Tractica

Automotive AI Applications and Outlook

April 2019

CLINT WHEELOCK
Chief Research Officer

Tractica Introduction and Methodology

Introduction

Tractica, an Informa business, is a market intelligence firm that focuses on human interaction with technology.

The firm's market research and consulting services provide industry participants and stakeholders with in-depth analysis of emerging technology trends, business issues, market drivers, and end-user demand dynamics across multiple application domains.

Sector Focus

- Artificial Intelligence
- Robotics
- User Interface Technologies
- Advanced Computing
- Connected & Autonomous Vehicles
- Wearables & Digital Health

Research Services

- Research Reports
- Research Subscriptions
- Analyst Inquiry Sessions
- Consulting Projects
- Go-to-Market Services
- End-User Surveys

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Artificial Intelligence Advisory Service

TOPICS COVERED

- Cognitive Computing
- Computer Vision
- Deep Learning
- Machine Learning
- Machine Reasoning
- Natural Language Processing
- Predictive Computing
- Virtual Digital Assistants

RESEARCH REPORT SCHEDULE

3Q16	Video Analytics
3Q17	Robotic Process Automation
3Q17	Artificial Intelligence for Consumer Applications
4Q17	Virtual Digital Assistants for Enterprise Applications
1Q18	Artificial Intelligence for Enterprise Applications
1Q18	Computer Vision Technologies and Markets
1Q18	Emotion Recognition and Sentiment Analysis
1Q18	Artificial Intelligence Services
1Q18	Artificial Intelligence Hardware and Software Infrastructure
2Q18	Artificial Intelligence for Telecommunications Applications
2Q18	Enterprise High Performance Computing
2Q18	Deep Learning Chipsets
3Q18	Quantum Computing for Enterprise Markets
3Q18	Artificial Intelligence for Automotive Applications
3Q18	Artificial Intelligence Market Forecasts
3Q18	Blockchain for Enterprise Applications
3Q18	Artificial Intelligence for Healthcare Applications
3Q18	Artificial Intelligence for Edge Devices
4Q18	Artificial Intelligence Market Ecosystem
4Q18	Artificial Intelligence in Asia Pacific
4Q18	Deep Learning
4Q18	Natural Language Processing
4Q18	Artificial Intelligence Use Cases
4Q18	Using Artificial Intelligence for a Smart Cable Customer Experience
1Q19	Artificial Intelligence Market Forecasts
1Q19	Artificial Intelligence for Manufacturing Applications
2Q19	Artificial Intelligence for Enterprise Applications
2Q19	Artificial Intelligence for Telecommunications Applications
1Q19	Virtual Digital Assistants
4Q19	Artificial Intelligence Business Models
2Q19	Artificial Intelligence in the Cloud
2Q19	Artificial Intelligence Enterprise Adoption Survey
3Q19	Artificial Intelligence Market Forecasts
3Q19	Artificial Intelligence for Smart City Applications
3Q19	Video Analytics
3Q19	Computer Vision Technologies and Markets
4Q19	Machine Reasoning
4Q19	Artificial Intelligence Market Ecosystem

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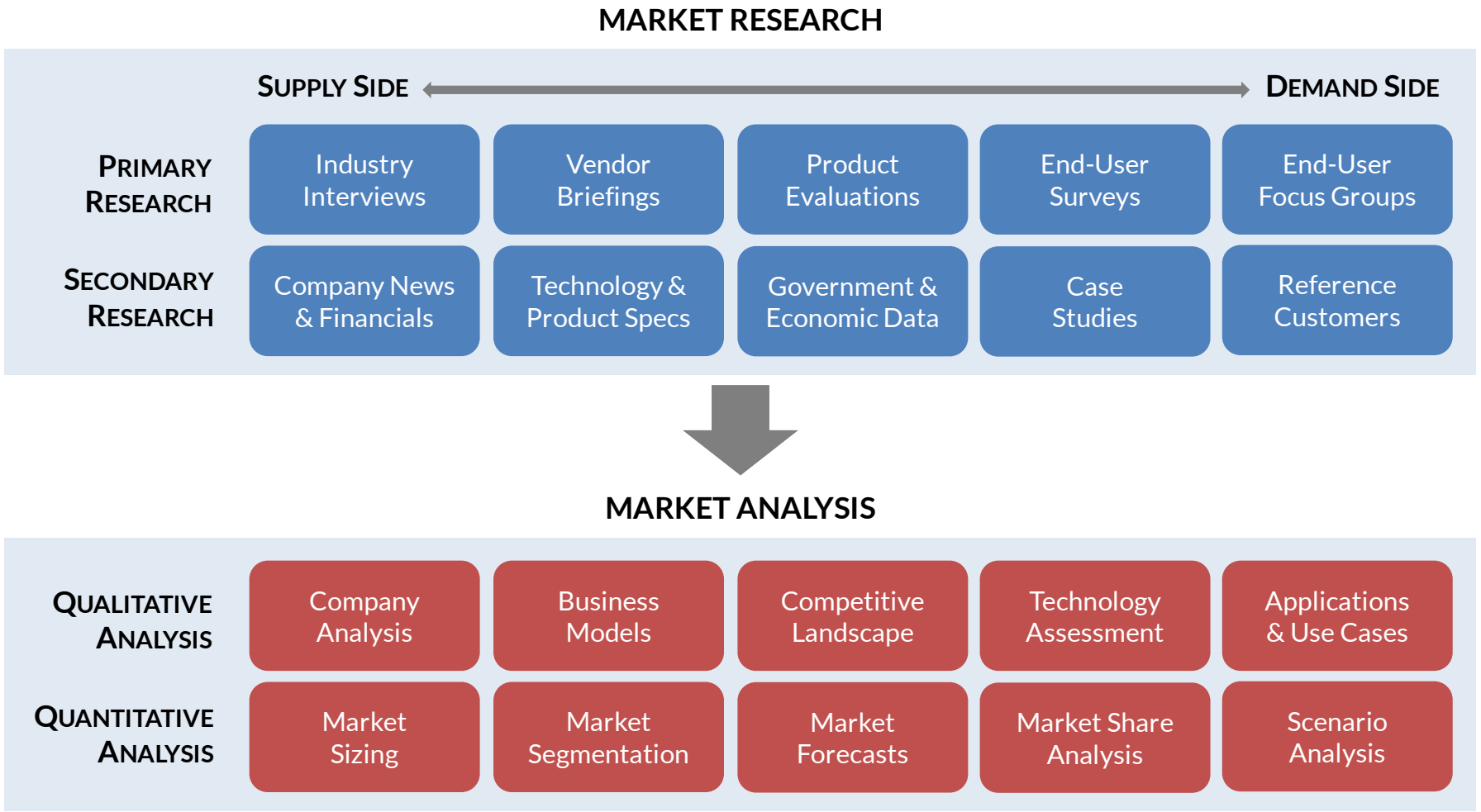
Tractica Research Methodology



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AI is a Loose Umbrella Term for Technologies Inspired by Biological Systems

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Technologies	Definitions
Machine Learning	Standard classical/statistical machine learning techniques such as clustering, regression, random forests, SVMs, naïve Bayes, etc.
Deep Learning	Form of machine learning that uses multi-layered neural networks such as CNN, RNN, LSTM, etc.
Natural Language Processing (NLP)	Technologies that allow computers to understand, translate, and produce human speech and writing including tokenization, parsing, stemming, semantic analysis.
Computer Vision	Technologies that allow computers to identify, tag, and understand images, video, and raw pixel data. Includes feature extraction, pose normalization, and part annotations.
Machine Reasoning	Learning that is not programmed, learning based on cognitive processes, knowledge based inference engines, expert systems, associative memory based learning.
Strong AI	As opposed to narrow domain AI, generalized AI can solve problems in a wider domain, such as language, vision.

Key Takeaway

Many categories overlap

New AI Invented Constantly → Successful Technologies Are No Longer Considered AI

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AI Forecast Model Methodology

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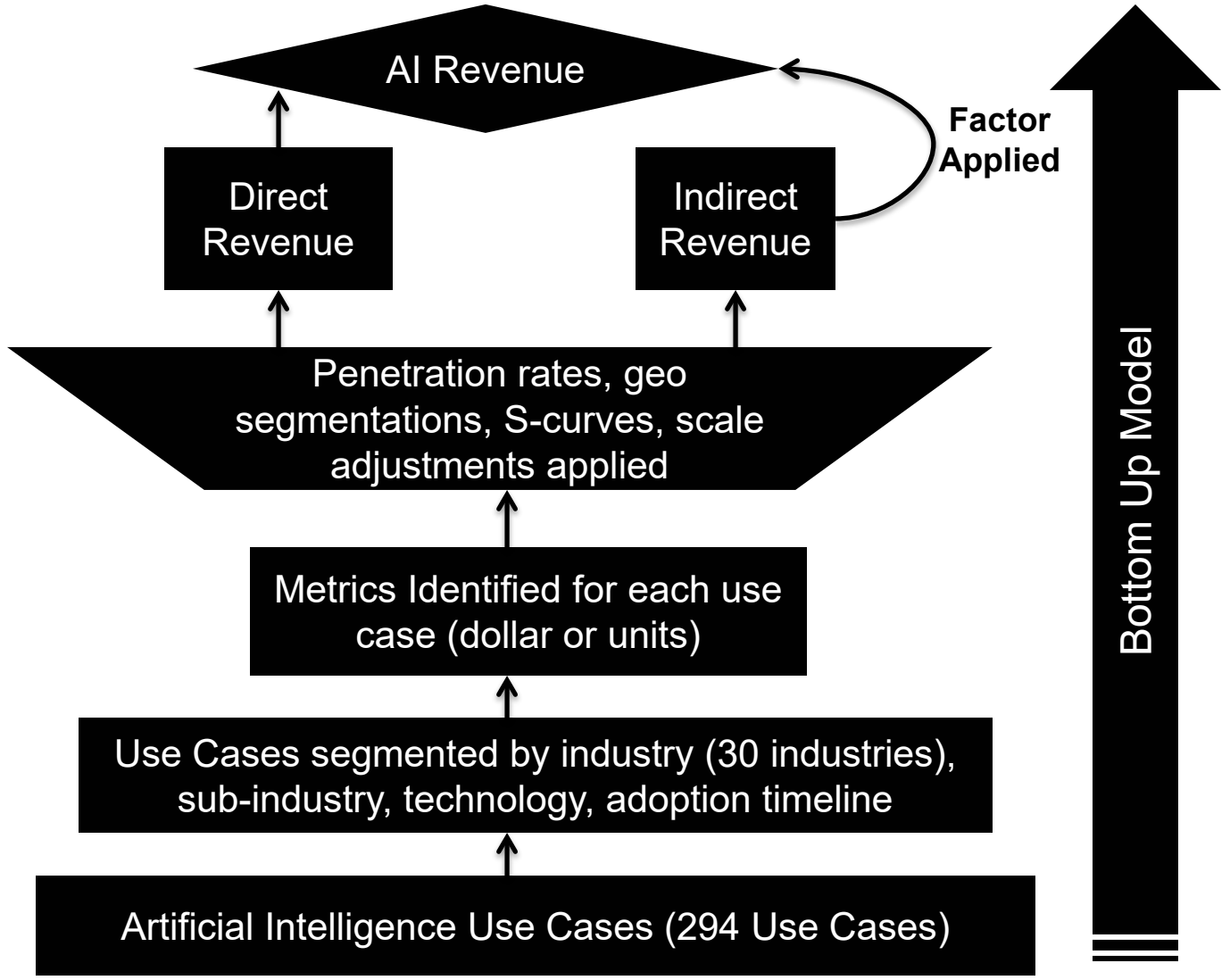
Estimating the Software Revenue Quotient of AI*

*Not the revenue enabled by AI



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Automotive AI Applications

Automotive AI Market Ecosystem

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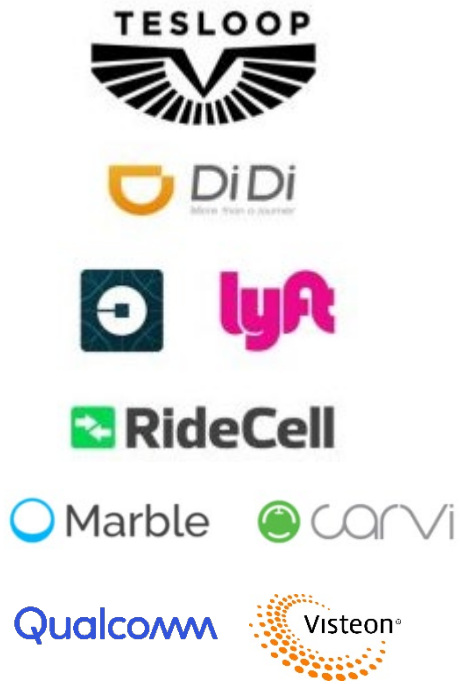
The market for AI-based software and hardware is both wide and deep, populated by both legacy automotive companies and suppliers, as well as startups.

Technology Providers

OEMs and Tier-1 Suppliers

Service Providers



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Use Case Categories

Automotive AI market can be divided into three key categories:

Autonomous Vehicle Development

- Development of hardware, software, and services designed to support vehicles that can be operated with limited or no human control or interaction.
- Currently in testing and evaluation phase for fully autonomous (Level 4-5) operations.

Connected Vehicle Environment

- Development of hardware, software, and services designed to support vehicle-to-vehicle and vehicle-to-infrastructure communication.
- Goal is to allow a safer, more responsive and more intelligent transportation system.

In-Vehicle Services Technology

- Development of hardware, software, and services designed to support personalized and connected infotainment services for vehicle occupants and maintenance activities.
- Goal is to create an intuitive, personalized, and automated environment in the car, as well as with service and maintenance organizations.

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Defining Automotive AI

Automotive AI uses a combination of techniques, including machine learning (ML), deep learning (DL), natural language processing (NLP), and computer vision (CV) to identify patterns in sensors or operational data, and then infers actions based on a set of pre-determined rules for operation.

- ML can be used to enable autonomous vehicle (AV) operation, by training systems on the various objects or scenarios that may be encountered while driving, and then using the inference algorithms to adapt and react to real-world scenarios.
- AI can also be used to make life in the car more convenient and safer, for both the driver and the passengers.
  - In-car assistants allow the vehicle's systems to respond to voice commands and infer what actions to take, without human intervention.
  - Learning algorithms can find personalized operational patterns, and use them to control in-vehicle media and entertainment systems, and also manage navigation systems, climate control systems, and some limited vehicle systems.

Key Attributes of Automotive AI

- **Requires a network of sensing technologies and data streams.**
- **Generally features a two-step process of training and inference in order to activate the models.**
- **For AVs, training progress is generally expressed in miles driven, ensuring that the algorithms have a large dataset from which to learn.**
- **The goal with AI is to allows vehicles to respond to scenarios and inputs faster, more accurately, and more safely than humans.**

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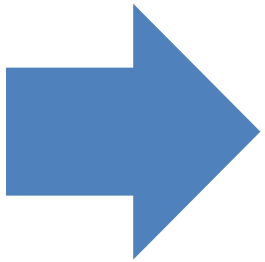
Market Drivers and Barriers

Market Drivers

- Desire for enhanced safety
- Desire for more convenience and personalization of in-vehicle services
- New revenue streams
- Reduced operating costs of taxi/ridesharing/trucking



Market Barriers

- Technological challenges
- Negative publicity due to AV accidents
- Uncertain legal and regulatory environment
- Development costs
- Model training time

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Market Opportunity for Automotive AI Applications

Automotive AI Market Forecasts by Segment

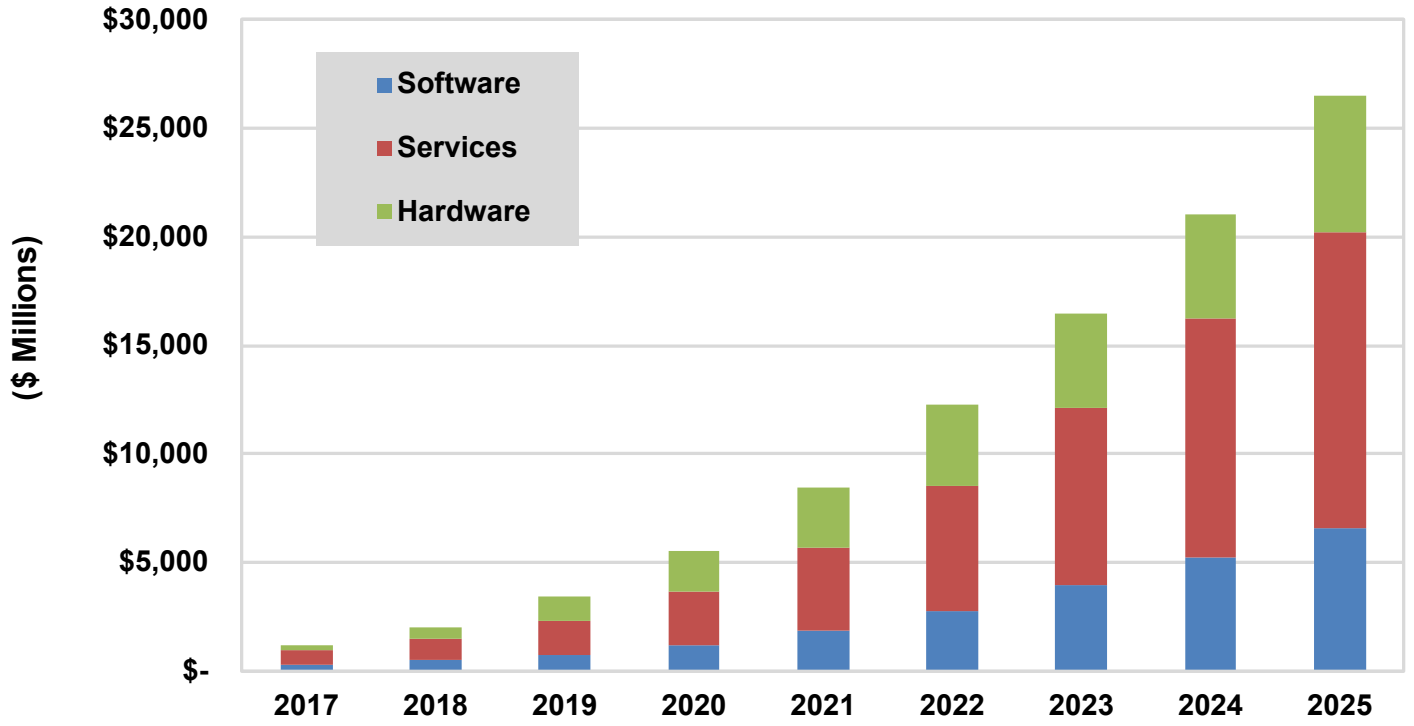
Total Automotive AI Market

	2018	2025
Software:	$483.3m	$6.6b
Hardware:	$504.3m	$6.4b
Services:	$1.0b	$13.6b
TOTAL:	**$1.2b**	**$26.5b**

AI-Based Services

- Includes both B2B services (AV simulation testing) and in-vehicle services (behavioral, situational, and personalized service recommendations).
- Will be the top revenue segment, as nearly all OEMs, suppliers, and tech providers are focused on developing recurring revenue streams across the forecast period.

Automotive AI Total Revenue by Segment, World Markets: 2017-2025



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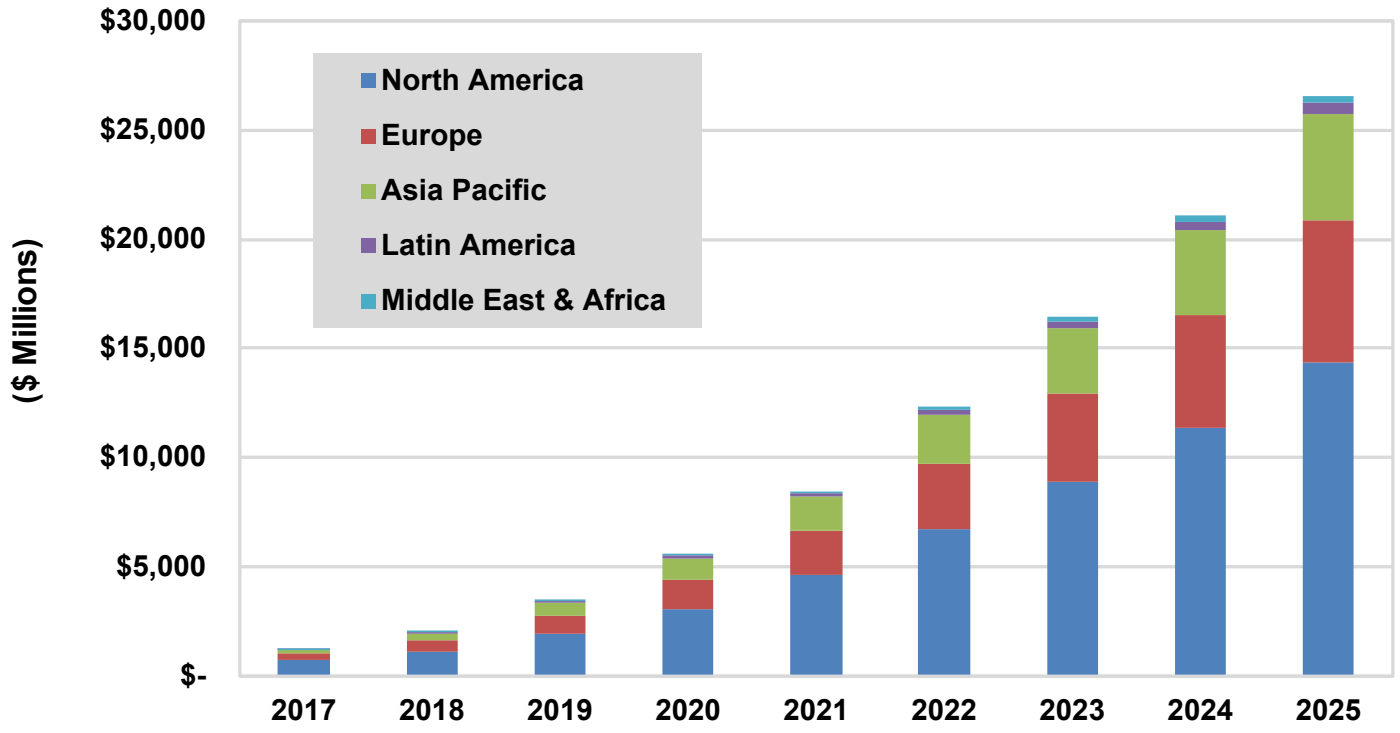
Global Automotive AI Market Forecasts by Region

Geographic Distribution of Revenue

- AI technology will be deployed in regions where there is a significant base of testing facilities, manufacturing locations, and potential end-user market opportunities, which are concentrated in North America, Europe, and Asia.
- Most AV testing today is occurring in these regions.
- Pockets of on-road testing exist in other select markets, including cities in the Middle East and Latin America.
- China represents a huge potential market for both AV and connected vehicle services.

Automotive AI Total Software, Service, and Hardware Revenue by Region, World Markets: 2017-2025



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Global Automotive AI Forecasts by Use Case

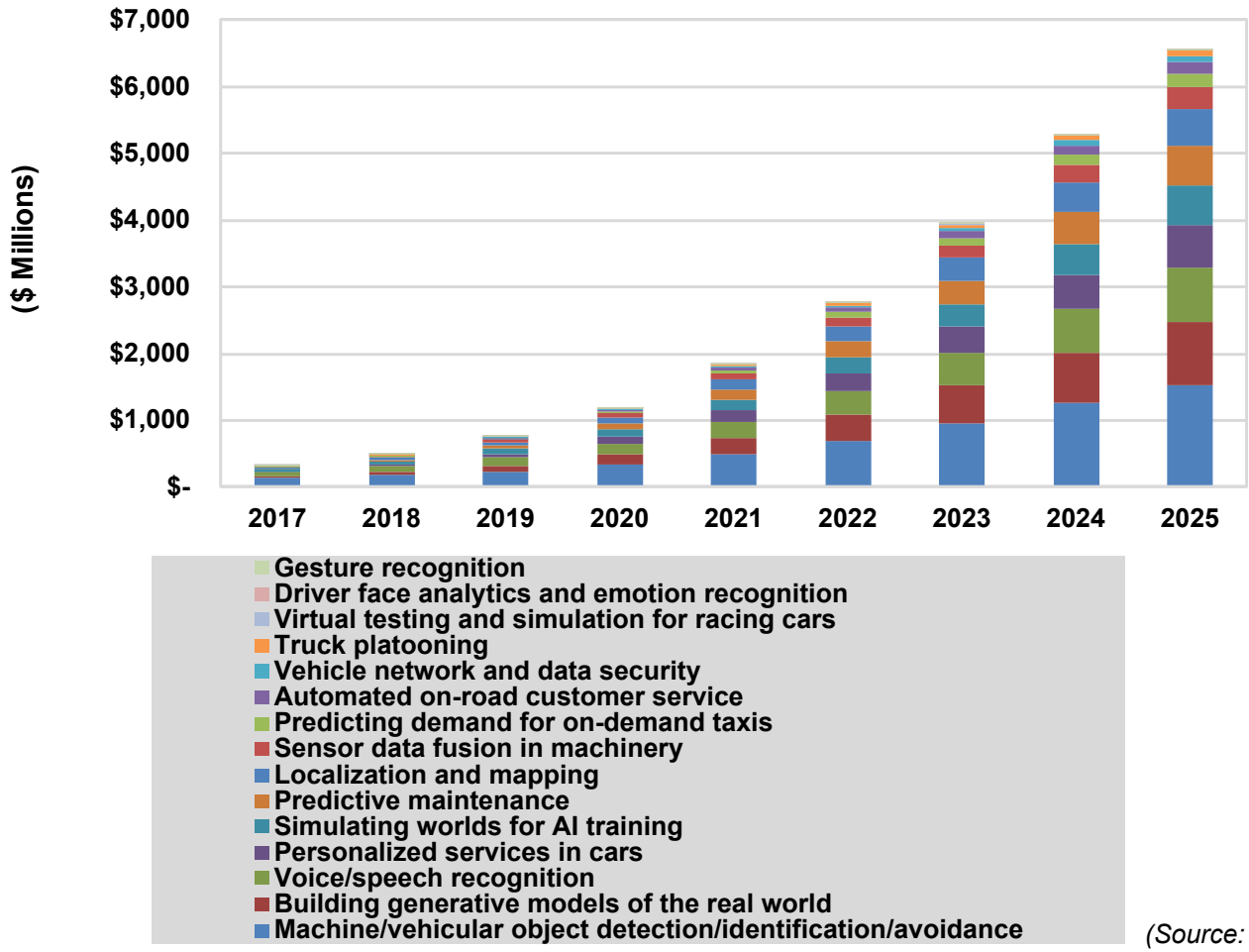
15 automotive use cases will collectively generate more than $23 billion in cumulative software revenue between 2017 and 2025.

The top 5 use cases (each generating more than $2 billion in cumulative revenue) include:

- Object Detection and Avoidance
- Building Generative Models of the Real World & Simulating Worlds for AI Training
- Voice/Speech Recognition
- Personalized Services in Cars
- Predictive Maintenance

While Level 4 and Level 5 AVs and fully-connected cars are not projected to become commonplace within the forecast period, there is significant development and testing activity occurring across each use case.

Automotive AI Total Revenue by Use Case, World Markets: 2017-2025



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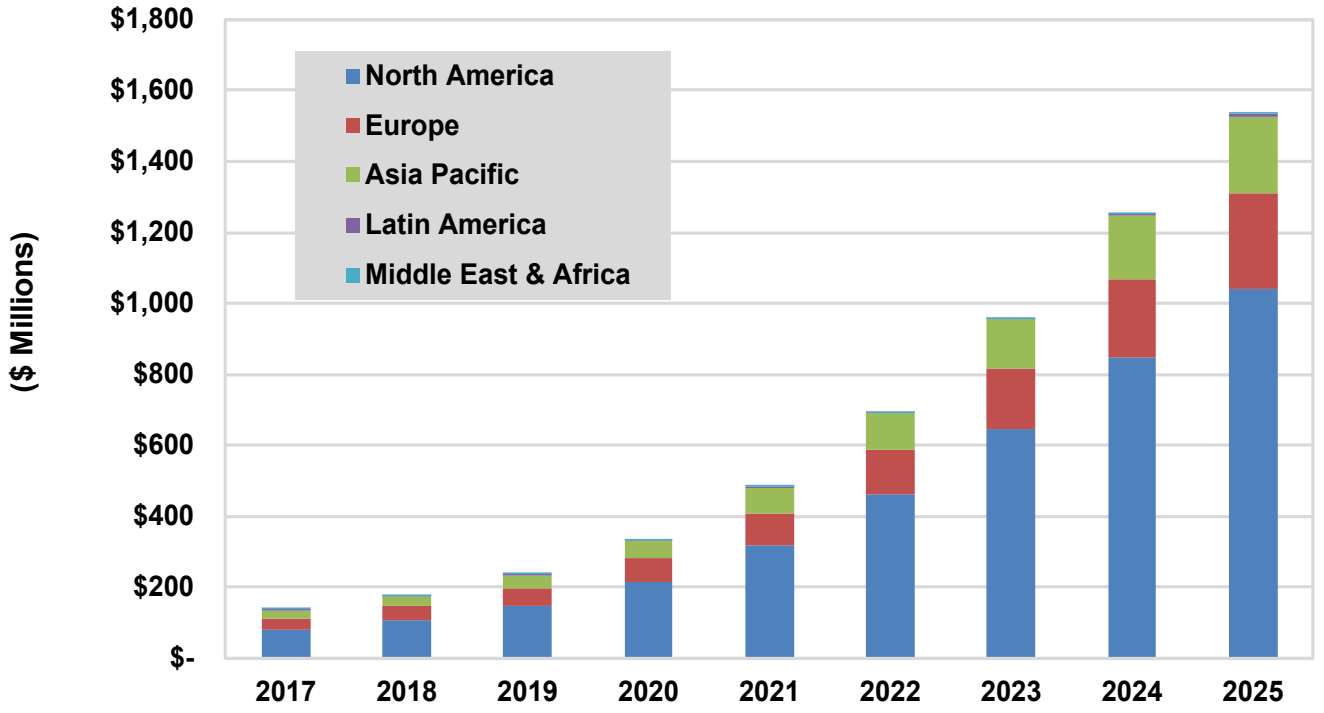
Use Case: Object Detection/Identification/Avoidance

- Object avoidance technology is a cornerstone of AV functionality, and will generate $1.5 billion in annual revenue by 2025, up from $174.5 million in 2018.
- ML algorithms are applied to object databases to train machine vision and other sensors to recognize these objects during different driving scenarios (high vs. low-speed, variable lighting conditions, weather, partial obstruction, etc.)
- AVs use a combination of sensors (lidar, radar, machine vision, mapping) to allow the vehicle to "see" objects; then inference models are used to guide the vehicle's responses.
- Testing is initially conducted in 3D simulation, followed by real-world, on-road testing.
- AI is used to continually refine and train the system, so that the accuracy and speed continually improves.

Automotive AI Software Revenue for Machine/Vehicular Object Detection/Identification/Avoidance by Region, World Markets: 2017-2025



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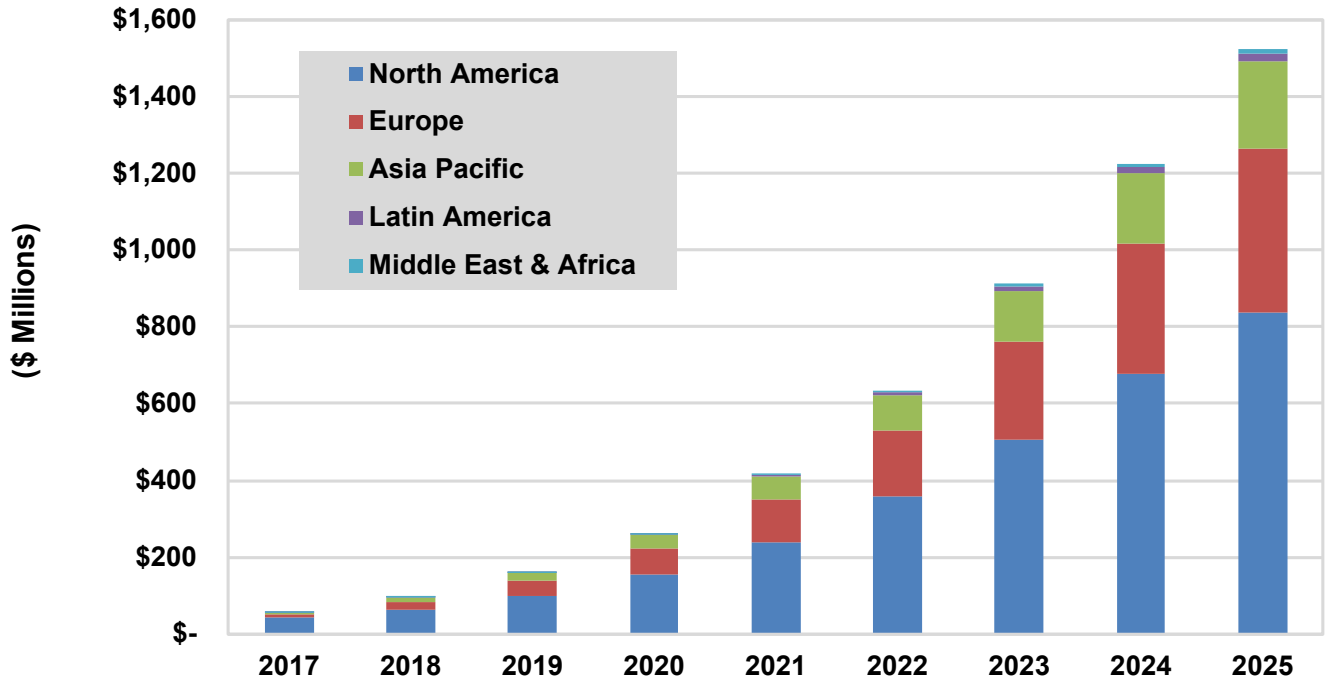
Use Case: Building and Simulating Models of the Real World

- Revenue from building and simulating models of the real world for AV testing will reach $1.5 billion by 2025, up from $94.6 million in 2018.
- Testing of AVs usually begins in virtual worlds, which feature accurate models of specific highways, roads, and environments.
- Additional agents are inserted, including people, animals, other drivers, to create a life-like scenario. Specific behavioral patterns can also be applied, such as making drivers in New York more aggressive than those in Mountain View.
- Advanced models also include other elements, including weather, variable lighting conditions, road construction, and vehicle system failure models.
- Simulation models developed by AV technology companies are being used to train their own systems, but some companies may license these simulators for other vendors to use, as well.

Automotive AI Software Revenue for Building and Simulating Models of the Real World, by Region, 2017-2025



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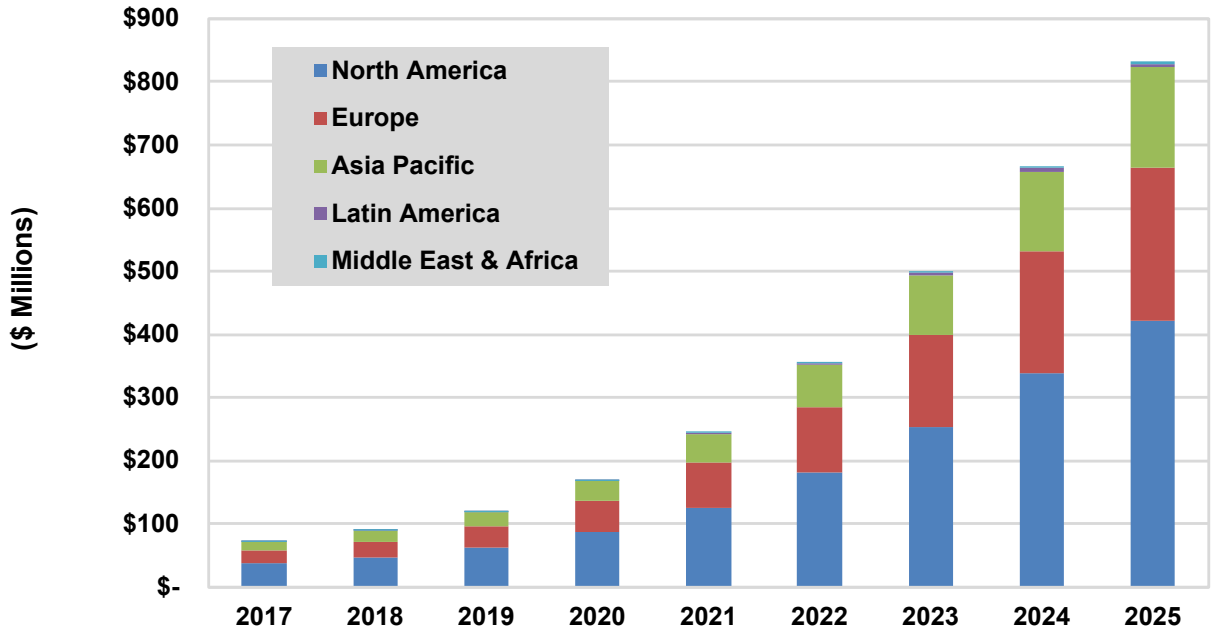
Use Case: Voice/Speech Recognition

- Voice/speech recognition will generate $831.6 million in annual revenue in 2025, up from $89.6 million in 2018.
- NLP enables voice/speech recognition, the most logical input method for vehicles, to avoid driver distraction.
- AI can be used to address specific challenges.
  - Humans convey thoughts in a non-linear fashion, and don't always use specific keywords or phrases
  - Humans may jump to different content threads, or speak to others in the car in the midst of providing a command to the system.
  - Accent, tone and sentence construction style are all highly individualized.
- Powerful NLP engines, combined with ML algorithms, can quickly learn how individuals speak, thereby improving the use of voice/speech recognition as a key method of controlling a vehicle's primary and secondary (infotainment) systems.

Automotive AI Software Revenue for Voice/Speech Recognition by Region, World Markets: 2017-2025



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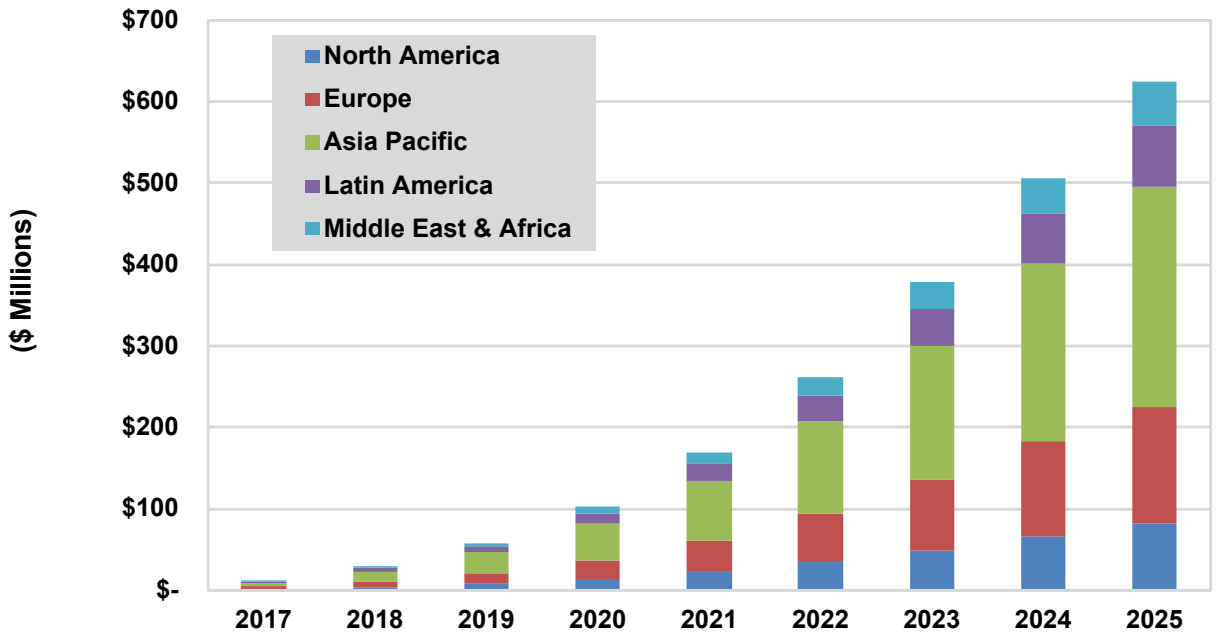
Use Case: Personalized Services in Cars

- Vehicle personalization, including learning the preferences of drivers, will generate $624.9 million in 2025 revenue, up from $29.3 million in 2018.
- ML algorithms can learn basic infotainment preferences, such as selecting favorite radio stations or automatically selecting preferred routes to destinations, simply by driving the vehicle and allowing the algorithm to process and find patterns in the data.
- Algorithms can also extend to driving tasks like automatically adjusting how the engine responds to an individual's driving style, such as automatically engaging a "sport" mode, or adjusting the sensitivity of lane-keeping assist or automatic braking technology, based on driver tendencies.
- Personalized services likely will be heavily tied into the V2X ecosystem, leveraging personal data, location data, and advertiser activity.

Automotive AI Software Revenue for Personalized Services in Cars by Region, World Markets: 2017-2025



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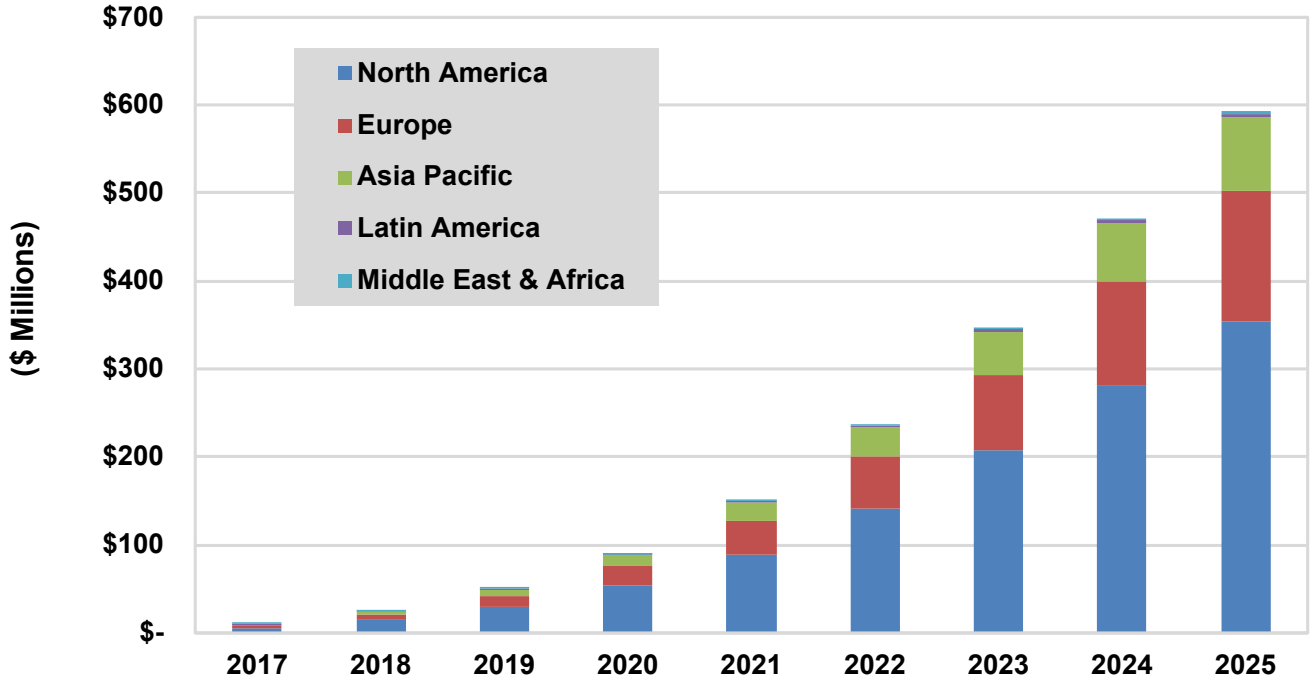
Use Case: Predictive Maintenance

- AI-based predictive maintenance will reach $593.3 million in annual revenue by 2025, up from $24.8 million in 2018.
- AI systems can take into account additional data, such as the style of driving, as well as more detailed assessments of wear to create more accurate models for scheduling maintenance on a particular vehicle's systems.
- By analyzing data generated by vehicle sensors, anomalies and issues can be detected early before they turn into component or system failures.
- Analysis of the data can inform precise, proactive repairs that save time and money.
- AI-based maintenance algorithms can also identify specific patterns of use (e.g. heavy braking, excess off-road operation) that may be impacting a specific component or system, and alert the owner.

Automotive AI Software Revenue for Predictive Maintenance by Region, World Markets: 2017-2025



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Future Outlook

Total AI Software Market Opportunity: $26.5 billion in annual global software revenue by 2025; six use cases will pass $500 million in annual revenue by 2025.

Near Term

- Real-world and simulated testing will continue in select markets; focus is shifting from pure highway driving to suburban and urban environments.
- OEMs and developers may introduce scaled-down Level 4-5 features on Level 2+ cars to incorporate tech in the real world.
- Personalized services are begin to appear in vehicles over the next 2 years; will incorporate more AI learning models over time.

Long Term

- AVs need more than 11 billion miles of training to be deemed fully road worthy: a combination of simulation and real-world testing will be required to make this happen.
- Personalized services will be commonplace in vehicles, given the strong desire of market participants (carriers, OEMs, and third-party service providers) to create and grow recurring revenue streams.

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