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Investigation of Critical Sustainability Decisions in Product Recycling and Remanufacturing to Increase Productivity in Automobile Industry in India

M.Tech. Scholar Mayank Nigam, Prof. Trilok Mishra
Department of Mechanical Engineering,
BIST,Bhopal

Abstract- Remanufacturing is value recovery from used products by reusing the durable parts for the manufacturing of a product with an original functionality. Product recovery causes the reverse flow of used and discarded products, and a closed- loop supply chain is formed when the goods flow back to their original manufacturers. This research aims at identifying the root cause of the operations problem related to the availability of reusable parts that causes delays in the remanufacturing process and propose a solution to the problem. This research uses internal data from Rai Automobile & Machinery as secondary data. The data were obtained from several departments that were involved in remanufacturing process during the period of August 2019 to October 2019.This study resulted in the improvement of the productivity of engine remanufacturing industry by identifying the problems in the current process of the company and hence propose a solution to improvise. The influence of process improvement on minimizing process time has resulted in a significant improvement in productivity and will also help to decrease the cost of the engine and increase in sales.

Keywords: Remanufacturing, recovery, closed- loop supply chain, goods, manufacturers, productivity, reusable parts.

I. INTRODUCTION

The remanufacturing process is actually a type of product recovery; the other four types are repair, refurbishment, cannibalization, and recycling [1].

Repair has the objective of restoring the function of the returned product. In refurbishment, the quality of the returned product will be restored to a certain level, which is typically lower than that of new products. The goal of cannibalization is to replace broken spare parts with ones in good condition. Recycling aims to reuse the materials from the returned products. From a quality perspective, a recycled product is classified based on the location of its future positioning.

Krikke [10] further divides recycling into three classes: (1) high-quality recycling material (used for original quality), (2) low-quality recycling material (used for a lower class than the original one), and (3) alternative recycling material (commonly applied to new material).

Product recovery causes the reverse flow of used and discarded products, and a closed- loop supply chain is formed when the goods flow back to their original manufacturers. A closed-loop supply chain is conventionally seen as a combination of forward material flows and reverse material flows.

Closed-loop supply chain management is the design, control, and operation of a system to maximize value creation over the entire life-cycle of a product, with the dynamic recovery of value from different types and volumes of returns over time [11].Remanufacturing is "the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts". [1]

It requires the repair or replacement of worn out or obsolete components and modules. Parts subject to degradation affecting the performance or the expected life of the whole are replaced. Remanufacturing is a form of a product recovery process that differs from other recovery processes in its completeness: a remanufactured machine should match the same customer expectation as new machines.

In 1995, the United States Environmental Protection Agency (EPA) implemented the Comprehensive Procurement Guideline [2] (CPG) program to promote waste reduction and resource conservation through the use of materials recovered from solid waste, and to ensure that the materials collected in recycling programs will be used again in the manufacture of new products.

The EPA is required to designate products that are or can be made with recovered materials, and to recommend practices for buying these products. Once a product is designated, state and federal procuring agencies are required to purchase it with the highest recovered material content level practicable. In 2004, the EPA published its third CPG update (CPG IV) which designated seven additional products and revised three existing product designations. One of the new product categories to be added was Rebuilt Vehicular Parts. [3]

The EPA defines rebuilt vehicular parts as "vehicle parts that have been re-manufactured, reusing parts in their original form. Rebuilt parts undergo an extensive re-manufacturing and testing process and must meet the same industry specifications for performance as new parts."

II. PAST STUDIES

Gu, Yifan et al. (2020) presented constructs an environmental performance accounting method based on MLCA, and simulates the overall impact of various policies such as implementing deposit system, promoting recycled materials, strengthening environmental regulation and enhancing regeneration technology on the recycling system of PET bottles.

Bag, Surajit et al. (2020) presented examines the role of resources influencing procurement 4.0 for driving productivity in remanufacturing operations and circular economy performance.

The survey data for this research was gathered from working professionals in South Africa and results reveal that technological resources are necessary in procurement 4.0, which can, in turn, improve productivity in remanufacturing operations.

Robertson et al. (2020) presented address the problem of future waste mitigation, whilst attempting to capture the medium scale market. As such, the study has looked at the idea of transitioning towards a circular economy, in which wind turbines are not considered as waste at the end of their service life, but rather an opportunity to recapture value through remanufacturing.

Dominguez et al. (2020) presented identify operational and resource inefficiencies present in FSC through environmental impact assessment and propose a framework for redesigning the FSC to improve environmental sustainability. Life cycle assessment approach is used for assessing the environmental impact.

Ansari et al. (2020) identify and rank the solutions to mitigate the sustainable remanufacturing supply chain (RSC) risks effectively. Risks and the solutions are identified based on a literature survey and discussion with the expert's panel. A hybrid multi-criteria decision making (MCDM) framework using fuzzy step-wise weight assessment ratio analysis (SWARA) and fuzzy complex proportional assessment of alternatives (COPRAS) is applied to analyze the risks and the solutions.

Kumar et al. (2020) presented that the automobile industry is under tremendous pressure from both customers and government for sustainable development. Therefore, Indian automobile industry focuses on business improvement through profitability enhancement as well as environmental development through sustainable lean manufacturing.

Bag, Surajit et al. (2020) examined the role of resources influencing procurement 4.0 for driving productivity in remanufacturing operations and circular economy performance.

The survey data for this research was gathered from working professionals in South Africa and results reveal that technological resources are necessary in procurement 4.0, which can, in turn, improve productivity in remanufacturing operations. An upsurge in performance in remanufacturing operations can enhance the circular economy outcome.

Reche et al. (2020) identified the main bibliographical references that deal with integrated product development process (IPDP) models for the green supply chain management (GSCM). This study starts by identifying some keywords and the main academic journals databases. From this search, the study selects the peer-reviewed articles from journals with high impact factor (SJR> 1; Q1), resulting in 9430 articles.

Ansari et al. (2019) identified and prioritized the performance outcomes (POs) due to adoption of SC remanufacturing critical success factors (CSFs). CSFs and the POs realized due do SC remanufacturing adoption, are identified based on past relevant literature analysis and subsequent discussions with the expert decision panel.

Chakraborty et al. (2019) identified both the enablers and the barriers in managing business of EUL products through remanufacturing in India. Subsequently the structural relationships among the enablers and barriers have been modeled in this paper.

Initially an extensive literature review is carried out to identify the factors depicting the enablers and barriers. Then, Fuzzy Interpretive Structural Modeling (FISM) is applied to develop and evaluate the structural relationships among the identified factors.

Gardas et al. (2019) identified and analyzed the influence of determinants of SSCM on the OPR of the case supply chain in the Indian context. This study has been carried out in two stages; in the first stage, Interpretive Structural Modeling (ISM) methodology was employed for establishing the mutual relationship between the determinants.

III. RESEARCH METHODOLOGY

This research aims at identifying the root cause of the operations problem related to the availability of reusable parts that causes delays in the remanufacturing process and propose a solution to the problem.A rebuilt engine is not completely disassembled and only addresses the current problem. A Re-manufactured Engine goes through complete overhaul process.

The remanufacturing activities need 141.5 days in total to complete. The modification in the process was done to reduce the time consumed in each process to improve productivity. The company faced uncertainty over the availability/supply of parts during the engine remanufacturing process. This is caused by the late arrival of cores, which affects the remanufacturing process negatively.

Some examples are as follows.

- The late arrival of new parts (to replace parts that cannot be reused). Table 2 shows the late arrival of new parts in the period of August 2019 to October 2019. It can be seen that only 16.5% of new parts are received a week prior to the production starting time, while 27.8% are received in the first week of the production month, and the other 55.7% are received in the second week.
- A failure to complete the assembly process on a timely basis, which leads to a failure to deliver the remanufactured products on time.
- Lower productivity and work efficiency of reassembly process workers due to the excessive amount of idle time.
- Underutilized production (reassembly) capacity.
- Difficulty in efficiently managing workload and capacity, where the tendency for overtime drastically increases when approaching a deadline due to the late arrival of the new parts.

1. Causes:

- Late arrival, and an inadequate quantity, of returned cores (as raw materials).
- This situation causes the ordering of new parts (to replace parts that cannot be reused) to be postponed due to the delay in obtaining information about the parts' condition after the disassembly process.
- The percentage of reusable parts from the returned cores is less than predicted.
- This situation will affect the second stage of an order, particularly when a high percentage of reusable spare parts (more than 70%) was predicted that does not match with the actual percentage, and the types of spare parts are vital, such as cylinder blocks.

- A discrepancy between the reassembly (production) and disassembly schedules.
- The late arrival of returned cores makes it very difficult for the scheduling department to put them into an ongoing disassembly process.

2. Proposed Solutions to Problems:

2.1 The late delivery of returned cores by the customers: This is usually due to geographical reasons: the used cores come from mining sites in remote areas, whereas the office or warehouse facility is located in a different city, which causes logistics problems.

2.2 Customs issues: If the documents and the physical condition of the imported core do not match, customs will not grant an exit permit from the seaport.

3. Solutions:

Regarding the above problem, company has implemented the following initiatives:

- Communicating extensively with each customer to remind them about the returned core(s), and also monitoring the delivery activity.
- Asking each customer to make sure that the export/import documents contain the correct product information (such as a core's serial number).
- However, these initiatives have not improved the situation significantly. Thus, other efforts are required.

The following are the proposed solutions to the problem:

- Collect the cores from diverse sources (customers, dealers, distributors)
- Some methods to do such core collection are: deposit, leasing, trade, or establishing a bank of cores. The collected cores should not be limited to certain types, so that company can obtain a wide variety of cores in a large quantity.

Offer an attractive core return scheme to customers. According to Guide and Jayaraman, returned cores come from end users (81.8%), brokers (9.2%), third party agents (7.3%), and seed stock (1.7%). To reduce the number of unreturned cores, an attractive incentive scheme must be created. One method to do this is a deposit-refund system. In this mechanism, company can charge a certain deposit fee when selling remanufactured products to its customers, which can be fully or partially refundable, depending on the returned cores' quality.

IV. RESULT AND DISCUSSION

The time taken by the processes Core Receiving Process, Salvaging/Reconditioning, Re- Checking, Short block Reassembly, Engine Reassembly were reduced to a great extent after implementing the proposed solutions in the processes.

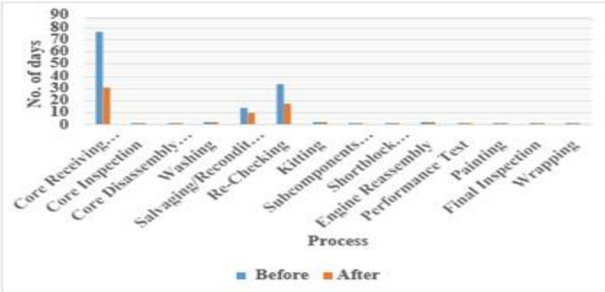

Fig 1. Comparison of Time Consumption before and After Remanufacturing.

From the above figure it can be seen that the processes Core Receiving Process, Salvaging/ Reconditioning, Re-Checking, Short block Reassembly, Engine Reassembly were reduced to a great extent after implementing the proposed solutions in the processes.The figure2 shows the Comparison of Total Time Consumption Before and After Remanufacturing. It can be seen from the graph that before any modifications the total time consumption was 141.5 days which is reduced by 67 days to 74.5 days.

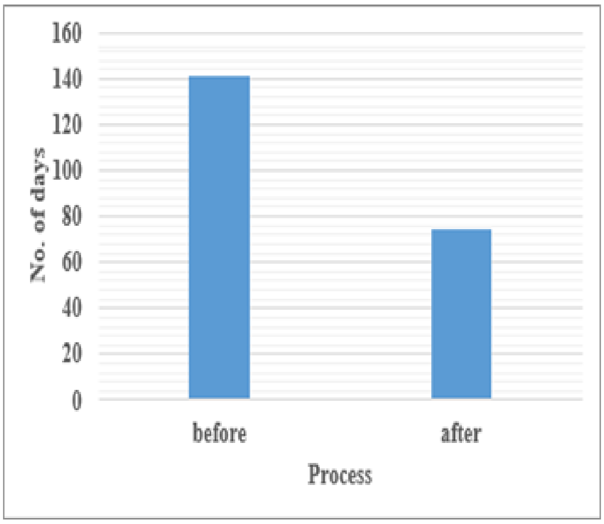

Fig 2. Comparison of Total Time Consumption Before and After Remanufacturing.

V. CONCLUSION

The engine remanufacturing industries need to employ innovation, cutting edge scientific and engineering knowledge, and the best principles of quality management to respond to the challenges of new discoveries. Although engine manufacturing is a well-established technology, its improvements, however, in some cases, have come with more stringent requirements for material and process control.

This study resulted in the improvement of the productivity of engine remanufacturing industry by identifying the problems in the current process of the company and hence proposes a solution to improvise. The influence of process improvement on minimizing process time has resulted in a significant improvement in productivity and will also help to decrease the cost of the engine and increase in sales. Moreover, a true comparison between the old process and the new process has demonstrated a major increase in productivity, which shows that applying simple tools and strategies accordingly leads to a large business impact.

REFERENCES

[1] Thierry, M.; Salomon, M.; Van Nunen, J.; Van Wassenhove, L. Strategic issues in product recovery management. Calif. Manag. Rev. 1995, 37, 114–135. [Cross Ref]
[2] Geyer, R.; Van Wassenhove, L. The Economics of Remanufacturing Under Limited Component Durability and Finite Product Life Cycles. Manag. Sci. 2007, 53, 88–100. [Cross Ref]
[3] Matsumoto, M.; Umeda, Y. An analysis of remanufacturing practices in Japan. J. Remanuf. 2011, 1, 2. [Cross Ref]
[4] Cummins Inc. Sustainability Progress Report 2016. Available online: https://www.cummins.com/sites/default/files/files/reports/2017_cummins_sustainability_progress_report_10 17.pdf (accessed on 1 June 2018).
[5] Blackstone, J.H. APICS Dictionary, 14th ed.; APICS: Chicago, IL, USA, 2013.
[6] Stahel, W.R. Caterpillar Remanufactured Products Group. 1995. Available online: http://www.product-life.org/en/archive/case-studies/caterpillar-remanufactured- products-group (accessed on 30 June 2018).
[7] Tang, O.; Grubbstrom, R.W.; Zanoni, S. Planned lead time determination in a make-to- order remanufacturing system. Int. J. Prod. Econ. 2007, 108, 426–435. [Cross Ref]
[8] Asif, F.MA.; Bianchi, C.; Rashid, A.; Nicolescu, C.M. Performance analysis of the closed loop supply chain.J. Remanuf. 2012, 2012. 2, 4. [Cross Ref]
[9] San, G.S.; Pujawan, I.N. Closed-loop supply chain with remanufacturing: A literature review. In Proceedings of the International Conference on IML 2012, Chicago, IL, USA, 25–29 May 2012.
[10] Krikke, H.R.; Kooi, E.J.; Schuur, P.C. Network Design in Reverse Logistics: A Quantitative Model. In New Trends in Distribution Logistics; Lecture Notes in Economics and Mathematical Systems, Speranza, M.G., Stähly, P., Eds.; Springer: Berlin, Germany, 1990; Volume 480, pp. 45–61.
[11] Guide, V.D.R.; Van Wassenhove, L.N. managing product returns for remanufacturing. Prod. Oper. Manag.2001, 10, 142–155. [Cross Ref]
[12] Ostlin, J. Analysis and Managing Material Flow and Remanufacturing Process. Ph.D. Thesis, Linköping University, Linköping, Sweden, 2008.
[13] Steinhilper, R. Remanufacturing: The Ultimate Form of Recycling; Fraunhofer IRB Verlag: Stuttgart, Germany, 1998.
[14] Fleischmann, M.; Krikke, H.R.; Dekker, R.; Flapper, S.D.P. A characterization of logistics networks for product recovery. Omega 2000, 28, 653–666. [Cross Ref]
[15] Morgan, S.J.; Gagnon, R.J. A systematic literature review of remanufacturing scheduling. Int. J. Prod. Res.2013, 51, 4853–4879. [Cross Ref]
[16] Steinhilper, R.; Hieber, M. Remanufacturing—The Key Solution for Transforming Downcycling into Upcycling of Electronics. In Proceedings of the 2001 IEEE International Symposium on Electronics and the Environment, Denver, CO, USA, 9 May 2001.
[17] U.S. Department of Commerce. On the Road: U.S. Automotive Parts Industry Annual Assessment. 2011. Available online: https://www.trade.gov/td/otm/assets/auto/201 1Parts.pdf (accessed on 31 August 2018).
[18] Tian, G.; Chu, J.; Hu, H.; Li, H. Technology innovation system and its integrated structure for automotive components remanufacturing industry development in China. J. Clean. Prod. 2014, 85, 19–432. [Cross Ref]
[19] Guide, V.D.R. Production planning and control for remanufacturing: Industry practice and

research needs. J. Oper. Manag. 2000, 18, 467–483. [Cross Ref]

[20] Ostlin, J.; Sundin, E.; Bjorkman, M. Importance of closed-loop supply chain relationships for product remanufacturing. Int. J. Prod. Econ. 2008, 115, 336–348. [Cross Ref]

[21] Yusop, N.M.; Wahab, D.A.; Saibani, N. Analysis of Remanufacturing Practices in the Malaysian Automotive Industry. J. Teknol. 2012, 59, 77–80.

[22] Prod. 2015, 105, 311–323. [Cross Ref]

[23] Behret, H.; Korugan, A. Performance analysis of a hybrid system under quality impact of returns. Comput. Ind. Eng. 2009, 56, 507–520. [Cross Ref]

[24] Wei, S.; Tang, O.; Sundin, E. Core (product) Acquisition Management for remanufacturing: A review.J. Remanuf. 2015, 5, 4. [Cross Ref]

[25] Gaur, J.; Subramoniam, R.; Govindan, K.; Huisingh, D. Closed-loop supply chain management: From conceptual to an action oriented framework on core acquisition. J. Clean. Prod. 2017, 167, 1415–1424. [Cross Ref]

[26] Daniel, V.; Guide, R., Jr.; Jayaraman, V. Product acquisition management: Current industry practice and a proposed framework. Int. J. Prod. Res. 2000, 38, 3779– 3800. [Cross Ref]

APPENDIX

Table 1. Time Consumed in Each Process.

PROCESS	No of days to complete the process
Core Receiving Process	77
Core Inspection	1
Core Disassembly And Parts	1
Recommendations	1
Washing	2
Salvaging/Reconditioning	14
Re-Checking 33.5	33.5
Kitting	2
Subcomponents Reassembly	1.5
Short block Reassembly	1.5
Engine Reassembly	2.5
Performance Test	1.5
Painting	1.5
Final Inspection	1.5
Wrapping	1
Total	l 141.5

Table 2. The new parts' arrival time (August 2019 to October 2019).

Arrival Time	Number of Jobs	Percentage
N-1 Week	8	16.5
Week 1	14	27.8
Week 2	27	55.7

Table 3. Summary of the process unit after modifications in the process.

PROCESS	No of days required to complete aprocess
Core Receiving Process	31
Core Inspection	1
Core Disassembly And Parts Recommendations	1
Washing	2
Salvaging/Reconditioning	10
Re-Checking	17.5
Kitting	2
Subcomponents Reassembly	1
Short block Reassembly	1.2
Engine Reassembly	2.3
Performance Test	1.5
Painting	1.5
Final Inspection	1.5
Wrapping	1
Total	74.5

Table 4. Comparison of Time Consumption Before and After Remanufacturing.

PROCESS	No of days required to complete process (before)	No of days required to complete a process (After)
Core Receiving Process	31	77
Core Inspection	1	1
Core Disassembly And PartsRecommendations	1	1
Washing	2	2
Salvaging/Reconditioning	10	14
Re-Checking	17.5	33.5
Kitting	2	2
Subcomponents Reassembly	1	1.5
Short block Reassembly	1.2	1.5
Engine Reassembly	2.3	2.5
Performance Test	1.5	1.5

Painting	1.5	1.5
Final Inspection	1.5	1.5
Wrapping	1	1