

# **Towards a Function-based Module Variant Management: An Automotive Case Study**

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## **Abstract**

Modular architecture provides the advantage of efficiently expanding product ranges through selective module differentiation, while reusing others. However, as modular product families mature, the growing number of variants creates significant management challenges. The increasing complexity reduces transparency, obscuring functional differences between variants and hindering effective module reuse in future derivative product development. We observed this phenomenon with our automotive industry partner, where module variants are typically managed based on their incorporated products rather than their inherent functional characteristics. Furthermore, since variants are created reactively for specific products in an ad-hoc manner, engineers often implement excessive differentiation across modules irrespective of actual functional requirements. This approach diminishes the traceability of variant creation rationale and leads to unnecessary differentiation of potentially reusable modules, resulting in redundant variants. To address these issues, we introduce Variant Mode and Effects Analysis (VMEA)—a structured framework for systematic module differentiation, aiming to shift from product-based to function-based module variant management. VMEA captures key variant characteristics, including the mode of differentiation, its causes, and its effects. Through an automotive suspension system case study, we demonstrate how VMEA enables functional cataloging of module variants, facilitating future reuse opportunities. It also provides analytical insights into variant proliferation patterns within maturing product families, informing strategic architectural decisions.

## **Keywords**

Module differentiation, Modular product family, Module reuse, Product development, Variant management.

## **Biographies**

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