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Multi-period Two layer supply chain Corporate Social Responsibility model with industrial waste management planning and Green House Gas emission control

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Abstract

In this paper two layer supply chain network model has been constructed with promotional effort and corporate social responsibility (CSR) activities considering the environment pollution control through industrial solid waste management (ISWM) (Bastianoni et al. 2004). Here we have assumed that the market demand is satisfied from three different point of views (i) demand for the customers are motivated by promotional effort (ii) demand is highly sensitive for selling price and (iii) demand is enhanced by making CSR to the locality. In this paper our aims are to maximize the objectives of the manufacturers and retailers with simultaneously minimize the Green House Gas (GHG) emission from industrial waste (EPA, 2008). Moreover, this management have proposed to transform some portion of the industrial waste into energy and some portion is used for recycling and the rest portion is used for land filling. Treatment of industrial waste is considered to protect the environment from water pollution (Finnveden, 1998). Again by reducing GHG emission from the landfill facility through industrial waste is became a serious environmental issues. Finally, the model is illustrated with numerical example to understand the model.

Key words: Production, Industrial waste, Promotional effort, supply chain, CSR, Green House Gas (GHG)

1. Introduction

Expanding the organizations' responsibility for their products beyond their sales and delivery locations (Buck et al. 1999), the CSR of their partners within the supply chain (Reuter et al. 2010) can also be achieved. The supply chain networking model (SCNM) is presented for multilevel structure for Solid Waste Management (SWM) through CSR. Prices are associated with the nodes in the network which is correspond to the different decision makers of the different tiers. Manufacturers are assumed to produce homogeneous product and to sell them either over physical or electronic links to retailers and consumers. Retailers, in turn, can be sell the products for the purpose of CSR practice to perform Industrial Solid Waste Management (ISWM).

Industrial waste management for environmental problems' solution and causing more and more attentions. Industrial Waste (IW) releases greenhouse gases (GHGs) to the atmosphere, including CO2 emissions associated with composting, non-biogenic CO_2, N_2O from combustion, and CH_4 from landfills. In 2008, IW contributed (i) 2.3% of total US GHG emissions (ii) landfills were the second largest source for total U.S. anthropogenic CH_4 emissions. The increased anthropogenic GHG concentrations in the atmosphere may pose serious negative impacts and risks to the humans, society and eco-environment in the earth. Substantial reduction of the GHG emissions from IW is the concern and should be integrated into decision schemes for industrial waste management planning.

In this context CSR activities can be played a vital role to minimize the environmental and health risks in Industrial areas while fulfilling the aspects of stakeholders in the supply chain (Anschütz et al. 2004; Mrayyan et al. 2006). Friedman, 2007 has been highlighted the evolution of the corporate social performances mainly on three challenges i.e. economic responsibilities, community responsibilities, and social responsiveness. The SWM to reduce GHG emissions through CSR is required for business and society (Rommelfanger 1996, Peters, 2008).

The CSR performances of environmental assessment and stakeholder management (Orlitzky, et al. 2001) are anticipated to reduce the risk of continuous rise of ISW in developing countries. SWM is a greater concern of recent decades (Guerrero et al. 2013; Anschütz, 2004; Zurbrügg, 2005; Finnveden, et al. 2003). Integrated sustainable SWM system and its implementations is a challenge for third world countries (Shikdar 2009; ISSOWAMA Consortium, 2009).

In connection with the growing CSR performances the issue of environmental risk (Rivoli, 2003; Roberts, 2003; Reuter, et al 2010; Haynes, et al. 1991; Razzaque, et al. 2002), recycle (Bastianoni, et al. 2004, Shikdar, A., 2009), procurement (Scheffler, et al. 2016; Carter, et al. 2004; Qio, et al. 2001), affirmative actions of purchasing (Razzaque, et al. 2002), integrated SWM (Shikdar, 2009, ISSOWAMA Consortium, 2009, Finnveden, et al. 2003) and unhygienic landfilling (Mosier et al. 1998, Stehfest, et al. 2006, Denison 1996) are the greater concerns for the researchers.

The framework is formulated the way to minimize the GHG through ISWM. In section 2: Preliminaries of SWM consist of SCNM, industrial inventory, cost and demand functions etc. through CSR. In section 3: The mechanism of ISWM and thus the multi-objective model has been framed to reduce the GHG emission. In section 4, 5 we have been found the numerical example and its results in the last section the detail summary of the framework has been highlighted as conclusion.

2. Preliminaries of Model

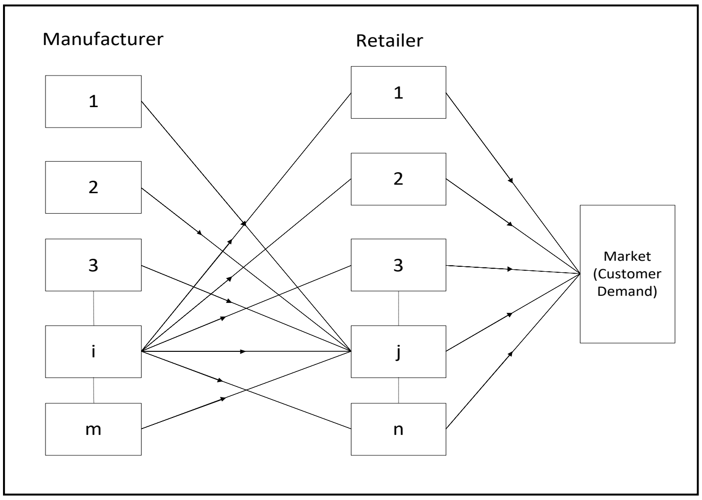
The Developing Countries is increasing the volume of Industrial Waste (IW) rapidly due to increasing population and change in lifestyles (EPA, 2008). The market demand is highly sensitive with selling price, increasing by advertisement effort and making CSR by the members of the supply chain (Finnveden, et al. 2003; Guerrero et al. 2013). More market demand leads to larger production and higher production leads to greater waste generation, which polluted the environment by more GHG emission (Bastianoni et al. 2004).

The proposed framework of IWM is to determine the stakeholders' action/behaviour firstly to maximise the profits of the manufacturers and retailers. Secondly, concern of the stakeholders to protect from environmental and health hazards through CSR under supply chain that have a role in the waste management process and to analyse influential factors on the system (Mrayyan et al. 2006). The emphasis of waste and GHG reduction and recycling requirements prior to incineration and the protection of environmental quality during CSR activity for waste shipping, treatment, and disposal have resulted in a set of new solid waste management goals in this system planning (Shikdar, 2009). This model describes the concept of a GRG numerical model that has been developed to contain and link of landfill processes in order to simulate solid waste degradation and GHG generation in landfills. Land is scarce and public health and environmental resources are precious thus the energy potential of waste should be utilized within the region.

2.1. Assumptions

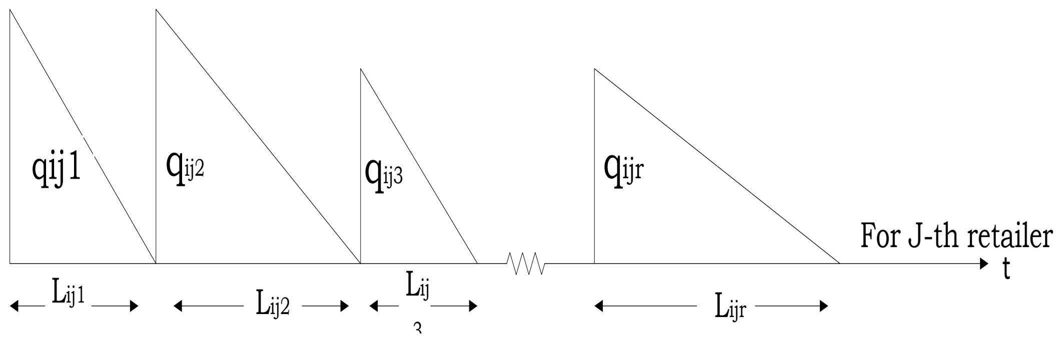
- Each ith manufacturer for $i = 1, 2, \dots, m$ seeks to determine his optimal production and his sales allocations of the product to the jth retailers for $j = 1, 2, \dots, n$ in order to maximize his own profit.
- Each ith manufacturer seeks to minimize the total cost of emission and risk associated with production and transportation to the jth retailers and demand markets.
- Retailers are represented in the second-tiered nodes in Figure 1 and inventory situation (Figure 2) of the jth retailer is dependent on time $t = 1, 2, \dots, T$

Figure 1: Schematic Presentation of the SC Model



- The retailers compete with one another in a non-cooperative manner.
- The retailers are decision makers with environmental and risk concerns and they also seeks to minimize the cost of emissions and risk associated with GHG emission form industrial waste (which can include recycle or land filling by and with the solid waste) with manufacturers and consumers as well as in operating their retail outlets.
- The social responsibility activities production cost functions as well as the promotional effort cost functions are convex and continuously differentiable.
- The cost of emission functions and demand functions are assumed to be continuous.
- The demand function is also continuously differentiable with inventory for the manufacturer and retailers.
- Each manufacturer may spend money in the form of service, investment in new technology, training employees, and information sharing in order to promote a sound environmental policy considering time $t = 1, 2, \dots, T$.

Figure 2: Inventory situation of j-th retailer



2.2. Notations:

q_{ijt}	The quantity of the product produced by manufacturer i transacted with retailer j in time period t
q_{jt}	The quantity of the product transfected from retailer j to the customers and $q_{jt} = \sum_{i=1}^{m} q_{ijt}$
q_{it}	The quantity of the product produced by manufacturer i in time period t and $q_{it} = \sum_{j=1}^{n} q_{ijt}$
ρ_{it}	Promotional effort through advertisement by the manufacturer i in time period t .
η_{it}	CSR level performed by the manufacturer i in time period t
s^*_{ijt}	Selling Price charged for per unit quantity by the manufacturer i in tranjecting with retailer j in time period t
s_{ijt}	Selling Price charged for per unit quantity by the retailer j in tranjecting with customer in the market in time period t
L_{ijt}	Time period (Length of the time period) of jth retailer to sale the q_{ijt} quantity in time period t
f_{cwi}	Total cost of manufacturer i to industrial waste produced by the manufacturer i
f_{cwGi}	Total GHG emission from waste management facilities.

2.3. Cost Functions

2.3.1. Promotional cost function of the manufacturer

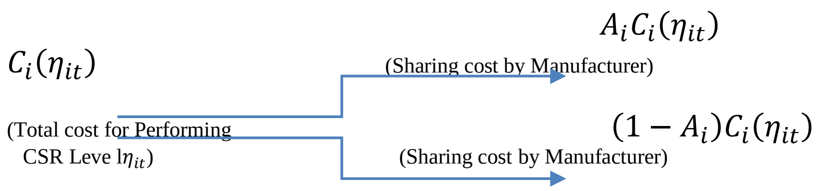
There is a Promotional cost functions consist of advertisement by the manufactures while this cost is divided as sharing cost to both manufactures and retailers.

Promo. Cost Index	Details
$G_{it}(\rho_{it})$	Total cost for promotional effort through advertisement by manufacturer i in time period t but the manufacturer is not responsible to pay the full amount, where $G_{it}(\rho_{it}) = k_i + k_i'\rho_{it}^{a_i}$, $k_i, k_i', a_i > 0$.
$(1 - B_i)G_{it}(\rho_{it})$	Sharing cost by the manufacturer i for promotional effort ρ_{it} in time period t.
$B_iG_{it}(\rho_{it})$	Sharing cost by the retailers $(j = 1,2,3, \dots, n)$ for promotional effort ρ_{it} by the manufacturer i in time period t such that $B_i = B_i^1 + B_i^2 + \cdots . B_i^n = \sum_{j=1}^{n} B_i^j$ $where \quad B_i^1, B_i^2, \dots, B_i^n > 0$.

2.3.2. CSR cost function of the manufacturer

There is a cost invested for performing CSR level by the manufactures while this cost is divided as sharing CSR cost to both manufactures and retailers.

CSR Cost Index	Details
$C_i(\eta_{it})$	Total cost invested for performing CSR level η_{it} by the manufacturer i in time period t where $C_i(\eta_{it}) = L_i + L_i'\eta_{it}^{b_i}$, $L_i, L_i', b_i > 0$.
$(1 - A_i)C_i(\eta_{it})$	Sharing cost by the retailer j for performing CSR level η_{it}.
$(A_i)C_i(\eta_{it})$	Sharing cost by the manufacturer i for performing CSR level η_{it}.



2.3.3. Production and transaction cost function

Prod. and Tran. Cost Index	Details
$f_i(q_{it})$	Production cost function which is depend on the total production q_{it} in time period t and we assume $f_i(q_{it}) = \alpha_i(q_{it})^{\beta_i}, where\ \alpha_i , \beta_i > 0$.
$C_{ijt}(q_{ijt})$	Transaction cost associated with manufacturer i tranjecting with intermediary j in time period t and we assume $C_{ijt} = \delta_{ij}(q_{ijt})^{r_{ij}}$ $where\ \delta_{ij} , r_{ij} > 0$ (it includes the holding cost also).

2.4. Volumes and Indexes of Industrial Waste

2.4.1 Volume of Industrial waste

Waste Index	Details
x_{ipt}	Total amount of industrial waste generates (including used collected items from market/users) to produce q_{it} units of products by the manufacturer i in time period t for facilities p ($p = 1, 2, 3$) where $p = 1$ indicates Land filling facility, $p = 2$ indicates waste to Energy (WTE) facility and $p = 3$ indicates waste to Recycling (WTR) facility.
x_{it}	Total amount of Industrial Waste (IW) (including used collected items from market/users) generates by the manufacturer i in time period t i.e. $x_{it} = \sum_{p=1}^{3} x_{ipt}$.
$\beta_{ipt} q_{it}$	Total amount of IW produced by the manufacturer i in time period t for facilities p ($p = 1, 2, 3$) to produce q_{it} units of products by the manufacturer. i.e. $x_{ipt} = \beta_{ipt} q_{it} = \beta_{ipt} \sum_{j=1}^{n} q_{ijt} = \sum_{j=1}^{n} \beta_{ipt} q_{ijt}$, where $\beta_{ipt} > 0$.

2.4.2. Index of Industrial waste management

IWM Index	Details	IWM Index	Details
WTE	Waste to energy	WTR	Waste to re-cycling.
p	Index for industrial solid waste and return items (ISWARI) management facilities($p = 1: landfil$; $p = 2$: $WTE\ facility$; $p = 3: WTR\ facility$)	$CC_{it}^{/}$	Purchase cost for CO_2 equivalent emission credits ($\$/tons\ CO_{2e}$) in time period t.
CC_i	Capital cost of land fill expansion for manufacturer $'i'$.	ERL_{it}	Emission rate of GHG in landfill by $'i'$th manufacturer (CO_{2e} per ton mixed waste) in time period t.
ERW_{ipt}	The emission rate of GHG in WTE/ WTR facility p ($p = 2, 3$) (CO_{2e} per ton mixed waste) in time period t.	RE_{ipt}	The revenue from WTE/ WTR facility 'p' for manufacturer i in time period t, p=2, 3.
TR_{ipt}	The transportation costs from manufacturer $'i'$ to facility $'p'$ in time period t.	ETL_{i2t}	The residue transportation cost from WTE facility to Landfill facility for manufacturer i in time period t.
ETR_{i2t}	The residue transportation cost from WTE facility to WTR facility for manufacturer i in time period t.	RTL_{i3t}	The residue transportation cost from WTR facility to Landfill facility for manufacturer i in time period t.
EL_{it}	Residue flow from WTE facility to Landfill for manufacturer i in time period t.	ER_{it}	Residue flow from WTE facility to WTR facility (% of total incoming waste flow) for manufacturer i in time period t, where $EL_{it} + ER_{it} < 1$.

RL_{it}	Residue flow from WTR facility to landfill (% of WTE) for manufacturer i in time period t.	ERG_{ipt}	Percent of emission of GHG from facility 'p' for manufacturer i in time period t, where p=1, 2, 3.
f_{Gi}	Total GHG emissions from waste management facilities for manufacturer i.	f_{cwi}	Total system cost by the manufacturer due to waste management for manufacturer i .

2.5. Manufactures Demand Function and its behaviours

2.5.1. Construction of Demand Function

$D(\eta_{it}, \rho_{it}, s_{ijt})$: Demand rate (Market demand) for the product produced by the manufacturer i and $D(\eta_{it}, \rho_{it}, s_{ijt}) = \{D_{1i}(\eta_{it}) + D_{2i}(\rho_{it})\}. e^{D_{3i}(s_{ijt})}$

Where $D_{1i}(\eta_{it}) = d_{1i}.\frac{\eta_{it} - \eta_{it}^{min}}{\eta_{it}^{max} - \eta_{it}}$, $where\ d_{1i} \geq 0\ \&\eta_{it} \in [\eta_{it}^{min}, \ \eta_{it}^{max}]$

$$D_{2i}(\rho_{it}) = d_{2i} - d'_{2i}e^{-d''_{2i}\rho_{it}},\ where\ d_{1i}, d'_{2i}, d''_{2i} \geq 0$$

$$D_{3i}(s_{ijt}) = d_{3i}.\frac{s_{ijt}^{max} - s_{ijt}}{s_{ijt} - s_{ijt}^{min}}, where\ \ d_{3i} \geq 0\ \&s_{ijt} \in [s_{ijt}^{min}, \ s_{ijt}^{max}]$$

2.5.2. Behaviour of the demand function

The demand function has the following characteristics:

i) a) If $d_{1i} = 0$ and $d'_{2i}, d_{3i} > 0$ than the demand rate D_i is dependents on $\rho_{it}\ and\ s_{ijt}$
   b) If $\eta_{it} \rightarrow \eta_{it}^{min}$ then market demand D_i does not depend on η_{it} (as$D_{1i} \rightarrow 0$)
   c) If $\eta_{it} \rightarrow \eta_{it}^{max}$ then market demand $D_i \rightarrow \infty$

ii) If $d'_{2i}, d''_{2i} = 0$ and $d_{1i}, d_{3i} > 0$ than the demand function D_i depends on $\eta_{it}\ and\ s_{ijt}$

iii) a) If $d_{3i} = 0$ and $d_{1i}, d'_{2i}, d''_{2i} > 0$ than the demand rate D_i dose not dependents on $the\ selling\ price\ s_{ijt}$
   b) If $s_{ijt} \rightarrow s_{ijt}^{max}$ then market demand $D_{3i} \rightarrow 0$ i.e. D_i does not depend on s_{ijt}
   c) If $s_{ijt} \rightarrow s_{ijt}^{min}$ then market demand $D_{3i} \rightarrow \infty$ i.e. $D_i \rightarrow \infty$

iv) Here the demand function $D(\eta_{it}, \rho_{it}, s_{ijt})$depends on the joint effect of $\eta_{it}, \rho_{it}\ and\ s_{ijt}$. It shows that if the manufacturer i have the good performance on CSR level η_{it} and make sufficiently promotional effort ρ_{it} then market demand is highly sensitive with the selling price s_{ijt}

v) $q_{ijt} = D(\eta_{it}, \rho_{it}, s_{ijt}). L_{ijt}$

Lemma 1: The cost function $G_i(\rho_{it})$ due to promotional effort ρ_{it} by the manufacturer i in the time period t is

a) Increasing with ρ_{it} at a decreasing rate when $0 < a_i < 1$and
b) Increasing with ρ_{it} at an increasing rate when $a_i > 1$.

Proof: $G_i(\rho_{it}) = k_i + k_i' \rho_{it}^{a_i}$ *where* $k_i, k_i' > 0$

$$\frac{dG_i}{d\rho_{it}} = a_i k_i' \rho_{it}^{a_i - 1} > 0 \; for \; a_i > 0$$

$$and \; \frac{d^2 G_i}{d\rho_{it}^2} = a_i k_i' (a_i - 1) \rho_{it}^{a_i - 2} > 0$$

since $\frac{dG_i}{d\rho_{it}} > 0$ for all $a_i > 0$ so $G_i(\rho_{it})$ is increasing with ρ_{it}

$$Also \; \frac{d^2 G_i}{d\rho_{it}^2} < 0 \; for \; 0 < a_i < 1$$

i.e., $\frac{d}{dt}\left(\frac{dG_i}{d\rho_{it}}\right) < 0 \; for \; 0 < a_i < 1$

Which shows that $G_i(\rho_{it})$ is increasing but increasing at a decreasing rate.

Again $\frac{d^2 G_i}{d\rho_{it}^2} > 0 \; for \; a_i > 1$

i.e., $\frac{d}{dt}\left(\frac{dG_i}{d\rho_{it}}\right) > 0 \; for \; a_i > 1$

Which shows that $G_i(\rho_{it})$ is increasing and the rate of increasing is also increasing.

Lemma 2: The CSR cost function $C_i(\eta_{it})$ due to performing CSR level η_{it} by the manufacturer i in time period t is

i) Increasing with η_{it} but the rate of increasing is decreasing when $0 < b_i < 1$.
ii) Increasing with η_{it} but the rate of increasing is also increasing when $b_i > 1$

Proof: Proof is similar to the proof of Lemma 1.

Lemma 3: The market demand function $D(\eta_{it}, \rho_{it}, s_{ijt})$ for the product produced by the manufacturer i is

i) Increasing with the CSR level η_{it}
ii) Increasing with the promotional effort ρ_{it}
iii) Decreasing with the increasing of selling price s_{ijt}

Proof: $D(\eta_{it}, \rho_{it}, s_{ijt}) = \{D_{1i}(\eta_{it}) + D_{2i}(\rho_{it})\}. e^{D_{3i}(s_{ijt})}$

Where $D_{1i}(\eta_{it}) = d_{1i}. \frac{\eta_{it} - \eta_{it}^{min}}{\eta_{it}^{max} - \eta_{it}}$

$$D_{2i}(\rho_{it}) = d_{2i} - d_{2i}' e^{-d_{2i}'' \rho_{it}}$$

$$D_{3i}(s_{ijt}) = d_{3i}. \frac{s_{ijt}^{max} - s_{ijt}}{s_{ijt} - s_{ijt}^{min}}$$

Now, $D_{1i}'(\eta_{it}) = \frac{d}{d\eta_{it}} D_{1i}(\eta_{it}) = d_{1i}. \frac{\eta_{it} - \eta_{it}^{min}}{(\eta_{it}^{max} - \eta_{it})^2} > 0$

$$D_{2i}'(\rho_{it}) = \frac{d}{d\rho_{it}} D_{2i}(\rho_{it}) = d_{2i}'. d_{2i}''. e^{-d_{2i}'' \rho_{it}} > 0$$

$$D_{2i}''(\rho_{it}) = \frac{d}{d\rho_{it}} D_{2i}'(\rho_{it}) = -d_{2i}' (d_{2i}'')^2. e^{-d_{2i}'' \rho_{it}} < 0$$

$$D'_{3i}(s_{ijt}) = \frac{d}{ds_{ijt}} D_{3i}(s_{ijt}) = -d_{3i}.\frac{s_{ijt}^{max} - s_{ijt}}{\left(s_{ijt} - s_{ijt}^{min}\right)^2} < 0$$

$$\frac{dD_i}{d\eta_{it}} = D'_{1i}(\eta_{it}) e^{D_{3i}(s_{ijt})} > 0\,, \quad [since\ D'_{1i}(\eta_{it}) > 0\,]$$

Therefore $D(\eta_{it}, \rho_{it}, s_{ijt})$ is increasing with η_{it}.

Also, $\frac{dD_i}{d\rho_{it}} = D'_{2i}(\rho_{it}) e^{D_{3i}(s_{ijt})} > 0\ since\ \ D'_{2i}(\rho_{it}) > 0$

$$\frac{d^2 D_i}{d\rho_{it}^2} = D''_{2i}(\rho_{it}) e^{D_{3i}(s_{ijt})} < 0\ since\ \ D''_{2i}(\rho_{it}) < 0$$

Therefore $D(\eta_{it}, \rho_{it}, s_{ijt})$ is increasing with ρ_{it} but the increasing rate is decreasing.

Again, $\boldsymbol{\frac{dD_i}{ds_{ijt}} = (D_{1i} + D_{2i}).D'_{3i}(s_{ijt}).e^{D_{3i}(s_{ijt})} < 0\ \ since\ \ D'_{3i}(s_{ijt}) < 0}$

3. The Model

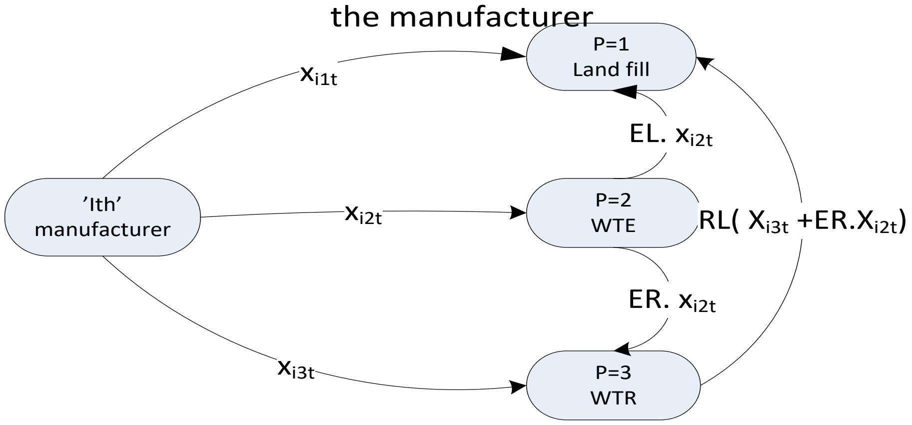
3.1. Industrial waste management framework

Co-ordination is the act of organizing, making different people or things work together for a goal or effect to fulfil desired goals in an organization. Co-ordination is a managerial function in which different activities of the business are properly adjusted and interlinked (Wanichpongpan, et al. 2007). Decentralized production systems are considered organizational structures able to match agility and efficiency necessary to compete with the market. One of the challenges faced by the decentralized production systems is to ensure the coordination of heterogeneous decisions of the multi-agent populated system (Finnveden, et al. 2005). In the decentralized production system, the double marginalization results the upstream agent is conservative to expand the system for optimal capacity up-gradation. The research proposes the cost-revenue sharing schema and the transfer-payment schema to overcome the system inefficiency. The schemas are self-enforcing, which allow the maximization of the system profit as well as the improvement of the agents' profits.
Moreover, for the policy purpose of sustainability not only requires the profits of the agents but needs to concentrate on environmental degradation at the time of profit escalation (Arena, et al. 2003). With the distillation of ISW treatment the ambition of our study is 1stly, maximise the profit of the co-ordinating partners' integrating the promotional effort and CSR activity, 2ndly, minimise the total system cost that comprises transaction cost, capital cost and purchase cost for CO2 equivalent emission credits ($\$/tons\ \ CO_{2e}$) 3rdly, minimisation of the total GHG emission from waste management facilities with eye on (Weitz, et al. 2002).
Analysis of the mechanism of IWM shows in Figure 3 suppose there are $'i\,th\,'$manufacturer in a region and think about to manage the solid waste they create/collected during the production process.

3.2. Analysis of the mechanism of Industrial waste management

Suppose there are $'i\,th\,'$manufacturer in a region and think about to manage the solid waste they create/collected during the production process. The x_{ipt} *is the* total amount of industrial waste from manufacturer i to the facility p. This total amount is being separated for three purposes i.e., land fill, WTE, WTR purposes. For the land fill ($p = 1$) purpose, the

Figure 3 : The mechanism of solid waste management by the manufacturer



usable volumes are-x_{i1t} amount of total waste, the part of x_{i2t} i.e., $EL_{it}.x_{i2t}$ and the usable unused part of WTR i.e., $(x_{i3t} + x_{i2t}.ER_{it})\, RL_{it}$. For the WTE ($p = 2$) purpose the usable volume is only - x_{i2t} amount of total waste. And the WTR ($p = 3$) purpose the usable volumes are- x_{i3t} amount of total waste and the other part of x_{i2t} i.e., $ER_{it}.x_{i2}$.

The total GHG emission from waste management facilities is to be minimised and the mathematical expression can be represented as

f_{Gi} = Total GHG emission from waste management facilities

$$= \sum_{t=1}^{T}[ERG_{1it}.\{x_{i1t} + EL_{it}.x_{i2t} + (x_{i3t} + x_{i2t}.ER_{it})RL_{it}\} + ERG_{i2t}.x_{i2t} + ERG_{i3t}(x_{i3t} + x_{i2t}.ER_{it})] \quad (1)$$

The total cost of Industrial waste management to be minimised and mathematically represented as

$$\mathrm{f}_{cwi} = \sum_{t=1}^{t=T} \left[\sum_{p=1}^{3} x_{ipt}TR_{ipt} + EL_{it}.x_{i2t}.ETL_{i2t} + ER_{it}.x_{i2t}.ETR_{i2t} + RL_{it}(x_{i3t} + x_{i2t}ER_{it}).RTL_{i3t} - \sum_{p=2}^{3} x_{ipt}.RE_{ipt} - ER_{it}.x_{i2t}.RE_{i3t}\right] + CC_i^{/}.f_{Gi} \quad (2)$$

where

- $EL_{it}.x_{i2t}.ETL_{i2t}$ = Residue transportation cost to transport $EL_{it}.x_{i2t}$ amount from WTE to land fill facility.
- $ER_{it}.x_{i2t}.ETR_{i2t}$ = Residue transportation cost to transport $ER_{it}.x_{i2t}$ amount from WTE to WTR facility.
- $RL_{it}(x_{i3t} + x_{i2t}ER_{it}).RTL_{i3t}$ = Transportation cost from WTR to landfill facility.
- $\sum_{p=2}^{3} x_{ipt}.RE_{ipt}$ = revenue from WTE/WTR.

3.3. The behaviour of the manufacturers

The manufacturers are involved in the production of a homogeneous product and in transacting with the retailers physically or electronically. Each manufacturer faces three criteria: the maximization of profit, the minimization of cost incurred due to industrial waste management and the minimization of emission of GHG (produced by industrial waste) to protect the environment. By protecting the environment from industrial waste, they establish social responsibility activities indirectly by IWM. Not only the indirect social responsibility activities, they also involve to perform CSR activities (η_{it}) directly in the community. CSR can potentially decrease production inefficiencies, reduce cost and risk, and at the same time allow companies to increase sales, increase access to capital, new markets, and brand recognition. As a result of lower cost, lower risk and increase in sales, companies become more profitable.

The i th manufacturer faces total costs that equal to sum of his production costs, transaction costs, sharing cost due to promotional effort, sharing cost due to CSR activities and waste management cost. His revenue in turn is equal to the sum of price multiplied by quantities of the product transacted.

The profit function for manufacturer i is

$$Z_i^m = \sum_{t=1}^T \sum_{j=1}^n s_{it}^* q_{ijt} - \sum_{t=1}^T f_{it}(q_{it}) - \sum_{t=1}^T \sum_{j=1}^n C_{ijt}(q_{ijt}) - \sum_{t=1}^T (1-B_i) G_{it}(\rho_{it}) - \sum_{t=1}^T (1-A_i) C_{it}(\eta_{it}) - f_{cwi} \quad , \quad i = 1,2,\dots,m \qquad (3)$$

3.4. The behaviour of the retailers

The retailers are involved in transactions both with the manufacturers and with customers. Each retailer faces total cost that equal to sum of purchasing costs, inventory-holding costs, sharing cost due to promotional effort and sharing cost due to CSR activity.

The profit function for retailer j is given by

$$Z_j^R = \sum_{t=1}^T \sum_{i=1}^m \{(s_{ijt} - s_{it}^*) q_{ijt} - A_i C_i(\eta_{it}) - B_i G_i(\rho_{it}) - \tfrac{1}{2} q_{ijt} L_{ijt}\}, j = 1,2,\dots,n \qquad (4)$$

3.5. Multi-objective Model

Following equations (1)- (4) the objectives are to maximize the profit of the members of the supply chain incorporating the minimization of GHG emission to protect the environment from global warming by the industrial waste. To serve the purpose, we consider the following multi-objective problem:

$$\textbf{Maximize } Z_i^m = \sum_{t=1}^{T} \sum_{j=1}^{n} s_{it}^* q_{ijt} - \sum_{t=1}^{T} f_{it}(q_{it}) - \sum_{t=1}^{T} \sum_{j=1}^{n} C_{ijt}(q_{ijt}) - \sum_{t=1}^{T} (1-B_i) G_{it}(\rho_{it}) - \sum_{t=1}^{T} (1-A_i) C_{it}(\eta_{it}) - f_{cwi}, \qquad i = 1,2,\dots,m. \qquad (5)$$

$$\textbf{Maximize } Z_j^R = \sum_{t=1}^{T} \sum_{i=1}^{m} \left\{ (s_{ijt} - s_{it}^*) q_{ijt} - A_i C_{it}(\eta_{it}) - B_i G_{it}(\rho_{it}) - \frac{1}{2} q_{ijt} L_{ijt} \right\}, j = 1,2,\dots,n. \quad (6)$$

where

$$f_{cwi} = \sum_{t=1}^{t=T} \left[\sum_{p=1}^{3} x_{ipt} TR_{ipt} + EL_{it}.x_{i2t}.ETL_{i2t} + ER_{it}.x_{i2t}.ETR_{i2t} + RL_{it}(x_{i3t} + x_{i2t} ER_{it}).RTL_{i3t} - \sum_{p=2}^{3} x_{ipt}.RE_{ipt} - ER_{it}.x_{i2t}.RE_{i3t} \right] + CC_i^{/}.f_{Gi},$$

$$f_{Gi} = \sum_{t=1}^{T}[ERG_{i1t}.\{x_{i1t} + EL_{it}.x_{i2t} + (x_{i3t} + x_{i2t}.ER_{it})RL_{it}\} + ERG_{i2t}.x_{i2t}$$
$$+ERG_{i3t}(x_{i3t} + x_{i2t}.ER_{it})],$$

$$q_{ijt} = D(\eta_{it}, \rho_{it}, s_{ijt}).L_{ijt},\ \eta_{it}^{min} < \eta_{it} < \eta_{it}^{max},\ s_{ijt}^{min} < s_{ijt} < s_{ijt}^{max},\ \rho_{it} \geq 0,\ \forall i, j, t.$$

and $x_{ipt} = \beta_{ipt} q_{it} = \beta_{ipt} \sum_{j=1}^{n} q_{ijt} = \sum_{j=1}^{n} \beta_{ipt} q_{ijt},\ \beta_{ipt} > 0,$ p=1,2,3.

4. Numerical Illustration

To illustrate the model following equations (5) and (6), we take two manufacturers (i =1, 2), two retailers (j=1, 2) and single time period (t =1). We consider the values of parameters as follows:

k_1 =24, $k_1' = 0.4$, k_2 =24, $k_2' = 0.4$, $L_1 = 12$, $L_1' = 0.3$, $L_2 = 12$, $L_2' = 0.3$, b_1= 0.2, b_2= 0.3, $A_1^1 = 0.1$, $A_1^2 = 0.1$, $A_2^1 = 0.11$, $A_2^2 = 0.11$, $B_1^1 = 0.2$, $B_1^2 = 0.2$, B_2^1 =0.21, B_2^2 =0.21, α_1=62, β_1=0.4, α_2=62, β_2=0.4, δ_{11}= 0.61, r_{11}=0.2, δ_{12}=0.61, r_{12}=0.2, δ_{21}=0.61, r_{21}=0.2, δ_{22}=0.61, r_{22}=0.2, β_{111} = 0.35, β_{121} = 0.01, β_{131} =0.23, β_{211} =0.36, β_{221} =0.01, β_{231} =0.22, q_{111} = 350, q_{121} = 340 , q_{211} =270 , q_{221} =280, η_{11}^{min} = 0.1, η_{11}^{max} =0.8 , η_{21}^{min} =0.1 , η_{21}^{max} = 0.8, s_{111}^{min} =5 , s_{111}^{max} = 8, s_{121}^{min} =5 , s_{121}^{max} =8 , s_{211}^{min} =5 , s_{211}^{max} =7 , s_{221}^{min} = 5, s_{221}^{max} = 7, d_{11} = 15 , d_{12} = 16 , d_{21} = 37, d_{21}'=0.4 , d_{21}''=0.2, d_{22} = 38, d_{22}'= 0.41, d_{22}''= 0.21, d_{31} = 75 , d_{32} = 76 , TR_{111} = 0.1 , TR_{121} =0.01 , TR_{131} = 0.01 , TR_{211} =0.1 , TR_{221} =0.01 , TR_{231} =0.01, EL_{11}= 0.4, EL_{21}= 0.41, ETL_{121}= 0.01, ETL_{221}= 0.01, ER_{11}= 0.3, ER_{21}= 0.31, ETR_{121}= 0.01, ETR_{221}= 0.01, RL_{11}= 0.2, RL_{21}= 0.21, RTL_{131}= 0.01, RTL_{231}= 0.01, ERG_{111} = 0.2, ERG_{121}=0.11 , ERG_{131} = 0.1 , ERG_{211} = 0.21, ERG_{221}= 0.11 , ERG_{231} = 0.1, RE_{121}=0.9 , RE_{131}=0.5 , RE_{221}= 0.91, RE_{231}=0.51

Optimal Results: Following the input values, using GRG method, the optimal values of ρ_{11} , ρ_{21}, s_{111}, s_{121} , s_{211jt}, s_{221}, η_{11} , η_{21} are shown in Table 1

ρ_{11}^*	ρ_{21}^*	s_{111}^*	s_{121}^*	s_{211}^*	s_{221}^*	η_{11}^*	η_{21}^*
0.6	0.59	7.69	7.71	6.99	6.99	0.45	0.451

5. Result Discussion

The optimum results for this model catches the major findings as i) the manufacturer are able to decide on price at maximum level despite of substantive CSR performance (η_{11}^*, η_{21}^*) and positive promotional effort (ρ_{11}^*, ρ_{21}^*) ii) the proposed model has determined the retailer's encouraging sharing portion of CSR (A_i) and advertisement (B_i) made by manufacturers and optimize the framework. iii) Cost of Industrial waste management (f_{cwi}) may be minimise further as the unit prices are decided by manufacturer are seems to be high iv) total GHG emission (f_{Gi}) from IWM can be minimise following this multi-objective framework where both manufacturer and retailer are able to maximise their profits.

6. Conclusion

The numerical illustration of this model determines the authentication of the framework as it is found the optimum values of promotional effort, unit selling price and CSR performance. The current WM crisis in developing countries and its long term solutions, focus on the solving the present problems. The Government and local authority's needs to work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. This can be achieved with WTR increased where provisions have been made to handle the non-recyclable wastes that are generated and will continue to be generated in the future.

State Governments should take a proactive role in leveraging their power to optimize resources. Improper WM presents imminent danger to public health, environment and the quality of life. Materials and energy recovery from wastes is an important aspect of improving WM in every countries while economically feasible for sustainability.

Diverting WM from landfills and especially from unhygienic landfills to any extent will be contributed to the cause of health problem. We have combined i) all the issue of overall solid waste management, ii) the least/no impact on public health and environment, iii) consume minimal resources and iv) be economically feasible. Recycling, composting of land and waste-to-energy are integral parts of the solution and they are all required; none of them can be solved the WM crisis alone.

The weakness of the model to make a policy to include waste-pickers in this management sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations. Compost facilities may be used for cash crops, lawns or landfill cover instead of food crops. Rejects from composting is required to be combusted to produce energy and reduce their volume. Only the degradable items or ash from the WTE plants or co-combustion facilities are needed to go for landfill. If WTE industry can exhibit self-responsibility in GHG emissions control with constant emissions monitoring, and reporting the feedbacks can results into a loop of self-improvement as analysed in CSR approach. This will leads the way for reforms in implementation of regulations across all other industries.

The success of recycling depends upon the control of advantage in the form of informal recycling sector. There is a world-wide consensus of recycled materials will spears in the next decade. The informal sectors have to meet the social and environmental demand. Thus the future scope of this study also increases opportunities for private companies who can be aggregated large amounts of waste to supply in bulk.

Prevalence of co-existence depends upon the quality of the product and the quantity (bulk) they can be supplied. The Informal Sectors are needed be integrated into formal system as i) Compost from IW and WTE needs to use for landfill cover/ cash crops/ lawns ii) IW to WTE and the rest of the waste also go for WTR in waste management plants while part of WTR again go for landfill iii) Majority source separation has been targeted as primary works of industrial Solid Waste Management. This will impacts on public health and environment and prospects for the future can be further researched.

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