Monte Carlo Simulation: Remanufacturing or not –A Newsvendor perspective

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ABSTRACT

The concept of random yields or uncertain supply is not new in inventory management. While this aspect has been extensively studied in the literature over several decades, the factors impacting uncertain supply have been largely been limited to quality defects, uncertain capacity and sourcing issues. The concept of random yields is very much applicable to the reverse logistics and remanufacturing activities that has received increased attention in recent years. The purpose of this paper is to demonstrate the modeling of the newsvendor problem with uncertain supply via spreadsheet based simulation as a managerial tool for optimizing the performance of a remanufacturing operation.

1. INTRODUCTION

Extensive amount of literature has been developed on the subject of Monte Carlo simulation and Newsvendor problem over the last several decades. The purpose of the paper is to demonstrate the use of spreadsheet simulation for remanufacturing operation from a managerial point of view, and hence we limit the discussion of the mathematical models in this area of study to a brief discussion. The second section of the literature review discusses the literature that has utilized spreadsheets as a means of simulation. Literature pertaining to the advantages of using spreadsheets for simulation and the various applications developed using spreadsheets would be the point of discussion in this section. In the last section we would review the literature addressing the issue of random yields in reverse logistics/remanufacturing scenario.

The classical newsvendor/ newsboy problem also known as the single period problem (SPP) aims at maximizing the expected profit for a single period under uncertain demand scenario. Khouja (1999) has presented a detailed review of literature pertaining to the SPP and classifies the extensions to this problem in eleven categories. One of the categories amongst these eleven is that of 'random yields'. The classical newsvendor problem assumes deterministic supply. The 'random yields' extension relaxes this assumption and considers stochastic supply. This type of situation is particularly applicable to electronic fabrication and assembly, chemical processes and in general processes having an unpredictable quality performance (Yano & Lee, 1995). The concept of random yield was initially introduced by Silver (1976) in which he proposes an extension to the EOQ (Economic order quantity) model by assuming uncertain yields. Yano & Lee (1995) present a comprehensive review of literature dedicated to inventory models assuming random yields. They report that modeling of costs, modeling of yield uncertainty and measures of performance are the three main issues while analyzing inventory systems with random yields. Silver (1976) provides a list of causes that may lead to uncertain supply which includes inventory errors, capacity issues, raw material constraints, quality issues (internal and supplier). The literature can generally be divided depending on the source of supply uncertainty. Uncertain supply due to quality issues have been discussed by Shih (1980), Gurnani et al. (2000), Inderfurth (2004), Maddah and Jaber (2008), Maddah et al. (2009). Capacity issues have been addressed by Erdem and Ozekici (2002), and Hariga and Haouari (1999). Ozekici and Parlar (1999), Keren (2009), Yang et al. (2007), and Rekik et al. (2007) consider sourcing and supply chain factors of random yield while defective inventory records leading to random yield have been discussed by Sahin et al. (2008), Fleisch and Tellkamp (2005), Hesse (2007).

A brief overview of each section is presented as follows. Section 2 and 3 describes some relevant work in spreadsheet simulation and reverse logistics and random yields. Section 4 and 5 presents the research question and decision environment respectively. Section 6 explains and applies the research approach using Monte Carlo simulation viewed as a newsvendor problem in the context of a remanufacturing decision. Section 7 analyzes the output data and provides a specific scenario analysis. Finally, the last section details the conclusions and briefly summarizes the contribution of the paper.

2. SPREADSHEET SIMULATION FOR INVENTORY PROBLEMS

Spreadsheets provide an easy and effective tool for building simulation models. Spreadsheet simulation is especially suited for static simulations such as the Monte-Carlo method. The ready availability and widespread familiarity make spreadsheets a useful platform for developing simulation and decision making tools that are simple and user friendly. Such tools can provide valuable assistance to the managers for decision-making and would help them improve the performance of their operations. Several papers discussing the use of spreadsheet simulation for facilitating the understanding of supply chain concepts amongst students can be found in recent literature. One of the first papers on this subject is Al-Faraj et al. (1991). They address the newsvendor problem and provide a spreadsheet based support system for controlling the inventory and service level. Pfeifer et al. (2001) make a case for using spreadsheet based simulation for teaching the classical newsvendor problem in management schools. They claim that spreadsheet based simulations are more realistic, and are a more suitable way of introducing students to uncertainty and more complicated scenarios as compared to other approached like decision trees and mathematical analysis. Walker (2000) presents a spreadsheet based decision support tool for managing the single period inventory problem. Sezen and Kitapci (2007) also present similar demonstration of spreadsheet based simulation for analyzing a supply chain inventory problem. Evans (2000) proposes the use of spreadsheets for teaching for simulation concepts. He uses the newsvendor problem for demonstrating the methodology of utilizing spreadsheets for constructing such simulation while noting several advantages of using them. Stahl (2005) also provides a spreadsheet based demonstration for the newsvendor problem based on Monte-Carlo simulation and reiterates the usefulness of such application in teaching as done by other authors. Seila (2005) also discusses the usefulness of spreadsheets for constructing simulations. He also provides a demonstration using the inventory model while also putting forth the limitations of the spreadsheets when dealing with complex data structures and algorithms, their slow speed and limited data storage.

3. Reverse logistics and random yields

The number of research papers considering random yield in reverse logistics/remanufacturing activities is comparatively low. Thierry et al. (1995) identify the information on the magnitude and uncertain of the returned products as one of the strategic issues in product recovery management. Guide (2000) has identified, uncertain timing and quantity of returned products as one of the seven characteristics that impact the reverse logistics/remanufacturing production planning and control activities. Ferrer (2003) evaluates the options that a manager of a remanufacturing unit has when faced with random yields and high lead time supplier and evaluates various scenarios comparing the value of information on random yields and having a highly responsive supplier. In more recent works, Bakal and Akcali, (2006) evaluates the effects of random yields on the profitability of an automotive remanufacturing facility where the firm has the power to influence both the supply and demand of the remanufactured products through pricing. Diaz (2010) used random varieties to exemplify the application of Monte Carlo simulation in a shorter version of problem while educating in supply chains and reverse logistics concepts. Longo and Mirabelli (2008), De Sensi et al. (2008), Curcio and Longo (2009), Cimino et al. (2010) used random variates and simulation both in normal supplì chains and in the case of reverse logistics for studying inventory problems.

In the preceding sections, we have reviewed the literature pertaining to random yield in general and to reverse logistics/remanufacturing in particular. We have also reviewed the literature highlighting the importance and usefulness of spreadsheets based simulation. This review emphasizes the overall lack of literature dedicated to developing managerial tools for management of reverse logistic/remanufacturing operations and also points to the spreadsheet based simulation as a suitable platform for developing such a tool. In the next section, we would discuss a research associated to these issues and propose a model to assist the decision-making process in this context.

4. RESEARCH QUESTION

In general, firms that are faced with critical decisions in relation to undertaking significant additional production loads tend to be risk averse. The inherent uncertainty related to resources, demand, and supply, makes the decision difficult. However, most firms are pressured to increase efficiencies while keeping or increasing responsiveness. Thus, the enterprise is expected to find and engage in activities that maintain or increase the difference between revenues and costs. Remanufacturing is an alternative activity that reduces this gap. What is uncertain are the various impacts on profits stemming from decision related to remanufacturing. Thus, the goal is to model and simulate the impacts on profits for the likely near-future electric energy portfolios within Southeastern Virginia

5. DECISION ENVIRONMENT

The objective of this case study is to present a common decision-making situation that can be modeled and simulated using Monte Carlo. This paper considers a hypothetical but realistically represented firm that manufactures a large number of electronic components. As most firms, there are subsets of components that are highly demanded and very profitable. The products analyzed in this paper are assumed to be highly sold in the winter season. The cost of producing each item is \$8.15 while sold at \$10.00. The volume of sales is 10,000,000 items per season. Returns varies between 3%-6%. Traditionally, items that have been returned to the firm are sold to third party companies that scrap them, and according to market circumstances, these companies dissemble them to be used as raw components. They receive \$0.25 apiece. However, the demand for their product has increased exponentially. Expansion of current capacity is on its way. Marketing research indicates that new segments are willing to purchase like-new remanufactured products. Remanufactured items can be sold at \$7.85 per item. The forecasted demand has discrete probability distribution according to table 2. The associated costs of retrieving and collecting are \$0.50 each Inspecting and dissembling \$2.30 per item 50% of this product can be remanufactured. Remanufactured costs are estimated to be \$4.25 per item. After the season, unsold remanufactured items can be sold to other forms of secondary markets for 2.50 each. While you don't have to make the decision, you have been asked to analyze the current situation and make a final recommendation on whether or not to remanufacture this item. Based on the probabilities distribution of remanufactured products you have to suggest how many of the next's period items to collect and remanufacture. Because the profits have been extensively studied in the Tidewater region, you know that they are normally distributed.

Table 1: Return Rates

Demand	*Probability*
150	0.3
200	0.2
350	0.3
250	0.15
300	0.05

Table 2: Probabilistic Demand

Supply	*Probability*
400	0.2
350	0.3
600	0.15
300	0.2
500	0.15

6. RESEARCH APPROACH

This research proposes a Modeling and Simulation (M&S) approach to investigate decisions concerning the remanufacturing process. The four basic steps that gird our approach are as follows: 1) represent input data and generate random variates, 2) simulate the supply and demand 3) determine Measures of Performance, and 4) analyze output data.

Monte Carlo simulation produces a probability that an outcome will occur. As a result, multiple sets of trials are required. Since the frequency of possible outcomes can be controlled, this frequency is always known. In this context, we need to mimic how the supply of returned products as well as the demand for them will be. We generate random numbers for the demand and the supply in separated streams. Each stream represents the supply and the demand respectively. A uniform distribution is used to perform the drawing of these random numbers.

Let ξ represent the stochastic supply, C the collection costs, I the inspection costs, $RmPerc\%$ portion of remanufacturable products, RmC the remanufacturing costs, R the revenues, RP the remanufacturing price, Rf the refunds, and P profits generated by the sales of remanufactured components.

The collection and inspection cost, TCC, are determined by:

$$TCC = \xi(\mathrm{C} + \mathrm{I}) \quad (1)$$

The total remanufacturing costs, $TRmC$, is given by:

$$TRmC = \xi * RmC * RmPerc\% \quad (2)$$

The total revenues, TR from remanufactured items sales is given by the Remanufacturing price times the minimum between the supply and demand.

$$TR = RP * \min(\xi, \delta) \tag{3}$$

Refund for unsold items:

$$TRf = Rf * \max(\xi - \delta, 0) \tag{4}$$

Total Profits, P :

$$P = TR + TRf - TCC \tag{5}$$

After calculating the mean, it is usual to accompany this with a confidence interval. It provides the accuracy of the estimate. From statistics: estimated mean (+ /- a multiple of the standard error, so:

$$Confidence\ Interval = \bar{X} \pm (Multiple \times Std.\ Error\ \bar{X})$$

$$Std.\ Error\ \bar{X} = \frac{Std.\ Deviation}{\sqrt{number\ observations}} = \frac{s}{\sqrt{n}}$$

According to normal distribution Multiple for confidence level 95% = 1.96 (Central limit theory). Thus, for 95% confidence:

$$Confidence\ Interval = \bar{X} \pm (1.96 \times \frac{s}{\sqrt{n}}) \tag{6}$$

7. RESULTS

In this exercise, we analyze three possible scenarios that include:

Probability of making any profit P(Profit>0)

$$P(\text{Profit} > 0) = \frac{\text{Count Number of Profits} > 0}{n} \tag{7}$$

Probability of any lost P(Profit<0)

$$P(\text{Profit} < 0) = \frac{\text{Count Number of Profits} < 0}{n} \quad \text{or} \ = 1 - P(\text{Profit} > 0) \tag{8}$$

Probability of making more profits than the most conservative strategy P(Profit>125)

$$P(\text{Profit} > 125) = \frac{\text{Count Number of Profits} > 125}{n} \tag{9}$$

The estimated average of *current situation* can be calculated by the cost of good sold times the volume, which results in $815. The total revenues is given the current price times the current volume, so we have $1,000. As a result, the difference between revenues and posts provide us with profits, which is estimated to be $125.

The estimated average profit resultant from the Monte Carlo simulation is $278.87. The average profits considering current situation (without remanufacturing) is $125. Since the difference is positive 153, there is no doubt that engaging in remanufacturing activities improves the probabilities of making additional profits. The estimated Confidence Interval (95%) is between 258.11 and 299.63.

Additional information will assist the decision-making process from the risk aversion perspective. We used the three scenario described above to guide our suggestion.

- Probabilities of making any profit = 67.10%
- Probabilities of lost = 32.90%
- Probabilities of more profits than current situation= 54.45%

Given this outcome, the critical question to answer is deciding what to recommend. Firm's risk aversion is intimately related to answering this question.

CONCLUSIONS

Analyzing uncertainty in supply and demand is not new. Research related to these issues has been studied widely. However, most studies focus on quality defects, uncertain capacity, and sourcing issues. Random yields definitions can be related to the reverse logistics and remanufacturing analyses. In this paper, we modeled a common reverse logistic problem using a newsvendor formulation. In the analysis, we used a spreadsheet model to represent not only the stochastic demand, but also the uncertain supply. We used Monte Carlo simulation to determine the effects of several operational constraints on several measures of performance including costs, revenues, and profits. We used a theoretical --but realistic model-- to illustrate such procedures. We applied scenario analysis to study the effects on making profits and obtaining a profit threshold.

We conclude that Monte Carlo Simulation is a well-suited approach to represent probabilistic demand and supply. We determine that Monte Carlo yield insights into various effects on common operational measures of performance such as costs, revenues, and profits. The approach is used in the newsvendor context that assists decision-makers in single period decisions.

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