A pollution sensitive remanufacturing model with waste items: Triangular dense fuzzy lock set approach

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1. Introduction

1.1. General overview

In the first world countries, the basic challenges are to reduce pollution upon industrialization and to reduce unemployment for social accountability. Although industrial revolution used to enhance the economic growth to a certain extent but at the same time it has an adverse effect on the environment. Decreasing the negative impact on the environment, increasing the sustainability of earth by means of pollution control we might reach into reverse logistics network alternatively. Generally, reverse logistic widely covers the area related to re-using of goods and materials. Moreover, government policies, increasing ecological awareness among masses and legislation have directed to increase the development of reverse logistics activities. The existing literature on reverse logistic excludes the cases of unemployment reduction but our present study considers this through the study of recycling-remanufacturing model over environmental pollution. Schrady (1967) made the first attempt to develop a deterministic inventory model with repair items considering manufacturing quantity and repair quantity as a decision variable. After that, researchers like Nahmias and Rivera (1979) and Mabini et al. (1992) extended Schrady’s work and incorporated the waste material into economic order quantity (EOQ) model where they considered the waste disposal rate as a decision variable. Fleischmann et al. (1997) categorized the reverse logistics into distribution planning, inventory control, and production planning.

Over the years, companies are experiencing problems when customers are returning items for various reason. Accordingly, reverse logistics propose much more models and techniques to overcome these issues. Roy et al. (2009) developed the used-items...
collected from the market and defective items in a production-
remanufacturing model over a finite horizon. El Saadany and
Jaber (2010) analyzed a remanufacturing inventory model where
the return rate is a function of the purchasing price and the quality
level of returned items. Also, a number of surveys were made on reverse
logistics by the eminent researchers like Agrawal et al. (2015) and Guo et al. (2017).

On the other hand, deterioration is a genuine problem for the
companies to maintain the quality of the fresh items, reworked
items as well as the defective items. Tai (2013) proposed an EPQ
model where the deteriorated items are screened out for n pro-
duction plants. Alamri (2011) presented a deteriorating inventory
model for returned items.

Moreover, for pollution aspects, Zeng et al. (2017) proposed a
hybrid population-production-pollution nexus model for air
pollution. Antoci et al. (2017) discussed the dynamics of a small
open economy with two sectors. There are numerous studies in the
literature that analyze the environmental effects (Chen, 2017; Lu
et al., 2017; Wen, 2009; Yeboah, 2008; Yu and Solvang, 2017;

Furthermore, the production-remanufacturing systems mini-
mize the environmental pollution of industry by reducing the en-
ergy use and reusing the materials. Govindan et al. (2016)
addressed a multi-echelon multi-period multi-objective model
for sustainable reverse logistics under fuzzy environment. Alshamsi
and Diabat (2015) proposed a mixed-integer linear program for
a complex network reverse logistic system.

In many production-inventory, in process of maximizing the
productivity to satisfy the customer’s demand, the manufacturer
often exceed the pollution control limit specified by the govern-
ment. Mukhopadhyay and Goswami (2014) developed an economic
production quantity (EPQ) model where the pollution is generated
from the imperfect items. Bazan et al. (2015a) analyzed the energy
used in a (re)manufacture inventory model and considered the
greenhouse gas emissions from plant and transportation activities.

However as per tradition, the parameters, variables and other
constraints associated with production process are assumed to be
either deterministic or stochastic. But the modern trend explores
that these parameters are controllable and considered to be
imprecise type in a non-stochastic sense. Zadeh (1965) is the
pioneer of the fuzzy set theory and Bellman and Zadeh (1970)
applied this in decision making problems. Since then many re-
searchers (De et al., 2014; De and Sana, 2013, 2015; Kumar et al.,
2012) have given considerable attention to the area of fuzzy set
theory in various inventory management problems. Recently,
Rodger and George (2017) studied triple bottom line accounting
and considered threats to cybersecurity to optimize natural gas in
sustainable supply with fuzzy ILOWA operator.

During the last decades, the fuzzy set theory has been developed
with the streamline of intuitionistic fuzzy set, hesitant fuzzy set,
Pythagorean fuzzy set etc. De and Beg (2016a, 2016b) developed a
new defuzzification rule on triangular dense fuzzy set and applied it to the neutrosophic set theory also. This invention might keep a
new destination of any kind of decision-making problems under
learning experiences over the years. De and Mahata (2016) studied
the time variable in cloudy fuzzy set to reduce the uncertainty of the fuzzy parameters. Karmakar et al. (2017) developed the pollu-
rated relation to excess production and defined a functional rela-
tion between production and environmental pollution under
dense fuzzy environment. De (2017) proposed the TDFLS, an
extension of triangular dense fuzzy set (TDFS). Utilizing this any
decision maker (DM) could reach his/her goals confidently through
proper use of keys of the fuzzy locks.

In this paper, a production-recycling and pollution reduction
inventory model has been developed. Used or scrap items are
collected by the hawkers by means of some marginal wages for
remanufacturing purpose. We also assume the recycled items are
as-good-as-new and demand is satis
ized by the govern-
met. Mukhopadhyay and Goswami (2014) developed an economic
production quantity (EPQ) model where the pollution is generated
from both the new items and the remanufactured items. Also, we have considered the remanufacturing rate is dependent on the production rate and the production rate is a function of cycle time. An explicit functional
relation among the production rate, remanufacturing rate and
environmental pollution rate have been derived from a three-
species Lotka-Volterra model. The environmental risk from indus-
trial production and remanufacture have been considered. To study
the usefulness and validity of the model we have utilized p-value
of the Z-statistic exclusively. Finally, we take the help of the dense
fuzzy lock set rule to reach a final decision.

1.2. Motivation and specific study

In the existing literature, the major part of the reverse logistics
includes greenhouse, greenhouse gas emissions, emission, fuel etc.,
but the modern researchers did not incorporate them in terms of
mathematical models yet. An attempt was made by Bazan et al.
(2015b), but they also suggest further investigation on pollution
upon environment. For a long time, there is a research gap con-
cerning the environmental issue in reverse logistics. Over the years,
maximizing the productivity through customer’s satisfaction was
the prime aim of the manufacturing companies. Due to globaliza-
tion, the consumption rate of the common commodities viz elec-
tronics and electrical items, chemical and plastic items, tanary and
spunge-iron items, text-tiles items, drugs etc. are increasing day by
day and have been pilling as a waste materials in the environment
also. As per Bureau of International Recycling, there are 300 million
computers and 1 billion cell phones produced every year-they all
become obsolete or unwanted, often within 2–3 years of purchase.
By this way, the unwanted materials become hazardous waste and
generate different environmental risk factors.

Furthermore, the production industry generates both traditional
pollutants (e.g. organic substances, SO2, particulates and nutrients) and
newly-recognized pollutants (e.g. specific toxic substances) which affect people’s health badly (Table 1). Moreover, industry
accounts for about one-third of global energy consumption, and for
about 10% of the total water withdrawal (OECD estimates).

Generally, the common scenario among business industries is
they are using low production cost, low-paid unskilled labor and
moderate environmental regulations to be the major incentives.
Any production industry has to rely on the natural resources for
adequate supply of raw materials. Consequently, mining industry
supplies the raw materials to produce many of the consumer goods.
The environmental and health impacts of mining on surrounding
communities have been a major concern to the general public and
the stakeholder organizations and individuals. The research reveals
that mining activities have resulted in land degradation leading to
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