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INTEGRATED MODELING OF ECONOMICAL, ENVIRONMENTAL AND SOCIAL ASPECTS FOR MANUFACTURING FACILITY

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ABSTRACT

Increasing concerns regarding environment has made sustainable development essential factor and not the optional one. Any manufacturing operation is considered to have some negative impact on the environment. Hence it is essential to have sustainable operations on manufacturing facilities to minimize the enviormental damage if not completely stop it. The aim of this paper is to reduce the impacts due to manufacturing facilities on environment by modifying certain parameters of social and economic factors. A hierarchal structure is developed consisting all the three aspects of sustainability i.e. social, environmental and economic. Further each of the aspect is sub divided into manufacturing terminology i.e. energy, material, emissions, profit, defective products, training budget, overtime, etc.

KEYWORDS: Sustainability, Social, Economic, Environmental.

Production is an essential part of today's world as well as nation for its economic welfare. The manufacturing facility while producing a product requires raw materials as its input and releases a finished product as output or result, while in this process it also generates emissions and waste, due to poor efficiency.

Hence, to reduce or minimize this adverse effect on environment and for an increased efficiency of the whole system sustainable manufacturing has been developed and promoted throughout the world these days.

The purpose of this paper is to maximize the sustainability index so as to minimize the damages caused by production process.

LITERATURE REVIEW

Letmathe and Balakrishnan [1] have incorporated environmental constraints with other traditional production planning constraints. In this paper the objective was to maximize profit under carbone mission trading policy.

Tsai et al. [2] objective was to maximize profit, considering the following cost elements: machine cost, direct labor cost, direct material cost, environmental pollution and product level cost.

Glavič, P., Lukman, R. [3] They have defined the problems of clarifying ambiguity and classifying terms used in the sustainability field. This paper provides results of the literature survey and summarizes the definitions of the terms, focusing on the environmental engineering field.

Jovane, F. et al. [4] in their work they have shown the major global challenges that we are facing today are needed to be addressed in the multifaceted context of economy, society, environment and technology i.e. ESET

Joung et al. [5] conducted are view on indicators for sustainable manufacturing encompassing a set of 11 indicators. They presented a classification covering five dimensions of sustainability: environmental stewardship, economic growth, social well-being, technological advancement and performance management.

Chen et al. [6] conducted a literature review to assess a set of twelve sustainability tools used at the factory level. The investigated tools were evaluated against four criteria: rapid assessment, application at the factory level, generic applicability and holistic view of sustainability. They concluded that the existing tools fail to satisfy all four criteria.

MATHEMATICAL MODEL DEVELOPMENT

Sustainability consists of three pillars i.e. Enviormental, economical and social, hence, any production process involves these three aspects and all its effects can be classified in these three pillars of sustainability. In fig.1 is shown the outline of any production process which requires input as raw material, man power and capital and as an output we get the desired finished product with some waste due to inefficiency of the system and some reusable or recycleable energy or product.

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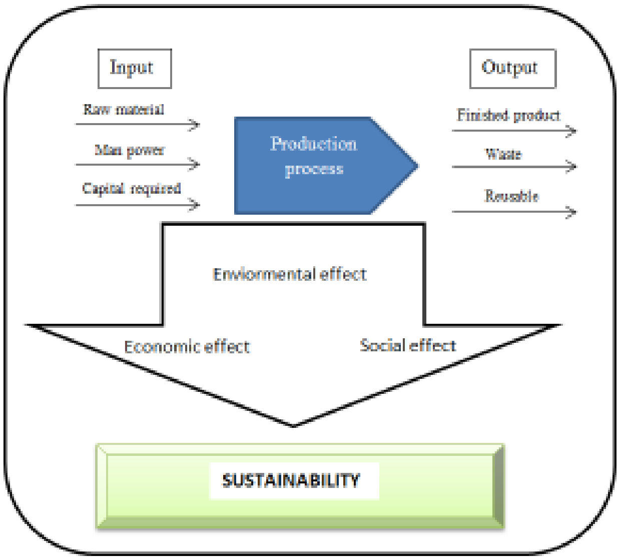
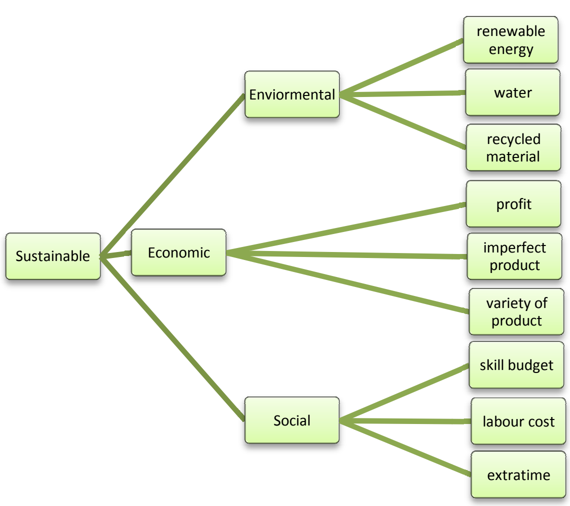


Figure 1: Outline of a production process and its 3 effects

The aim of our paper is to derive a mathematical model so as to find optimal sustainability index and maximize sustainability. Hence is this process three pillars of sustainability are taken i.e. Enviormental, social and economic.

MATHEMATICAL MODEL GENERATION

This model of sustainability with all the 3 aspects of sustainability unlike other models which deals basically with economic and enviormental aspects of sustainability. Here, sustainability and its three aspects are sub classified.



For each sub classification a equation is developed [7] for finding the optimum sustainability index.

Parameters:

u	Elements of the first hierarchy levelof environmental indicators
v	Elements of the second hierarchy level in environmental indicators
w	Product type, k = 1, …, N
x	Elements of thefirsthierarchylevel in economic and social indicators
y	Input type
z	Hazardous material type
MH w	Man-hours/unit weight of product w
P	Number of products
Φw	Ratio of recyclable products
εzw	Amount of hazardous materialz in product w (kg)
AT	Available regular time (h)
Gw	Amount of waterconsumed per unit weight of product w(m^3/kg)
WG w	Amount of waste water per unit weight of productw (m^3/kg)
DE w	Amount ofCO_2generated inthe production ofthe unit weight of productw
ey1	AmountofemissionsresultingfromonekWhofelectricityg eneratedfromconventional generation (kg CO_2/kWh)
ey2	Amountofemissionsresultingfromthetransportationofthe unitweightperunitdistance (kg CO_2/tkm)
αw	Percentage of defects of product w
Jw	Demand forproduct w(kg)
hw	Amount of energy consumed in producing a unit weight of product w (kWh/kg)
Rmi n	Minimumallowable percentage of renewable energy used (%)
Rma x	Maximumpercentage of renewable energy used (%)
I	Available working capital (Egyptian Pound (EGP); 1EGP=0.13 USD)
Eh	Cost of 1 kWh of electricity via renewable resources (EGP/kWh)
Ee	Price of electricity purchased from the grid (EGP/kWh)
ryw	Quantity of inputtype y in product k(kg/kg)
ey	Unit cost of input type y (EGP/kg)
yw	Selling price of the unit weight of product w(EGP/kg)
gw	Transportation distance of productw(km)
D	The maximum possiblenumber of diversified products in theconsidered industry
M	Total manpower
lw	Product fraction
Rx	Labor rate for regular time (EGP/worker hour)

Ro	Labor rate for over time (EGP/worker hour)
Hz	Maximum permissible amount of hazardous material of typezto include (kg)
Lβmax	Maximum allowed overtime expressed as a percentage of regular time (%)
Ijmin	Minimumtraining budget (EGP)
W7uv	Weightofsub-indicatoruofthev-thelementinfirsthierarchallevel ofthe environmental indicators
W8x	Weight of the x-th element of economic indicators
W9x	Weight of the x-th element of social indicators

Decision Variables:

Ij	Training budget (EGP)
sw	Amount producedfromproduct w(kg)
ht	Renewableenergyusedexpressedasthepercentageoftotal energynecessarytoproducea unit weight of product (%)
tw	Amount of product w to be recycled (kg)
qw	Amount of product w to be scrapped (kg)
La	Amount of overtime needed (h)

Equations:

$$I11 = \frac{ht \sum_w swhw}{\sum_w swhw}$$

$$I12 = 1 - \frac{\sum_w WGwsw}{\sum_w swGw}$$

$$I13 = \frac{\sum_w tw}{\sum_y \sum_w rywsw}$$

$$I21 = \frac{\sum_w swyw - \sum_y \sum_w rywswey\,[Ehht + Ee\,(1-ht)] + ATMRx + Ro(max(\sum_w MHwsw - ATM, L)) + Ij}{\sum_w swyw}$$

$$I22 = 1 - \frac{\sum_w \alpha wsw}{\sum_w sw}$$

$$I23 = \frac{\sum_{w=1}^{N} fk\, ln\,(fk)}{ln\,(^1/_D)}$$

$$I31 = \frac{Ij}{\sum_y \sum_w rywsw\, ey + \sum_w swhw\,[Ehht + Ee(1-ht)] + ATMRx + Ro(\max(\sum_w \mathrm{MHwsw} - \mathrm{ATM, L})) + \mathrm{Ij}}$$

$$\mathrm{I32} = 1 - \frac{\max(\sum_w \mathrm{MHwsw} - \mathrm{ATM, L})}{\mathrm{ATM}}$$

$$\mathrm{I33} = \frac{\mathrm{ATMRx} + \mathrm{Ro}(\max(\sum_w \mathrm{MHwsw} - \mathrm{ATM, L}))}{\sum_y \sum_w \mathrm{rywsw\ ey} + \mathrm{ATMRx} + \mathrm{Ro}(\max(\sum_w \mathrm{MHwsw} - \mathrm{ATM, L})) + \sum_w \mathrm{swhw}\,[\mathrm{Ehht} + \mathrm{Ee}(1-\mathrm{ht})] + \mathrm{Ij}}$$

CONCLUSION

This work has introduced a integrated modeling of sustainable manufacturing using the three pillars of sustainability i.e. social, economic, enviormental. Waste reduction, labour, renewable energy each aspect of a manufacturing firm has been taken into consideration and necessary formulation has been developed. This formulation can be used by manufacturing facilities for applying sustainable concepts in there firm.

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