The Promise and Challenges of Automated Technologies

Walking and Bicycling in an Automated Future (Part I)

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August 16, 2017

Housekeeping

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Policies to Prepare for an Automated Future

August 31, 1:00 – 2:30 PM Eastern Time

Mollie Pelon
National Association of City Transportation Officials

Susan Handy
UC Davis National Center for Sustainable Transportation

Joe Iacobucci
Sam Schwartz

Art Pearce
City of Portland

Walking and Bicycling in an Automated Future

Laura Sandt,

Senior Research Associate, UNC Highway Safety Research Center

Director, Pedestrian and Bicycle Information Center

8/16/17

Billions invested in AV tech

CNN tech BUSINESS CULTURE GADGETS FUTURE STARTUPS

Ford just invested $1 billion in self-driving cars

by Matt McFarland @mattmcfarland

February 10, 2017: 3:16 PM ET

Intel's $15 billion purchase of Mobileye shakes up driverless car sector

Published 6:57 AM ET Tue, 14 March 2017 | **Updated 8:32 AM ET Tue, 14 March 2017**

REUTERS

MAR 3, 2017 @ 09:00 AM 17,690

12 Stocks to Buy Now

10 Million Self-Driving Cars Will Hit The Road By 2020 -- Here's How To Profit

TECH

Apple's Latest $1 Billion Bet Is on the Future of Cars

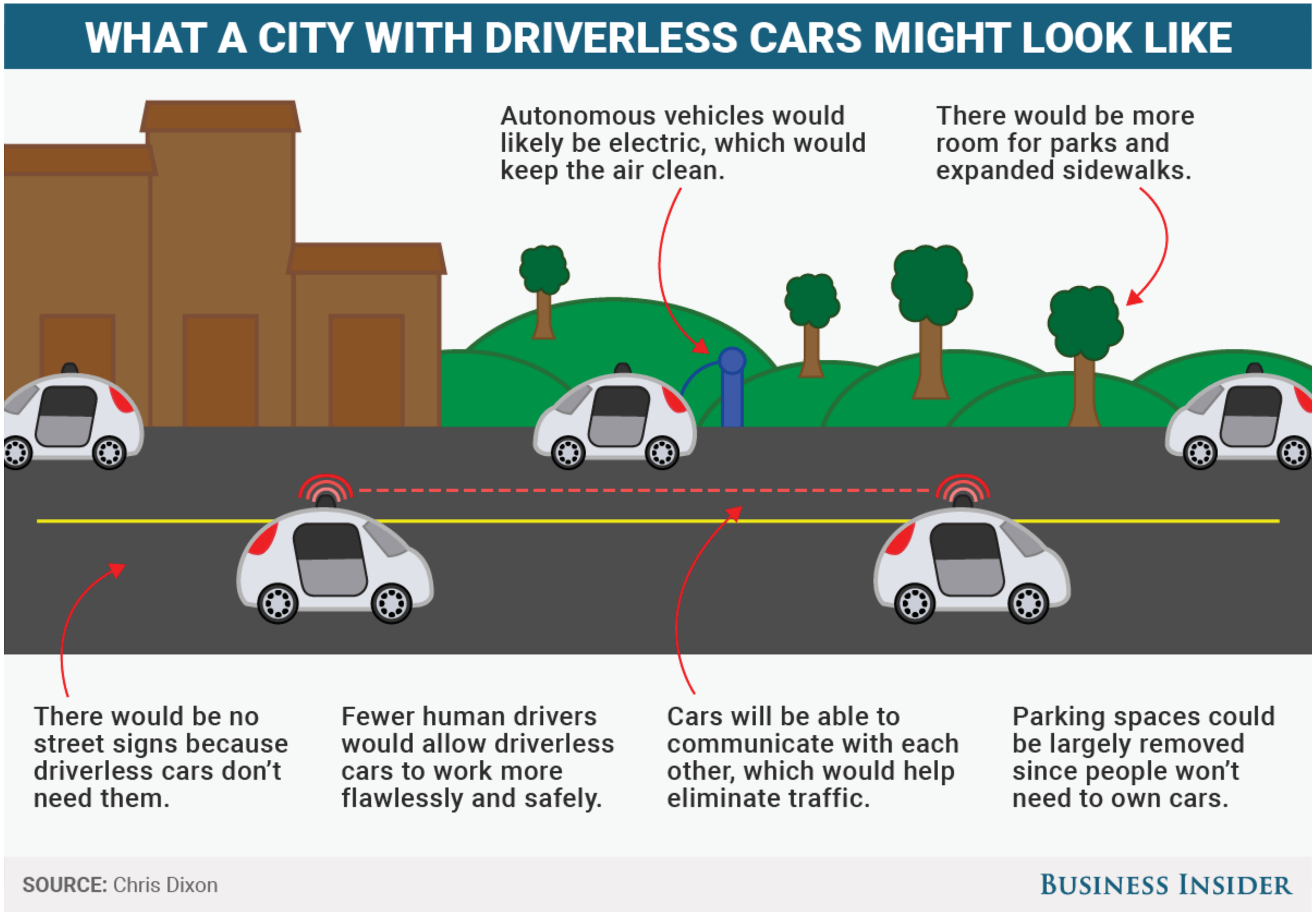
Chinese car-hailing service Didi Chuxing is an ally in a key market and a rich data source for self-driving vehicles

JAN 27, 2017 @ 05:00 PM 3,506

Car Tech Startup Investment Exceeds $1 Billion In 2016

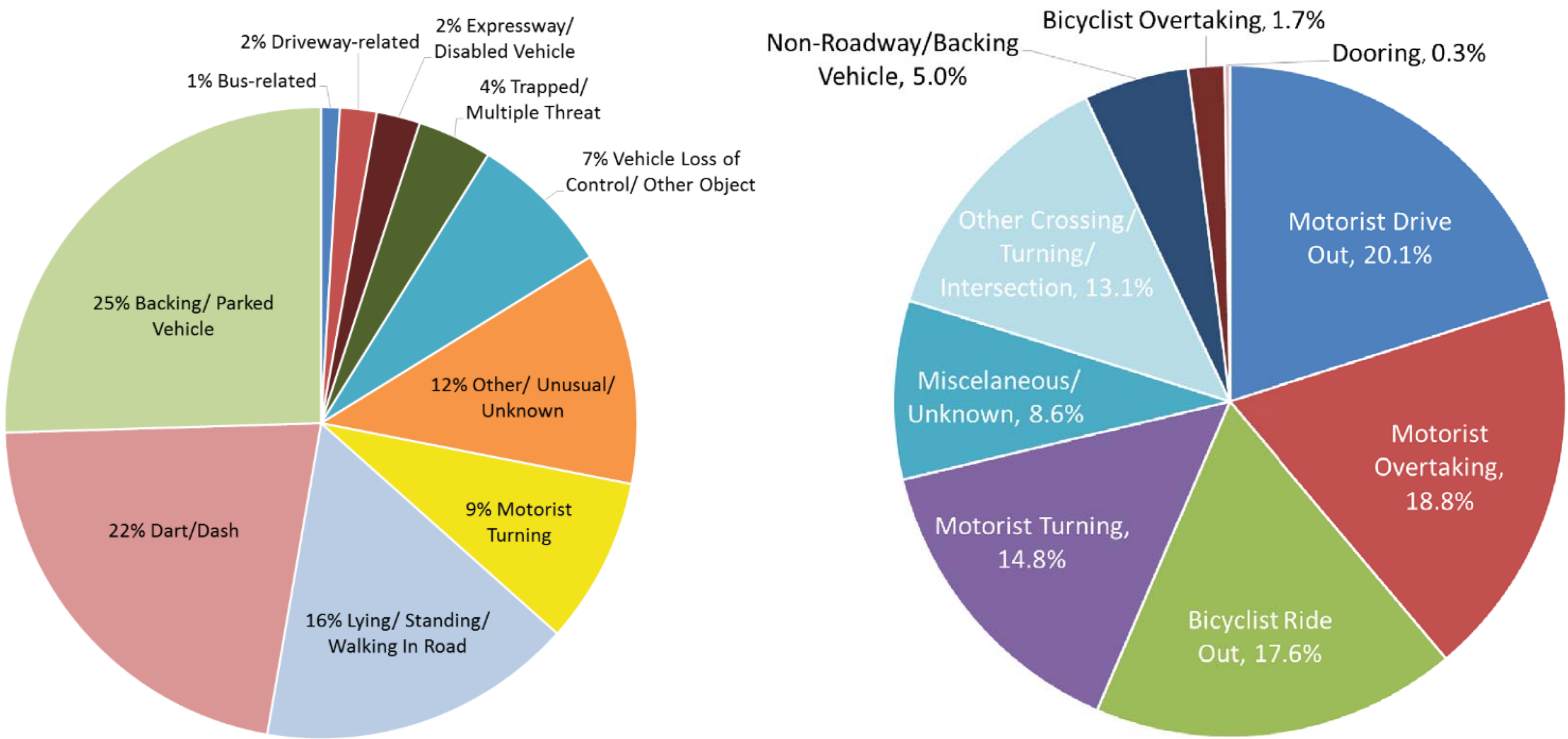
The promise of AV

- Safety
- Personal mobility
- Time productivity
- Energy use/fuel consumption
- Roadway capacity and land use efficiencies
- Profits



(Retrieved from: http://www.businessinsider.com/chris-dixon-future-of-self-driving-cars-interview-2016-6?r=UK&IR=T)

Common ped & bike crash types, at present

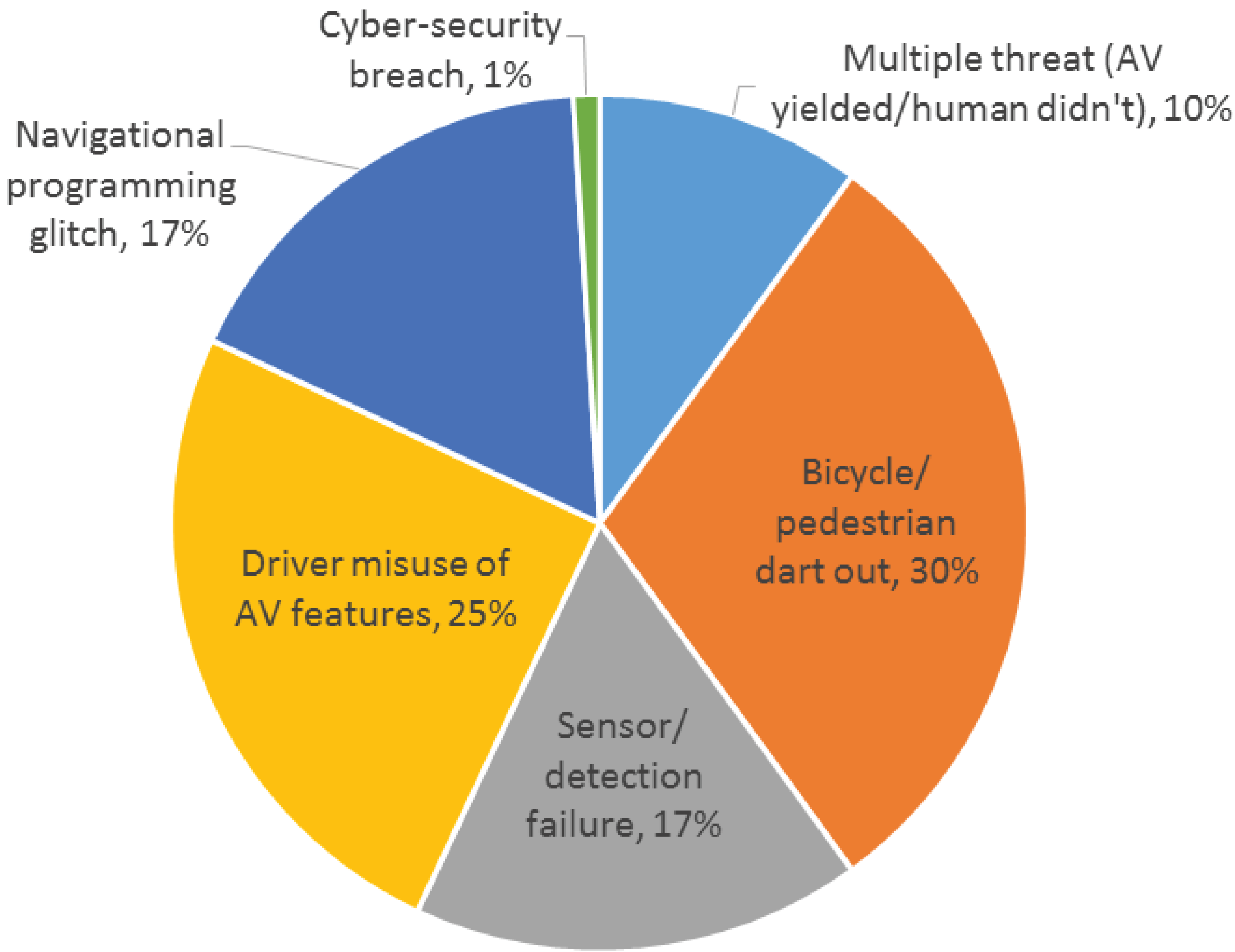


Source: UNC Highway Safety Research Center, NC Crash Data, 2007-2014

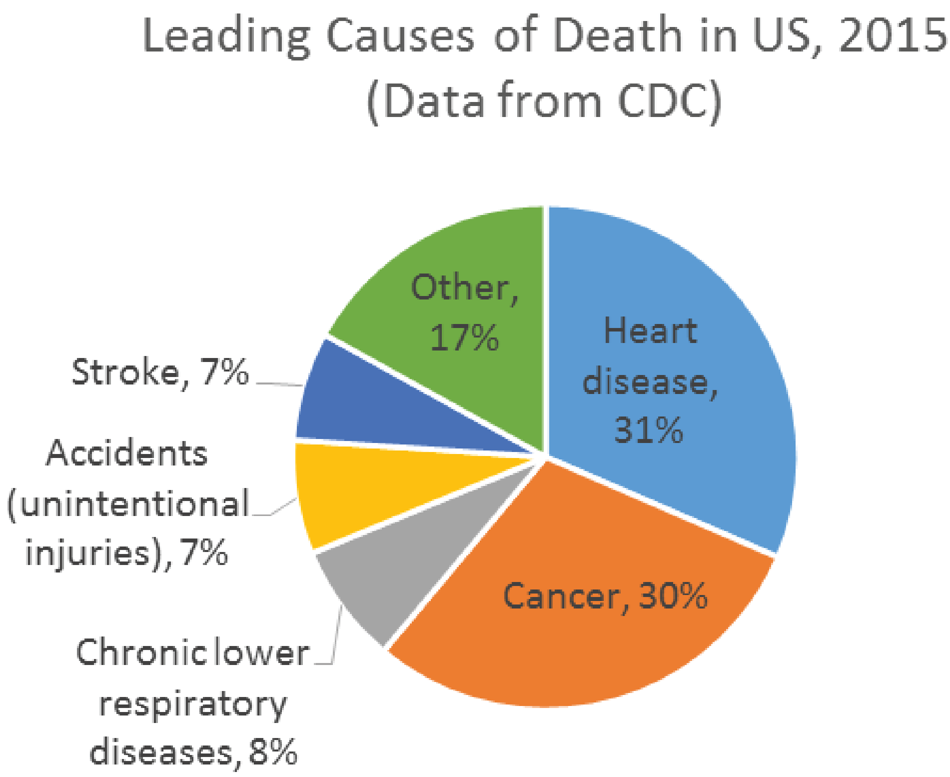
But what about unintended consequences?

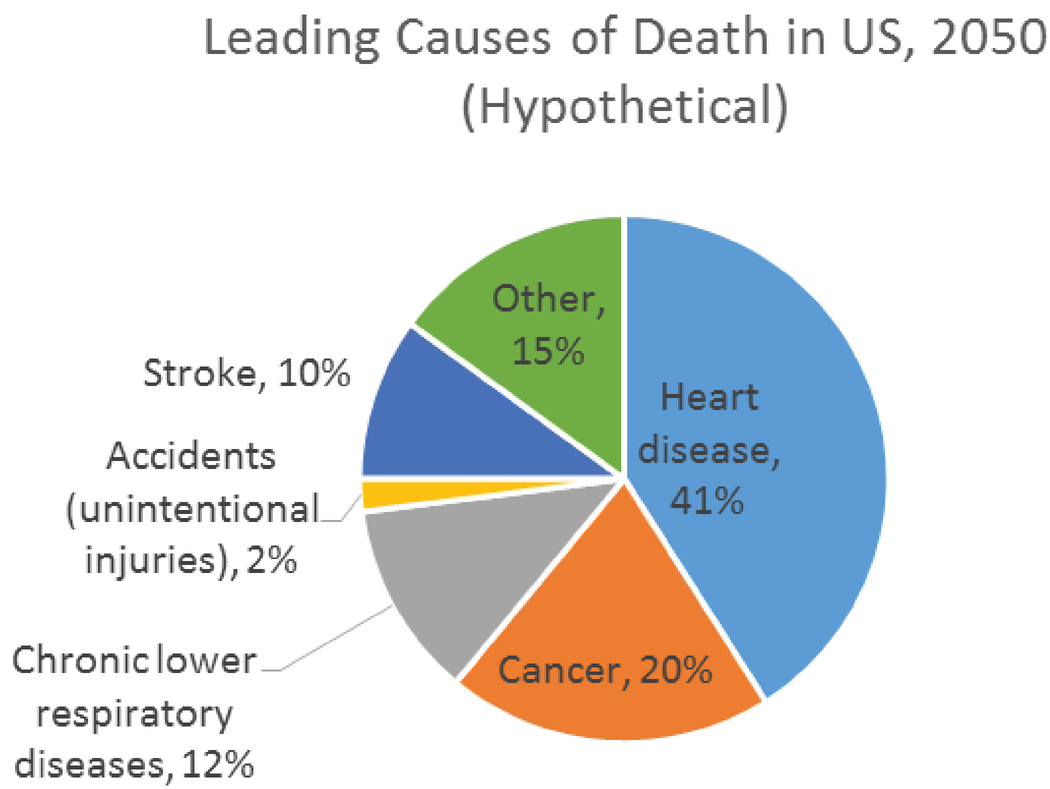
Downtown Atlanta interstate-highway construction in 1962 (Source: Darin Givens, twitter.com/atlurbanist/media)

What will the ped & bike crash types of the future be (hypothetical data)?



How will public health change?





Where are we now?

The technology is still limited

Table 1: ADAC test results; 100 % means that the dummy was not touched, 0 % means that the car has not reduced the speed

Car	Sensors	Crossing adult (up to 60 km/h)	Adult along (up to 60 km/h)	Child behind car (up to 50 km/h)	Slow cyclist (up to 40 km/h)	Night with reflective vest (up to 45 km/h)	Night with dark cloth (up to 45 km/h)
Audi A4	Mono camera	72 %	88 %	93 %	50 %	71 %	17 %
Subaru Outback	Stereo camera	89 %	100 %	46 %	0 %	100 %	100 %
KIA Optima	Radar and camera	72 %	75 %	54 %	0 %	50 %	0 %
Daimler C-Class	Stereo camera and radar	67 %	75 %	43 %	25 %	0 %	0 %
Volvo V60	Radar and camera	39 %	50 %	21 %	0 %	0 %	0 %
BMW 3er	Mono camera	28 %	38 %	7 %	13 %	0 %	0 %

Source: German ADAC Automobilists' Club Study, retrieved from https://can-newsletter.org/engineering/engineering-miscellaneous/160823_night-blind-still-problems-to-detect-pedestrians-in-night_adac/

Coverage of pedestrian and bicycle issues is still sparse

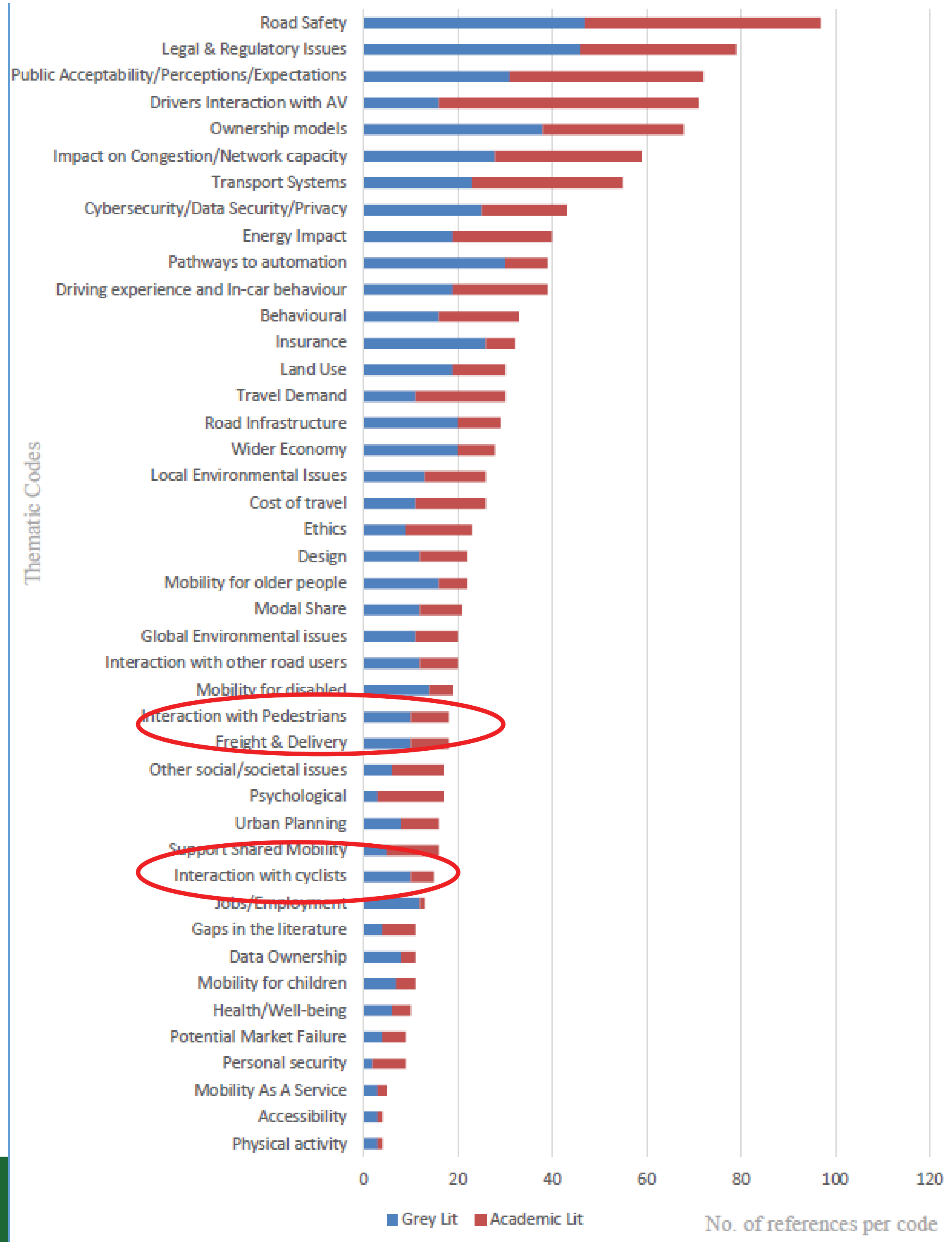


Figure 6 Frequency of topic codes in grey and academic literature

Source: Cavoli, C. et al., 2017. *Social and behavioural questions associated with Automated Vehicles. A Literature Review*, London: Department for Transport.

Overall, pedestrian and bicycle issues related to AVs have not been richly explored

Fully automated vehicles must anticipate all people…

Critical time to engage in research and policy discussions

- AASHTO Research Roadmap: 23 AV project ideas, $15M+
- 3 explicitly reference ped/bike issues
- Opportunities to advance research needs yearly

Webinar Series Goals

Poll: How are you involved in AVs?

Automated and Connected Vehicle Technologies, Promises, and Challenges

Justin M. Owens, Ph.D.

Research Scientist
Center for Vulnerable Road User Safety
Virginia Tech Transportation Institute

PBIC Webinar Series Part I:

The Promise and Challenges of Automated Technologies

August 16, 2017

VirginiaTech
Transportation Institute

What are "Automated Vehicles"?

Driver Responsibility	Active Control		Monitoring/ Awareness		Passive Occupant	
Automation Level	LEVEL 0 No automation	LEVEL 1 Automated systems can sometimes assist the human in some parts of the driving task	LEVEL 2 Partially automated systems can conduct some driving tasks while human monitors and performs other driving tasks	LEVEL 3 Conditionally automated systems can conduct some driving tasks in some conditions, but the human driver must be ready to take back control	LEVEL 4 Highly automated systems can conduct all driving tasks in some conditions without human control	LEVEL 5 Fully automated systems can perform all driving tasks, under all conditions in which humans could drive without human control

AVs: VRU Safety Potential

- Improved Perception
- ...especially at night (?)
- ...or with occlusion
- No Distraction/ Fatigue/ Emotion
- Faster Reaction Time
- Better Affordances for Peds w/Disabilities
- Improvements in Efficiency

Currently…

Why thank you most kindly!

Please continue, my friends!

(…ideall

Public Safety Campaigns

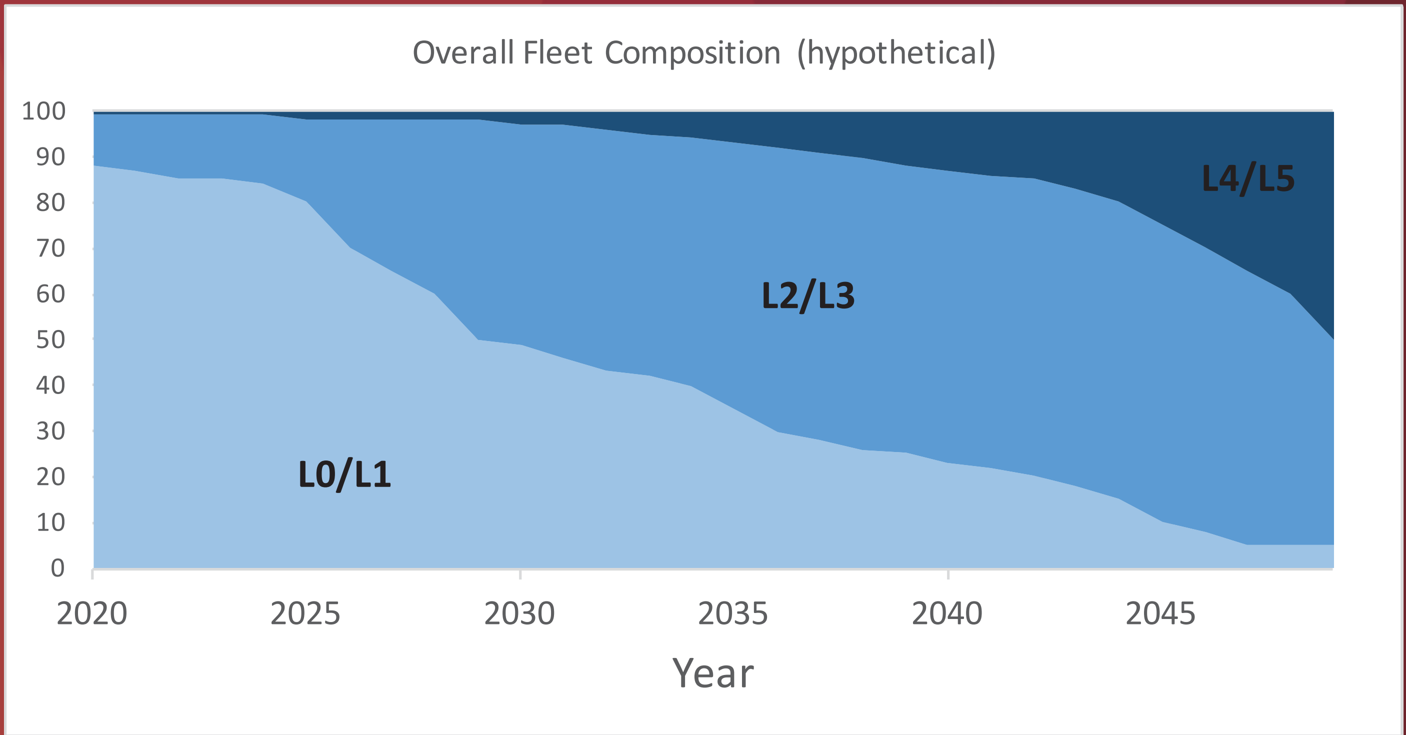
In a highly automated future…

Huh?

[beep
boop]

(…may

Hypothetical AV Penetration Rate



- Market readiness rate still unclear, but…
- Mixed fleet for decades to come

Challenges for AV/VRU Interactions

- Following images taken from draft PBIC paper*
- Some technical issues, some social, some both
- Most apply to all levels of AVS control
  - Some apply in different ways
  - L2/3 – when to demand operator takeover?

**Thanks to Graham Russell, Pedestrian and Bicycle Information Center*

Detecting Pedestrians & Bicyclists

- How does an AVS detect vulnerable road users (VRUs)?
- **Challenges**:
- Multiple technologies (machine vision, Lidar, etc)
- All have tech limitations
- How can AVSs parse & track crowds of VRUs?

V2X Considerations

- Wireless communication may improve perception
- **Challenges**:
- Technical limitations
  - Battery drain
  - Device failure
- Human factors
  - Privacy
  - Choice
  - Forgetfulness

Bidirectional Prediction of Intent

- Once VRU is detected, then what?
- Determination of *VRU intent?*
- Determination of *vehicle's intent*?
- Particularly in a mixed fleet
- Cultural norms & differences
- Children; People w/Disabilities

Determining Right of Way

- Legal, social & cultural issues
  - Interpretation & respect for local customs and norms?
- Replicate or replace personal communication?
- Shift from bidirectional human-to-human to user-machine interface

When to Pass & Distance

- How does an AVS determine when to pass a cyclist/pedestrian in the road?
  - Vs. hanging back given roadway parameters
- How does it weight giving lateral passing distance vs. crossing lane line?

Legal/Ethical Questions

Who to harm?

Who is liable?

When can AVs break the law?

Limitations on Operational Domain?

Minor/Major

Research Tool: VR Pedestrian Simulator

Summary: A Call for HF Research

- Even (especially!) with automation, questions about interaction between humans & machines
- Opportunities for improvements over current (fallible) human perception & performance
- But many outstanding issues about how to detect VRU, predict intent, and interact

Questions?

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Virginia Tech Transportation Institute

traffic21
a transportation research institute of Carnegie Mellon University

Technologies for Safe and Efficient Transportation
A U.S. DOT UNIVERSITY TRANSPORTATION CENTER
Carnegie Mellon University
University of Pennsylvania

AV's Blindspot: Detecting Pedestrians and Bicyclists

Bernardo Pires

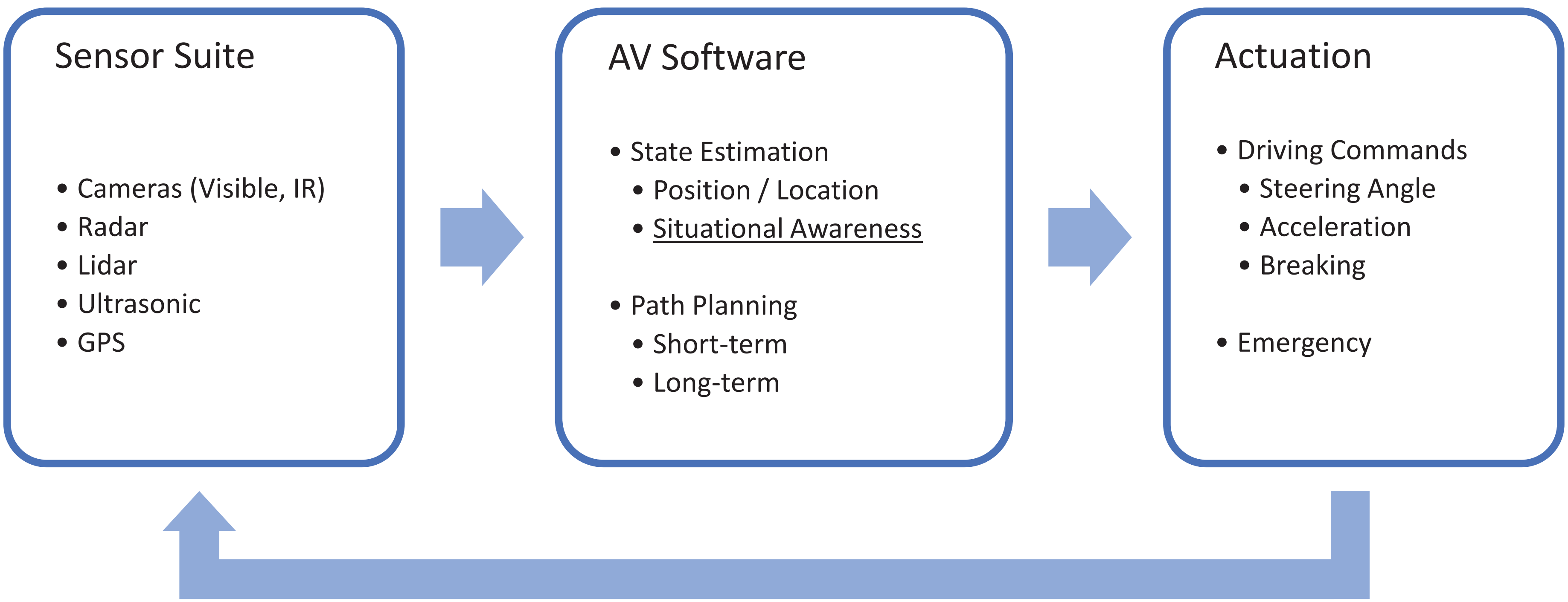
Includes work by: Mehmet Kocamaz,
Chris Kaffine, John Kozar, and Jian Gong

08.16.2017

Summary

- Situational Awareness is the Key Challenge for AVs
- Example of Bike and Pedestrian Detection
- Autonomy is becoming a Data Race
- Policy Implications and Infrastructure Support for AVs

Autonomous Vehicle Overview



Situational Awareness is the Key Challenge to achieve Full Autonomy

Evolution of Situational Awareness
Examples of AV Technologies

- Highway Lane Keeping
  - ‘Rule’: Follow high contrast road markings
- Highway Adaptive Cruise Control
  - ‘Rule’: Sensors (radar, lidar, stereo vision) can tell distance to next car
- Road Sign Interpretation
  - ‘Rule’: Have a database of all possible signs
- Infrastructure Detection (viable paths, merges, splits, intersections)
  - No ‘Easy Rule’
  - Often map-assisted, hard when reality diverges from map (e.g. construction work)
- Pedestrian & Cyclist Awareness
  - No ‘Easy Rule’
  - Hard to detect and track

Increased Autonomy

Evolution of Situational Awareness

- ’Rule-based’ solutions will not work
  - World (e.g. infrastructure) is too complex or varied
  - Objects (e.g. people) can change appearance
- Need more complex perception models
- Machine Learning (e.g. Neural Networks)
  - Software learns from examples (often millions)
  - Loosely mimics human brain functionality
  - More powerful but harder to evaluate / assure correctness

Pedestrians And Bicyclists

- Harder to detect and track
  - Smallest road users
  - Most varied appearance
- Harder to predict motion
  - Pedestrian: Unexpected road crossing
  - Bicycle: Movement within lane, “unexpected” turns
- Most exposed / fragile road users

Example: Pedestrian And Bicycle Detection, Tracking and Counting

- Intelligent Mobility Meter
- Evaluate usage of dedicated bike lanes
- Evaluate impact of adaptive traffic lights on pedestrian wait time at busy intersections
- In partnership with City of Pittsburgh

Manually Labeled Data

Approx. 10 hours of data manually labeled

- 1,078,920 frames in total
- 541 pedestrians & 111 cyclists

Overview of Cascade Classifier for Bicycles and Pedestrians

Automated Bike and Pedestrain Counter

Overall Accuracy: 95.1%

Race to Autonomy is becoming a Data Race

- Quantity and Quality of Data is often the primary driver of Machine Learning algorithm success

- Numerous start-ups and established manufacturer’s have deployed large-scale data collection efforts

- Particularly Impactful: Tesla is Collecting Customers’ Driving Data (On May 2016, Tesla had 780 million miles of data and was collecting at a rate of 1 million miles every 10 hours[1])

[1] “Tesla Tests Self-Driving Functions with Secret Updates to Its Customers’ Cars”. Tom Simonite. MIT Technology Review. May 24, 2016

Policy Implications of the Data Race

- Consumer Privacy and Education
- Data Sharing vs Proprietary Information
  - Sharing with Government, Academia, Research Organizations
  - Sharing between Inter-Manufacturers (Mandatory?)
- How to test large-scale, data driven AV systems

Infrastructure Support For AVs

- Communication between road users and infrastructure
  - See next speaker & Part II of the series

- Removal of Ambiguous Situations
  - Informal / Unenforced speed limits (above posted)
  - Ambiguous Right of Way (ex. 4-way stops)
  - Unclear / Informal Pedestrian Paths
  - Often disregarded rules of the road (ex. yield to pedestrians)

Intelligent Mobility Meter

- Fine-grained statistics on pedestrian, bicyclist and vehicular traffic
- Hardware Platform (loaned to organizations) + Data Analysis at CMU
- Free for Government and qualified non-profit organizations
- Contact bpires@cmu.edu to learn more

The Connected Bicycle: Communicating with Vehicles and Infrastructure

MAIN ST

Multimodal Alerting Interface with Networked Short-range Transmissions

charles river analytics

Prepared for:
PBIC Autonomous Vehicle Webinar
(Part I - Technology)
Wednesday, August 16 2017

Vehicle automation is advancing despite vulnerable transportation users being most at-risk to this technology

LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
No automation	Automated systems can sometimes assist the human in some parts of the driving task	Partially automated systems can conduct some driving tasks while human monitors and performs other driving tasks	Conditionally automated systems can conduct some driving tasks in some conditions, but the human driver must be ready to take back control	Highly automated systems can conduct all driving tasks in some conditions without human control	Fully automated systems can perform all driving tasks, under all conditions in which humans could drive without human control

Traditional Approaches

- Protect the cyclist from harm in the event of a crash (i.e., PPE)
- Make the cyclist more salient to surrounding vehicles/drivers (Lights & Sounds)
- Promote heads-up / engaged riding to make the cyclist more aware of their surroundings

- Challenge:

  Autonomous vehicles don’t benefit form more salient riders – and riders need to develop mental model of autonomous vehicle behaviors

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Multimodal Alerting Interface with Networked Short-range Transmissions (MAIN-ST)

- USDOT FHWA-Funded Phase II SBIR Effort
- **Objective:** Develop the technology to bring bicycles onto connected vehicle (V2X) networks

Tech Upgrade → Broadcast BSM-B → Receive and Parse Others → Predict Hazards → Warn Cyclists

- **Secondary Objective:** Explore Automated Cyling Assistance System (ACAS) feasibility as short-term solution

Significant Tech Upgrade

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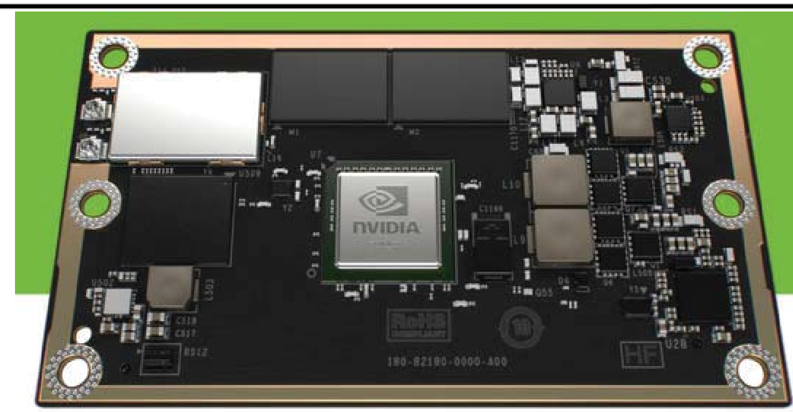
Tech State of the Art – Platform to Drive Connectivity

- Jetson TX2 with Auvidea J90 Carrier Board
  - 10 watts for 1 Teraflop of Computing Power
  - Same architecture (Pascal) as DRIVE PX2 (e.g., Tesla ACAS)
- Accelerometers (MPU 9250 IMU)
- Forward & Rear-Facing Scanse Sweep Scanning LIDAR
- Rear and Front Wide Dynamic Range (WDR) Cameras
- smrtGRiPs haptic handlebar grips
- CAN Port
- 4 USB 3.0 Ports
- USB 2.0 OTG
- GPS Navilock u-blocks 8 – 2.5 meter accuracy
- Bluetooth Low Energy
- USB Port for DSRC Unit
- 12 volt out
- Wi-Fi / LTE Connectivity
- IP67 Case
- 16v volt charger
- Data logging & Real-time Boréal API
- 128 GB SSD
- 500 Wh Lithium Battery



BORÉAL
BIKES

ACAS: Collision Detection

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- Jetson TX2 makes Computer Vision and Machine Learning possible on a Bike
- MAIN-ST→ Deploying YOLO
- ACAS Functions for Bikes:
  - Forward Vehicle / Pedestrian / Bicycle Collision Warnings
  - Rear Collision Warnings
  - Signage Detection
  - GPS-Denied Localization
- Short-Term Solution → Same fallbacks as AV solutions
  - Still focused on enhancing the cyclist's awareness of their environment – so doesn't overcome autonomous vehicle problems
  - BURDEN STILL ON THE CYCLIST TO SURVIVE!!!!

ACAS: Signage Detection & Localization

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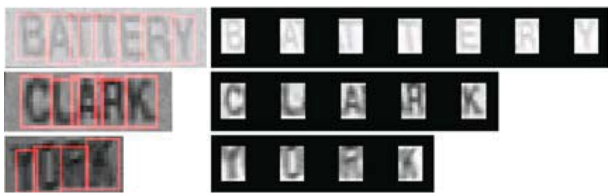
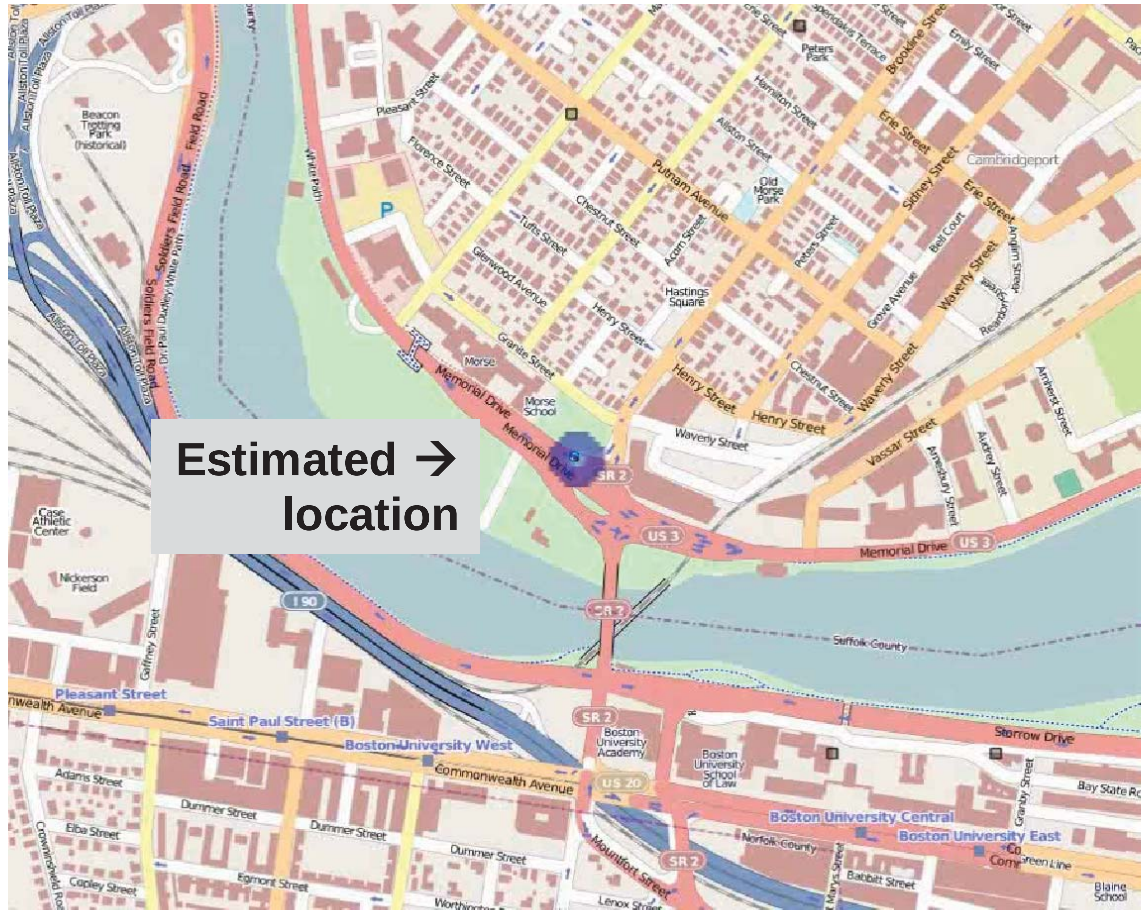
Detected → signs appear here



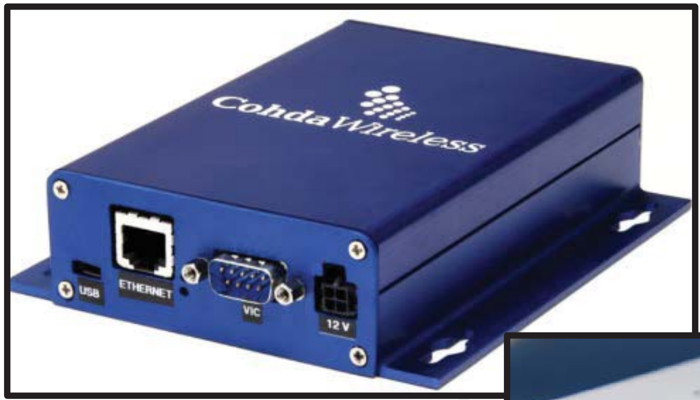


Estimated → location

- Facilitates GPS-free localization
- Enables added roadway context to be added to collision detection assessments
- Helps detect non-collision based hazards (e.g., railroad tracks, grooved pavement, shoulder work)

DSRC and X2X Networks

- Primary goal of enabling technologies that support safety applications and communication between vehicle-based devices and infrastructure to reduce collisions.
- Low Latency and does not require line of sight
- Works in high vehicle speed mobility conditions
- Performance immune to extreme weather conditions (e.g., rain, fog, snow)



On-Bike DSRC Connectivity

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✓ Hardware:

- ✓ COTS DSRC radios are seeing reduction in SWAP
- ✓ Small-scale batteries and e-bikes becoming more prolific
- ✓ GPS and other ride sensors improving

❑ Software:

- o Current DSRC messaging standards (SAE J2735) only cover limited bicycle-specific capabilities, such as bicycle lane localization
- o No algorithms related to prediction of cycling behaviors and hazardous situations

BSM-B + Tier 1 Protection

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Mode 1: Bare Bones

- DSRC Radio + GPS
- Position, Heading, Velocity

Mode 2: Sensor-Equipped E-Bike

- Mode 1 + IMUs + Mechanical Sensors + Precision GPS
- Mode 1 Enhanced + Acceleration, Braking Status, Lane Position, Power Input, Gear Position, Turn State, Signaled Turn*, Bicycle Systems State

*****Tier 1***:** Other connected vehicles and entities know where I am and where I'm headed – enables their autonomous capabilities to benefit the cyclist.

Hazard Detection + Tier 2 Protection

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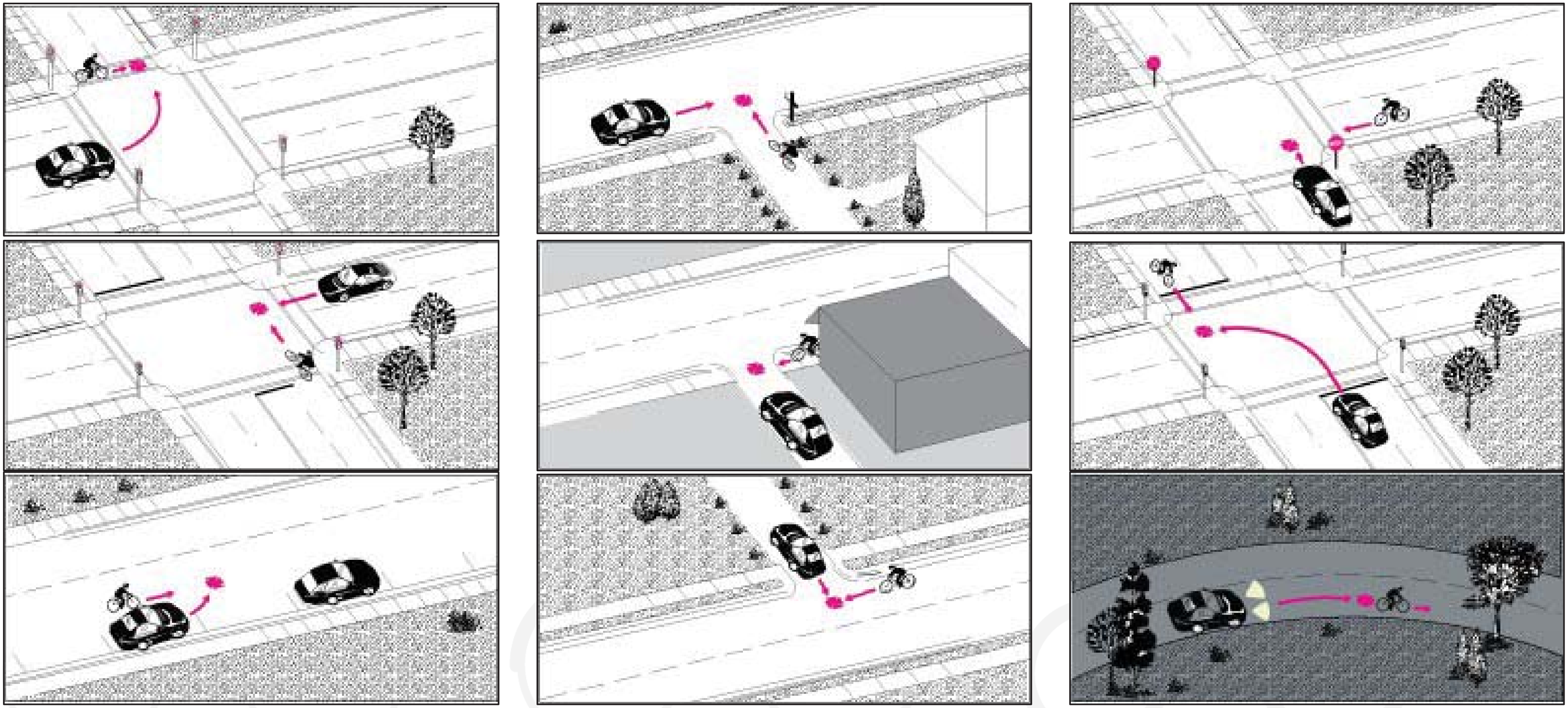
- On-Bike message receipt and parsing
- Creating models of *DSRC-Detectable* B2X Hazard Situations
- Incorporation of road laws and road designs
- Hazard predictions to enable cyclist alerting

src: PBCAT



Hazard Alerting

- Multimodal real-time warnings
  - Visuals – via SmartHalo LED array
  - Haptic – via smrtGRiPs left and right grip vibration
  - Audio – via SmartHalo speaker
- Display-free warnings assure shorter reaction times
- Universal Accessories (can be retrofitted to any bike)

Audio & Haptic Warning Symbology

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ID	Hazard Category	Hazard Severity	Time-to-Collision Trigger	Modality	Alert Type	Frequency	Duration	Intensity	Interburst Interval	Other Characteristics
1	Imminent	High	2 sec	Abstract/ Haptic	Pulsed/ Continuous	1700 Hz/ 250 Hz	440 ms pulse/ Continuous	30 dB above MT	360 ms/ 100 ms	Quick onset, directional
2	Cautionary – Action Required	Moderate	5 s	Graded Abstract	Pulsed	1250 Hz	400 ms – 150 ms	15 dB above MT	300 ms – 150 ms	
3	Cautionary – Heightened Attention	Low	5 s	Haptic	Continuous	150 Hz	400 ms	N/A	500 ms	Directional
4	Hazard – Cautionary	Variable	5 s	Auditory Icon	Single-Stage	N/A	Variable	15 dB above MT	N/A	
5	Hazard-Avoidance	Moderate	5 s	Speech/ Graded Haptic	Single-stage/ Continuous	N/A 250 Hz	Variable/ 400 ms – 150 ms	20 dB above MT	N/A 300 ms – 150 ms	200 words per minute/2-word maximum

- Five general hazard categories
- Defined alert modality and characteristics
- Based on riding context (e.g., ambient noise)
- Sourced from studies on in-car and in-cockpit alerting design
- Ecological validation needed

Hazard Detection & Alerting Validation

Testing in the Wild – Las Vegas, NV

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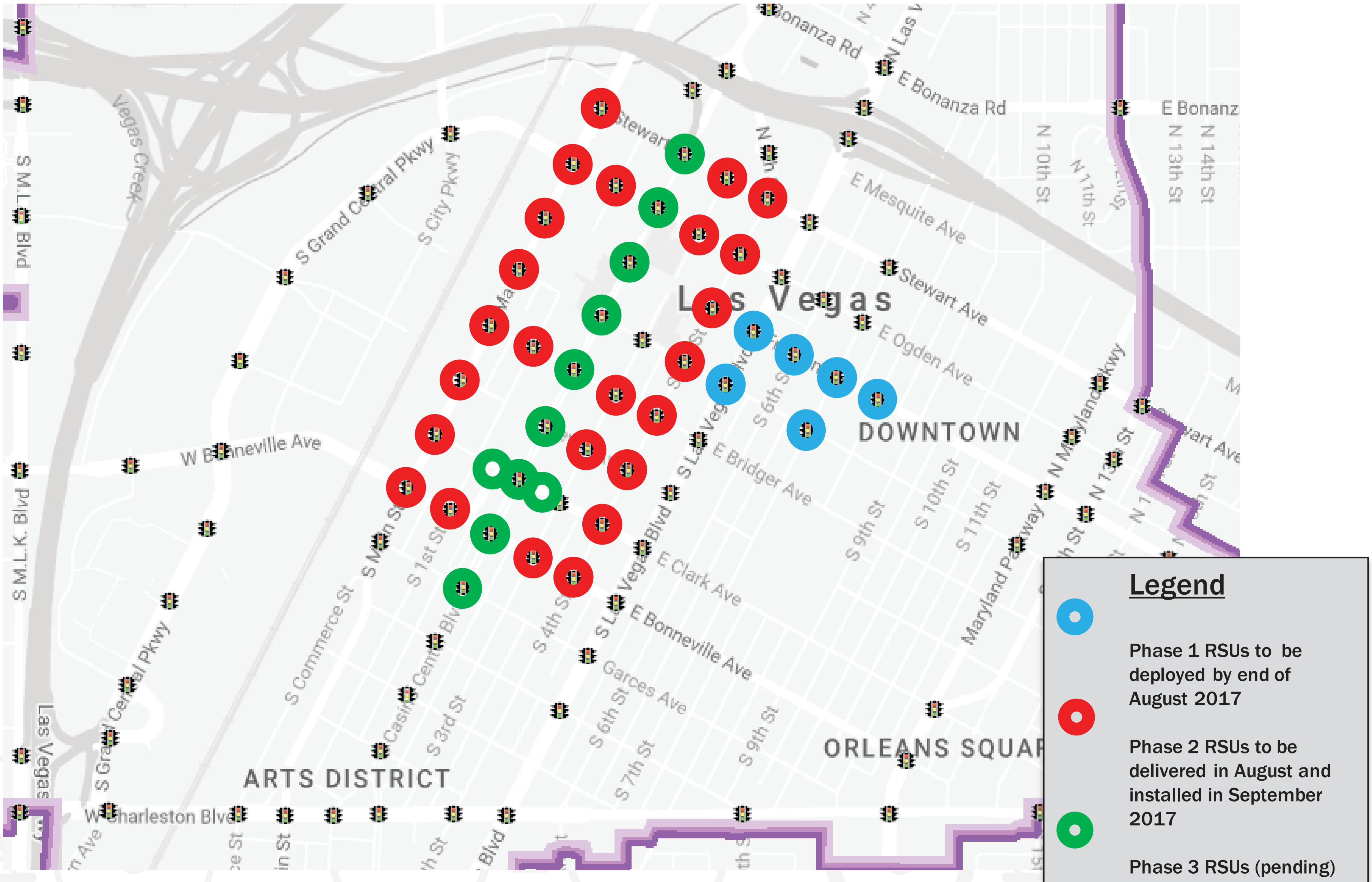
CITY OF Las Vegas

Planned DSRC Installation Locations



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Upcoming Events

- Pedestrian and Bicycle Information Center (PBIC) AV Webinar Series Part II: pedbikeinfo.org/webinars
- TRB 2018 Human Factors Workshop
- ALR Conference: Future-Proofing Policies
- Forthcoming PBIC Resource: *A Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists;* available later this month

Discussion

- Send us your questions →
- Follow up with us:
  - Laura Sandt sandt@hsrc.unc.edu
  - Justin Owens jowens@vtti.vt.edu
  - Bernardo Pires bpires@cmu.edu
  - Michael Jenkins mjenkins@cra.com
  - General Inquiries pbic@pedbikeinfo.org
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