



Modelling of core quantity traded-in in automobile remanufacturing industry

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Abstract: Remanufacturing business is still in the developmental stage and the data on core availability is relatively scarce especially in developing economies. The growing need of remanufacturing business relies heavily on the availability of core. However, remanufacturing investment in these countries suffer from the insufficient core due to lack of take back legislations, environmental policy on end-of-life product and low customer awareness on where to trade core. Estimating core for cost-benefit analysis becomes a big task due to lack of information and scarcity of data. To estimate number of core in a locality at a given period of time, a model is proposed. This model relied on the mathematical model for spread of technological innovation. This model takes care of media advertisement which provides an avenue to measure effects of advertisement on the acquisition of end-of-life and end-of-use products. The estimated core is used to determine the number of remanufactured product if defective core in each process follow poison distribution. This approach will help to determine the viability of remanufacturing investment in a locality and provide a qualitative approach to study the entire process since the success or otherwise of this business rest heavily on availability of core.

Keywords: *remanufacturing; core quantity; mathematical modeling; end-of-life product*

1 INTRODUCTION

Modeling is a powerful tool commonly useful to study the big and complex system due to time and money required to set up the system. The complexities in the design of a system, promotes high cost and difficulties during analysis. It is much more effective and convenient for the complex design and system to be analyzed and expressed using mathematical modeling. The sophistication in modern day design and availability of powerful computer has made mathematical modeling of system a toast for design and analysis. This is an edge mathematical modeling has over other forms of modeling. Mathematical modeling is a description of a system using mathematical concepts and language to solve real life problems. The usefulness of modeling in remanufacturing is to compute the optimal value of a given objective function subject to the constraints or limitations available. As such, modeling can help decision maker to maximize availability of core quantities, production, profit, productivity, revenue, etc. in a company; given the predominant constraints such as less capital, limited space, and uncertainty

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in quality, time and timing in acquisition of core. Given the high level of uncertainty in remanufacturing, which is associated with the quantity and quality of core (Ilgin and Gupta 2012, Barquet, Rozenfeld, and Forcellini 2013); the uncertainty in acquisition of core has led to the under exploitation of this viable means of sustainable manufacturing as companies are unable to explore and evaluate the limitless possibilities and potentials which remanufacturing holds.

In today's world, the emerging needs of customers to acquire new and advanced technology products compel manufacturing industries to continue to introduce new product and abandon the existing product prematurely. This situation is fuelling the use of virgin materials while creating scarcity of resources and increasing environmental burden due to the hastily discarded products. To rescue the aforementioned problem, remanufacturing has been widely accepted process which helps to prolong product life cycle and reduce environmental pollution in terms of waste disposal and landfills as well as limit the amount of raw materials and energy that would have been used to produce virgin products. With improving technology and increase of discarded products prematurely, remanufacturing business continue to benefit from abandoned products which serves as raw materials for the process. However, the major challenges faced by remanufacturing companies are still on the acquisition of the optimal quantity and precise information about the location where these discarded products can be accessed. These are stumbling blocks as the trading of core is the backbone of remanufacturing business (Guide and Wassenhove 2001, Caterpillar Inc 2014). Moreover, another factor which directly affects remanufacturing business is the lack of reliable information about quality of core that has negatively impacted the process. Core acquisition is difficult especially in developing countries due to less awareness of customer owning core and therefore the return rate is relatively small and it is hard to achieve investment (Yang, Wang, and Ji 2015). Therefore, getting reliable data and information on number of cores in quantity and quality will determine the viability of the business and encourage investment. Core acquisition is of great importance because it is crucial as it affects company profit and operations issues such as production planning, facility design and control activities (Guide and Wassenhove 2001). In this respect, therefore, the core collection should rather be regarded as a decision instead of being determined by chance availability as the performance of remanufacturing investment depends on quantity of core supply. Regardless of importance of core acquisition in remanufacturing, yet related studies are still relatively limited and no review specifically addresses this as main focus in remanufacturing (Wei 2015). Few studies considered core acquisition in remanufacturing like Pokharel and Liang (2012) focuses on acquisition of core quantity based on price and considering consolidation and collection center while Jiang et al. (2013) developed a method for optimal acquisition of core considering three types of inventories. Clottey and Benton Jr (2014) also developed a method for accurately forecasting core return and control of inventory in remanufacturing system. Yang, Wang, and Ji (2015) developed a model for core acquisition problem in the presence of quality variability and condition uncertainty. However, none of the studies reported the acquisition of core considering the effect of media advertisement. Therefore, in order to ascertain availability of core quantity, the remanufacturing companies need to determine the type and amount of cores needed, from various sources and location through natural cause and media advertisement.

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Advertisement is a tool for non-personal communication focus at distributing marketing related information to a targeted audience in order to achieve the company objective (Ghoreishi, Jakiela, and Nekouzadeh 2011). Advertisement can play a constructive role to convey information to the owners of used product about the existence of remanufacturing company, location, needed cores volume, etc. Core being the raw materials can be forecasted by support of the media advertisement. However, forecasting core quantity should go beyond academic writing alone but an approach that can easily be used and accessible by practitioner in the industries. Because the industrial needs data and information on core, hence such studies are still unlimited due to a quick and fast changing of remanufacturing, especially in developing countries (Wei 2015). This study proposes a qualitative analytic approach for core estimation and analyzes the impact of advertisement on quantities of core traded-in as addition means for core availability. It considered acquisition of core quantity based on natural return from owners of original product sold in certain locality and with influence of advertisement. The purpose of this study is to develop model for core acquisition decisions to help investors to determine quantity of core direct from customers and considers the impact of advertisement on return volume. The main results and contributions of this paper are different from most of other study, which did not incorporate advertisement into the core acquisition. Therefore, this study contributes to the existing knowledge about the availability of core quantity as prerequisite for remanufacturing investment.

The rest of the paper is organized as follows. Section 2 provides brief review of remanufacturing, core acquisition and impact of advertisement in core quantity. Section 3 describes model formulation, estimation of core quantity under natural cause and with effect of advertisement. Section 4 highlight results of model implementation numerical examples and provides insights on analysis to obtain non-defective core. Section 5 presents discussion based of results. Finally, Section 6 concludes the paper with future research direction.

2 LITERATURE REVIEW

Remanufacturing is a complex business process due to the high degree of uncertainty, caused by two factors viz: the quantity and the quality of returning products commonly known as the core (Vasudevan, Kalamkar, and Terkar 2012). The core is used/discarded product collected from the consumers as input to the process, and then transformed into recovered products (Golinska-Dawson and Nowak 2015). The core occurs for different reasons such as commercial returns, End-of-Life (EoL) or End-of-Use (EoU) return. It has multiple modules that are materially recycled, reused, refurbished or disposed (Jayaraman 2006, Jindal and Sangwan 2014). In remanufacturing, cores are essential resources for production thereby it guarantee sustainability of business. In this perspective, remanufacturer needs a core component/part of the product sold to customers from original product manufacturer. Zhou and Yu (2011) mentioned that acquisition of core is the key that decides whether the remanufacturing could success or not. Therefore, '*cores are the backbones of the Caterpillar remanufacturing*' (Caterpillar Inc 2014). Core is indispensable resources for remanufacturing process as there is no production in absence of core. In other

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words, low quantity of core may lead to low production and, on the other hand high availability of core may result in high production. However, core being prerequisite in remanufacturing process has been facing challenges of uncertainty in quality and quantity during acquisition.

On recent, as supported by Wei (2015) that the challenges in the core acquisition process are mainly caused by the uncertainties of return volume, timing and quality. Lind, Olsson, and Sundin (2011) they also revealed that it is difficult to achieve steady flow of core quantity in remanufacturing due to uncertainty in return. Yang, Wang, and Ji (2015) on examining the value of cores under uncertainty of price with low demand and return, they revealed that there is marginal value of obtaining additional cores. Golinska-Dawson and Nowak (2015) mentioned that uncertainty of core in quantity, timing and quality continue to attract researches in different countries and therefore they proposed exploration of more possible scientific means to eliminate these problems. Similar, in the areas of cores supplies, it has been reported that despite quantity, there is insufficient availability of better quality cores, high product variability, a variation of the rate of materials recovered and materials matching problems as the major dominant challenges (Rubio and Corominas 2008, Golinska-Dawson and Nowak 2015, Ostlin and Ekholm 2007). In fact, core acquisition is uncertain and its high quality variability is a big challenge which contributes difficulties to decision maker to ascertain the quantity of core to be acquired (Yang, Wang, and Ji 2015). This fact may evidence that quality of core is directly associated with the quantity traded in, so the higher the quantity the increase probability of acquiring good or defective core. There is therefore a need to determine the number of defective core with percentage good and defective core significantly to show investment breakthrough. It is unfortunate that most of the existing studies focus on acquisition control, as such, the studies on return strategies and return forecast are relatively limited (Wei 2015). However, core management attempts to reduce these uncertainties and achieve a better balance of demand and core returns. Xie et al. (2015) advised remanufacturer to hold higher stock of core and increase price to attract return in order to minimize uncertainty. With a high level of uncertainty on quantity and quality of core, investors may find it difficult to plan, analyze, implement and consolidate the remanufacturing investment business (Kafuku et al. 2015). In this respect, investor need to determine quantity of core, hence the research in various forms of the core acquisition such as acquisition volume is still important and need further investigations (Wei 2015). There is therefore need to establish the availability of core by developing a mathematical model to forecast quantity; and based on number of core, decision makers can evaluate investment viability on whether or not to venture into the remanufacturing undertakings.

The information on the estimated core quantity in a certain locality is prerequisite for investors. Investors need to know specifically where and how many projected cores are available in order to determine extent of investment needed. As also mentioned by Saavedra et al. (2013) that to determine quantity of core is essential for the process, and therefore it should be guaranteed. Similar, knowing viable sources of core and forecasting quantity help the decision makers to conduct investment analysis and forecast company performance. Generally, managing remanufacturing is not a simple task due to complexity of core flows and information

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transparency as the greater degree of information transparency increases the higher uncertainty of core (Tang and Naim 2004).

Cores availability is sometimes compromised with inadequacy information on place and willingness of individual to trade-in. However, the use of information system and better communication with the customer reduces uncertainty in acquisition of core (Ketzenberg 2009). Therefore, information through media advertisement to individuals who are willing to trade-in core will enhance availability. In practice, most individuals recognize a place to trade-in core when they see advertisement (Johnson 2013). Therefore, it is important to attract individuals owning core by providing information on the location, type and quantity of the cores needed through advertisement.

Advertisement has been a tool to inform customers on location to trade core and it has been strongly influencing decisions on collection of core (Hong et al. 2015). Well-designed advertisement can have a motivating effect by informing the customers about the profits of returns for core, environmental benefit including reducing energy, waste and conserving natural resources (Ghoreishi, Jakiela, and Nekouzadeh 2011). In remanufacturing business, however, it is rare to see research which consider the effect of advertisement in collection of core (Hong et al. 2015). Huang et al. (2013) discussed the effect of the advertisement decision on the competing intensity between the third party and retailer in collection of core. Ghoreishi, Jakiela, and Nekouzadeh (2011) addressed advertisement as one of the factors for optimizing take back used product. The advertisement factor was used to analyze costs and benefits to an informed customer on motivation for take back policy. Minner and Kiesmüller (2012) mentioned that advertisement is an instrument to create awareness to customer as proactive strategy for taking back core at the end of their use. Numerous studies in remanufacturing assume customers owning core are informed on place to trade-in core. This assumption is contrary to the real situation that numerous firms acquire remanufacturing core through high incentive which impact the initial investment (Yang, Wang, and Ji 2015). Generally, a need for advertisement to enables a firm to get more cores to match with production demand is essential. As supported by Ketzenberg (2009) that information enables a firm to match accurately supply with demand in production system. Therefore, from the discussed literature, it is clear that acquisition of core quantity is an imperative research problem, and there is a need to formulate model for estimation of core quantity with customer interaction and considering effect of advertisement. This research considers the assumption made by (Savaskan, Bhattacharya, and Van Wassenhove 2004) that remanufacturer choose to obtain core direct from the market (M-collection mode). Unlike other studies, this study explores the quantity variation of core collection by a natural cause as well as through advertisements.

3 ESTIMATION OF CORE FOR REMANUFACTURING

Remanufacturer usually obtain core direct from customers and third parties vendors such as brokers and salvage operators. However, core acquisition direct from customer is the primary and cheapest way which assures sufficient quantity of cores to remanufacturer (Clottey and Benton 2010). The schematic Figure 1 shows a production system with flows of new product from

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manufacturer to customer, where EoL or EoU product is sold to remanufacturer. The remanufacturer can be obtained core through various channels such as collection centers, third party vendors, owner of original product and other sources like producer of original product. In this paper, we assume that the core is obtained from EoL or EoU return that original customers (Figure 1) of products are willing to trade in core without any influence of policy or legislation such as take back policy and environmental legislation respectively. The model for core acquisition reflects real data of Perodua, the national car manufacture in Malaysia, launched on August 1st, 1994. A company produced a total of 653,800 units in 2013 and has sales volume of of technological innovation which have been used to farmer's response to new innovation (Antman et al. 2001) and use to predict spread of technological innovation in rural India (Amritbir and Ravi 2010), this is adapted to determine the number of core at any time (t).

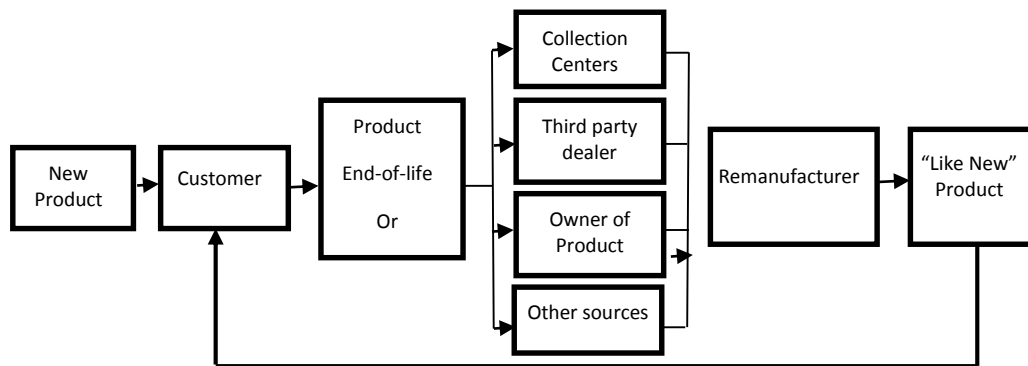


Figure 1: A schematic diagram showing movement cycle of core.

3.1 Description of the model

Most of the research in remanufacturing considered static models and therefore ignore time dependencies of the parameters (Minner and Kleber 2001), unlike the real life that availability of core quantities and changes in collection effects are functions of time (Zhang, Qiu, and Yi 2014). This limit the optimal solution to acquire core as the static model does not consider increasing awareness to trade-in core from owners as it is a function of time. The proposed model estimates the number of cores acquired with interaction between the owners of the core in a given locality and remanufacturing company. As revealed in literature, the acquisition of core under natural cause may not be sufficient to get the required quantity to serve for the optimal performance of company; hence, to increase the volume of core, advertisement is built into the model. With respect to the number of cores, this model relies on knowledge of the number of original products sold and used in the locality.

To get reliable results, we also assume that the number of defective cores follows a Poisson distribution; this is extended to all the stages of remanufacturing. By this extension our assumption guides us in estimating the number of remanufactured cores. Successful estimates of expected numbers in a particular location at a particular time will help investors to carry out

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cost and benefit analysis of remanufacturing business. As mentioned by Kafuku et al. (2015), reduction of uncertainty in remanufacturing investment depends on accurate data which support analysis for decision making. Therefore, uncertainty about the quantity and quality of core, as a result of lack of appropriate data on the number of cores and its forecasting will be abridged by this proposed mathematical model.

3.2 Model development

To develop this model, we make the following assumptions, one the number of core is dependent on the number goods sold in a given location, so it is assumed that no other item comes from other sources. Each manufacture goods sold is unique irrespective of multiple buying by customers. Finally, the product remain the same i.e. no changes of components/parts during useful life of product. Now, let

δx = change in the number of people traded in core

$x(t)$ =number of people trade in core

N =number of people who bought original manufactured good

δt = change in time

3.2.1 Core Quantity with Customer Interaction

The change number of people trade in core δx is proportional to the number of people trade in core and the number of people who have not trade in core i.e.

$$\delta x \propto x(N - x)\delta t \quad (1)$$

But

$$\lim_{\delta t \rightarrow 0} \frac{\delta x}{\delta t} = \frac{dx}{dt} = kx(N - x) \quad (2)$$

where k is a constant of proportionality. Since (2) is a separable first order differential equation we have

$$\int \frac{dx}{x(N - x)} = \int k dt$$

Resolving the partial fraction on the integral we have

$$\frac{1}{x(N - x)} = \frac{A}{x} + \frac{B}{(N - x)} = \frac{A(N - x) + Bx}{x(N - x)}$$

$$\therefore A = B = 1 / N$$

Hence,



$$\begin{aligned}\int \frac{1}{x(N-x)} dx &= \int \frac{1/N}{x} + \frac{1/N}{(N-x)} dx = \int k dt \\ &= \int \left[\frac{1}{x} + \frac{1}{(N-x)} \right] dx = \int Nk dt \\ &= \ln|x| - \ln|N-x| = Nkt + K\end{aligned}$$

where K is constant of integration and the solution becomes

$$\begin{aligned}\ln \left| \frac{x}{N-x} \right| &= Nkt + K \\ \left(\frac{x}{N-x} \right) &= e^{kNt+K} \quad \text{which implies} \quad x = (N-x)K_1 e^{kNt}; K_1 = e^K \\ x(1 + K_1 e^{kNt}) &= NK_1 e^{kNt} \quad \text{and} \\ x &= \frac{NK_1 e^{kNt}}{1 + K_1 e^{kNt}}\end{aligned} \quad (3)$$

Assuming $x(0) = 0$ there will be no solution, this shows that at time $t=0$, the number of core cannot be equal to zero. Now $x(0) = N_0$, (3) becomes

$$N_0 = \frac{NK_1}{1 + K_1}$$

Where N_0 is the initial trade in core at $t = 0$ and

$$K_1 = \frac{N_0}{N - N_0} \quad (4)$$

Substituting (4) in (3) we have

$$x(t) = \frac{NN_0 e^{kNt}}{N + N_0 e^{kNt} - N_0} = \frac{NN_0 e^{kNt}}{N + N_0 (e^{kNt} - 1)} \quad (5)$$

Therefore, the expression on the number of cores at any time t once the constant of proportionality k is determined.

3.2.2 Core quantity with customer interaction and media advertisement

The natural flow of spread is shown in (5) but there may be another factor that affects the number of cores to be traded in as time progresses. One of such is the level of awareness due to advertisement through the mass media. In this case also the change in number of core traded in is proportional to the number of those that have not traded in the core i.e. equation (1) is modified as

$$\delta x \propto x(N-x)\delta t + (N-x)\delta t \quad (6)$$

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And

$$\lim_{\delta t \rightarrow 0} \frac{\delta x}{\delta t} = \frac{dx}{dt} = kx(N-x) + m(N-x) \quad (7)$$

Where m is a constant due to advertisement, and

$$\int \frac{dx}{(N-x)(x+a)} = \int kdt \quad (8)$$

Where $a = m/k$ Resolving (8) we have

$$\frac{A}{N-x} + \frac{B}{x+a} = 1$$

This gives $B = A$ and $A = (N+a)^{-1}$ and our integral (8) becomes

$$\frac{1}{N+a} \left(\int \frac{1}{N-x} dx + \int \frac{1}{x+a} dx \right) = \int kdt \quad (9)$$

and

$$\ln \left(\frac{x+a}{N-x} \right) = (kt+c)(N+a) = kt(N+a) + c(N+a)$$

$$\left(\frac{x+a}{N-x} \right) = Ke^{kt(N+a)} ; K = e^{c(N+a)}$$

$$x(t) = \frac{NK e^{kt(N+a)} - a}{1 + Ke^{kt(N+a)}} \quad (10)$$

at $t=0$

$$x(0) = \frac{NK - a}{1 + K} = N_0, K = \frac{N_0 + a}{N - N_0}$$

and

$$x(t) = \frac{N(N_0 + a)Ke^{kt(N+a)} - (N - N_0)a}{N - N_0 + (N_0 + a)e^{kt(N+a)}} \quad (11)$$

While (5) gives the estimated number of core due to interaction between those who traded-in core, (11) estimate the number of core when the media advertisement is done to inform people. The difference between (11) and (5) will give the volume of core quantity increase and therefore reflect profit margin due to rise of company performance as an outcome of advertisement. This gives an insight to the effectiveness of the advertisement and justifies advantage of advertisement. However, the number of core through this approach automatically gives the

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number of core that will go through the process, i.e. $x(t) \equiv n_1$ which is the average number of core forecasted per day or per month or per year as the case may be.

4 MODEL IMPLEMENTATION

In this section we highlight the results of Sections 3.2.1 and 3.2.2, which estimate the quantity of core traded-in based on customer interaction and with effect of advertisement.

4.1 Results for core trade-in based on natural flows and effects of advertisement

The implementation of the model relies on the numerical data to validity the constructs. The data used for analysis were obtained from company remanufacturing cylinder heads of automobile engine. Cylinder head is a most common component in engine remanufacturing (Seitz and Wells 2006). The initial time plan considered for investment is $t = 10$ years as time to predict investment stability. Forecasted number of customer traded-in core $x(t)$ for the period t is calculated based on individuals who bought car with original cylinder heads $N = 196100$. The initial condition for core acquisition $N_0 = 1$, while other factors considered in this numerical example are constants k and m representing rate of trade in core under natural cause and with effect of advertisement respectively. The constants k and m can be determined by daily/monthly/yearly data in respect to number of trade-in core per time. The model results are presented using Matlab® to illustrate core traded under natural cause and effect of advertisement. Mathematically, as $t = 0, x = N$ $t \rightarrow \infty x \rightarrow N$ in (5) and (11) but the time at which each will attain this level will be different. The behaviour of both graphs indicates increase of core quantity in natural cause x_1 and with effect of advertisement x_2 as shown in Figure 2 (a) and (b).

The proposed models depicting graph x_1 and x_2 for equation (5) and (11) also shows increase of core traded-in with respect to increase of time. However, the variation of core quantities due to the effect of advertisement Figure 2 (a) shows percentage increase to a maximum of 43.3% quantity increase; thereafter the marginal difference as time increase is realised. Furthermore, to verify the trend of results, the core quantity was also analyzed based on variation of people bought original core (N). With estimate of number of customer who bought original cores, the variation of number of the cores traded in shows the difference of 0.004 percentage increases

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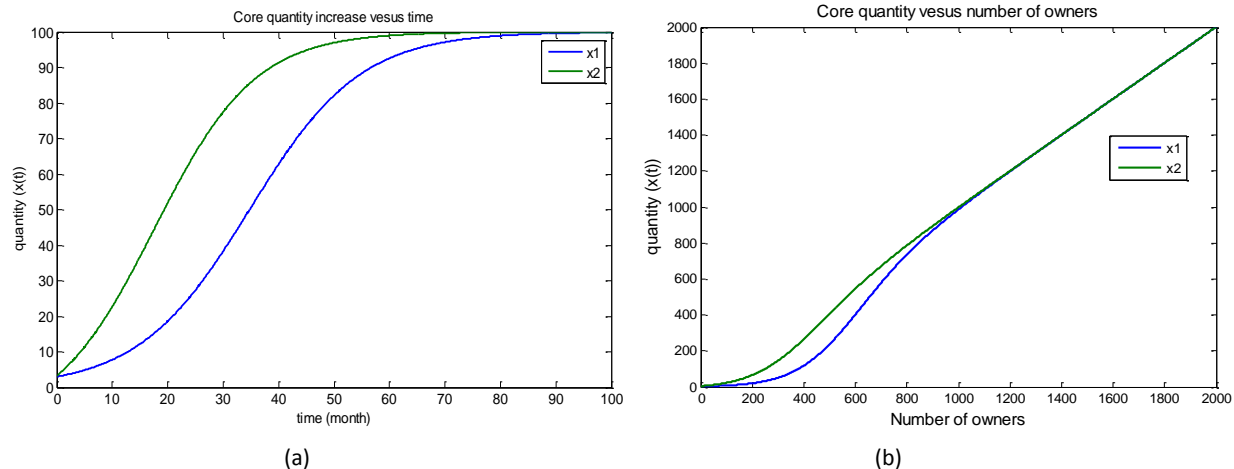


Figure 2. (a) Customers traded-in core with time (t) variation. Figure 2 (b) with variation of people bought original product (N)

for acquisition of core in both cases. The behaviour of graphs to both model indicate increase of core quantity traded-in over time; however the rate of increase of core quantity traded-in with effect of advertisement (x_1) is higher compared to natural contact (x_2). These graphs allow us to know how much cores can be obtained at a particular interval of time and give a comparison between the two scenarios within a specified time horizon. Mathematically, the behavior of both equations shows the success of the model to help decision maker on estimating core quantity in both cases. The model supports investors to decide within a specified time interval, number of core available; therefore, they can plan and arrange financial commitment for the remanufacturing business.

4.2 Estimation of non-defective cores for remanufactured processes

From an investment analysis perspective, remanufacturing process involves stages, namely; collection, inspection, disassembly, cleaning, sorting, testing, commissioning, upgrading, assembly and packaging (Kafuku et al. 2015). The stages mentioned are common process for remanufacturing of automotive engine (Andrew-Munot, Ibrahim, and Junaidi 2015). However, the actual number of process and operations sequence depends on the type and nature of core being remanufactured. In estimating defective core, our model assume that at collection stage a preliminary inspection can locate defective core which can be rejected if it is severely damaged unable to serve the purpose. As common practice in remanufacturing, it is also expected that during sorting process, we may find defective or missing components/parts which need repair or replacement respectively. This is due largely to undergoing inspection and upgrading system which lead to the shorting fall of standard core specification in the respective process. Hence the number of non-defective core that scale through all stages will determine the viability of the business. Conversely, a company incurs costs from utility, manpower, and waste; while gaining benefits from reuse and recycled components/parts altogether. However, determination of costs and benefits due to acquisition of core is out of the scope of this paper. The thrust of this research is to determine the number of non-defective core obtained after all the stages, which will then govern the success in terms of investment gain.

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The number of trade in core in (11) is $x(t) \equiv n_1$ i.e. the number of trade in core from (11) is equal to the number of core that survive the first stage of remanufacturing. To determine the number of core for stage 2, with the distribution of defective core follows Poisson distribution (Ismaila, Akanbi, and Charles-Owaba 2009) i.e. If $\alpha\%$ is the number of defective core in total population n where $0 \leq \alpha \leq 5$ then,

$$\begin{aligned}
 n_1 & \\
 n_2 &= (1 - \alpha)n_1 \\
 n_3 &= (1 - \alpha)n_2 = (1 - \alpha)^2 n_1 \\
 n_4 &= (1 - \alpha)n_3 = (1 - \alpha)^3 n_1 \\
 n_5 &= (1 - \alpha)n_4 = (1 - \alpha)^4 n_1 \\
 n_6 &= (1 - \alpha)n_5 = (1 - \alpha)^5 n_1 \\
 n_7 &= (1 - \alpha)n_6 = (1 - \alpha)^6 n_1
 \end{aligned} \tag{12}$$

The number of core that succeeded in the entire process is n_7 which when compared with $x(t) \equiv n_1$ should make remanufacturing business profitable. With the assumption of Poisson distribution of the defective core with percentage defective between 0 and 5%, the number of remanufactured product will be significant to have a breakthrough.

5 DISCUSSION

The procedure proposed in this work relied solely on the number of core sold in the locality. The model assumptions are suitably validated in Malaysia where the country prohibits imports of used automotive parts (Commission 2012). Our model illustrates that core acquisition through media advertisement strongly influences increases of core volume. The study also considers quality perspective on the decision to accept or reject core based on remanufacturer's evaluation. As mentioned by (Chen, Chan, and Chung 2015) that fewer research indicates classification of core quality as good or poor for acceptance. This study proposed poison distribution to evaluate the core quality in batches. The quality of traded core is sometimes depends on legislation on EoL vehicle, usually the age of car allowable and number of accident. The volume of core traded on the other hand depends on awareness of the market. Once these conditions proved favourable then the number of trades in the core can be significant. Having determined the number remanufacture good, the assumption that brought the percentage defects to be within $0 \leq \alpha \leq 5$ can be varied provided in the final analyses, the process remain viable. Of importance in this formulation, is the time estimation for core acquisition, the flexibility of the formulation can guarantee estimation of core at an interval of time of interest. The overall success of this process will give credibility to data acquisition, which laid a foundation for future forecasting in any aspect of remanufacturing industry.

6 CONCLUSION

The simple mathematical model for estimating core quantities in remanufacturing process is proposed. The model considers core acquisition in natural cause and with effect of advertisement

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in a certain locality. Considering two equations on acquisition of core in natural cause and with effect of advertisement, factors which are function of investment, mathematical model to forecast core quantity was developed. The model uses numerical example and both cases of core acquisition were analyzed and revealed that the rate of increase of core quantity increases with respect to time. However, the increasing rate of core quantity with effect of advertisement is higher compared to the increase of quantity in natural cause. Due to limitation on availability of core in locality as assumption made when developed model, it was found that there is marginal variation of increasing core quantity as time increase. This explains that the impact of advertisement in locality after a certain time period it has minimal effect in increasing availability of core quantity.

In this paper, a mathematical model for acquisition of core is adopted to forecast core quantity for determination of investment cost. Investor they should intensely focus on exploring ways to develop the remanufacturing companies across the world. The model to help investor to estimate availability of core in a certain locality is one of the strategies to support green manufacturing system. However, the green manufacturing has been confronted by uncertainty in core quantity, quality, and timing (Witek 2015, Pokharel and Liang 2012, Zhou and Yu 2011). Therefore, developed model to determine quantity of core in a certain locality is significant for investors to decide on existing potentials of remanufacturing. With presence of model, the greater intensity is thus required for more firms to explore this unleash potential of remanufacturing investment, acknowledged to spend minimum investment cost while safeguarding environment pollution. To consider how investment will perform successfully, the expenditures and revenues have to be estimated in advance through understanding the available quantity of core in locality. In this context, application of this model to the remanufacturing firms will emphasize decision-making process to determine level of investment. However, a model limitation assumes that availability of cores in locality are needed by only one firm and core data depends on history of customers owning original product. This model can be applied to any remanufacturing firms and can be extended to evaluate the cost and benefit in industry.

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