (MU).
 $\%Util$: : The percentage of utilities cost of final product (MU).
 t_p : Percantage cost of raw materail incurred for acquiring raw materail from external supplier (MU).
 $T_{Si,v,m}$: The tensor of cost of transportation per specific critical measurement (MU).
 t_m : measurement of critical transportation of raw materail freighting by using mode of transportation m .
 $\%V$: the percentage value of volume for transporting raw materail to the customer.
 D_i : rate of duty (%) per price of raw materail provided be external supplier (MU).
 $\%sale$: The percentage value of sales presentedfrom selling furher raw materail during the same order.
 N_{RM} : The number of raw materials provided to the system of production (unit).
 C_E : Carbon emission.
 C_{En} : Energy consumption kwh/year by machines.
 C_{OP} : Operating cost of machine
 C_E : Energy cost, the cost of energy used to operate the machines
 $C_{Li,y}$: Cost of labour by time of one operation.
 P : power (kWh).
 P_E : Price of one kWh used to operate machine.
 Sk : Skill level of worker.
 P_r : Price of the machine.

C_{Ei} : Carbon dioxide (CO_2) emission for the quantity of raw material i ordered in each patch required to produce the final product per week (unit)
 Q_{Mi} : i Raw material weekly batch quantity ordered to produce final required product (unit)..
 C_{EC} : Carbon dioxide (CO_2) emission from machines c in each department.
 TEU : Twenty Foot Equivalent Unit. The two most common international standardized container types are twenty and forty foot. A twenty foot unit measures about 6 meters, a forty foot about 12
 M_i : The type of raw material required to produce one unit of product.
 meters (external dimensions).
 C_{CP} : The cost of waste collection per CP per year
 c_{vy} : is the annual cost of collection per vehicle
 N_{cp} : is the number of served CPs.
 b_v : is the backup rate for the collection vehicle (backup vehicle per collection vehicle).
 C_{cv} : The capital cost of vehicle amortized over its economic life.
 N_{wb} : The number of waste bins that a vehicle can service during one collection trip.
 C_{cwb} : The annual capital cost per waste bin.
 C_{ov} : is the annual operating cost of vehicle.
 e : is the administrative rate.
 C_v : is the unit price of vehicle.
 CRF_{wb} : is the capital recovery factor.
 U_c : is the vehicle utilization factor (usable per total vehicle capacity).
 V_c : is the vehicle capacity.
 F_c : is the frequency of waste collection per week.
 W_{mix} : is the weekly waste generation rate per CP.
 P_{mix} : is the overall density of mixed waste. Overall density of mixed waste.
 P_i : is the weight fraction for waste component i .
 p_{ci} : is the compacted density of waste component i .
 C_{vwb} : is the unit price of waste bin
 CRF_{wb} : is the capital recovery factor.
 i : The yearly discount rate.
 L : is the economic life of collection vehicle.
 a : is the fringe benefit rates.
 b_w : is the backup rate for collection workers.
 S_w : is the salary rate per hour per worker.
 N_w : is the number of collection workers per vehicle.
 S_d : is the driver salary rate per hour.
 MH_D : Man-hours/Day
 η_a : The value of each one of the four performance measures.
 U_η : The upper limits of each one of the four performance measures.
 L_η : The lower limits of each one of the four performance measures.

w1: Indicates the weight of each one of the four performance measures.

Decision Variables

- γ Skill levels of workers
- N_W No. of workers
- N_C No. of machine
- T_{RM} Type of material

3.2.3 The Objective Function

Comprehensive sustainability index proposed as the objective function of the model which to be maximised by minimizing the total manufacturing cost C_{Tm} , carbon emission C_E , in production system. This objective can be formulated as following:

$$\text{Minimise } \sum (C_{Tm} + C_E) \quad (1)$$

I. Total manufacturing cost C_{Tm}

Various costs associated with total manufacturing costs, in this paper total manufacturing cost includes the operating cost " C_{op} ", , raw material cost " C_{RM} ", Utilities Cost " C_U ", , and cost of waste collection " C_{cp} " therefor it can be calculate as :

$$C_{Tm} = C_{op} + C_{RM} + C_U + C_{cp} \quad (2)$$

Each component of the total cost of the final product is described as follows:

1. Operating cost (C_{OP})

Operating cost is the expenses related to operating machines to produce final product, involves cost of workers operate on the machine to produce product and cost of energy to operate machines, it can be calculated as:

$$C_{OP} = \sum (C_E + C_W) \quad (3)$$

C_W worker cost is considered as the rate resulting from multiplying the cost of working time by the time required for producing the final product (hour), which can be calculated as follows Equation (4):

$$C_{OP} = \sum (C_E + C_W) \quad (4)$$

Skill of i = (1 or 0.9, 0.8, 0.7)

$$C_E = AU \times P_E \quad (5)$$

2. Cost of the Raw Material (C_{RM})

The cost of raw materials required to produce the final product in the system of production. In this research, raw material cost includes the ordering cost C_O , holding cost C_H , purchasing cost C_P ,

transportation cost C_{TR} , duties cost C_D and transfer price cost TP. Therefore, it can be calculated as equation (6) [15].

$$C_{RM} = C_O + C_H + C_P + C_{TR} + C_D \quad (6)$$

• **The cost of Ordering raw material (C_O)**

The cost of ordering and receiving raw materials at each order [15].

$$C_{UOj} = \frac{C_{Tomang}}{\%d_{RM} \times L_T} \quad (7)$$

$$\%d_{RM} = \frac{d_p}{d_{RM}} \quad (8)$$

$$C_O = C_{UO} \times OF \quad (9)$$

• **The cost of Holding raw material (C_H)**

The cost of keeping raw materials in warehouses for a specified period of time period. Equation (10) [15].

$$C_{UHj} = \frac{C_{THmang}}{N_{RM}} \quad (10)$$

$$C_H = \sum_{i=1}^{N_P} (C_{UHi})_s \times \%d_{RM} \times (LT + SF) \quad (11)$$

$i = 1, 2, 3, \dots, N_P$.

• **The cost of Purchasing raw material (C_P)**

The cost of goods procured from provider required to produce final product in the facility of production. Can be calculated as in Equation (12) [15]:

$$C_{UMSEj} = \%sale \times C_{UPi} \quad (12)$$

$$C_P = \sum_{i=1}^{N_P} (C_{UMSE_i}) \quad (13)$$

• **Duties Cost (C_D)**

The tax incurred because of bringing goods from provider in one country to customer in another country. It is based on the value of goods or upon some criteria of the item such as dimension and weight. Can be calculated as Equation (14) [15]:

$$C_D = \sum_{i=1}^{N_P} C_{UPi} (1 - IF) \times D \quad (14)$$

$IF_j = 0$ if $SE_j = 1$, otherwise $IF = 1$.

3. The cost of Utilities of raw material (C_U)

The cost emerging from using the required utilities such as, gas, electricity, water and maintenance to produce the final product in the facility of production. This paper considers C_U as a percentage of raw material cost of the final product. Can be calculated as in Equation (15) [15]:

$$C_{UMSEj} = \sum_{i=1}^{N_p} \%C_{RMI} \quad (15)$$

4. The cost of waste collection (C_{CP})

The cost of waste collection per CP (collection point) per year is calculated according to [16].

$$C_{CP} = \frac{c_{vy}}{N_{cp}} \quad (16)$$

$$c_{vy} = [(1+b_v) \times C_{cv}] + N_{wp} \times C_{cwb} + C_{ov} \quad (17)$$

$$C_{cv} = (1+e) \times C_v \times CRF \quad (18)$$

$$N_{wp} = \frac{N_{cp}}{a_{wp}} \quad (19)$$

$$N_{cp} = \frac{U_c \times V_c \times F_c}{\frac{W_{mix}}{P_{mix}}} \quad (20)$$

$$P_{mix} = \frac{1}{\sum p_{ci}} \quad (21)$$

$$C_{cwb} = (1+e) \times C_{vwb} \times CRF_{wb} \quad (22)$$

$$CRF_{wb} = \frac{i \cdot (1+i)^L}{(1+i)^L - 1} \quad (23)$$

$$C_{ov} = (1+e) \cdot (1+a) \cdot (1+b_w) \cdot (S_w \cdot N_w + S_d) \quad (24)$$

II. CO2 emissions (C_E):

In regard to the carbon emissions from machines, formula (24) computes the total carbon emissions occurring during the operating of machines.

$$C_{EC} = E_c \times E_{fi} \quad (25)$$

3.2.4 Constraints

The proposed model considered three types of constrain. Production quantity: The amount of product that produces each month must be less than or equal to the maximum demand of product as in the equation (26),

$$S_K \leq D_K \quad (26)$$

Manufacturing cost: the cost of manufacturing product that comprises, energy cost, labour cost, raw material cost, and utilities cost should be not exceeded working capital as in Equation (27),

$$C_{TM} \leq B_{TM} \quad (27)$$

CO2 emission: the amount of CO2 must be Ensures CO2 cannot overpass the maximum technically feasible emission amount during manufacturing processes as in Equation (28),

$$C_E \leq \lambda_E \quad (28)$$

Finally Type of material, Number of machines, number of labor and skill: must be between the maximum and minimum objective values set by the

organization or the authority as in equation (29), (30), (31), and (32) respectively:

$$RM_{min} \leq RM_t \leq RM_{max} \quad (29)$$

$$C_{min} \leq C_n \leq C_{max} \quad (30)$$

$$W_{min} \leq W_n \leq W_{max} \quad (31)$$

$$\gamma_{min} \leq \gamma \leq \gamma_{max} \quad (32)$$

3.2.5 desirability function

The desirability function approach is used to convert from multiple measures to a single measure as described in the following equation.

$$d_a(\eta_a) = \begin{cases} 1, & \eta_a \leq L_n \\ \left(\frac{\eta_a - L_n}{U_n - L_n}\right)^{w1} & L_n \leq \eta_a \leq U_n \\ 0, & \eta_a \geq U_n \end{cases} \quad a = 1, \dots, A$$

4. Case Study

In this section, a case study is tested to evaluate the performance of the proposed framework. The objective is to demonstrate how the proposed framework works in optimizing the product design and its manufacturing processes based on maximum sustainability. For this purpose, alternative configurations of the product are performed to obtain highest level of sustainability. The proposal considers a bottle opener design and its manufacturing processes (see table 1) in local small-sized manufacturing company. The purpose of this experimentation is to obtain all possible design solutions (using the proposed mathematical model) and finding the optimal one according to a set of design objectives. The experimentation is specified in terms of:

- The set of values for each decision variable.
- The set of values for fixed data.
- Microsoft excel software (2010) was used to build genetic algorithm, to obtain the optimal values of performance measures with corresponding optimal decision variables combinations.

Table 1: Bottle opener design and manufacturing alternatives




Alternative Design	Material	Manufacturing Processes	No. of stations
1 	Steel	<ul style="list-style-type: none"> Cutting Punching Quality control 	3
2 	Aluminium	<ul style="list-style-type: none"> Cutting Extrusion Sawing Remove burrs Drilling Quality control 	6
3 	Thermoplastic	<ul style="list-style-type: none"> cutting Punching Insert molding Quality control 	4

Table 2: Search range for decision variables and the corresponding number of levels

Decision variables	Range	No. of levels
Variable x_1 Skill levels of workers	70%-100%	4
Variable x_2 - No. of workers on the line	2_6	5
Variable x_3 - number of workstations	2-5	4
Variable x_4 - Type of material	1 -3	3
Variable x_5 . Lead time	1-30	30

Table 3: Input data

Parameter	Value	units	Parameter	Value	unit
MH_D	7	hour	N_{RM}	500.5 100.5 60.5	kg
$C_{L_i, \gamma}$	7 8 9 10	\$	C_{UPi}	3.42 1.92 2.4	\$
AU	21 36.4 176.4	kwh	D	0.15 0.05 0.05	\$
P_E	0.2	\$	E_{fi}	0.812045	(kg CO ₂ -e/kWh)
N_p	0.05 0.01 0.006	kg	C_v	9000	\$
C_{T0mang}	10 8 9	\$	CRF_{wb}	7	
C_{THmang}	100 70 50	\$	U_c	8	
			V_c	2	
			F_c	1	
d_{RM}	25 5 3	kg	W_{mix}	1	
			P_i	5	
D_K	500	part	p_{ci}	5	
I	2		C_{vwb}	2	
			C_{max}	4	—
			C_{min}	2	
			W_{max}	5	—
L	12		W_{min}	2	—
S_w	15		γ_{max}	100%	—
N_w	2				
S_d	15				
RM_{max}	3		γ_{min}	70%	—
RM_{min}	1	—			

The input data are based on the following assumptions: number of hour's work is 8 hour/day; the production ability of machines is 500 parts each day; and scrap and recyclable percentages is constant product.

5. Results and Discussion

The proposed model has been solved using (Microsoft Excel 2010) by applying equation illustrate in previous section [1_24] after convert to equation system of (Microsoft Excel 2010) and a global optimum solution has been obtained. Table 4 summarizes results. The optimum sustainability obtained for the manufacturing system under study is 0.8. The results call, the best type of material is 2 Aluminium, Number of worker is 2, Number of machine 3, and skill level of worker is 80%.

Table 4: Summary of results ber 200 generation

Generation	Generation Elite Fitness	Dec. Var. 1	Dec. Var. 2	Dec. Var. 3	Dec. Var. 4	Dec. Var. 7
1	0.79426074	1	2	2	90%	14
2	0.791416168	1	2	2	90%	17
62	0.764608681	1	2	2	80%	17
167	0.73796016	2	2	3	80%	17

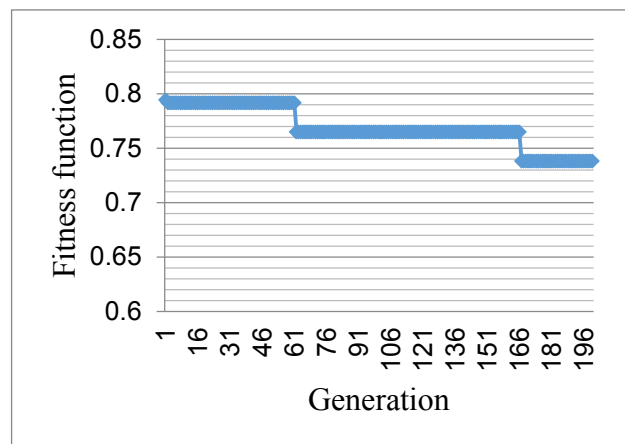


Table 5: Performance measure value and sustainability index

Performance measures values and individual desirability's				Sustainability index (CSI)
Environmental Impact		Economic Impact		
C_E	$d_q(C_E)$	C_{Tm}	$d_q(C_{Tm})$	D_a
0.00085	1.00	0.73796	0.778	0.73

6. Conclusion

In this paper a proposed model introduced a formulation for a sustainable product problem in the manufacturing industry to solve the problem of increasing environmental damages due to the Manufacturing processes in industrial companies.

To solve this problem a proposed formulation is suggested which has the ability to address pillars of sustainability to match cost reduction starts from the pioneer level. The essential feature of the proposed model for measuring sustainability is to depend on available data collected according to cost analysis. This fact makes the model applicable in facilities introducing sustainability concepts. It thus contributes to encouraging the implementation of sustainable practices in manufacturing, especially in emerging economies, where there is still a lack of sustainability awareness and related legislation. Microsoft excel (2010) is used to apply optimization in the form of alternative scenarios for manufacturing product, which makes the model suitable for small-scale manufacturers to meet the required specifications according to the customer order. The result provides the least total cost and at the same time maintain environment by decreasing emission of carbon dioxide. Improvement of the proposed model includes applying it on wider environment and more complicated products using artificial intelligence tools.

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