

Environmental Impact Assessment for the Remanufacturing of Automotive CVT

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The automotive industry is undergoing a major transition toward a circular economy that aims to reduce environmental burdens by extending product life cycles while preserving the value of materials and components. Among various circular strategies, remanufacturing has attracted considerable attention because it restores end-of-life products to a condition equivalent to new products through systematic inspection, replacement of damaged parts, and reuse of functional components. Although remanufacturing has been widely applied to automotive components, particularly in Europe and North America, the domestic remanufacturing market in Japan remains relatively small. Furthermore, only a limited number of studies have quantitatively evaluated the environmental benefits of remanufacturing based on detailed industrial data, especially at the process level. To address this research gap, this study conducts a comprehensive Life Cycle Assessment (LCA) of automotive Continuously Variable Transmission (CVT) remanufacturing using primary industrial data collected from both remanufacturing and original manufacturing processes. Environmental benefits are evaluated from both midpoint and endpoint perspectives to provide a comprehensive assessment of remanufacturing.

The assessment focused on a specific CVT model, and the system boundary was defined from the receipt of used CVTs to the inventory management of remanufactured products. Primary operational data were collected over a 24-month period from April 2024 to March 2026 through direct measurements conducted at the remanufacturing plant. Monthly production volumes were used to allocate energy and material consumption, reflecting seasonal and operational fluctuations. Comparable manufacturing data for newly produced CVTs were also obtained directly from the original manufacturer. The environmental inventory analysis was performed using the IDEA version 3.5.1 database, and the functional unit was defined as the production of one CVT. Midpoint environmental impacts, including climate change and resource consumption, were characterized using LIME2. Endpoint impacts on human health, social assets, biodiversity, and primary production were evaluated and integrated into a single monetary indicator based on user costs using LIME3. Environmental benefits were quantified by comparing the material procurement and manufacturing stages of remanufactured and newly manufactured CVTs, while transportation, product use, and end-of-life treatment were assumed to be identical for both systems.

The results demonstrate that remanufactured CVTs reduced greenhouse gas (GHG) emissions by an average of 46% compared with newly manufactured units, mainly due to the reuse of sub-parts and the resulting reduction in material inputs. Analysis by material type indicates that aluminum components, such as transmission cases and housings, contribute significantly to the reduction because of their high reuse rates, whereas heavy steel components still require relatively large material inputs. Within the remanufacturing process itself, electricity consumption for cleaning and final product testing accounted for 49% and 38% of process-related GHG emissions, respectively, indicating the largest opportunities for further improvement.

Resource consumption was reduced by an average of 59%, with particularly large reductions observed for molybdenum, nickel, and several other metals because many steel components containing these materials were reused instead of replaced. Although silver consumption increased slightly owing to electricity supplied by photovoltaic systems, fossil resource consumption during manufacturing decreased because of the higher share of renewable electricity. The integrated endpoint assessment further showed an average environmental cost reduction of 61%. Resource consumption contributed primarily to impacts on social assets, whereas climate change affected multiple impact categories, including human health, biodiversity, and social assets. These findings demonstrate that remanufacturing substantially reduces both greenhouse gas emissions and resource consumption while highlighting the importance of multicriteria environmental assessment for evaluating circular manufacturing systems and supporting the expansion of the remanufacturing industry in Japan.

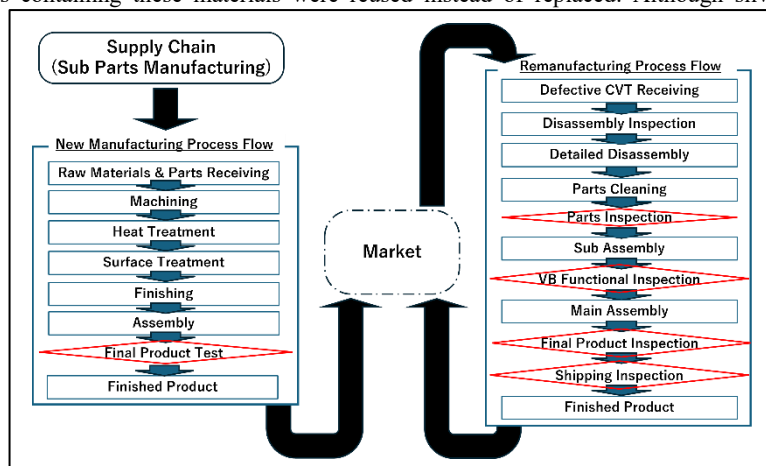


Fig. 1 System Boundary