Critical review of sustainable remanufacturing among different sectors

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Introduction

Remanufacturing is defined "returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product" (British Standards Institution, 2009). It could represent a key strategy to implement Circular Economy principles, as it fulfils the three sustainability dimensions -environmental, economic and social- providing environmental benefits, economic advantages and social growth. This work is aimed at reviewing the scientific papers published in the last decade describing the sustainability assessment of remanufacturing across different industrial sectors.

Methodology

The literature review was based on Scopus database, and on the selection of scientific papers published in the last 10 years through the keywords "remanufacturing", "sustainability", "Life Cycle Assessment", "LCA", "environmental", "economic", "social" and "assessment". Then the references have been classified (Figure 1) considering the industrial sector, the sustainability dimension and the phase of the life-cycle analyzed by the reference.

Figure 1. Selected literature classified by (a) sector, (b) analysed sustainability dimension and (c) investigated phase of lifecycle.

Results and discussion

The 55 selected references (9 review and 46 research articles) showed that the interest in the sustainability assessment of remanufacturing has increased over time: 34% of the references have been published before 2019, while 66% after 2019. The sustainability of remanufacturing practices has been studied in general (9 references), and also across specific industrial sectors (Figure 1a): vehicles (25 references), machinery (10 references), electrical and electronic equipment (6 references), medical devices (3 references) and furniture (2 references).

Considering the three pillars of sustainability (Figure 2b), the Enviromental dimension (47%) was mostly investigated, followed by coupled Environmental and Economic dimensions (18%), by the analysis of all three dimensions (11%), only Economic aspects (7.2%) and only Social aspect (1.8%). Finally, considering the system boundaries (Figure 1c): many references (17) adopted a cradle to grave approach, while others focused only on the remanufacturing process (12) or applied a cradle to gate approach (10). Few references examined only the end of life phase (6), or applied gate to gate (1) and cradle to cradle (1) boundaries.

Conclusions

The key outcomes of the performed literature review highlighted that the sustainability of remanufacturing is becoming deeply studied over the years, across different sectors and applying various point of views. The obtained results suggest that remanufacturing is mostly performed on vehicles (within both the automotive and off-road sectors), adopting a cradle to grave approach (to compare a remanufactured product and a new one). Considering the three sustainability dimensions, the most investigated is the environmental, with less studies available combining different domains (economic and social), also in combination. In conclusion, further research is needed to evaluate the economic and social aspects of remanufacturing, across industrial sectors that include not only vehicles but others as well.

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References

Alanya-Rosenbaum, S., Bergman, R., Gething, B., & Mousavi-Avval, S. H. (2022). Life cycle assessment of the wood pallet repair and remanufacturing sector in the United States. *Biofuels, Bioproducts and Biorefining*, *16*(5), 1342–1352. https://doi.org/10.1002/BBB.2379

Ardente, F., Talens Peiró, L., Mathieux, F., & Polverini, D. (2018). Accounting for the environmental benefits of remanufactured products: Method and application. *Journal of Cleaner Production*, *198*, 1545–1558. https://doi.org/10.1016/J.JCLEPRO.2018.07.012

Burggräf, P., Wagner, J., Steinberg, F., Heinbach, B., Wigger, M., & Saßmannshausen, T. (2022). Life Cycle Assessment for Adaptive Remanufacturing: incorporating ecological considerations into the planning of maintenance activities – a case study in the German heavy machinery industry. Procedia CIRP, 105, 320–325. https://doi.org/10.1016/J.PROCIR.2022.02.053

Chen, Q., Lai, X., Gu, H., Tang, X., Gao, F., Han, X., & Zheng, Y. (2022). Investigating carbon footprint and carbon reduction potential using a cradle-to-cradle LCA approach on lithium-ion batteries for electric vehicles in China. *Journal of Cleaner Production*, *369*, 133342. https://doi.org/10.1016/J.JCLEPRO.2022.133342

Cordella, M., Alfieri, F., & Sanfelix, J. (2021). Reducing the carbon footprint of ICT products through material efficiency strategies: A life cycle analysis of smartphones. *Journal of Industrial Ecology*, *25*(2), 448–464. https://doi.org/10.1111/JIEC.13119

Dias, A. S., Kim, H., Sivakumar, P. K., Liu, Z. C., & Zhang, H. C. (2013). Life cycle assessment: A comparison of manufacturing and remanufacturing processes of a diesel engine. *Re-Engineering Manufacturing for Sustainability - Proceedings of the 20th CIRP International Conference on Life Cycle Engineering*, 675–678. https://doi.org/10.1007/978-981-4451-48-2_110/COVER

Eze, S., Ijomah, W., & Wong, T. C. (2020). Remanufacturing: a potential sustainable solution for increasing medical equipment availability. *Journal of Remanufacturing*, *10*(2), 141–159. https://doi.org/10.1007/S13243-020-00080-0/TABLES/4

Ferreira, C., & Gonçalves, G. (2021). A Systematic Review on Life Extension Strategies in Industry: The Case of Remanufacturing and Refurbishment. *Electronics 2021, Vol. 10, Page 2669*, *10*(21), 2669. https://doi.org/10.3390/ELECTRONICS10212669