Industrial Internet of Things (IIoT) and the Future of Electric Vehicle Manufacturing - Overcoming Challenges to Achieve Profitability

Prepared for:
Lightweight Materials Joining, Forming, & Manufacturing Innovation 2019 Summit

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Research Manager – Mobility
Frost & Sullivan
Presentation Agenda

Digital Transformation of the Automotive Industry

IIoT and Future of Electric Vehicles

Focus on Electric Vehicles Profitability
Presentation Agenda

1. Digital Transformation of the Automotive Industry
2. IIoT and Future of Electric Vehicles
3. Focus on Electric Vehicles Profitability
Digital Transformation of the Automotive Industry
Focal Points

Automotive digitalization focuses on five key pillars
- Connected Supply Chain
  (*Value chain disruption
  *Intelligent fulfilment
  *Responsive supply networks
  *Smart logistics)
- IIoT
- A.C.E. vehicles
- Digital Retailing
- Mobility as a Service (MaaS)

Automotive IIoT spend is bound to increase at a CAGR of 11.5% (2015-2025)
- $12.30 billion in 2015 to
- $36.70 billion in 2025.
- Over 1700 new digital startups
  (*Simulation modelling
  *Cloud-based IoT platform
  *Cognitive manufacturing
  *Contextual intelligence)

Manufacturing (including EVs) impacted by ongoing Digital Transformation
- Highly configurable and flexible production operated by robots
- Real-time production optimization through integration with simulation techniques
- Predictive analytics through pattern recognition methods
- Data packets enhanced encryption
- Automatic capturing, modelling, and optimizing of production systems
Industrial Internet of Things—The 4 Functional Facets

The cross-pollination of ideas, technologies, and processes between the worlds of information technology and operations technology will form the crux of the fourth industrial revolution.

Exploring newer avenues for service innovations, such as cloud-based service platforms, and evaluating potential for new profit centers; opportunity analysis for ICT technology in services

The dawn of the future factory is set to disrupt existing supply chain networks. Digitalization and increased connectivity are set to disrupt and realign existing value-chain networks in the future.

The advent of advanced ICT technologies will promote new inter-relationships and interdependencies giving way to unexpected business collaborations and partnerships in the future.

IT-OT = Information Technology-operational Technology; ICT = Information and communication Technology

Images Source: Thinkstock
Source: Frost & Sullivan
IloT—Key Attributes of a Smart Factory

The broader technology themes will give rise to new attributes in the shop floor.

IloT—Key Attributes of a Smart Factory, Global

Tech Themes

Virtual Reality
Big Data
Mobility
Sensors 4.0

Edge Intelligence
Industrial Cloud
Cognitive Intelligence

Wireless Sensor Networks
Additive Manufacturing

M2M Connectivity
Industrial Robotics

IP-based Communication
Mobile Apps

Predictive Maintenance
Drones

Connected Logistics

Smart Factory

Attributes of smart factory connected to tech themes

Source: Frost & Sullivan

(C) Frost & Sullivan, 2019

ABC Lightweighting Conference, 2019 (Detroit)
Example: Jeep Transforms its US Factory Realizing IIoT
Kuka and Microsoft Supports Jeep help realize IIoT driven plant efficiency benefits at its Toledo factory.

Internet of Things transforms a Jeep factory

Business Challenge

- KUKA needed an automated manufacturing solution that could produce multiple car models on the same assembly line while meeting a rigorous production schedule.

Solution

- KUKA implemented an intelligent system anchored by Windows Embedded and Microsoft SQL Server that connects 259 assembly-line robots, a controller, more than 60,000 device points, and backend systems.

Impact

- It produces a car body every 77 seconds.
- It provides 24 hours of production per day for more than 8 years.
- It improves efficiency and reduces training time with a familiar interface.

(C) Frost & Sullivan, 2019
Example: Toyota Operations Technology (OT) for Efficiency

Predictive maintenance tool has enabled Toyota’s paint engineers to identify a problem within two hours, which typically would take eight weeks to spot.

Case Study: Toyota Operations Technology for Efficiency, Global

<table>
<thead>
<tr>
<th>Operations in United States</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct CAPEX</td>
<td>$22 B</td>
</tr>
<tr>
<td>Number of jobs created</td>
<td>365,000</td>
</tr>
<tr>
<td>Investment in parts and materials</td>
<td>$35 B</td>
</tr>
</tbody>
</table>

Operational Challenges

- Very high production lead time.
- No real-time data capture facility.
- Low level of flexibility, wherein multiple product types cannot move on a single line.

Toyota Operations Availability System (TOAD)

—In-house Data Visualization and Predictive Analytics Platform

- 32 Smart manufacturing systems implemented
- $6 million Savings in OPEX
- $187 million/year Downtime avoidance through IIoT in supply chain
- 40,000 minutes Saved production time in single plant

Existing & Future Strategy

- It currently augments the existing capacity by improving operational efficiency and working alternative shifts.
- It temporarily reduces the production cycle time by making small strategic investments.
- In future, implement a new business strategy called the Advanced IT for Manufacturing across all the plants.

Source: Toyota Motor Sales, U.S.A.; Frost & Sullivan

ABC Lightweighting Conference, 2019 (Detroit)
Example: Connected Supply Chain as a Means to Achieve Profitability

<table>
<thead>
<tr>
<th>Performance Attribute</th>
<th>Metric</th>
<th>Estimated Reference Value</th>
<th>Improvement potential (%) with CSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Chain Reliability</td>
<td>Perfect order fulfillment</td>
<td>75-85%</td>
<td>10-30% Improvement</td>
</tr>
<tr>
<td>Supply Chain Responsiveness</td>
<td>Order fulfillment cycle time</td>
<td>30-45 days</td>
<td>30 - 50% Reduction</td>
</tr>
<tr>
<td>Supply Chain Flexibility</td>
<td>Upside supply chain flexibility</td>
<td>45-60 days</td>
<td>30-50% Reduction</td>
</tr>
<tr>
<td></td>
<td>Upside supply chain adaptability</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downside supply chain adaptability</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Supply Chain Costs</td>
<td>Supply chain management cost</td>
<td>10-12% of Revenues</td>
<td>25% - 50% Reduction</td>
</tr>
<tr>
<td></td>
<td>Cost of goods sold</td>
<td>70-80% of revenues</td>
<td>5-10% improvement</td>
</tr>
<tr>
<td>Supply Chain Assets Management</td>
<td>Cash-to-Cash cycle time</td>
<td>30-95 days</td>
<td>25-50% improvement</td>
</tr>
<tr>
<td></td>
<td>Return on supply chain fixed assets</td>
<td>...</td>
<td>10 - 20% Improvement (based on capacity realization/ revenues)</td>
</tr>
<tr>
<td></td>
<td>Return on working capital</td>
<td>...</td>
<td>25 - 50% Increase (based on C2C cycle time)</td>
</tr>
</tbody>
</table>

Connected Supply Chain has the potential to reduce vehicle cost by up to 6% through reduction in supply chain management cost and additional up to 10% reduction through savings in Cost of Goods Sold using IIoT.

Source: Several and Frost & Sullivan

ABC Lightweighting Conference, 2019 (Detroit)
Presentation Agenda

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3. Focus on Electric Vehicles Profitability
IIoT System Architecture

IIoT and Future of Manufacturing: IIoT System Architecture, Global

Key: PLC—Programmable Logic Controller
(C) Frost & Sullivan, 2019

Source: Frost & Sullivan
ABC Lightweighting Conference, 2019 (Detroit)
# IIoT Different Layers

7 different layers

<table>
<thead>
<tr>
<th>Layers Segmentation</th>
<th>Representation</th>
<th>Devices and Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensing Layer</td>
<td>![Representation]</td>
<td>Terminal Devices&lt;br&gt; E.g., Sensors, camera, global positioning system (GPS)</td>
</tr>
<tr>
<td>Device Layer</td>
<td>![Representation]</td>
<td>Communication Terminals and Gateways&lt;br&gt; E.g., Modem, Mobile Phone, Satellite Dish</td>
</tr>
<tr>
<td>Network Layer</td>
<td>![Representation]</td>
<td>System Networks&lt;br&gt; E.g., Internet, local area network (LAN), multi-channel network (MCN)</td>
</tr>
<tr>
<td>Platform Layer</td>
<td>![Representation]</td>
<td>Database, File Storage&lt;br&gt; E.g., Operation management, administration management, system management</td>
</tr>
<tr>
<td>Application Layer</td>
<td>![Representation]</td>
<td>Gateways, Firewalls, All End Devices like PCs, Phones, Servers&lt;br&gt; E.g., Coal, electricity, transport</td>
</tr>
<tr>
<td>Terminal Layer</td>
<td>![Representation]</td>
<td>OpenCard Framework&lt;br&gt; E.g., Human machine interface (HMI), computer panels</td>
</tr>
<tr>
<td>User Layer</td>
<td>![Representation]</td>
<td>Simple Mail Transfer Protocol (SMTP)&lt;br&gt; E.g. Directory services</td>
</tr>
</tbody>
</table>

Source: Frost & Sullivan
Exploring IIoT’s End-to-End Industrial Architecture

The standardization of architecture will create a $90 billion opportunity by 2021.

Exploring IIoT’s End-to-End Industrial Architecture, Global, 2016–2021

1. Sensing Layer
   - Terminal Devices, Example: Sensors, Camera, GPS

2. Device Layer
   - Communication Terminals and Gateway
     - Example: Modem, Mobile Phone, Satellite Dish

3. Network Layer
   - System Network
     - Example: Internet, LAN, Mobile Communication Network

4. Platform Layer

5. Application Layer
   - Example: HMI, Computer Panels

User Layer

Terminal Layer

Example: HMI, Computer Panels

Application Layer

Example: Coal, Electricity, Transport

2016 Market Size: $15–$25 Billion
CAGR (2016-2021): 27%–29%
2021 Market Size: $50–$90 Billion

Operation Management
- Task Management
- Software Management
- Terminal Device & Application Management

Short Distance Communication

Long Distance Communication

Administration Management
- Enterprise Account Management
- M2M Application Management

System Management
- Resource Management
- Data Management

Source: Frost & Sullivan
Example: Plant of the Future—Industry 4.0 Ecosystem

Industry 4.0 connects embedded system production technologies and manufacturing processes to drastically transform industry and production value chains and business models.

Plant of the Future—Industry 4.0 Ecosystem, Global

- Cybersecurity
  - Stronger protection for Internet-based manufacturing
  - Technology products with longer life cycle

- Cloud Computing
  - Sensors
    - Zero default/deviation
    - Reactivity
    - Traceability
    - Predictability

- Advanced Manufacturing Systems
  - Give sense to complexity
  - Creativity
  - Collaborative manufacturing

- Big Data
- Cloud Computing

- Additive Manufacturing
  - Scrap elimination
  - Mass customization
  - Rapid prototyping

- Nano Technology
  - Smart value-added products
  - Technical differentiation
  - Connectivity

- Robot
  - Real-time autonomy productivity
  - Full transparency on data reporting

- EV/Autonomous Vehicles
  - Flow optimization
  - Increased security
  - Lower costs

- IIoT
  - Object tagging
  - Internet-object communication via low power radio
  - Real-time data capture
  - Optimized stocks
  - Reduced wastes

- Resources of the Future
- Alternative/Non-conventional
- Solar
- Geothermic

- Cluster of Suppliers
- Supplier
- Logistics 4.0
  - Fully integrated supply chain
  - Interconnected systems
  - Perfect coordination

- Mass Customization
- Clients

- Plant of Future ‘A’
- Plant of Future ‘B’
- Cluster of Plants

Source: Frost & Sullivan
ABC Lightweighting Conference, 2019 (Detroit)

(C) Frost & Sullivan, 2019
Example: Bosch Analogy—A Smart Watch Solution
A Bosch plant, based in South Carolina, has successfully integrated iPhones and Pebble Watches into assembly lines.

Bosch Analogy—A Smart Watch Solution, Global

How it used to be

Production line → Machine stops → Red Lights & Buzzers go off

A Typical Production Floor

• Machine stoppages occur due to feeder jams and other specific faults, triggering the Buzzers
• Operator response time increases thereby resulting in increased wastage of time and money.

Key Convergence of Technology

PLC → Apple iPhone → Pebble Smart Watch

Robert Bosch’s Anderson Plant

• The PLC communicates to server when a problem or jam is about to occur.
• The server interprets the signal and sends a SMS to iPhone.
• The iPhone relays message to all Pebbles (worn by line operators) via Bluetooth.

• For every 3 production days, 1 hour of downtime eliminated.
• This is 122 hours of additional production per year.

Inferred Strategy

• Engineering a strategy to integrate minimal technology with extended possibilities will reap huge benefits.
• Open firmware, like that of Pebble Smart watch, can help in customized implementation of its features in real-time production floor.
• Need for next-generation technology platform that spurs convergence concepts and simulations.

Source: Bosch Software Innovations; Frost & Sullivan
ABC Lightweighting Conference, 2019 (Detroit)

(C) Frost & Sullivan, 2019
Automotive Industry Key Future Trends Overview

New opportunities in technologies and businesses have expanded the ecosystem of car manufactures to enhance their products and manufacturing process.

IIoT and its Impact On Manufacturing: KEY IMPACTS ON MANUFACTURING, GLOBAL

**PRODUCT TRENDS**

- Electrification
- Connected Vehicles
- Autonomous Driving
- Multi Material Structures

**BUSINESS TRENDS**

- Modularization
- New Mobility
- e-Retailing
- Environmental Compliance

**SUPPLY CHAIN TRENDS**

- Value Chain Expansion
- Connected Supply Chain
- EOL disposal

Source: Frost & Sullivan
**Electrification—Key to Meeting Future Emission Regulations**

Electrifying ICE models is no longer an optimal solution to meet emission regulations because of the limitations in extending range and battery capacity; OEMs are expected to utilize their platforms for EVs.

### EV Platform Strategy: OEM EV Platform Forecast, Global, 2016 and 2025

<table>
<thead>
<tr>
<th>Year</th>
<th>FCA</th>
<th>GM</th>
<th>Ford</th>
<th>Hyundai</th>
<th>Honda</th>
<th>Toyota</th>
<th>RNM</th>
<th>Volvo</th>
<th>JLR</th>
<th>PSA</th>
<th>Daimler</th>
<th>BMW</th>
<th>VW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2025</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>4</td>
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<td>4</td>
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</tr>
</tbody>
</table>

13 global OEMs; 44 platforms

#### Key Takeaways

- A 37.5% increase in platforms that underpin EVs (including PHEVs, BEVs, and FCEVs) is expected between 2016 and 2025.
- OEMs will add a dedicated platform by 2025 that can house vehicles across multiple segments.
- The challenges with electrifying existing platforms include extending battery capacity and range, which are crucial to meeting emission regulations.

BMW’s CLAR will underpin its future PHEVs, replacing its LG/LK and ULK-2 platforms

Note: All figures are rounded. The base year is 2016. Source: Frost & Sullivan

(C) Frost & Sullivan, 2019
EV Platform Strategy: Number of Platforms and Average Models per Platform, Global, 2025

OEMs are expected to utilize 2 to 4 platforms to underpin future EVs, with an industry average of 5 to 6 models per platform by 2025.

Size of Bubble = Average Production per Platform

Note: All figures are rounded. The base year is 2016. Source: Frost & Sullivan
New Dedicated Platforms—Powertrain Flexibility Comparison
With the exception of a few OEMs, many automakers are expected to build only BEVs on their dedicated platforms.

### New Dedicated Platforms’ Powertrain Flexibility Comparison, Global, 2016–2025

<table>
<thead>
<tr>
<th>Brand</th>
<th>Pure ICE</th>
<th>PHEV</th>
<th>BEV</th>
<th>FCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>European OEM 1</td>
<td></td>
<td></td>
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<tr>
<td>European OEM 2</td>
<td></td>
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<tr>
<td>European OEM 3</td>
<td></td>
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<tr>
<td>European OEM 4</td>
<td></td>
<td></td>
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<tr>
<td>European OEM 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA OEM 1</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>NA OEM 2</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Asian OEM 1</td>
<td></td>
<td></td>
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<tr>
<td>Asian OEM 2</td>
<td></td>
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<tr>
<td>Asian OEM 3</td>
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<tr>
<td>Asian OEM 4</td>
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<tr>
<td>Asian OEM 5</td>
<td></td>
<td></td>
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<tr>
<td>Asian OEM 6</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Key Takeaways**

- More than 75% of major global OEMs are expected to have a BEV-only platform by 2025.

Note: List is not exhaustive
Source: Frost & Sullivan
**Battery Specification Roadmap**

The trend is moving towards higher battery capacities over 60kWh to increase the range of an electric vehicle up to 200 miles on a single charge.

**Electric Vehicle Market : Battery Capacity and Range Roadmap, Global, 2010–2020**

<table>
<thead>
<tr>
<th>Battery Type &amp; Chemistry</th>
<th>PHEV</th>
<th>BEV</th>
<th>PHEV</th>
<th>BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Capacity</td>
<td>5-10 kWh</td>
<td>10-20 kWh</td>
<td>20-30 kWh</td>
<td>30-80 kWh</td>
</tr>
<tr>
<td>Electric Range</td>
<td>Up to 30 miles</td>
<td>30-60 miles</td>
<td>Up to 90 miles</td>
<td>150-250 miles</td>
</tr>
<tr>
<td>DC Charging Capacity</td>
<td>Up to 50 kW</td>
<td>Up to 150 kW</td>
<td>Up to 350 kW</td>
<td></td>
</tr>
<tr>
<td>Min Time Taken to Charge PHEV</td>
<td>~10-20 minutes</td>
<td>~7-13 minutes</td>
<td>~&lt;5 minutes</td>
<td></td>
</tr>
<tr>
<td>Min Time Taken to Charge BEV</td>
<td>~40-60 minutes</td>
<td>~20-55 minutes</td>
<td>~&lt;15 minutes</td>
<td></td>
</tr>
</tbody>
</table>

**Battery Type & Chemistry**

- **BEV / PHEV**
  - Prismatic / Pouch
  - Cylindrical
- **HEVs**
  - LMO / NMC / LFP
  - NCA / NiMH / NMC
  - Solid State / Lithium Air

**Battery Cooling System**

- **BEV / PHEV**
  - Liquid Glycol - Refrigerant Coolants
  - Glycol Water based cooling
  - Air cooled
  - Forced Air cooling system
- **HEVs**
  - Active Liquid Cooling system
  - Forced Air cooling system with light weight aluminum vents

**Source:** Frost & Sullivan

(C) Frost & Sullivan, 2019

ABC Lightweighting Conference, 2019 (Detroit)
Technology Roadmap by P – BTMS Solution

Flame barriers with epoxy and PCM materials will be the key trend in the future to adhere to the stringent battery thermal safety regulations such as GB/T regulations.

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat Sink</strong></td>
</tr>
<tr>
<td>2010</td>
</tr>
<tr>
<td>Copper based foam-thermal fins</td>
</tr>
<tr>
<td>Liquid glycol cooled aluminum heat sink liquid cold plate</td>
</tr>
<tr>
<td><strong>Heat Spreader</strong></td>
</tr>
<tr>
<td>copper-molybdenum (Cu-Mo)</td>
</tr>
<tr>
<td>Aluminum Foil, Copper Foil, Polyester, Synthetic Graphite</td>
</tr>
<tr>
<td><strong>Flame Barrier</strong></td>
</tr>
<tr>
<td>Composites/Ceramic insulation plates</td>
</tr>
<tr>
<td>Barrier insulator</td>
</tr>
<tr>
<td><strong>Thermal Conduction</strong></td>
</tr>
<tr>
<td>Plastic polymers, foam, copper graphite alloy</td>
</tr>
<tr>
<td><strong>Thermal Insulation</strong></td>
</tr>
<tr>
<td>Polyvinyl Chloride (PVC) or Polyethylene Terephthalate</td>
</tr>
<tr>
<td>Calcium Silicate, pyrotechnic materials, fiberglass battery separator, foam, ceramic foam, synthetic graphite</td>
</tr>
</tbody>
</table>

Source: Frost & Sullivan

(C) Frost & Sullivan, 2019
Key Question Remains - How to achieve Profitability

Managing Manufacturing Complexity becomes Key
Presentation Agenda

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Example: BMW Smart Factory Technologies—Implementation

Collaborative robots (cobots), wearables, augmented reality applications, smart glasses, exoskeletons, and innovative work gloves are the key technologies that are being integrated at BMW’s global plants.

- ~ 60 lightweight robots in BMW group plants
- 230 innovative work gloves at the BMW Group
- ~ 68 exoskeleton vests in use in the series production at Spartanburg BMW plant

Image Source: BMW
(C) Frost & Sullivan, 2019

Source: Frost & Sullivan
ABC Lightweighting Conference, 2019 (Detroit)
Example: Popular EV Model Cost Breakdown Profitability Analysis

Source: Frost & Sullivan
Thank you

Q&A