Product Development in the Automotive Industry: Strategies to Circumvent the Complexity Challenge

January 31, 2002

Ulrich Näher, Wolfgang Neubert, Arno Antlitz
Number of models is increasing and product life cycles are decreasing

Source: Press clippings
Time-to-market is reduced dramatically
MONTH FROM DESIGN FREEZE TO SOP

Golf III / IV
1991/96

C-class
1995/2000

Mondeo
1993/2000

Reduction driven by implementation of stringent quality gates

Reduction driven by implementation of simulation technologies

38
32
16%

40
29
28%

60
24
60%

* Start of production
Source: Automobile production, AN, MID
In addition, urgency towards innovation drives vehicle complexity

### Type of innovation in electronics

<table>
<thead>
<tr>
<th>Percent</th>
<th>Radical innovation</th>
<th>Individual innovation</th>
<th>Incremental modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today</td>
<td>30</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>2010</td>
<td>43</td>
<td>27</td>
<td>30</td>
</tr>
</tbody>
</table>

- **Radical innovation**
- **Individual innovation**
- **Incremental modification**

### Vehicle complexity – example BMW Z22

- BMW Z22 carries 70 major innovations and 61 patents
- Objective is to ensure new technology concepts for 2005 and beyond
- Approx. 70 - 80% of innovations are in the field of electronics:
  - X-by-wire
  - Car PC
  - Center monitor
  - Fingerprint recognition
  - Head-up display
  - Integrated starter/alternator
  - Curvelight
  - Speech control
  - Cameras for rear view
  - Telematics

Source: Automobil Entwicklung, survey results, McKinsey/ika
Key levers to address complexity challenge

1. Clear and precise customer knowledge and orientation
2. Efficient product architecture – from identity to similarity
3. Value chain adaptation towards competence based structures
4. Improved development processes leveraging IT opportunities
5. Stringent quality processes along entire development process
6. Project organization combining high functional and integration capabilities

Source: McKinsey
Increase in product variety and model change rate is driving passenger car market fragmentation

SHARE OF TOP-10 SELLING MODELS WESTERN EUROPE, 1980 - 2000
Percentage of total sales units

In mature and highly fragmented markets two strategies are possible: Targeting average vs. tailored market segment.

**Market size**
- Market segments
- Competing vehicles: A, B, C, D

**Coverage of many prominent market segments**

**Tailoring of models to specific customer segments**

Source: McKinsey
To understand what customers really want is key

Source: Automotive branding survey, May 2001

- Derived importance dominated by emotional attributes
- Stated importance dominated by rational attributes

- Customer want and state it
- Customer want but don't state it
- Customer state though really don't want it
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Source: McKinsey
Efficient architectures have to be optimized on vehicle and component level

Vehicle design (macroarchitecture)
- Define packaging zones
- Determine organization of components
- Define levels of freedom for microarchitecture
- Organization of engine components
- Interior dimensions, interior packaging
- Cable harness

Component design (microarchitecture)
- Design components
- Systematically optimize number of variants

Foot controls example
- Foot controls for vehicle type A
- Foot controls for vehicle type B

Architecture redesign
- Joint component for vehicle family

Ensure compatibility of macroarchitecture in family concepts (e.g., electronics architecture)

Increase share of standardized parts in vehicle family

Focus of a standardized parts strategy

Source: McKinsey
Existing product architectures are redesigned with highest share of identical parts possible while maintaining sufficient differentiation.

### Product architecture

- **Function separation**
- **Function integration**
- **Function elimination**
- **Variant combination**
- **Restructuring**
- **Combination reduction**

### Parts/module architecture

#### Identity
- **Identical parts/modules**
  - 100% identical parts
  - Same variants across vehicle types
  - Building block modules

#### Adapted parts/modules
- Existing parts/modules with adjustments

#### Principle or concept parts/modules
- Related functions or geometries ("pantograph")

#### Solitary parts/modules
- Parts/modules specific to vehicle types

**Foot controls example**

- Foot controls for vehicle type A
- Foot controls for vehicle type B

Source: McKinsey
For deriving communality potentials four cost levers have to be understood:

<table>
<thead>
<tr>
<th>Potential levers</th>
<th>Description</th>
<th>Examples</th>
<th>Complexity cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed-cost dilution</td>
<td>• Payback on investments across large numbers of units</td>
<td>• Much lower development costs for vehicle type B</td>
<td>• Reduction of variety costs</td>
</tr>
<tr>
<td>Technology leaps</td>
<td>• Reduction of variable costs by changing production concept</td>
<td>• Higher utilization of machinery</td>
<td></td>
</tr>
<tr>
<td>Flexibility reserves reduction</td>
<td>• Lower flexibility requirements due to higher share of ongoing core operations</td>
<td>• Increase in level of automation</td>
<td>• Reduction of process costs at supplier: Purchasing, sales, production planning, administration, logistics, etc.</td>
</tr>
</tbody>
</table>

Source: McKinsey
### Cost types are impacted differently by cost levers

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Fixed-cost dilution</th>
<th>Technology leaps</th>
<th>Flexibility reserves reduction</th>
<th>Complexity reduction</th>
<th>Impact at 100% communality Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bought-in materials</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>7 - 9</td>
</tr>
<tr>
<td>Manufacturing costs</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>9 - 10</td>
</tr>
<tr>
<td>Research and development</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>10</td>
</tr>
<tr>
<td>Warranty and goodwill</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>10</td>
</tr>
<tr>
<td>Administration and sales costs</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>5</td>
</tr>
</tbody>
</table>

Impact depends upon level of similarity/identity

Source: McKinsey
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Source: McKinsey
Price increases above the inflation rate cannot be enforced despite new technologies

Historical price development

- List price VW Golf base model*
- Not inflation-adjusted
- Inflation-adjusted

* Incl. value added tax
** Statistically not significant

Source: HAWK project team

Additional charge potential for new technologies – example brake-by-wire

- Average additional costs for brake-by-wire
- Luxury car segment: ~ 300
- Large car segment: ~ 1,000**
- Medium car segment: 300
- Compact car segment: 250
- Small car segment: 200

CAGR 3.2%

Additional charge potential

~ 5,000 end customers surveyed
Cost due to additional features have to be compensated by optimizing the value chain

PRODUCTION COSTS COMPACT CAR, NOT INFLATION-ADJUSTED EUR/unit

- Car today: Electronics share 20%
- Additional costs through new technologies
- Car 2015 (with old industry structures)
- Synergy and enhancement processes
- Car 2015 best practice value chain architecture

Source: HAWK project team

Costs:
- Electronics share 20%: ~20% cost effect through best practice value chain architecture and CIP
- Electronics share 40%
Functional value chain architecture will give way to one that is know-how-driven

INDUSTRY STRUCTURE

**Today**

<table>
<thead>
<tr>
<th>System development</th>
<th>System integration</th>
<th>Electronics</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake system integrator</td>
<td>Steering system integrator</td>
<td>Spring and shock absorber specialist</td>
<td>Mechanical integrator</td>
</tr>
<tr>
<td>Brake system manufacturer</td>
<td>Steering system manufacturer</td>
<td>Mechanical specialist</td>
<td>Mechanical specialist</td>
</tr>
<tr>
<td>Division mainly by function (system) or spatial placement (module)</td>
<td>Division mainly by function (system) or spatial placement (module)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**In the future**

<table>
<thead>
<tr>
<th>System development</th>
<th>System integration</th>
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<th>Mechanical</th>
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<td>Brake system manufacturer</td>
<td>Steering system manufacturer</td>
<td>Mechanical specialist</td>
<td>Mechanical specialist</td>
</tr>
<tr>
<td>Division mainly by know-how because of economies of scale, development synergies, complexity</td>
<td>Division mainly by know-how because of economies of scale, development synergies, complexity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Functionality-/position-driven**

**Know-how-driven**

Source: Expert interviews, HAWK project team
Specific competencies are required to capture new synergies

NEW SYNERGY POTENTIAL IN CHASSIS SEGMENT

USD per vehicle

<table>
<thead>
<tr>
<th>Synergies</th>
<th>Required competencies</th>
</tr>
</thead>
</table>
| **X-by-wire-integrator** | • System integration (e.g., ECU centralization)  
  • Innovative creativity (e.g., ECU and software design)  
  • Development efficiency in electronics (e.g., sensors)  
  • Operational excellence (e.g., actuators, sensors) |
| **Mechanical specialists** | • Operational excellence  
  • Ability to capture scale effects  
  • Factor cost efficiency |
| **OEM** | • Transaction cost efficiency  
  • Understanding of customer needs |

Synergy potential through value chain optimization

Synergy potential for x-by-wire integrator

Synergy potential for mechanical specialists

Synergy potential for OEM

Source: Team HAWK
Detailed analysis of competency gaps helps to derive specific activities

COST REDUCTION POTENTIAL FOR FUTURE STEERING SYSTEM INTEGRATOR

Percent

Competencies

Mechanical development efficiency
Electronics development efficiency
Innovative drive
Module/system integration
Realizing operational excellence/economies of scale
Factor cost efficiency
Purchasing efficiency
Overhead/transaction cost efficiency
Understanding of end customer

Source: HAWK project team

• Competency building is needed, particularly in the areas of development efficiency for electronics and innovative drive

• Competency gap could be closed by means of cooperating with an innovative electronics specialist
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Source: McKinsey
The 2005 target requires a reduction of development times by 50%.

AVERAGE DEVELOPMENT TIMES, PROJECT DECISION TO SOP

Month

Target
30 months or less

* Concept-freeze to SOP
Source: Publications on vehicle development times (70 vehicles worldwide) between 1988 and 2000, McKinsey-Research
A near future development process is characterized by virtual techniques and only 1 prototype cycle.

### 30 MONTH DEVELOPMENT PROCESS

<table>
<thead>
<tr>
<th>Month</th>
<th>-35</th>
<th>-30</th>
<th>-23</th>
<th>-5</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steps</strong></td>
<td>Project planning</td>
<td>Concept development</td>
<td>Series development/-preparation</td>
<td>Ramp-up</td>
<td></td>
</tr>
<tr>
<td><strong>Gateways</strong></td>
<td>Start of project</td>
<td>Concept decision</td>
<td>Production test series</td>
<td>Start of production</td>
<td></td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td>Package</td>
<td>Package definition (-19)</td>
<td>Package freeze (-19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Styling</strong></td>
<td>Exterior/Interior Design</td>
<td>Design freeze (-23)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engineering/CAE</strong></td>
<td>Virtual steps/process development</td>
<td>Design cycles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Prototypes</strong></td>
<td>Massive use of virtual simulation</td>
<td>Optimized test strategy driving cross functional vehicle perspective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td>Component tests</td>
<td>Integration tests</td>
<td>Validation</td>
<td>Endurance tests</td>
<td>Pre-series tests</td>
</tr>
</tbody>
</table>

Source: Harvard Business Review
Product testing must be optimized along different dimensions

1. Effective concept
   - Complete product
   - System
   - Component
   - Simulation
   - Laboratory
   - Field test

2. Efficient execution
   - Test planning
     - Risk prioritization
     - Optimization of utilization
     - Cross-functional use of prototypes
   - Execution of tests
     - Automation
     - Up-Speeding

Impact

- Specific parameters can be tested very early
- Test of more variants/options due to faster test cycles
- Significant reduction of effort
- Early test of highly critical criteria/properties
- Cost reduction

Source: McKinsey
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Source: McKinsey
Maturity problems at ramp-up/SOP have significant impact on profitability

<table>
<thead>
<tr>
<th>Possible SOP problems (assumptions)</th>
<th>Opportunity potential* USD millions**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late market launch</td>
<td>~750</td>
</tr>
<tr>
<td>15 percent migration of former customers</td>
<td>~1,250</td>
</tr>
<tr>
<td>Full production reached 6 months late</td>
<td>~500</td>
</tr>
<tr>
<td>10 percent over target production cost</td>
<td>~2,000</td>
</tr>
<tr>
<td>15 percent over target development cost</td>
<td>~190</td>
</tr>
<tr>
<td>50 percent over target SOP cost</td>
<td>~125</td>
</tr>
<tr>
<td>Long-term quality problems Ø USD 400/vehicle</td>
<td>~1,400</td>
</tr>
<tr>
<td>Changes to body pressing tools 6 months before SOP</td>
<td>~250</td>
</tr>
</tbody>
</table>

* Profit contribution from profits or cost differences over life cycle, assuming: 500,000 units p.a., USD 5,000 profit contribution/vehicle, production time 7 years

** Over total production time

Source: McKinsey
Software maturity is becoming a critical factor in automotive product development.

**Share of electronics and software problems**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Failures per 1000 vehicles</th>
<th>thereof caused by electronics and SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saab</td>
<td>66.4</td>
<td>55%</td>
</tr>
<tr>
<td>Alfa</td>
<td>52.8</td>
<td>44%</td>
</tr>
<tr>
<td>Daewoo</td>
<td>42.4</td>
<td>48%</td>
</tr>
<tr>
<td>Fiat</td>
<td>41.9</td>
<td>45%</td>
</tr>
<tr>
<td>BMW</td>
<td>19.9</td>
<td>46%</td>
</tr>
<tr>
<td>Nissan</td>
<td>19.2</td>
<td>46%</td>
</tr>
<tr>
<td>VW</td>
<td>18.4</td>
<td>48%</td>
</tr>
<tr>
<td>Porsche</td>
<td>17.7</td>
<td>53%</td>
</tr>
<tr>
<td>Audi</td>
<td>15.3</td>
<td>44%</td>
</tr>
<tr>
<td>Mazda</td>
<td>13.2</td>
<td>55%</td>
</tr>
<tr>
<td>Subaru</td>
<td>12.7</td>
<td>49%</td>
</tr>
<tr>
<td>Honda</td>
<td>11.3</td>
<td>48%</td>
</tr>
<tr>
<td>Toyota</td>
<td>10.6</td>
<td>53%</td>
</tr>
</tbody>
</table>

**Source of quality problems**

**Malfunction in Percent**

- Infotainment and body electronics: 32%
- Injection/ignition system: 20%
- Engine (w/o injection): 12%
- Radiator/cooling: 8%
- Wheels/tires: 7%
- Fuel systems: 6%
- Gears/transmission: 6%
- Chassis: 4%
- Other: 5%

SW problems are reasons for recall of more than 700,000 vehicles in 2002.

Source: McKinsey, Business Week, ADAC-AutoMarX (3-5 year old car failures 1998-2001), cars in Germany only
**Automotive software development adds a new layer of complexity compared to hardware**

<table>
<thead>
<tr>
<th>More complexity</th>
<th>Less transparency</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High number of tacit requirements</td>
<td>• Intangible product, hard visualization and performance tracking</td>
</tr>
<tr>
<td>• Heavy software and hardware interaction for embedded systems</td>
<td>• General mismatch between scope and available resources - projects always seem to be &quot;nearly&quot; complete</td>
</tr>
<tr>
<td>• Project complexity growing steeply with product size</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Less discipline</th>
<th>More technological risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Inherent tendency to over-engineering</td>
<td>• High degree of change in underlying complex technologies</td>
</tr>
<tr>
<td>• Seemingly low cost of changes</td>
<td>• No widely accepted platform standards</td>
</tr>
<tr>
<td>• Invariant resource under-estimation</td>
<td>• Immature tool landscape</td>
</tr>
<tr>
<td>• Irrational developer preferences</td>
<td></td>
</tr>
</tbody>
</table>

| More business risk | |
|---------------------|-----------------
| • Fast-moving (and in many cases immature) markets | |
| • Customer value hard to assess | |
| • Lack of experience translating customer requirements into functionality | |

**Fundamental differences:**
- Find specific solution

**Will disappear as industry matures:**
- Learn from hardware

*Source: Brooks: The Mythical Man-Month, McKinsey*
Operational improvement can be achieved in a three step approach

**Development organization**
- Restructuring of development organization for specific needs of SW projects is necessary
- Building of specific skills in SW development and SW project management is needed

**Process efficiency**
- Complex software projects are only feasible with standardized, repeatable processes
- Development effort depends heavily on process maturity - efficiency potentials of up to 90% are possible

**Product architecture**
- Modular, feature specific product design is key to reduce complexity and enable concurrent engineering
- Platforming and maximal degree of reuse is necessary to overcome complexity challenge and ensure software quality

Source: McKinsey
Process maturity is key for product quality

**Automotive industry**

**Characteristics**

1. **Initial**
   - Undefined processes, ad hoc working methods
   - Success depends on few specialists
   - Schedule, quality and cost unforeseeable

2. **Repeatable**
   - Process owned by project manager
   - Disciplined project management
   - Process varies from project to project

3. **Defined**
   - Standard process owned by organization
   - Process-specific tailoring of the standard process

4. **Managed**
   - Quantitative goals for product and process
   - Tracking of goals by metrics and statistical analysis

5. **Optimizing**
   - Process change management
   - Defect prevention processes
   - Technology charge management

**Continuous improving process**

**Automotive industry target**

**Aircraft industry**

**Source:** McKinsey
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Source: McKinsey
Significant issues after reorganizations

CHANGES IN ORGANISATIONAL ORIENTATION

Critical issues

- "Empire strikes back" – change not sustainable
- Project management without real power
- Support from top management and organization too weak
- Organization unable to accept shared responsibilities

Source: Interviews, press clippings
Project organizations must combine high integration and functional development capabilities

Integration capabilities
- Development time
- Target costs
- Known customer requirements
- Platform concepts

Functional capabilities
- Commercialized innovations
- Quality of vehicle features
- Efficiency of function

Source: McKinsey
Structure and roles within project organization defined to ensure high competency

**Roles**

- **Heavy weight**
- **Functional know-how and integration**
- **Single-project orientation**
- **Module orientation**

**Cross-functional teams**

- Body
- Electronics
- Chassis
- Powertrain
- Manufacturing/Engineering

Source: McKinsey
Organizational setup of line functions based on individual function

Types of line organizations

Powertrain

Manu-
facturing/
enginee-
ing

Body

Electro-
nics

Chassis

Program management

CEO

Cross-functional teams

Line function segmentation

A

B

C

Partial segmentation

A

B

C

Functional

A

B

C

R&D departments*

A, B, C programs

Other line functions

• Marketing

• Controlling

• Manufacturing Engineering

• Quality assurance

• Purchasing*

• Vehicle integration

• Body

• Chassis

• Electronics

• Powertrain

• Design

• Concept development

* Best organized along modules

Source: McKinsey
The necessary change process must be driven by top management and requires a long term change in people's mindsets.

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Characteristics of change process:
- Top management topic
- Change management approach required
- Long term process

Act now forward instead of reacting afterwards

Source: McKinsey