QUALITY FUNCTION DEPLOYMENT (QFD) & KEY BUYING FACTORS (KBF)

SUDARSHANA KARKALA | EV.ENGINEER | carsoftwaresystems@gmail.com | +91 9845561518 | LinkedIn | CAR SOFTWARE SYSTEMS

INTRODUCTION

What is Quality Function Deployment (QFD)?

Quality Function Deployment (QFD) is a structured approach used to transform customer needs (Voice of Customer - VOC) into engineering requirements. It plays a critical role in EV Battery Management System (BMS) software development by ensuring that design, production, and performance align with customer expectations.

Why is QFD Important in EV BMS Development?

- Aligns product development with customer expectations
- Ensures safety, reliability, and efficiency in BMS design
- Optimises manufacturing processes to meet performance standards
- Reduces time-to-market by minimising redesign efforts

FOUR PHASES OF QFD FOR EV BMS DEVELOPMENT

Phase 1: Product Definition (House of Quality - HOQ)

- Identify customer needs for EV battery efficiency, longevity, and charging performance.
- Define measurable engineering requirements (thermal management, SOC/SOH estimation, charge-discharge cycles).
- Benchmark against competitors (**Tesla, BYD, Rivian**).

Phase 2: Product Development

- Translate system-level specifications into BMS hardware and software requirements.
- Develop firmware optimisation techniques for real-time battery monitoring.
- Ensure compliance with ISO 26262 (Functional Safety), ASPICE, and IEC 61508.

Phase 3: Process Development

- Define manufacturing and assembly process flows.
- Identify critical process characteristics affecting battery efficiency.
- Develop process control strategies to enhance software integration.

Phase 4: Process Quality Control

- Identify critical failure modes in BMS software.
- Implement automated validation techniques (HIL, SIL, PIL simulations).
- Conduct real-world performance testing under extreme conditions.

HOUSE OF QUALITY FOR EV BMS DEVELOPMENT

Building the House of Quality (HOQ)

- **Step 1: Capture the Voice of Customer (VOC)** – Identify key customer expectations such as:
  - Faster charging times
  - Improved State of Charge (SOC) estimation
  - Long-term battery health management

- **Step 2: Define Technical Requirements (Voice of Engineer - VOE)**
  - Battery pack cooling efficiency
  - Energy management software accuracy
  - Real-time diagnostics & fault tolerance

- **Step 3: Relationship Matrix**
  - Map customer requirements to engineering specifications.
  - Establish strong, moderate, and weak relationships between attributes.

- **Step 4: Competitive Benchmarking**
  - Compare charging speeds, thermal performance, and software reliability with competitors.

Example - Applying QFD in EV BMS:

Customer Need	BMS Technical Feature	Relationship Strength
Fast Charging	Optimized Charge Algorithms	Strong
Battery Life	AI-driven SOC Estimation	Moderate
Safety	Thermal Overload Protection	Strong

KEY BUYING FACTORS (KBF) FOR ELECTRIC VEHICLE BMS

What are Key Buying Factors?

Key Buying Factors (KBF) are the primary aspects that influence customer decisions when purchasing an Electric Vehicle (EV). In BMS development, these factors determine:

- Battery safety and reliability
- Charging convenience and efficiency
- Total cost of ownership (TCO)

Top KBFs in EV BMS Software Development

- **Battery Range & SOC Accuracy**
  - Precise State of Charge (SOC) and State of Health (SOH) monitoring.
  - Adaptive energy optimisation algorithms to extend battery range.
- **Fast Charging & Thermal Management**
  - Minimised battery overheating using active thermal regulation.
  - Fast-charging algorithms without battery degradation.
- **Over-the-Air (OTA) Updates & Diagnostics**
  - Remote BMS firmware updates for continuous performance improvement.
  - Cloud-based predictive analytics for failure prevention.
- **Lifecycle & Durability**
  - AI-based battery wear prediction models.
  - Smart charging profiles for prolonged battery life.
- **Cybersecurity & Compliance**
  - Encrypted BMS communication to prevent hacking threats.
  - Compliance with ISO 21434 (Automotive Cybersecurity).

Example - Key Buying Factors in EV BMS Software:

Key Buying Factor	Impact on BMS Development
Battery Range	Optimized Energy Management
Charging Speed	Fast Charging Algorithms
Safety	AI-Based Fault Detection

WORKFLOW DIAGRAM FOR QFD & KBF IMPLEMENTATION IN BMS

Step-by-Step Workflow:

- **Customer Research** → Gather insights on EV buyer preferences.
- **Benchmarking** → Compare existing EV BMS solutions.
- **QFD House of Quality Development** → Define BMS technical attributes.
- **KBF Impact Assessment** → Prioritise development features.
- **Prototype & Validation** → Test algorithms under real-world conditions.
- **Production & Optimisation** → Implement findings into BMS firmware & updates.

(Workflow diagram will illustrate interconnections between QFD & KBF processes)

CASE STUDY : QFD & KBF IN FAST-CHARGING EV BMS

Case Study : Enhancing EV Fast Charging with QFD & KBF

Challenge: EV owners demand faster charging without overheating.

QFD Approach:

1. **Capture VOC:** Customers need 80% charge in 15 minutes.
2. **Define** Technical Requirements:
    - Implement adaptive cooling algorithms.
    - Reduce thermal stress during charging.
3. **Apply KBF Analysis:**
    - Benchmark against Tesla Supercharger & Rivian DC fast charging.
    - Optimise charge profiles for higher efficiency & battery longevity.

4. **Testing & Validation:**
    - Simulate fast-charging cycles in lab & real-world conditions.
    - Ensure minimal battery degradation post-500 charge cycles.

Results:

- Charging time reduced by 30%.
- Battery degradation minimised by 25%.
- Customer satisfaction increased due to improved predictability.

CONCLUSION & INDUSTRY BEST PRACTICES

- QFD aligns EV BMS software development with user needs.
- KBF analysis ensures customer-driven innovation in battery technology.
- AI-powered SOC/SOH estimation improves battery lifecycle management.
- OTA updates and cybersecurity safeguards enhance BMS performance.

Industry Best Practices for QFD & KBF in BMS Development:

- Implement AI-Driven SOC Prediction – Enhance range estimation.
- Prioritise Fast-Charging Optimisation – Improve battery lifespan.
- Leverage Cloud-Based BMS Monitoring – Enable real-time diagnostics.
- Ensure Regulatory Compliance – Follow ISO 26262 & ASPICE.
- Enhance Cybersecurity Measures – Protect against hacking threats.