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Outsourcing Strategy in Reverse Logistics Network: A Markov Decision Process and Simulation Approach

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Abstract

Main forces behind the growth of Reverse Logistics are the strict governmental rules that have been imposed on producers to seek environmentally conscious ways to dispose of their scrap waste and also the desire to improve profitability by satisfying a growing demand for low cost recycled products. RL has captured the attention of scholars and a large number of research contributions can be found in the literature that highlight the importance of efficient planning and control of the RL process. Another parallel trend that has also been growing in popularity is that of outsourcing. This paper considers the problem of an Original Equipment Manufacturer that uses outsourcing to a third-party logistics provider. A Markov decision model is developed that considers the options of outsourcing and in-house remanufacturing. The objective is to minimize the total costs of operating the system. The paper uses a simulation study to demonstrate the best policy the OEM should follow and test the hypothesis that variance in return rate is a function for outsourcing decision. The purpose of this paper is to perform simulation on numerical examples to demonstrate the applicability of the model which was built on the reward function model with Markov chain applicability.

Keywords
Reverse logistics, remanufacturing, outsourcing, simulation, industrial engineering

1. Introduction

The traditional perception of product-producer relation has undergone a great change in the modern supply chain concept. Instead of there being only a one-way flow from producer to user, many products (especially durables, consumables and machinery) witness a reverse flow from user to producer. Pochampally et al. (2008) point out the benefits as in saving natural resources, saving energy, saving clean air and water, saving landfill spaces and of course saving money. Guide and Van Wassenhove (2009) also state another reason for reverse logistics being such an eye catcher, for consumer electronic alone; there are billions of returned products annually in the United States, hence an enormous potential for value recovery. Another simultaneous emerging trend is the subcontracting of processes or logistics activities to another firm for the purpose of maximizing profit or minimizing cost, a process commonly known as outsourcing. In this paper, the concepts of outsourcing are studied and a mathematical model is developed to address the outsourcing strategy in the context of reverse supply chain.

Once the reverse logistics is acknowledged by the OEMs as a potential aspect of the supply chain system, there comes as a logical sequence the option of outsourcing the RL operations to a third party, popularly known as 3rd party reverse logistics provider (3PRLP). Some manufacturers have inefficient, slow and expensive processes for handling the returned products and a considerable amount of value is lost when these returns cannot be processed quickly and completely (Rupnow, 2004). This promotes the idea of outsourcing. There is also the fact that reverse logistics does not represent the core activity of a firm and the purpose of any company is not to manage the flow of products taken back from the sales point, but rather to distribute such products to its customers. The reasons for outsourcing can be the possibility of achieving lower costs due to economies of scale, greater flexibility, higher quality of service, better budget control, faster set-up of function or service, improved risk management and lower ongoing investment in internal infrastructure.

There have been many studies conducted on how to select the 3PRLP. However, very few researches (studies) have explored the question of “when” to outsource. There has been some research conducted on the mathematical modeling of the problem of when it is beneficial to outsource rather than perform in-house remanufacturing. Miao (2009) employed a Markov decision process model to study the interplay between disposition and outsourcing. Hui-Yun and Min-Li, (2007) applied simulation tool to explore the value of production outsourcing. Aras et al. (2004) categorized the returned products to study the outsourcing in reverse logistics network. Serrato et al. (2007) developed a Markov decision process model that incorporates the outsourcing decision. Wang and Fan (2007) discussed outsourcing in terms of collecting the used products. As inventory holding cost is an important factor in RL, Teunter and Flapper (2011) and Mahapatra et al. (2012) considered such a cost in their multi-period mathematical models. However, products which are acquired but not remanufactured in a period, charged holding costs for one period (Teunter and Flapper 2011, Mahapatra et al., 2012).

In this paper, the concept of outsourcing is analyzed based on the simple fact that it will sometimes be profitable to outsource rather than continue with in-house remanufacturing. Since no company is expected to be continuously changing their policy about outsourcing, it becomes imperative for the company to adopt a “take it or leave it” strategy at least for a moderately long period of time.

Drawing upon the wide range of experience accumulated in the literature and with an objective of contributing to decision making process for reverse logistics outsourcing, the objective of this paper is to identify the suitability of outsourcing option for a particular firm dealing with reverse logistics by the help of an analytical model in which a threshold policy is introduced.

2. Problem Definition

Lebreton (2007) suggests that a product can go back to its potential user after different degrees of intervention by its parent organization. Any of these interventions, commonly known as process, may be included in the reverse logistics system providing that a sufficient number of returns make the reverse process economically attractive. Theoretically, any of the activities can be outsourced. However, the present paper singles out “remanufacturing” as the strategic activity to be outsourced based on a rational decision making criterion.

A Markov Decision Model (MDM) is a mathematical framework for modeling situations where the outcomes are partly random and partly under the control of a decision maker. Uncertainty plays a big role in choosing the type of MDM to use. Although other model frameworks can be chosen to incorporate the system’s uncertainty, this paper formulates the problem to be described below as a Markov Decision Model. The state variables in our model are the RL system capacity and cumulative amount of returns. Transitions between states satisfy the Markov property in that to predict which state is to occur next, one need to know only the current state and the transition probability. The Markov decision process is described by 4 characteristics and is compatible with this research problem:

- In-house remanufacturing capacity and cumulative returned amounts represent the state variables
- In-house remanufacturing or outsourcing decisions are the decisions to be taken in each state
- The probability of transition between the states follows a Poisson distribution
- The “reward” (cost) function associated with each period includes the costs of in-house remanufacturing and/or outsourcing.

This analytical model will help identify the circumstances under which outsourcing is a suitable option to engage in for a firm dealing with reverse logistics. After considering the characteristics for the reverse logistics network and also the elements to be considered in this research, the hypotheses (Serrato et al., 2007) to be verified in this research is as follows. Outsourcing is more likely to be an optimal decision when the variance in return rate is high.

3. Simulation

Different scenarios are simulated in this section. The number of returned products is assumed to follow a Poisson distribution and are generated randomly (using default Poisson distribution function of ProModel), rather than being calculated from sales function and return rate. The model will check to see if the return rate variance affects the outsourcing decision. The variance in return rate is calculated from the number of returned products and sales, which is not considered in the simulation model; rather it is calculated at the end of the model output. This model is a conceptual representation of the problem under study. Its objective is to validate and verify the hypothesis mentioned above. The model should act as a guideline for future work on a specific industry type, where the constraint(s) and objective function parameters are known. The fact that the Product Life Cycle of a product cannot be large (here it is a very large number if counted in months) puts a limitation on the model. For this model to be representative, the mean arrival rate has to be scaled down so that it is within the working range.

These simulation runs also give an idea of how the system works under different conditions when number of returns is varied over a relevant range. The two scenarios are as follows. In scenario 1, all the returned products will be either completely outsourced or completely remanufactured in-house. Capacity is not considered fixed in this scenario; rather it can be increased to accommodate the number of returned products if necessary. In scenario 2, the remanufacturing capacity is assumed fixed. Hence, there will be three decisions to choose from. If the number of returned products is more than the capacity, then the returned products can be split between in-house remanufacturing and outsourcing or be completely outsourced. In other options, when the number of returned products is less than the in-house capacity, the total amount can be completely remanufactured in-house or outsourced. For scenario 2, the capacity is considered to be stationary, hence it cannot be increased. The cost function related to the calculation of decision is given later in Appendix A.

3.1 Scenario 1

In this current simulation, to generate the random numbers, the mean value of Poisson distribution is considered is given the values 21 and 42. The model is run for 5 replications. The reason for considering mean values of 21 and 42 is to show how the variance in return rate affects the optimal strategy and costs. These values are used here for illustrative purposes.

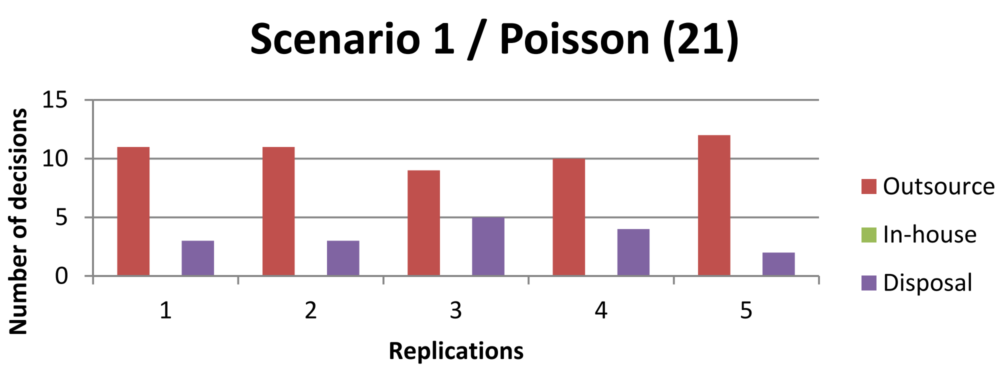

Figure 1: Simulation with mean 21 for Poisson distribution for scenario 1

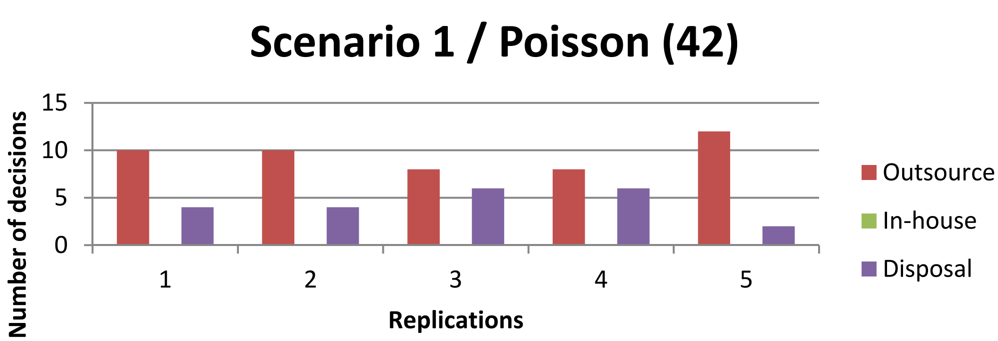

Figure 2: Simulation with mean 42 for Poisson distribution for scenario 1

For five different runs, the option of remanufacturing in-house and outsourcing is considered along with disposal. The main purpose here is to find out whether the outsourcing decision is depended upon return variance. With a different return rate, the number of remanufacturing in-house decisions would be different which is now 0. Now, to find the effect of return rate variability, five runs are considered and the variance in the return rate is shown in the following figures:

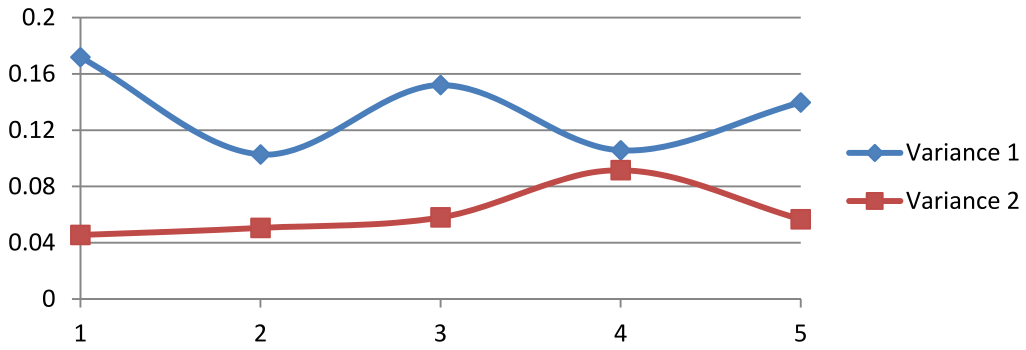

Figure 3: Variance in return rate for simulation with mean for Poisson distribution as 21 and 42 respectively for scenario 1

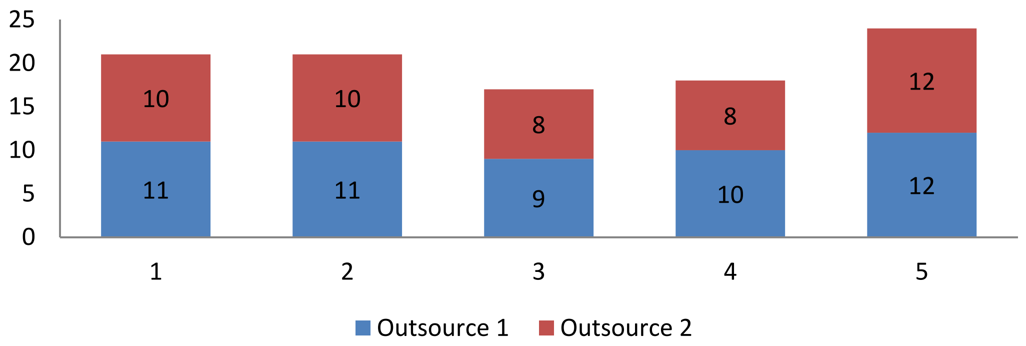

Figure 4: Number of outsourcing decisions for simulation with mean for Poisson distribution as 21 and 42 respectively for scenario 1

It is found that the number of outsourcing decisions is depended upon the variance of return rate. The higher the variance on return rate, the higher the number of outsourcing decisions will be for a dynamic capacity plan. So it can be concluded that the variance in the return rate influences the decision of outsourcing while the capacity is dynamic in nature.

3.2 Scenario 2 with capacity 25

In scenario 2, the mean value of Poisson distribution is considered 21 and 42 as in the previous model, and the model is run for 5 replications with capacity being stationary at 25 and 50 respectively. At the end the results are as follows:

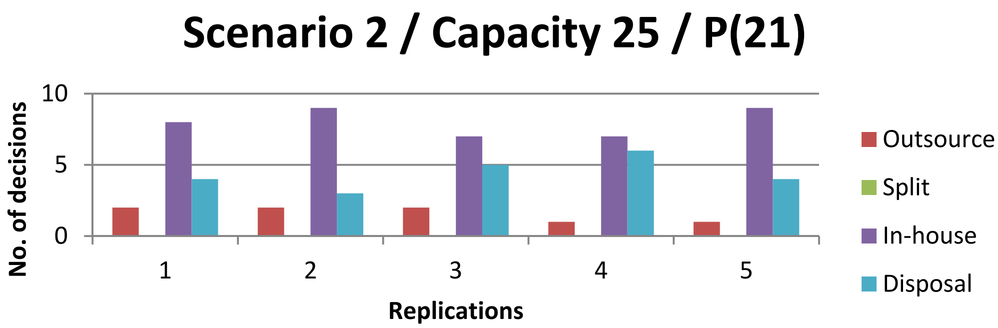

Figure 5: Scenario 2 with mean 21 for Poisson distribution and capacity 25

When the model is run with capacity 25 and mean values of 21 and 42 for the returns, the following result follows. As it can be seen from the two figures, the split decision is not considered in any of the five runs. The reason can be that, as the capacity remains fixed, the better option is all or nothing in most real life cases and hence also only the outsourcing or in-house remanufacturing came up in the simulation.

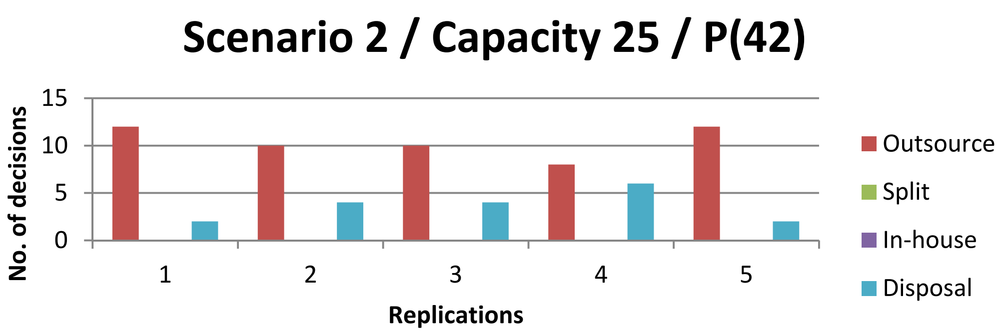

Figure 6: Scenario 2 with mean 42 for Poisson distribution and capacity 25

It can be seen in the two figures; 5 and 6, there is the option of outsourcing and disposal. It is believed that in some cases it would be beneficial to even dispose the returned products rather than remanufacture them. Splitting the returned products between outsourcing and remanufacturing, though considered in this case, it would not be so much considered in practical scenarios as explained earlier. It is also found that the higher the variance gets for the returned products, the less the in-house decision is considered based on this simulation.

Now let us consider the effect of return rate variance, the result is shown in the following figures:

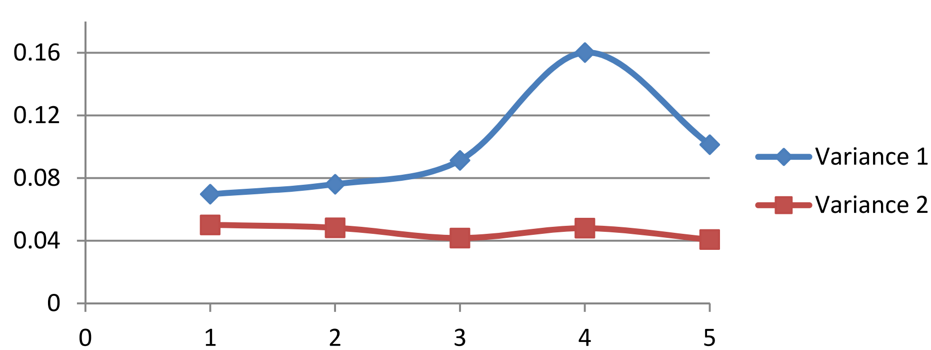

Figure 7: Variance in return rate for scenario 2 with mean for Poisson distribution as 21 and 42 respectively for scenario 2

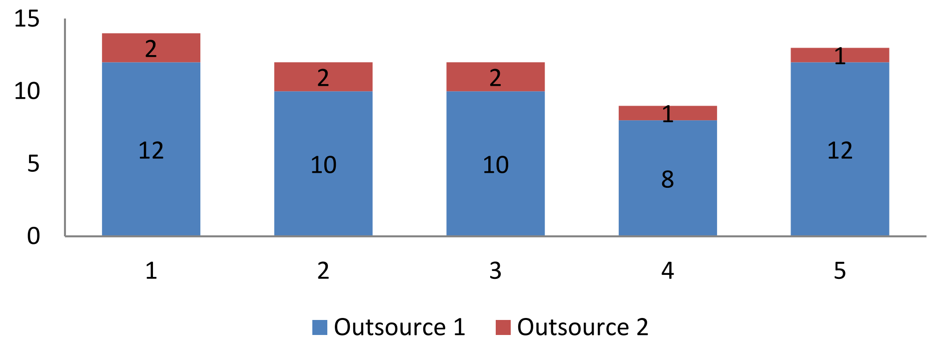

Figure 8: Number of outsourcing decisions for scenario 2 with mean for Poisson distribution as 21 and 42 respectively

It is found that the number of outsourcing decisions is depended upon the variance of return rate. The higher the variance on return rate, the higher the number of outsourcing decisions will be. The same conclusion as told previously can be reached here too that, with higher variance in returned products, the number of in-house decision decreases. So it can be concluded that the variance in the return rate influences the decision of outsourcing while the capacity is fixed.

3.3 Scenario 2 with capacity 50

Now the model is run with capacity 50 and the mean for Poisson distribution as 21 and 42 respectively and the results are shown below:

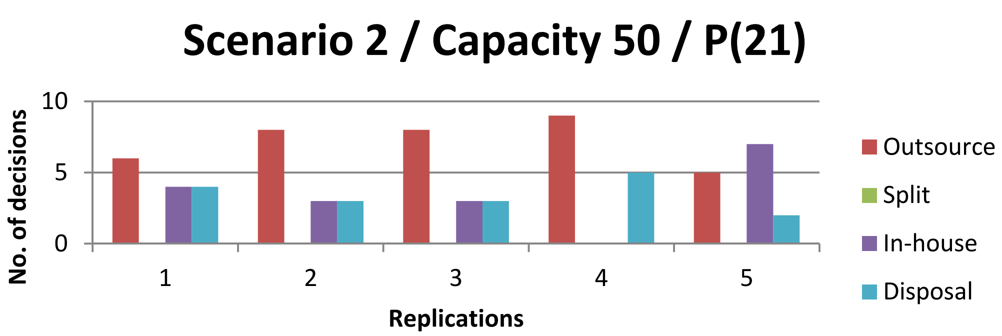

Figure 9: Scenario 2 with mean 21 for Poisson distribution and capacity 50

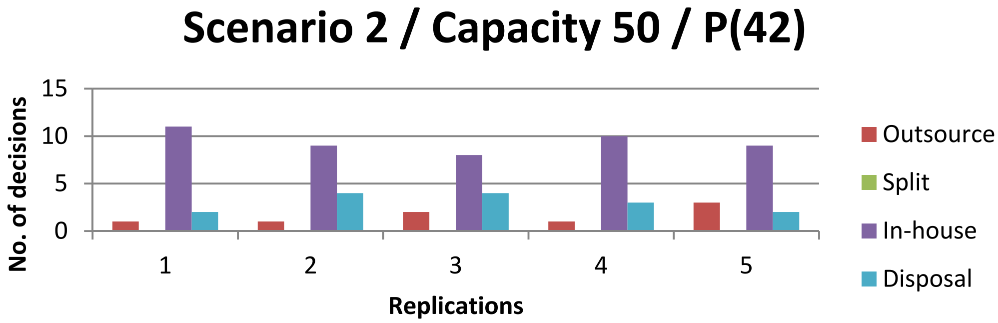

Figure 10: Scenario 2 with mean 42 for Poisson distribution and capacity 50

Now let us consider the five runs and the effect of the variance of the return rates on outsourcing. The results are shown in the following figures:

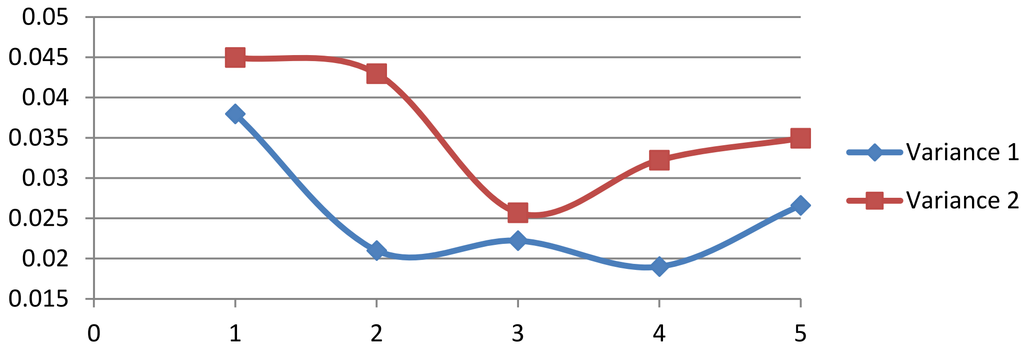

Figure 11: Variance in return rate for scenario 2 with mean for Poisson distribution as 21 and 42 respectively

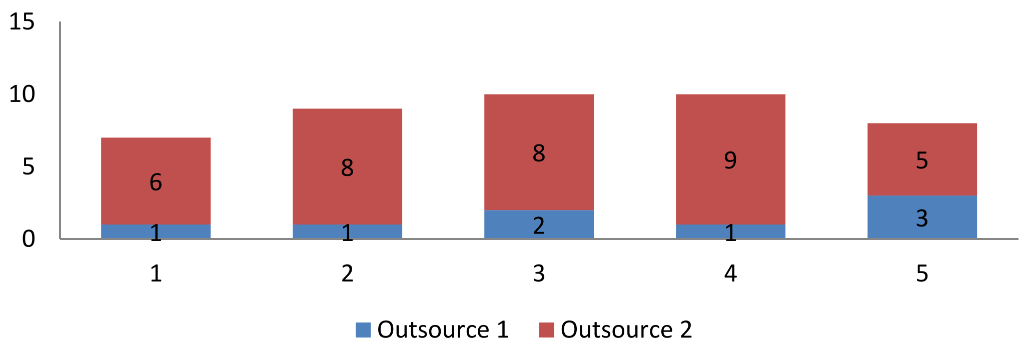

Figure 12: Number of outsourcing decisions taken for scenario 2 with mean for Poisson distribution as 21 and 42 respectively

The result shows that the variance in the return rate influences the decision of outsourcing, and also that with the capacity being higher, the number of outsourcing decisions is becoming less than when the capacity was relatively smaller.

4. Conclusion

The results obtained in this paper have clear and obvious policy implications. When the variance in the return rate is higher, the policy maker should choose the outsourcing option instead of in-house remanufacturing in order to ensure less capacity wastage. This is true in both dynamic capacity and fixed capacity scenarios. There is also another insightful finding. In the fixed capacity model, the higher the capacity remains for the OEM, the more the OEM would want to remanufacture in-house so that the capacity wastage is minimized as explained earlier. The conclusions are valid irrespective of whether the OEM is facing a dynamic capacity situation or a static one. In the paper two different scenarios have been simulated using ProModel software. In the first instance, the capacity is considered dynamic while in the second instance the capacity is considered static. These two scenarios are considered for the variance in return rate. Both scenarios, the simulation results lend strong support to the hypothesis that outsourcing is a more suitable option when the variance in return rate is high.

Appendix A

It is important to classify the related costs of the RL chain in order to define the cost function. Here capacity unit represents the firm's ability to process one returned item.

c_1: Unit investment cost: Cost of increasing the capacity of the RL by one unit to meet the demand for the returned products.

c_2: Unit idle cost: This represents the cost when the capacity remains unutilized in case the returned products are outsourced and also when the decision of in-house remanufacturing is considered but the number of returned products is less than the capacity available for remanufacturing.

c_3: Fixed cost: The cost of setup, machine cost, electricity, and order processing cost are considered as fixed cost.

c_4: Unit variable cost: Variable cost of labor and overhead cost are considered as unit variable cost of the firm which in turn can be thought of as unit remanufacturing cost.

c_5: Unit shortage cost: This cost is paid by the firm if it refuses to take responsibility of the returned products and thus get away by paying only a shortage cost.

c_6: Unit salvage value: This cost accounts for when the process is outsourced and the capacity is left unutilized; hence depreciation takes place and also if the decision is taken that the system capacity will be reduced to zero and consequently revenue will transpire for the OEM. Thus, this value can be both cost and revenue depending on the decision taken.

c_7: Unit outsourcing cost: This is the cost of outsourcing one unit which consists of both the variable cost and fixed cost on part of the 3rd party involved.

c_8 : Unit transportation cost: This cost represents transporting one unit of returned products back to the warehouse.

c_9 : Unit inventory cost: This cost accounts for handling the returned products in the warehouse.

c_{10} : Unit inspection cost: This is the cost of inspecting for quality of the returned products to decide on the disposal or remanufacturing option.

$c_1, c_2, c_3, c_4, c_5, c_7, c_8, c_9, c_{10} > 0$ as they represent costs for the firm, c_6 is unrestricted in sign as there is no reason to take for granted that it will become cost or not. Given that reverse logistics does not represent a core activity for the firm, profit from remanufacturing is not considered.

Some relationships among these cost variables exist. They are as follows:
Inequality (1) implies that the cost of investment while increasing the capacity is more than when the capacity is left unutilized.

$$c_1 \geq c_2 \tag{1}$$

Cost of unutilized capacity is less than maintaining for an additional period is given by.

$$c_3 + c_9 \geq c_2 \quad (2)$$

Cost of outsourcing is more than the variable cost as outsourcing comprises both variable and fixed costs while in-house is considering only variable cost.

$$c_7 > c_4 \quad (3)$$

Total internal cost should be less than shortage cost as it gives the motivation to develop internal capacity, given that the internal cost of having the capacity for one additional period and then processing one additional unit.

$$c_1 + c_3 + c_4 + c_9 + c_{10} \leq c_5 \quad (4)$$

These cost parameters define the following cost structures:

Investment cost: $c_1\,(\mathrm{y} - k_t)^+$ (5)

Idle cost: $c_2\,(k_t - \mathrm{y})^+$ (6)

Fixed cost: c_3 (7)

Variable cost: c_4 (y) (8)

Shortage cost: $c_5\,(E[(X - k_t)^+])$
where X is Poisson distributed with mean ($n_t r$) (9)

Transportation cost: $c_8\,(y)$ (10)

Inventory cost: $c_9\,(E[\min(X, k_t)])$
where X is Poisson distributed with mean ($n_t r$) (11)

Inspection cost:
$c_{10}(E[\min(X, k_t)])$ where X is Poisson distributed with mean ($n_t r$) (12)

These are for the case when the remanufacturing option is taken to be in-house.

The expected total cost for in-house remanufacturing is:

$$\begin{aligned} R_{t+1}\big((k_t\,, w_t)\,,0\big) &= \sum_{\mathrm{y}=0}^{\mathrm{n_t}} (c_1[\mathrm{y} - k_t]^+ + c_2[k_t - \mathrm{y}]^+ + c_3 + c_4[\mathrm{y}] + c_5(E[(X - k_t)^+]) \\ &+ c_8[\mathrm{y}] + c_9\,(E[\min(X, k_t]) + c_{10}(E[min(X\,, k_t)])) \times \mathrm{P(y)} \end{aligned} \quad (13)$$

Salvage value: $c_6\,[k_t]$ (14)

Outsourcing cost: $c_7[\mathrm{y}]$ (15)

The expected total cost for outsourcing is =

$$R_{t+1}\big((k_t, w_t), 1\big) = \sum_{y=0}^{n_t} (c_6[k_t] + c_7[y] + c_2[k_t]) \times P(y) \quad (16)$$

Reference

Aras, N., Boyaci, T., and Verter, V. (2004). The effect of categorizing returned products in remanufacturing. *IIE Transactions,* 36, 319-331.

Guide, Jr. V. D. R., and Van Wassenhove, L. N. (2009). The Evolution of Closed-Loop Supply Chain Research, *Operations Research*, 57 (1), 10-18.

Hui-yun, J., and Min-Li, X. (2007).The value of production outsourcing: A real options perspective. *Proceedings of* 2006 *International Conference on Management Science and Engineering, ICMSE'06 (13th),* 587-590.

Lebreton, B. (2007). Strategic closed-loop supply chain management (1stEd.). Berlin, New York: Springer.

Mahapatra, S., Pal, R. and Narasimhan, R. (2012). Hybrid (re)manufacturing: manufacturing and operational implications. *International Journal of Production Research*, vol. 50, no. 14, pp. 3786-3808.

Miao, Z. (2009). The returns disposition problem with outsourcing in reverse supply chain. *6th International Conference on Service Systems and Service Management (ICSSSM)*, 131-134.

Pochampally, K., Nukala, S., and Gupta, S. M. (2008). Strategic planning models for reverse and closed-loop supply chains. *Taylor & Francis, ISBN 1420054783, 9781420054781*.

Rupnow, P. (2004). Reverse logistics opportunity for 3PLs Reverse Logistics Professional.
Serrato, M. A., Ryan, S. M., and Gaytàn, J. (2007). A Markov decision model to evaluate outsourcing in reverse logistics. .*International Journal of Production Research*, 45(18-19), 4289-4315.
Teunter, R.H. and Flapper, S.D.P. (2011). Optimal core acquisition and remanufacturing policies under uncertain core quality fraction, *European Journal of Operations Research*, vol. 210, pp. 241-248.
Wang, C., and Fan, T., (2007). Outsourcing decision-making strategy for collecting used-products in reverse logistics. *IEEE International Conference on Service Operations and Logistics, and Informatics, SOLI.*1-6.

Biography

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