V2X AUTOMOTIVE ON-BOARD UNIT COST COMPARISON

SUMMARY

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This V2x OBU Cost Analysis Has Been Conducted To Serve Following Four Main Objectives

1. DEFINITION OF SCOPE
   Development of given scenarios into viable V2x product configurations for an automotive grade installation (components, software and packaging)

2. IDENTIFY COST REALITIES
   Identify cost factors for bill of material items (HW components), software fees and overhead related activities (sales, general & administrative expenses, research & development, testing & validation and manufacturing surcharges)

3. TRANSPARENT COMPARISON
   Provide an comparative overview of given scenarios to identify cost drivers and opportunities to reduce implementation costs

4. IDENTIFY INCREMENTAL COSTS FOR V2X FUNCTIONALITY
   On the cost basis of a Telematics Control Unit (TCU) determine the incremental V2x functionality cost value for each product scenario
On the Basis of the P3 Cost Model Expertise Following Premises and Scope Boundaries Have Been Set in Regard to This Cost Analysis

### P3 Cost Model

**Inputs**
- Functionality description of TCU and V2x system to be covered (broadband connection for vehicle gateway or infotainment system respect. BSM broadcast and receiving)
- Existing automotive grade BoM component costs
- Packaging options and requirements for vehicle integration
- TCU/V2x configuration scenarios to be analyzed (1, 2, 3 & 4)
- Industry comparable for software and overhead costs

**Approach**
- Creation of viable product configurations based on desired features
- Population of bill of material line items and corresponding component costs (similar to NPRM study)
- Capturing components costs price ranges to address OEM product design variabilities (minimum data processing/comm. environment vs. high performance & feature rich)
- Integration of subject matter expert and industry feedback

**Results**
- Transparent overview of nature and source of cost drivers within and between TCU/V2x deployment scenarios
- Reliable information of expected cost levels for future real-world deployment within the automotive space

### Model Coverage of Value Chain Costs

**Bill of Material**
- Processing: SoC, Low Energy MCU, HSM
- Connectivity: Modem, Radio Frontend
- Memory: RAM, ROM/Flash
- Power Management: PMIC, Standby Battery
- Sensors: GNSS, IMU
- Packaging: PCB, Connectors, Casing, Passive Elements
- Interfaces: CAN, Ethernet
- Antenna: Connectors, Wiring, Antenna

**Software**
- Real-Time Operating System & AUTOSAR Stack
- Application SW & Stacks: Broadband Connectivity Processing and V2x communication

**Overhead**
- Sales, General & Administrative Expenses
- Research & Development
- Testing & Validation
- Manufacturing Costs

**Not included:**
- Profit margins of Tier 1 or OEM
- Backend/infrastructure or provisioning costs
- Assembly costs on plant level
- Reoccurring license fees

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Following Scenarios for TCU/V2x Control Units Configurations Have Been Investigated Within the Same Framework and Premises

1. **Distinct Products Within Vehicle**
   - OBU (DSRC or C-V2X) detached from optional TCU
   - Physical and logical separation of processing and communication functions

2. **One Product/ Two Systems**
   - One control unit casing with two integrated systems for TCU and V2x communication (C-V2x or DSRC)
   - V2x card connected onto TCU main board
   - V2x card is self sufficient regarding processing and purpose related communication

3. **Highly Integrated System**
   - OBU (DSRC or C-V2X) integrated within TCU
   - Two distinct modems controlled by shared main application processor and other system modules/ functions e. g. HSM
   - Logical processing separation realized through hypervisor functions of main appl. processor

4. **Fully Integrated System**
   - OBU (C-V2X only) integrated with existing TCU (most vehicles circa 2025 will have V2V capable TCUs)
   - One modem with integrated LTE and C-V2x (+GNSS) functionality packaging, single interface to main application processor
   - Logical processing separation realized through hypervisor functions of application processor
All Four Product Scenarios Share the Same Cost Model Boundary Conditions. Furthermore Certain Cost Influence Parameters Have Been Set to Support the Comparison Efforts

**Comments**

- **HW bill-of-material and SW reflects a viable product configuration for**
- **Secure establishment of broadband connectivity between OEM backend and infotainment system or central vehicle gateway**
- **Transmitting and receiving BSM messages**
- **Communication path for SCMS is realized over broadband modem**
- **Sourced components comply with standard automotive qualifications**
- **Increase of HW requirements and costs (e. g. performance, hypervisor) reflected in scenarios 3 and 4 to meet also cybersecurity and privacy related requirements**
- **Products (HW, SW, packaging) fulfill QM-based functional safety level**
- **HMI related messages/warnings to driver announced through infotainment system or instrument cluster**

**System Boundaries**

- **Example based on Scenario 3**

**Assumed Packaging Locations**

- **Wiring costs estimates included up to next harness junction in trunk area**
- **Antennas costs do not include aesthetical integration products (e. g. shark fin module)**
Comparison Overview of Scenario Specific Incremental Costs for V2x Functionality Based on an Existing TCU Module Within Vehicle

1. Distinct Products Within Vehicle
   - **OBU (DSRC or C-V2X)** detached from *optional* TCU
     - Highest incremental cost: **$129** (Range: $104-$165)
     - Highest execution complexity
     - Moderate market alignment
   - **OBU (DSRC or C-V2X)** integrated within TCU
     - Moderate incremental cost: **$61** (Range: $50-$74)
     - Moderate execution complexity
     - Poor market alignment

2. One Product/ Two Systems
   - **One control unit casing with two integrated systems** for TCU and V2x communication (C-V2x or DSRC)
     - Incremental cost: **$120** (Range: $98-$153)
     - Complex to execute
     - Extremely poor market alignment

3. Highly Integrated System
   - **OBU (DSRC or C-V2X)** integrated within TCU
     - Moderate incremental cost: **$61** (Range: $50-$74)
     - Moderate execution complexity
     - Poor market alignment

4. Fully Integrated System
   - **OBU (C-V2X only)** integrated with *existing TCU* (most vehicles circa 2025 will have V2V capable TCUs)
     - Incremental cost: **$23 (B) / $40 (A)** (Range: $21-28 / $33-48).
     - Base modem cost $137 (Range: $104-174) is not mandate driven
     - Total cost $160/$177 is similar to cost of V2x Option 1
Scenario Specific Cost Comparison For Costs Generated by BOM Items and Software

Left Axis: Absolute Product Scenario Costs, Right Axis: Incremental V2x Costs for Product Scenario

- **Max. cost level for scenario:** High product requirements/ integration of overall features into product
- **Expected cost level for scenario:** Balance of costs versus amount of overall product features
- **Min. cost level for scenario:** Large economies of scale/ lower integration of overall features into product

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### Market Alignment & Packaging Complexity

**Unfavorable** — -- 0 + ++ **Beneficial**

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### Product Costs

- **Scenario 1: Distinct Products**
  - Cost: + $129
  - Market Alignment: -- 0 + ++
  - Engineering & Packaging Complexity: -- 0 + ++

- **Scenario 2: One Product/ Two Systems**
  - Cost: + $120
  - Market Alignment: -- 0 + ++
  - Engineering & Packaging Complexity: -- 0 + ++

- **Scenario 3: Highly Integrated**
  - Cost: + $61
  - Market Alignment: -- 0 + ++
  - Engineering & Packaging Complexity: -- 0 + ++

- **Scenario 4.A: Fully Integrated Concept A**
  - Cost: + $48
  - Market Alignment: -- 0 + ++
  - Engineering & Packaging Complexity: -- 0 + ++

- **Scenario 4.B: Fully Integrated Concept B**
  - Cost: + $23
  - Market Alignment: -- 0 + ++
  - Engineering & Packaging Complexity: -- 0 + ++

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### Incremental V2x Costs

- **Scenario 1: Distinct Products**
  - Incremental Cost: + $200

- **Scenario 2: One Product/ Two Systems**
  - Incremental Cost: + $150

- **Scenario 3: Highly Integrated**
  - Incremental Cost: + $100

- **Scenario 4.A: Fully Integrated Concept A**
  - Incremental Cost: + $50

- **Scenario 4.B: Fully Integrated Concept B**
  - Incremental Cost: + $21

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- **Cost band of TCU (LTE only) products based on same cost model premises**
- **Cost levels validated by industry feedback**
Summary

1. INCREASING DEGREE OF LOGICAL & PHYSICAL INTEGRATION YIELDS IN HIGHER COST SAVINGS AND LOWERED IMPLEMENTATION COMPLEXITY FOR AUTOMOTIVE INDUSTRY

   Direct costs savings can be realized through a decrease of redundant HW components respectively the activation of indirect cost reductions through over the down stream product realization process

   - **HW/ Bill of Material**
     - Consolidation of shared elements (AP, PMIC, GNSS/IMU, connectors, PCB) for LTE/V2x functions
     - Realization of economies of scale by virtualization of processing environments
     - Reusing of MIMO LTE antenna configuration for C-V2x use cases

   - **Software/ Development**
     - Reduction of efforts for SW development of base functions (RTOS, AUTOSAR, etc.)
     - Decrease of development and testing & validation efforts for highly/ fully integrated systems

   - **Packaging / Realization**
     - Complexity and failure potential decrease for overall product realization processes on OEM and Tier 1 levels
     - Indirect cost savings within manuf. & assembly activities

2. LTE + DSRC INTEGRATION SIMILAR TO SCENARIO 4 IS CHALLENGING DUE TO COMMERCIAL AND TECHNICAL ASPECTS OF AUTOMOTIVE PRODUCT REALIZATION

   Integration of dissimilar modem solutions (LTE & DSRC) potentially causing higher costs as LTE/C-V2x due to missing supplier products and aggravated economies of scale compared to 3GPP-LTE release roadmaps and annual production volumes

3. COST INCREASE OF INTEGRATED LTE/C-V2X MODULE TOWARDS SINGLE TCU MODULES IS RELATIVELY LOW IN COMPARISON TO DSRC SCENARIOS, RESULTING IN DECREASED MONETARY IMPACT ON CONSUMERS
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