AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Design and Production Engineering

Multi objective optimization of a green supply chain model

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Mechanical Engineering

(Design and Production Engineering)

by

Nouran Ibrahim Mohamed Ibrahim

Bachelor of Science in Mechanical Engineering

(Manufacturing Engineering Program)

Faculty of Engineering, Ain Shams, 2012

Supervised By

Prof. Dr.Amin Kaml El-Kharbotly

Dr. Yomna Sadek

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Examiners' Committee

Name and Affiliation	Signature
Prof.Dr.Mohamed Ibrahim El Said Etman Design and Production , Helwan University	……………….
Prof.Dr.Nahid Hussein Afia Design and Production , Ain Shams University	……………….
Prof.Dr.Amin Mohamed El-Kharbotly Design and Production , Ain Shams University	……………….

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Date: 20/9/2017

Researcher Data

Name	: Nouran Ibrahim Mohamed Ibrahim
Date of birth	: 02/07/1990
Place of birth	: Cairo, Egypt
Last academic degree	: Bachelor of Science
Field of specialization	: Manufacturing Engineering
University issued the degree	: Ain Shams University
Date of issued degree	: 2012
Current job	: Teaching Assistant in the UFE

Summary

The globe is now-a-days concerned with the impact of environmentally polluting industries which may affect drastically the health of people. The social aspects are also of a great concern to achieve stability in societies. As a result, developed countries have set firm regulations for industrial activities to minimize environmental and social damage due to polluting activities. Due to these facts, various researches in the industrial fields are directed in an attempt to reach industrial solutions that besides maximizing the profit; it maintains acceptable environmental and social levels.

In this research, a multi echelon multi product single facility reversed paper manufacturing supply chain is modelled and optimized for sustainability. The behaviour and performance of the supply chain is studied for several parameters and different supply chain designs.

The proposed supply chain in the present work is assumed to be of a reversed type where waste paper is collected from the market from different sources. The quantities of needed waste paper are used for paper manufacturing and the excess quantities may be sold to other facilities with profit. Unrecyclable waste materials are spent either by landfilling or incineration. The manufacturing facility produces three different types of paper of different qualities. The paper is manufactured either entirely from virgin pulp or entirely from recycled waste paper pulp or of a mixture of both.

The study of supply chain sustainability considers marginal profit, environmental impact and social aspects as represented by the number of generated job opportunities. The present study considers the optimization of the marginal profit as a single objective after which the obtained results are compared to that obtained from optimizing for sustainability (i.e. marginal profit, environmental impact and social aspect). The research is extended to study the effect of a number of supply chain drivers such as plant capacity, material mix on supply chain performance. Each of these drivers can be developed and managed to emphasize responsiveness or efficiency depending on the business requirements.

Linear programming was used to optimize the supply chain for maximum marginal profit. The linear programming problem was solved using excel solver. Multi-objective optimization for sustainability was made using NIMBUS software which uses interactive optimization.

It was found that the production capacity has an obvious effect on the three objectives subject to optimization. As the production capacity increases the marginal profit increases showing net profit at certain breakeven capacity which depends on the waste paper cost. The higher the waste paper cost the higher the breakeven capacity.

The product mix from the three types of paper (types A, B, and C) at any production capacity depended mainly on the waste paper cost introduced as a ratio of virgin pulp cost. It was found that in profit optimization, the higher the waste paper cost the higher the tendency for the manufacturing of high quality paper type A as the recycling becomes less profitable. On the other hand, in case of a supply chain that is optimized for sustainably, the opposite takes place as the product mix with increased waste paper cost, the supply chain has to keep producing from low quality paper type C. This is because that in this case, part of profit should be sacrificed to maintain good environmental and social aspects which recommend recycling.

The capacity of the facility plays an important role in determining the product mix. In case of single objective, at small limited capacity the facility has to produce from type C as this type gives the higher marginal profit. As capacity increases other types of papers are introduced according to marginal profit to gain profit limited by the maximum demand on each type. At high waste paper cost, because the marginal profit of type A may be higher that of C, the facility will prefer to produce from type A even at small capacities. In multi-objective, although the marginal profit is less, however the improvement in environmental impact and social aspects are high enough to encourage sacrificing part of the profit.

Key words:

Closed loop supply chain - Green supply chain-Multi objective optimization-Sustainability-Paper Recycling- Linear programming – Nimbus.

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Nomenclature

Sets:

G: Number of different paper grades produced in the factory; g= {1, ..., G}

Parameters:

Cap_F	Production capacity at the factory in Tons.
Cap_S	Sorting capacity in the sorting area in Tons.
C_W	Waste paper cost in $/ton
C_S	Cost of preparation and sorting of waste paper at sorting area in $/ton
DEM_g	Demand of customer of each paper grade g in tons , g={1,........,G}
Dp	Depreciation value in $.
EP_g	Environmental impact of producing each paper grade g; g={1,........,G] .
E_L	Environmental impact of waste paper landfilling.
E_N	Environmental impact of waste paper incineration.
E_R	Environmental impact of paper recycling.
E_T	Environmental impact of paper transportation.
L_C	Paper Landfill cost in $/ton.
N_C	Paper incineration cost in $/ton.
P_g	Cost of production of each paper grade g in $/ton; g ={1,.......,G}
$Perc_R$	Mill broke represented as a percentage of paper production to be returned back and remanufactured.
$Perc_w$	Fixed percentage of waste paper quantity is to be incinerated or landfilled as it is unrecyclable.
Q_J	Quantity of unsorted waste paper that offers a job opportunity.
R_g	Selling price of each paper grade g in $/ton ; g={1,.....,G]
R_S	Selling price of sorted waste paper in $/ton

T_C Paper transportation cost in $/ton kilometre.

V_J Variable number of jobs at the sorting area.

X_{FC} Distance from the factory to customer in km.

X_{MS} Distance from the Market to the sorting area in km.

X_{SF} Distance from the sorting area to the factory.

Decision variables:

Q_g Quantity of each of paper grades g produced in the factory in tons ; g={1,......,G}

Q_L Quantity of landfilled waste paper at the sorting area in tons.

Q_N Quantity of incinerated waste paper at the sorting area in tons.

Q_W Quantity of unsorted waste paper bought from the Market to sorting area in tons.

Q_{SR} Quantity of sorted wastepaper sent to factory to be recycled in tons.

Q_{SS} Quantity of sorted wastepaper to be sold in tons.

List of Abbreviations

LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LP	Linear Programming
MILP	Mixed Integer Linear Programming
MOO	Multi Objective optimization
SC	Supply chain