Title:
Innovative Remanufacturing of Automotive Lighting Assemblies: Advancing Circular Economy and Supply Chain Resilience

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Abstract:
The automotive industry faces growing regulatory and market pressure to reduce environmental impacts and strengthen supply chain resilience, particularly in high-value, high-complexity components such as lighting assemblies. Today, damaged headlamps and taillamps are typically landfilled after collisions, despite many internal components retaining near-new functionality. This practice prematurely ends product lifecycles, drives demand for virgin materials, and intensifies strain on critical supply chains such as semiconductors. While literature highlights remanufacturing as a key enabler of the circular economy, limited research has demonstrated scalable, industry-ready applications for automotive lighting. This paper addresses that gap by investigating how a patented remanufacturing process can transform damaged lighting assemblies into fully certified, OEM-grade replacements while lowering costs, reducing environmental impact, and improving OEM competitiveness. The approach draws on Llink Technologies' proprietary U.S.-patented process, which integrates automated and manual disassembly, component harvesting, and reassembly with new housings and lenses. Industry 4.0-based traceability and rigorous quality testing ensure compliance with regulatory and OEM standards, while analysis of over 100 lighting assemblies provides insights into design-for-remanufacturing principles. Preliminary implementation results show that up to 83% of returned cores are eligible for remanufacturing, with up to 95% of components recoverable for reuse. Remanufactured assemblies perform to OEM and regulatory standards while offering cost savings of up to 40% for end-users and generating 200–300% profit margins for OEMs. Sustainability benefits are significant: per 100,000 remanufactured units, an estimated 440 tons of cores and 76,000 cubic feet of packaging are diverted from landfills. By advancing both the technical foundation and business case for automotive lighting remanufacturing, this research demonstrates how circular supply chains can simultaneously reduce waste, conserve critical resources, and create profitable new revenue streams for manufacturers. The findings offer one of the first industry-scale case studies of circular remanufacturing applied to complex automotive lighting systems, with implications for design, policy, and broader adoption across the mobility sector.

Keywords: remanufacturing, automotive lighting, circular economy, supply chain resilience, design-for-remanufacturing, sustainability, OEM competitiveness, resource recovery