Economics of Materials Competition - Effects of Product Architecture Changes and the Level of Analysis

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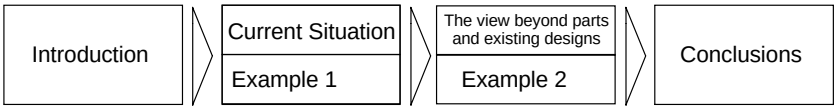
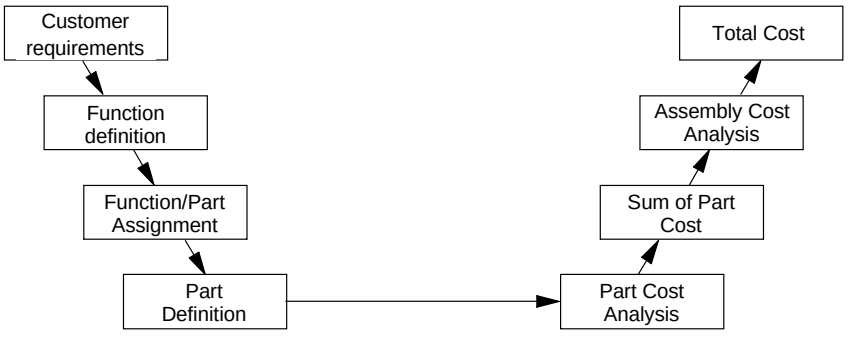


Introduction

- Current state of materials competition
  - In the past materials competition has often compared similar designs made from different materials.
- Problem
  This standard approach
  - often results in a part-by-part comparison
  - omits specific advantages of various materials, both primary and secondary
- Research questions:
  - What is necessary to allow a more comprehensive analysis of the competitive position of alternative materials?
  - What role can changes of the product architecture play?
  - How to think about future design/materials choices?

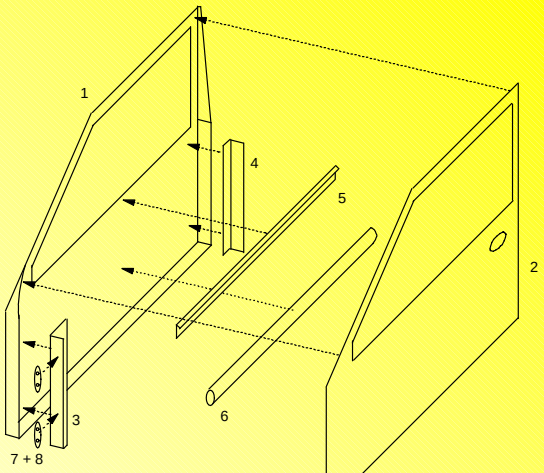
Traditionally, performance vs. cost has been the tradeoff criteria for materials selection

- Performance
  - Functionality
    - *Strength*
    - *Weight*
    - *Rigidity*
    - *...*
- Cost
  - Manufacturing cost
  - Design cost
  - Logistics cost
  - ...



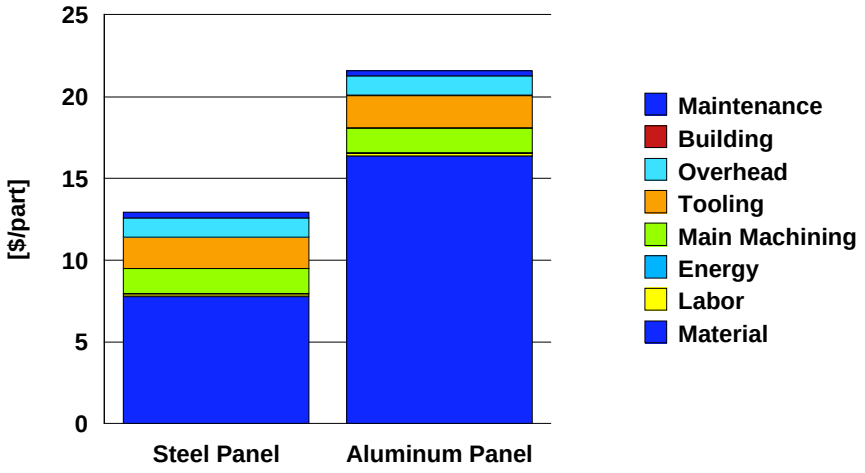
Conventional cost analysis approach works well for narrowly defined cases - Example: Car Door Outer Panel

Conventional Door:
1 Door Inner - Steel
2 Door Outer - Steel/Aluminum
3 Reinforcement Panel at Hinge - Steel
4 Reinforcement Panel at Latch - Steel
5 Reinforcement Panel at Waist - Steel
6 Intrusion Beam - High Strength Steel
7 Front Door Check (2x)
8 Nut Weld M8 Square (4x)



Frequent result of part-by-part comparison: the tradeoff is reduced to materials' density/cost ratios

Fabrication cost for a steel and an aluminum door outer panel

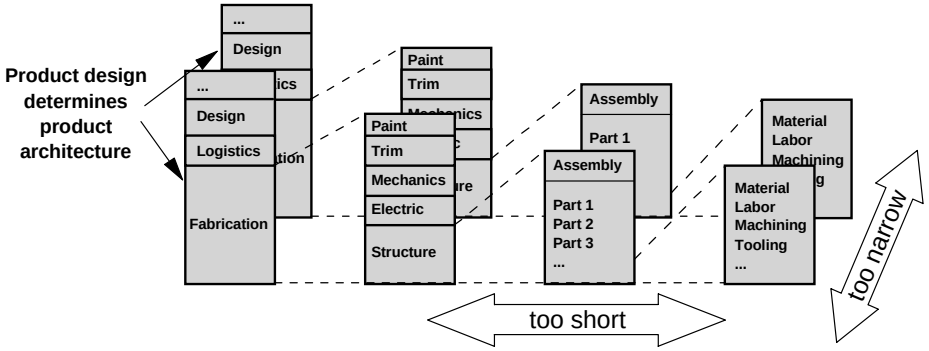


Annual Production Volume: 300,000

Secondary effects may as well be excluded as sufficiently unfamiliar design/material combinations

1. **Focus too narrow:** The fixation on (existing) parts may result in 'blind spots' for alternative design/material combinations

2. **Focus too short:** While often manufacturing part cost are compared, a 'systems' perspective including several parts, assembly, logistics, data maintenance, etc. would be appropriate



Suggested approach: extend view beyond parts and existing designs

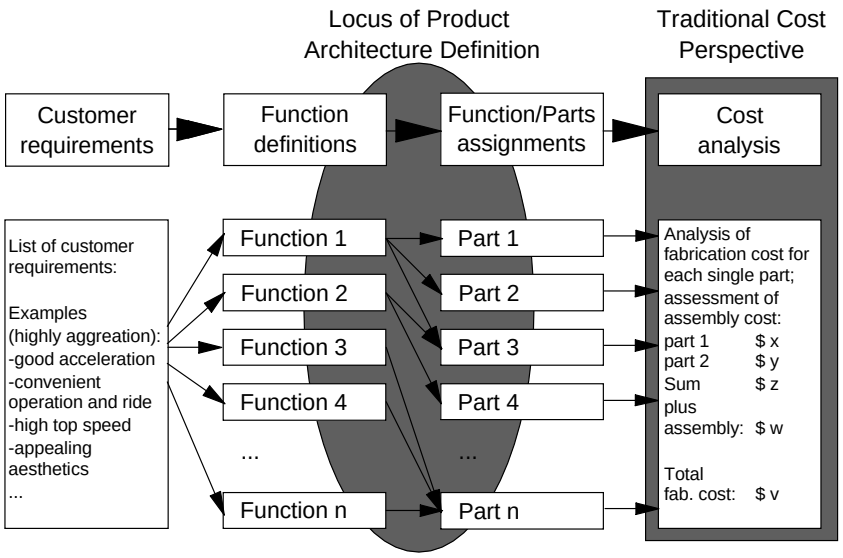
1. How to broaden the focus?

   - Evaluate changes in the product architectures; they may allow to exploit currently unused advantages of different materials and materials combinations
   - Current trends show that materials compete less and less within traditional boundaries, i.e.
     - *more materials combinations are deployed*
     - *more application dependent material developments*

2. How to lengthen the focus?

   - Comparative analysis needs to be extended beyond simple part considerations
     - *Include assembly of parts as well adjacent and architecturally affected parts and components*
     - *Analyze cost effects on non-manufacturing activities as logistics, data management, etc.*

Understanding materials' competitive positions better requires to include more of the design information

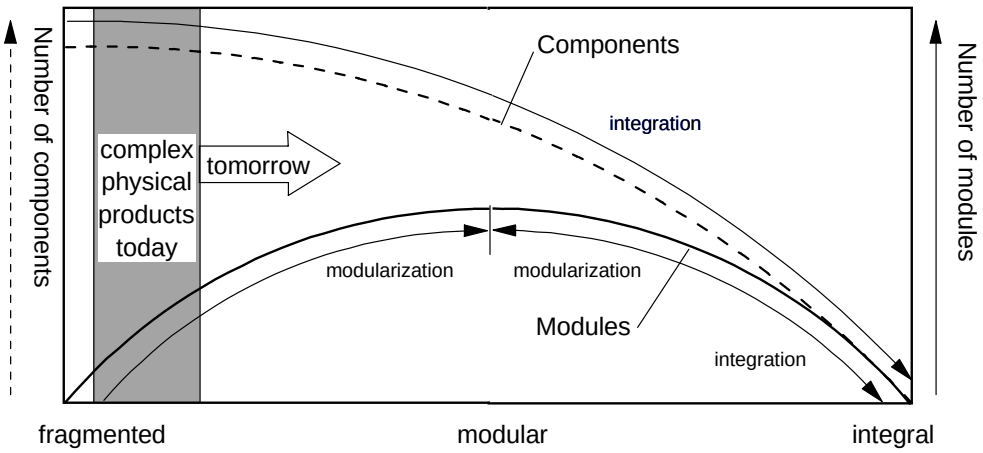


Various definitions are used for 'product architecture' and its characteristics: modular vs. integral

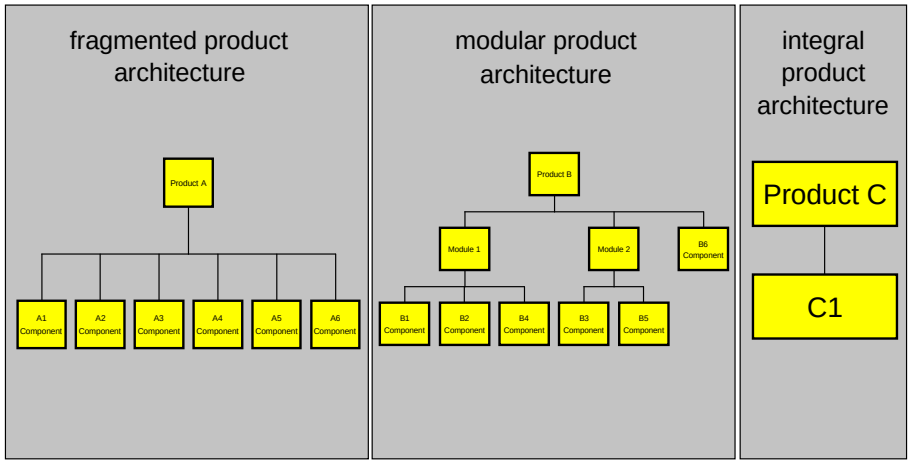
1. Module vs. System view - The industry distinguishes between modules and systems:
   - **"Modules"** are **groups of components** or parts arranged **in close physical proximity** to each other within a vehicle
   - **"Systems"** and "subsystems" are **groups of components** or parts **which operate together** to provide a specific vehicle function

2. Product architectural view - Academia defines 'integral' and 'modular' as features of the product architecture:
   - **"Product architecture is the scheme by which the function of a product is allocated to physical components."**
     - *modular architecture:a one-to-one mapping from functional elements to the physical components*
     - *integral architecture:a complex mapping from functional elements to physical components and/or coupled interfaces between components*

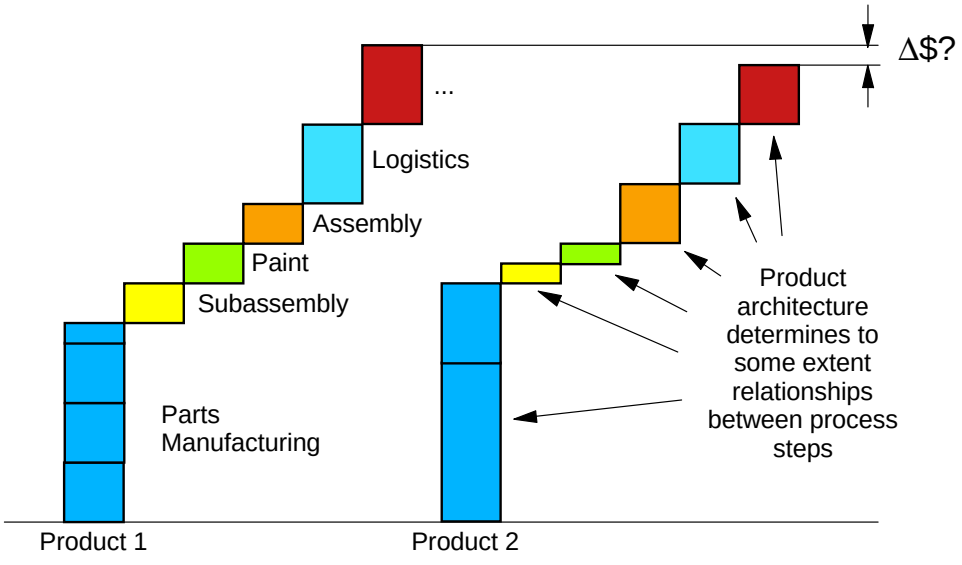
Modularization is not necessarily contradicting integration: important is the hierarchy level under consideration



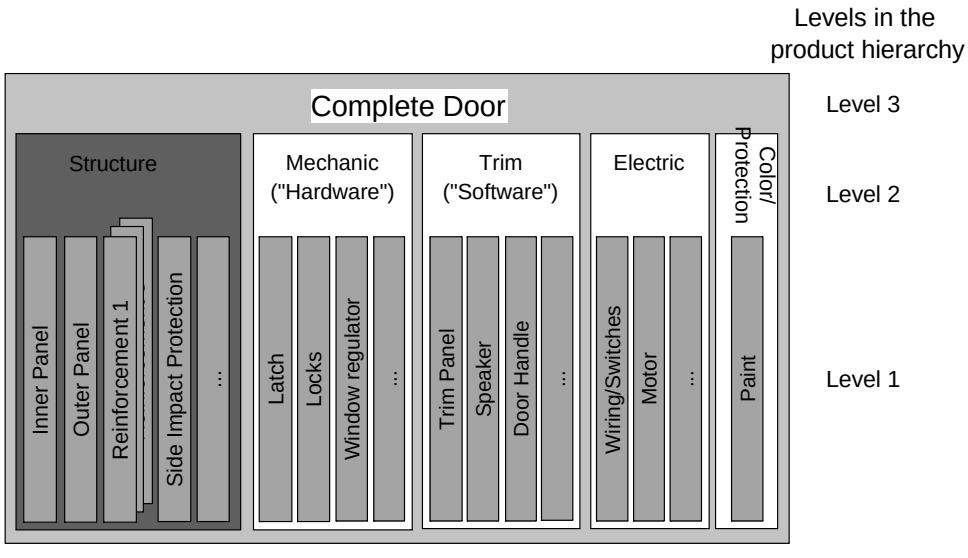
Fragmented, modular and integral product architectures



Different product architectures display different internal constraints and opportunities

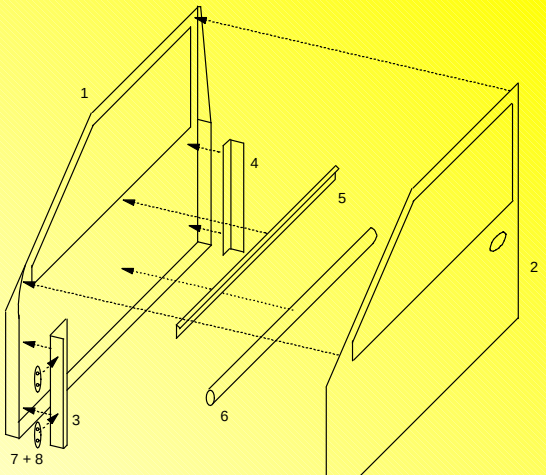


Grouping of functions allows to establish a product hierarchy - but also establishes constraints for the design



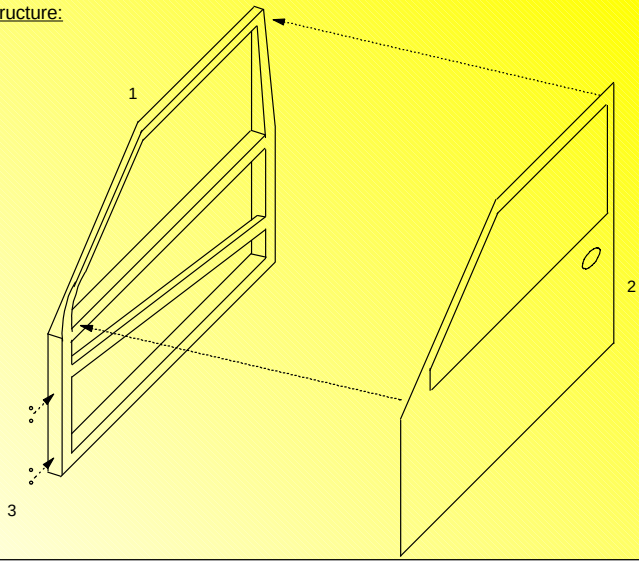
Level 2 module - structure (conventional door)

Conventional Steel Door:
1 Door Inner - Steel
2 Door Outer - Steel
3 Reinforcement Panel at Hinge - Steel
4 Reinforcement Panel at Latch - Steel
5 Reinforcement Panel at Waist - Steel
6 Intrusion Beam - High Strength Steel
7 Front Door Check (2x)
8 Nut Weld M8 Square (4x)

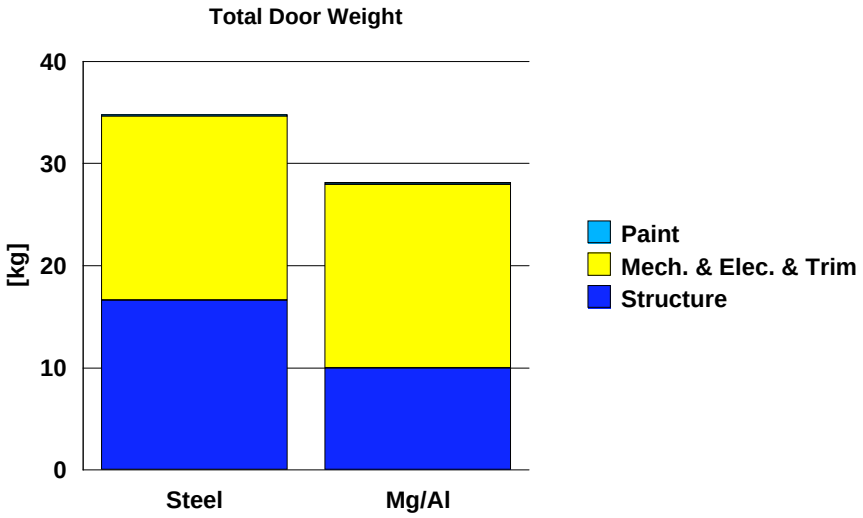


Level 2 module - structure (alternative material/design combination)

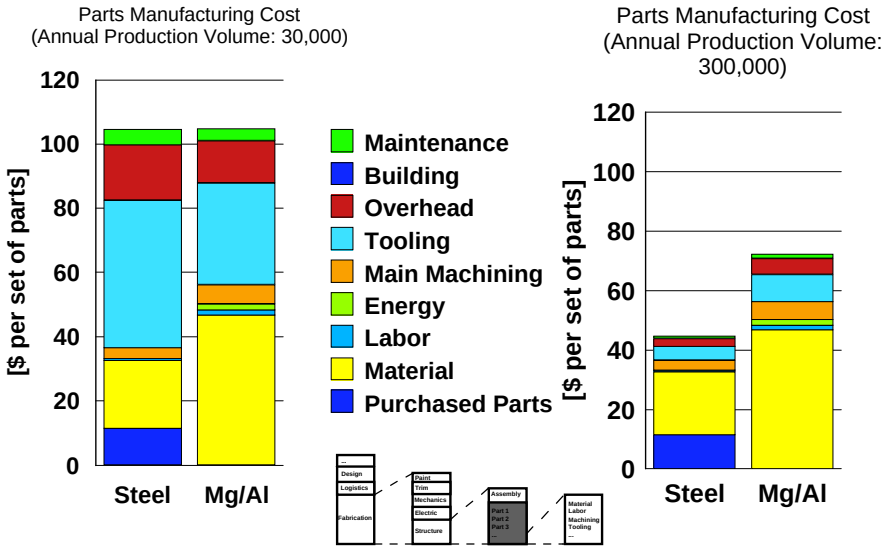
Cast Magnesium Door Structure:
1 Door Frame - Magnesium
2 Door Outer - Aluminum
3 Nut Weld M8 Square (4x)



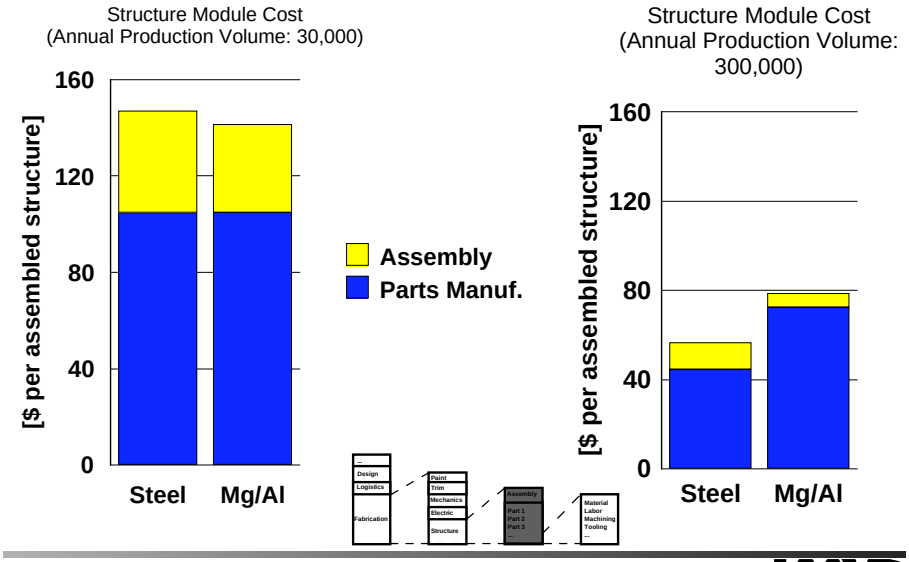
The alternative design/material combination offers about 20% primary weight savings



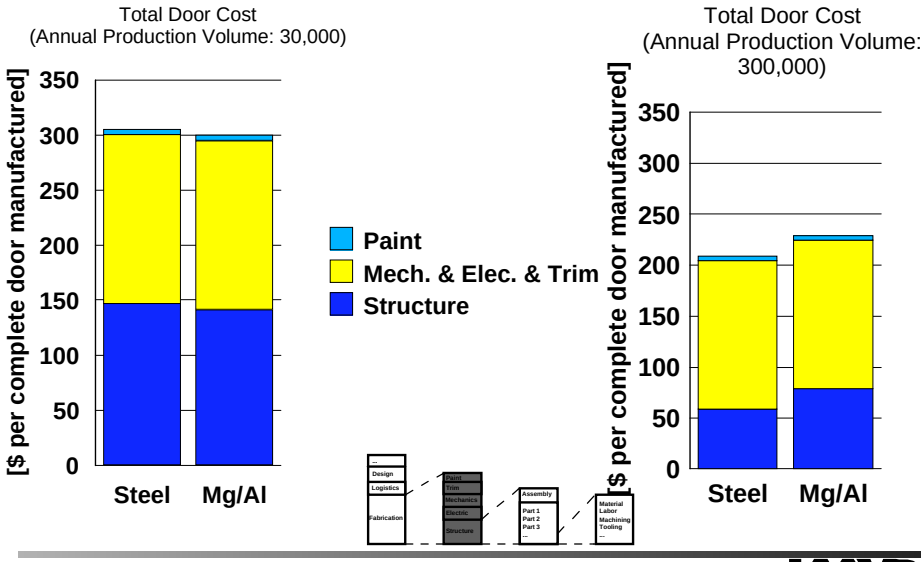
On level 1, the scale effects of the steel tooling determines the total cost



On level 2, the lower assembly cost makes the Mg/Al concept advantageous for low production volumes



On level 3, mechanic, electric and trim contribute 3/4 of the total cost at high production volumes



Conclusions

- Strategic material/design choices need to consider a longer and broader view:
  - Entirely different product architectures including modules and/ or integrated parts should be considered if they offer potential gains on a higher systems level (to broaden the view)
  - Larger chunks of the product can both be better optimized as well as offer through a lower number of interfaces easier ways to introduce entirely new material/design configurations (to lengthen the view)
  - On a corporate level, the view should include other product lines in order to determine an efficient level of modularity across the company