DRIVERLESS FUTURES

Scenario-Based Intelligence

Prospectus

Fall 2015

www.strategicbusinessinsights.com

Overview

Self-driving road vehicles represent a **disruption** that is unprecedented in both magnitude and scope.

At the same time, the extent and timing of self-driving vehicles' commercialization depends on the outcome of many uncertain forces that will play out in ways that **no one can accurately predict.**

Strategic Business Insights (SBI) has a **proven process** for considering the wide range of issues and uncertainties surrounding self-driving vehicles in a systematic way.

Driverless Futures uses this process to address the question: **What is the future of driverless cars, trucks, and other road vehicles from a global perspective?**

What are driverless road vehicles?

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SAE Levels of Automation

	Definition	System Example	Vehicle Example
1	Driver Assistance	Electronic stability control	Every new car sold in EU, US, Canada
2	Partial Automation	Stop-and-go cruise control with automatic steering	Select models from major automakers
3	Conditional Automation	Vehicle controls all safety functions some of the time; driver must assume control when required	Google driverless car (2010); experimental vehicles from automakers and universities
4	High Automation	Vehicle controls all safety functions some of the time, and can continue to operate safely if driver fails to take control	Google driverless car (2015); similar concept vehicles
5	Full Automation	Vehicle controls all safety functions all of the time, in all conditions that a human driver could handle	Concept vehicles only

What's available today?

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- Many vehicles available for purchase today feature limited self-driving capability (SAE level 2)
- Systems use a combination of adaptive cruise and automated steering

Adaptive Cruise

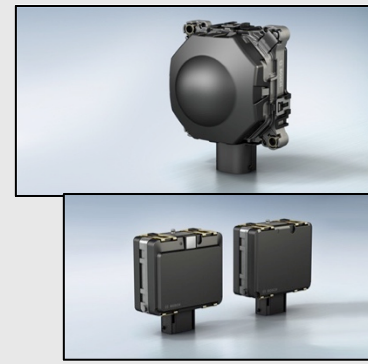
Adaptive cruise control keeps vehicle as close as possible to a preset speed, while maintaining a selectable following distance

Automated Steering

Automated steering with lane-centering actuates steering systems directly to keep vehicle traveling in the middle of its current lane

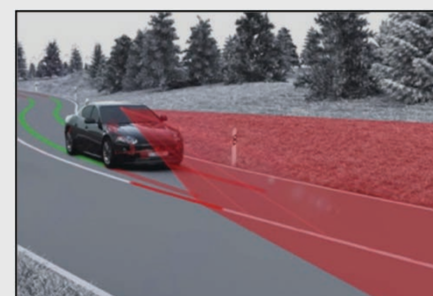
Radar Systems

A combination of short, medium, and long-range radars (rarely, 2D lidars) facilitates adaptive cruise



Machine-Vision Systems

Machine-vision systems (single/ stereo camera) facilitate lane-centering via reading lane markings, with input from ultrasonics



What's on the horizon?

LEVEL 2.5 SYSTEMS

- Deliver an increasingly "hands-off" experience for long portions of a drive
- May perform some maneuvers on demand while vehicle is in motion on a highway; for example, Tesla has implemented automated lane changes that a driver initiates via flicking the vehicle's turn signal
- May self-deliver unoccupied vehicles to and from parking spaces ("autonomous valet mode"), but only on private property
- Manufacturers still expect drivers to pay attention at all times

Tesla is unique among automakers in offering software-upgradeable automation features that install via over-the-air updates. Vehicles built after fall 2014 equipped all the hardware necessary to enable automation features. An October 2015 software update enabled self-steering adaptive cruise with automated lane changes

Now in testing

LEVEL 3 SYSTEMS

- Many companies—perhaps most famously Google—have been testing level 3 vehicles on public roads for years
- The prevailing experimental approach combines radar, camera, and ultrasonic sensors with very expensive 3D lidar scanners
- Lidar scanners are used mainly for precision localization—finding the vehicle's location very precisely with reference to a pre-computed map
- Secondary use of lidar scanners is obstacle detection (something that doesn't exist in the map usually is an obstacle)
- Downsides (besides sensor costs): map data sets are very large; maps need to be kept up to date (requiring probe vehicles to scout areas for operation)

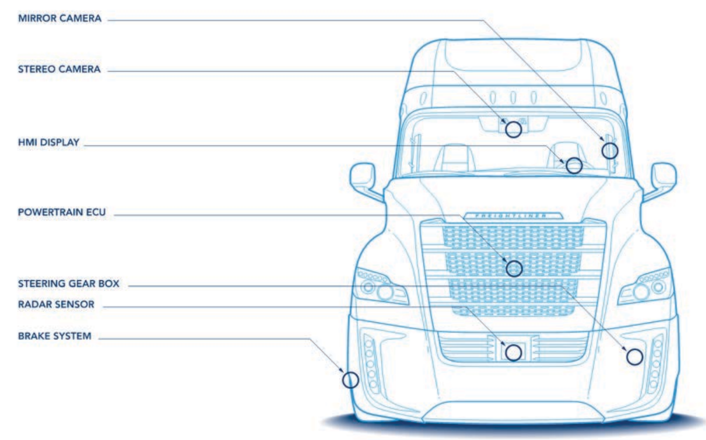
Limits and alternatives

HUMAN FACTORS

- Real-world testing has found that it is difficult for humans to take over control from the automated system when requested; drivers may take 60 seconds or more to regain the situational awareness needed to drive safely
- Of course, fully automated vehicles won't have this problem, and level 4 vehicles will have means to mitigate it

MAPPING AND SENSING

- Lidars are expensive and limited, but many companies are working on better and cheaper lidar
- Level 3+ might be achievable with existing camera/radar/ultrasonics fusion
- Advances in machine vision, V2X, platooning, and other techs/approaches could provide lidar alternatives

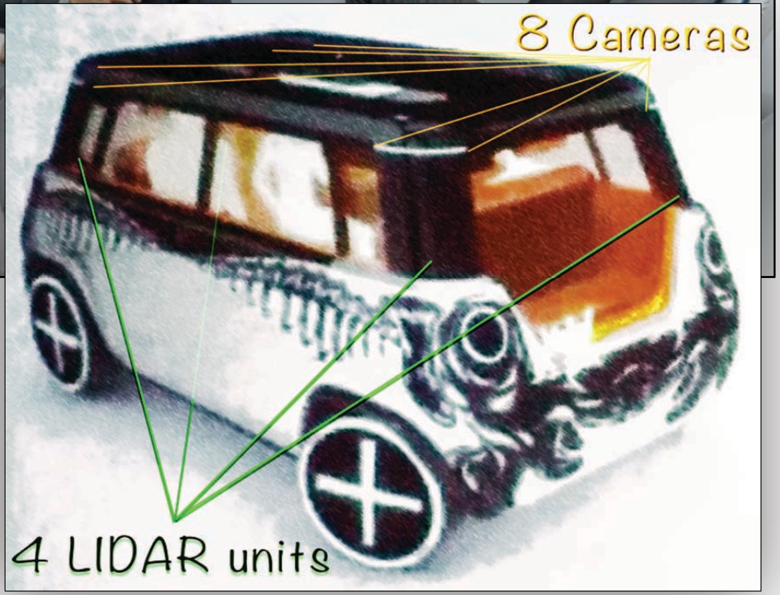


The Freightliner Inspiration autonomous truck uses largely conventional sensing to achieve level 3 operation

Future concepts

Many companies are envisioning how driverless technology may transform vehicle forms and functions

Concept driverless vehicle interiors are often flexible spaces that enable leisure, productivity, and social activity



Zoox's "Yolo" concept car has quadrant-based symmetry and bidirectional driving capability

Benefits of a driverless society

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In the United States alone, driverless vehicles could save

- **$563 billion** in costs from injuries and fatalities
- **$158 billion** in fuel costs
- **$149 billion** in costs from roadway congestion
- **$422 billion** in lost productivity
- **28,800** lives

Every year. *— Morgan Stanley*

"Our vision is that no one is killed or injured in a new Volvo by 2020." *— Anders Eugensson, Head of Govt. Affairs, Volvo*

Many industries could be disrupted

Agriculture

Automotive

- Manufacturing
- Sales/Leasing
- Financing
- Service
- Materials

Entertainment

Energy

- Conventional
- Natural Gas
- Smart Grid
- Energy Storage

Health Care

Human Resources

Information Tech

- Connectivity
- Cybersecurity
- Internet of Things
- Telematics

Infrastructure

- Construction
- Management

Insurance

- Vehicle Insurance
- Health Insurance
- General Liability

Logistics

Manufacturing

Public Administration

- Urban Planning
- Public Safety
- Land Use

Retail & Hospitality

Transportation

- Personal
- Transit
- Trucking
- Multimodal
- Railway

No one knows when the biggest disruptions will occur

"In **less than a year**, you'll be able to go from highway on-ramp to highway exit without touching any controls." *— Elon Musk, CEO Tesla, Speaking in 2014*

"Completely driverless cars are **20 to 30 years** away." *— John Capp, Dir. Active Safety, GM*

Series-built cars with autonomous functions "will be technically feasible **this decade**." *— Rupert Stadler, CEO Audi*

"Nissan will be ready with … Autonomous Drive in multiple vehicles by the year **2020**." *— Nissan USA*

"Self-driving cars that include driver control are expected … before **2025** and self-driving 'only' cars are anticipated around **2030**." *— IHS*

"Self-driving vehicles [will comprise] 75 percent of the traffic stream by **2040**." *— IEEE*

Many hundreds of forces influence the timing and nature of the outcome

Here are just a few:

- **TECHNOLOGY READINESS** — *Will self-driving cars work? How well will they work?*
- **SYSTEM COST** — *Will they be affordable? If so, when? By whom?*
- **REGULATIONS** — *What will be permitted? Where will it be permitted? When?*
- **CUSTOMER ACCEPTANCE** — *Will people trust, resent, and/or exploit self-driving cars?*
- **CONNECTIVITY REQUIREMENTS** — *How much bandwidth is needed? How often?*
- **MARKETS** — *Who will be the customers for self-driving technologies?*
- **URBAN ADAPTATION** — *How will cities welcome/leverage/limit self-driving cars?*
- **BUSINESS MODELS** — *Who will own the cars? How will people pay to access them?*

SBI's scenarios provide a sound basis for addressing uncertainty

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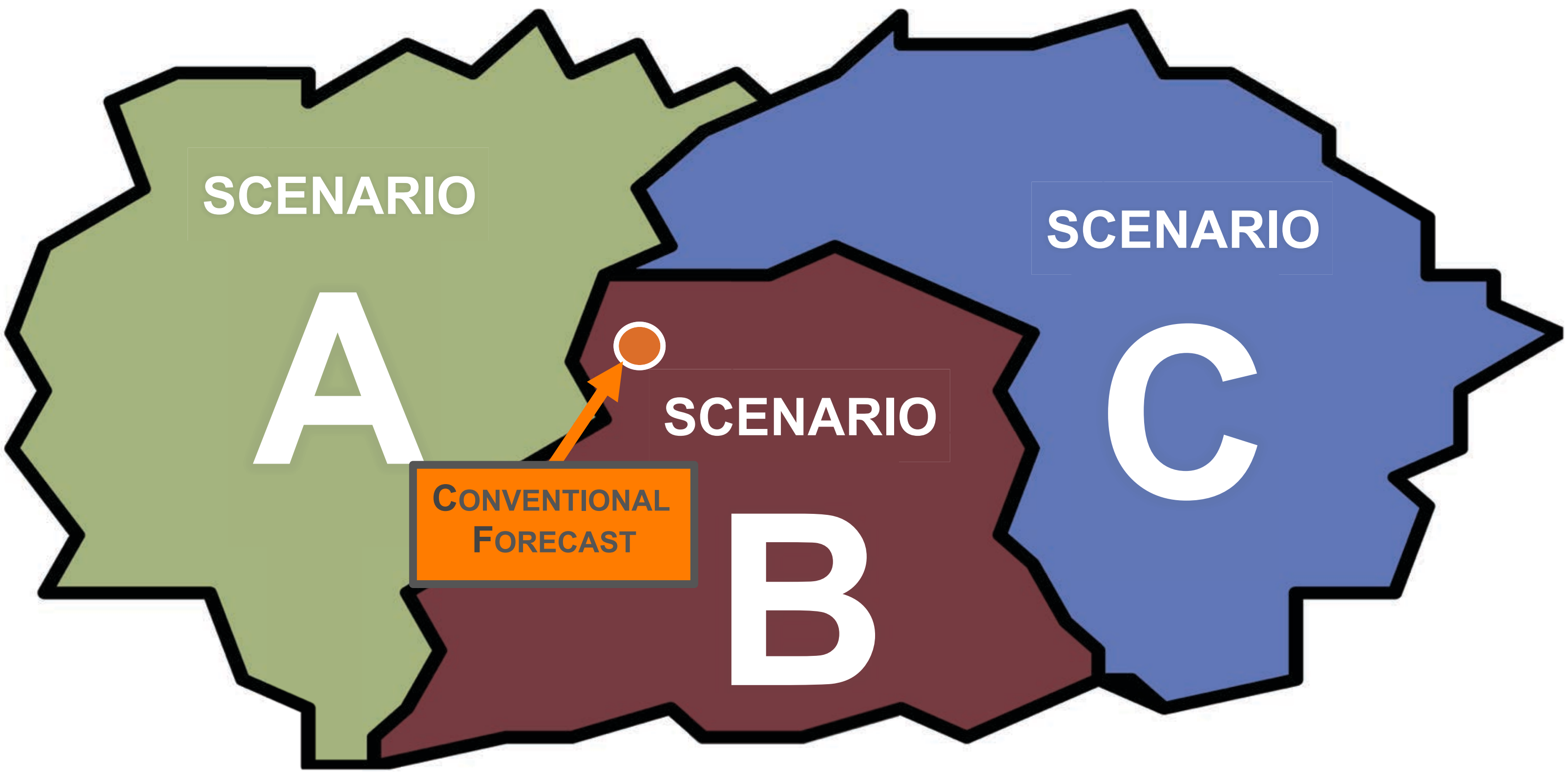
Conventional forecasts, including "most likely" cases, fall short.



Scenarios are not predictions. Scenarios are descriptions of alternate plausible futures.

SBI's approach

Issue Focus: What is the future of driverless cars, trucks, and other road vehicles from a global perspective?

Process	Deliverables
1. Collect Forces and Drivers	
2. Construct Scenarios	Scenario Narratives
	Comparison of Scenario Variables Table
3. Create Scenario Roadmaps	Scenario Roadmaps
4. Identify Discontinuities	Discontinuity Analysis Reports
5. Monitor Critical Developments	Targeted Monitoring + Scenario Updates
	Ongoing Client Support

Scenario narratives

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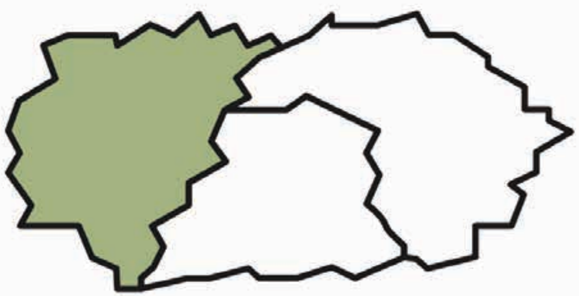
Narratives tell three distinct, challenging, self-consistent, and plausible stories about automated-vehicle development between now and 2030

Each narrative begins with quick highlights that cover the most important elements of the scenario.



Scenario A

Can't Keep Up

Scenario Highlights:

- HIGHEST LEVELS OF AUTOMATION
  In 2030, level-5 systems offer go-anywhere capability at a premium price; level-4 systems are luxury options; level-3 systems are becoming mainstream
- FASTEST PACE OF DEVELOPMENT
  First commercialized level-4 systems by 2021; first level-5 by 2023; widespread availability of cheap level-3 systems in 2030
- MAJOR INDUSTRY DISRUPTIONS
  Apple Auto is the first level-5 car; China becomes a global center for R&D and

The details of each narrative expose how the various scenario elements interact with one another in complex ways.

Cyber- and Real-World Vulnerabilities

Cyberattack methods have outpaced defenses consistently for years, resulting in frequent disruptions to infrastructure and business, some of which have had long-lasting consequences. Malicious actors have exploited vehicle systems successfully many times, although truly damaging exploits have generally required prolonged physical access to vehicle systems. Governments have taken advantage of lax security, using cyberattacks against adversary-nations' economies as a "shot across the bow" during confrontations.

Crime levels have trended upward—sometimes substantially—in many urban areas worldwide. Autonomous vehicles' relatively limited capabilities have in turn limited their

Regulations and Uncertainty Constraining Vehicle Automation Development

Most jurisdictions worldwide have adopted regulations that limit the use of vehicle-automation systems and prevent users from realizing many of their potential benefits. Restrictions have typically mandated that users keep their hands on the wheel at all times or otherwise maintain "demonstrable readiness" to take control; in both cases, driver-monitoring systems must continually verify drivers' readiness. Nevertheless, users routinely bypass many mandated safety features.

Product-liability issues regarding vehicle-automation systems have remained poorly settled in most major jurisdictions. Drivers have almost universally remained primarily liable for their

Comparison of scenario variables

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Supplementary material gives rich additional detail about the specific elements that comprise each scenario

Can't Keep Up	Hand in Hand	On Your Own
SECURITY AND PRIVACY		
Cybersecurity		
Cybersecurity is a major issue in 2030, but not in the domain of autonomous cars, which don't depend on communications signals for safety-critical functions. Nevertheless, manufacturers have taken security very seriously and have implemented robust safeguards and countermeasures.	**Cybersecurity risks have not vanished but have largely been contained, aided to a great extent by public willingness to endure security measures that cause inconveniences and privacy intrusions.**	**Cyberattack methods have outpaced defenses consistently for years, resulting in frequent disruptions to infrastructure and business, some of which have had long-lasting consequences. Malicious actors have exploited vehicle systems successfully many times, although truly damaging exploits have generally required prolonged physical access to vehicle systems.**
A tenuous balance between attackers and defenders demands ever more sophisticated means to manage cybersecurity risks. While those risks continue to proliferate, the safety-critical operations of driverless vehicles have some natural resistance to electronic interference: Their guidance systems rely on in situ awareness of the roadway environment—especially visual awareness—not on electronic signals. Thus, autonomous vehicles are unattractive targets for hackers. But in an environment of escalating	High profile cyber-crimes and cyberterrorist incidents have ensured a continued security arms race. But thanks to strong government and corporate investment in security, combined with a fearful public that cooperates with inconvenient and intrusive security measures, public and private organizations are largely able to stay ahead of bad actors. A handful of successful technology suppliers license proprietary security technologies that are embedded in standards and have become de facto legal requirements for governments and	Companies and governments (throug are neglectful of cybersecurity; they la accountability and a sense of respons hacks that penetrate entire enterprise some cases, entire industry verticals– occurred on a regular basis. Cyberter other bad actors have sporadically tar infrastructure (including autonomous as much damage and inconvenience Bad actors may shut down communic systems as a prank, but cyberterrorist

The Variables Table arranges all three scenarios side by side, facilitating element-by-element comparison between scenarios.

Each variable includes a high-level description in bold text, followed by a much more detailed description.

Variables are arranged in the same general order as they appear within the scenario narratives.

Scenario roadmaps

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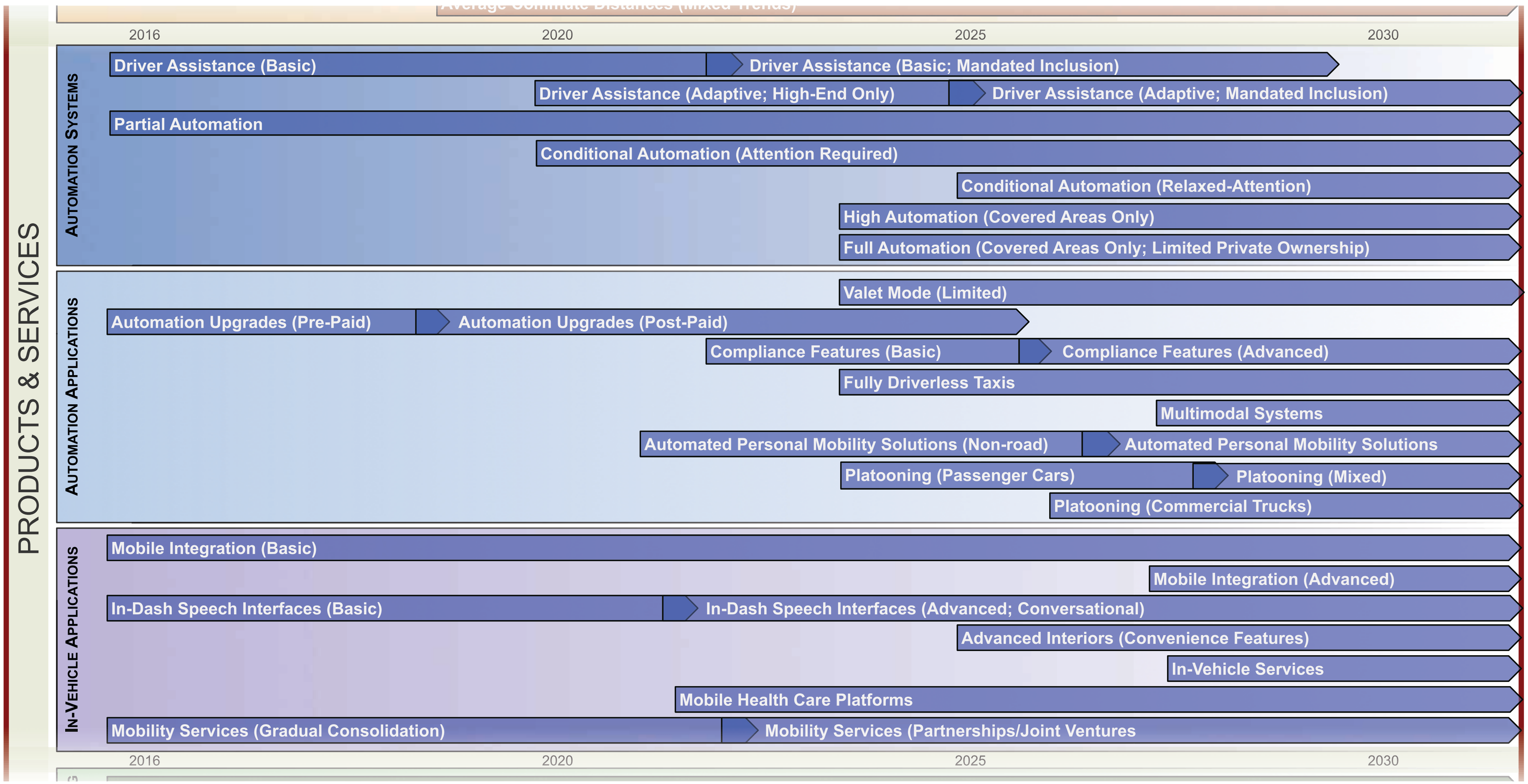
Three roadmaps illustrate key aspects of the scenarios, including business conditions, products, services, and technologies



Applications

Scenarios and Roadmaps are valuable tools for long-term strategic planning

OPPORTUNITY DISCOVERY	**Use the scenarios to help identify new product and service offerings that leverage organizational capabilities.** *"If we were in Scenario C, what products and services would we need to offer in order to succeed?"*
STRATEGY EVALUATION	**Stress-test alternative strategies against the scenarios.** *"How well would this strategy perform in Scenario B?"*
TARGETED MONITORING	**Use the scenarios and roadmaps to identify possible future events that could signal a need to change strategic direction.** *"You can't monitor everything…"*

Discontinuities

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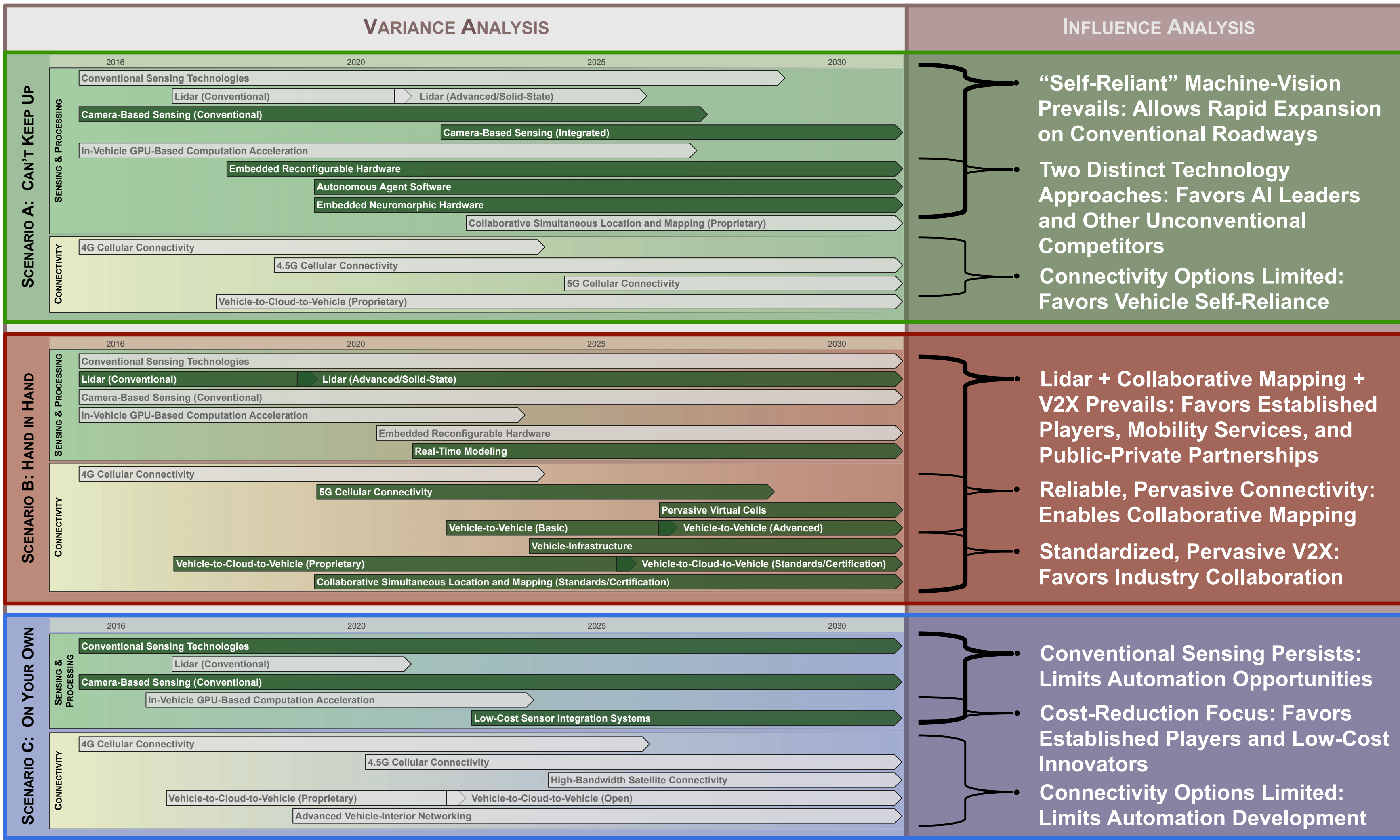
Comparative analysis of roadmaps reveals discontinuities: potential developments that have exceptional influence



Discontinuity analysis reports

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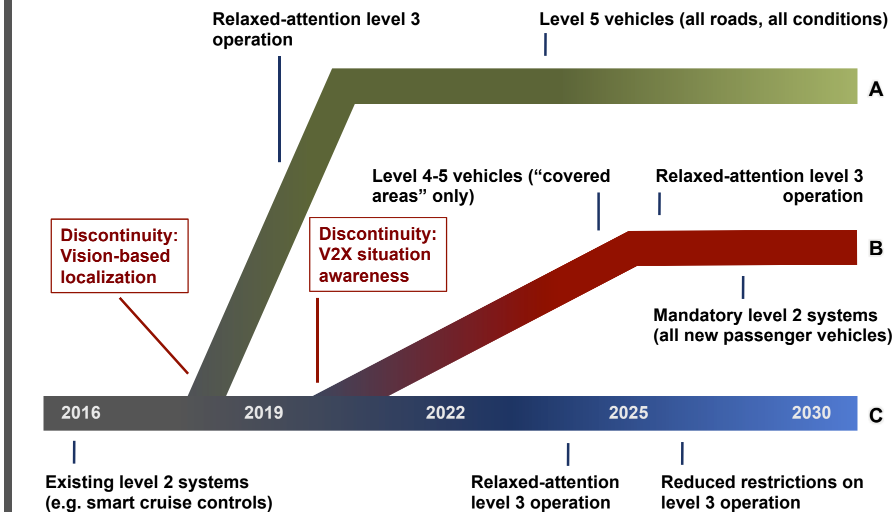
Detailed, research-based reports fully explore potential discontinuities, analyzing surrounding issues and identifying critical areas to monitor



Product Liability Laws

In many major markets, existing product liability laws may apply to current, emerging, and future automated vehicles

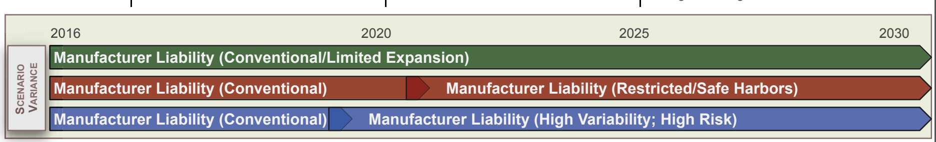
Theories of Liability

- **Negligence** may apply if a manufacturer (or other party) fails to exercise reasonable care, and that failure results in harm. Typically, liability is limited to "foreseeable plaintiffs"
- **Strict Liability** holds manufacturers liable for defective products even in the absence of negligence. Depending on jurisdiction, liability may also apply to importers, distributors, retailers, and other parties in the "chain of commerce" between producer and end consumer
- **Other theories** may include misrepresentation, breach of warranty, breach of contract, common carrier liability, unfair competition, and violation of statutory duty

Sources of Law

- **Statutes and regulations** are enacted through deliberate legislative or regulatory processes. Most product liability law outside the US is statutory in nature
- **Common law** derives from judicial precedent—the outcomes of prior similar cases. Adapts to new technologies and situations, albeit slowly

Types of strict liability	Design Defect	Manufacturing Defect	Failure to Warn
Description	Some element of a product's design causes harm, and a reasonable alternative design would not have caused the harm	A flaw in the particular product introduced at the time of manufacture caused harm	Manufacturer fails to provide adequate warning of the risks of using a product, and harm results on account of this lack of warning
Example	Vehicle's main sensor has a limited field of view, causing sensor blind-spots that led to collision; incorporation of a different sensor of roughly equal cost (or integration of inexpensive additional sensors) would have prevented the collision	Vehicle shipped with a faulty proximity sensor that fails to detect the presence of a bicyclist in area not covered by other sensors, causing a collision	Vehicle is unable to maintain automated driving mode when exposed to sudden direct sunlight and switches to manual mode immediately in such cases; driver does not expect this behavior and is not able to retake control of vehicle quickly enough, causing a collision



Scenario B: Certification Regimes

Government regulators proactively establish certification regimes that driverless vehicle makers and operators must adhere to, but these regimes limit liability; simultaneously, individuals must meet special licensure requirements

Major Developments:

Proactive regulators partner with major industry players to establish new liability regimes for vehicle automation technologies. In exchange for limitations on liability, manufacturers must certify new hardware and software with regulatory bodies and vehicle operators must certify maintenance and safety

Image: Federal Register

Regulators mandate adoption of standardized V2X and active safety

Orig. Image: Algkalv

Most jurisdictions limit level 4 and 5 vehicles to designated "autonomy zones"

Image: RGJ

New liability regimes allow easier recovery in lawsuits but greatly limit damages

Major Impacts:

New liability regimes help smooth commercialization of level 4 and 5 vehicles, but accompanying certification rules greatly lengthen time to market and result in fewer, more conservative designs, many of which are unattractive to end users. High ongoing certification costs and regulatory restrictions limit most level 4 and 5 vehicles to fleet use

Image: NHTSA

High V2X availability helps improve automation, while active safety mandates help make level 2 automation cheaper

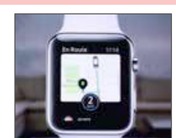


Image: TechCrunch

Most level 4 and 5 vehicles are available on-demand only as part of public-private transportation services

Image: Stephen Richards

Insurance loss ratios improve dramatically owing to smaller payouts, while liability is spread among more public/private entities

Driverless Futures in 2016

In addition to online access to existing scenarios and roadmaps, 2016 Driverless Futures sponsors will receive:

- **Analysis of four new discontinuity topic areas** including AI and Big Data and Security and Privacy, plus two others to be determined
- **Scenario and roadmap updates** reflecting information from SBI's targeted monitoring process
- **Additional client support options,** including customized workshops and opportunity profiles

DISCONTINUITY TOPIC AREAS:

- AI and Big Data
- Automation on Private Roads
- Autonomous Fleets and Smart Cities
- Business Models
- Cargo and Package Delivery
- Cloud-Based Systems
- Electrification Synergies
- In-Vehicle Services
- Liability and Regulation (2015)
- Off-Road Automation
- Ownership and Access (2015)
- Security and Privacy
- Sensing and Guidance (2015)
- Vehicle Forms and Materials

Plus two additional selections for coverage in 2016

Client Support

Each Driverless Futures 2016 sponsorship includes at least one presentation or workshop and ongoing access to SBI analysts

Basic Sponsorship	**Client-Private Presentation or Workshop** • *Presentation:* In-depth private review of scenarios, roadmaps, and one or more Driverless Futures 2016 Discontinuity Analyses • *Targeted Monitoring Workshop:* Use Driverless Futures scenarios to explore how specific potential developments may impact client business activities or strategic goals
Opportunity Discovery	**Customized Opportunity-Discovery Workshops** • Use Driverless Futures scenarios to uncover new applications for client's technology and capability portfolio • Identify and refine the most promising applications based on objective criteria
	Customized Opportunity Profiling • SBI team develops detailed, research-based profiles for one or more selected opportunities

About SBI

- SBI is the former Business Intelligence division of **SRI International** that has worked with clients on opportunities and change since 1958. Headquartered in Silicon Valley—with offices in Japan, the United Kingdom, and New Jersey—we have a global reach and work across a wide range of government and business sectors.

- SBI has **decades of experience** in scenario planning for commercial and government enterprises.

- SBI's scenarios teams include **consumer-behavior experts** from SBI's world-leading VALS™ service.

- SBI works with clients to identify and map new opportunities based on emerging technology and market insights. **We combine ongoing research with consulting services.** Our research services operate across industries and cover a very broad range of technology, market, regulatory, economic, and social developments.

- SBI has a long **history of working with major automakers, their suppliers, regulators, and other stakeholders** in automotive, intelligent transportation systems, and related industries.