

Application of Autonomous Driving Technology to Transit - Functional Capabilities for Safety and Capacity

**Presentation to
Federal Transit Administration and
American Public Transportation Association
July 30, 2013**

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NHTSA Preliminary Policy on Automated Vehicles

Level 0 (No automation)

- The human is in complete and sole control of safety-critical functions (brake, throttle, steering) at all times.

Level 1 (Function-specific automation)

- The human has complete authority, but cedes limited control of certain functions to the vehicle in certain normal driving or crash imminent situations. Example: electronic stability control

Level 2 (Combined function automation)

- Automation of at least two control functions designed to work in harmony (e.g., adaptive cruise control and lane centering) in certain driving situations.
- Enables hands-off-wheel and foot-off-pedal operation.
- Driver still responsible for monitoring and safe operation and expected to be available at all times to resume control of the vehicle. Example: adaptive cruise control in conjunction with lane centering

Level 3 (Limited self-driving)

- Vehicle controls all safety functions under certain traffic and environmental conditions.
- Human can cede monitoring authority to vehicle, which must alert driver if conditions require transition to driver control.
- Driver expected to be available for occasional control. Example: Google car

Level 4 (Full self-driving automation)

- Vehicle controls all safety functions and monitors conditions for the entire trip.
- The human provides destination or navigation input but is not expected to be available for control during the trip. Vehicle may operate while unoccupied.
- Responsibility for safe operation rests solely on the automated system

Functional Capabilities for Safety and Capacity

Many Autonomous Vehicle Level 2 Capabilities Now Available in Auto Market – Adapt Packages for Transit

- **Blind spot monitoring (for vehicles and pedestrians)**
- **Driver fatigue and attentiveness monitoring**
- **Cooperative Adaptive Cruise Control**
- **Autonomous emergency braking**
- **Lane departure detection and warning**
- **Lane keeping assistance**
- **Collision warning and mitigation**
- **Obstacle detection**
- **Parking assist**

2002-2012 Safety and Claims Data for Service Directly Operated by NJ TRANSIT Bus Operations

	Total for Period 2002-2012	Annual Average
Incidents	3,077	280
Collisions	1,753	159
Injuries	4,417	402
Fatalities	25	2.3
Estimated Bus Claims	\$112,400,000	\$10,220,000
Peak Buses	n/a	1,769
Total Buses Operated	n/a	2,106
Estimated Bus Claims/Total Buses Operated	\$53,305	\$4,846

Potential for Cost Savings in Annual Claims Paid by Installing a Collision Avoidance System on NJ TRANSIT Buses

Estimated Average Annual Claims Reduction per Bus		Collision Avoidance System Installation Costs Based on Mercedes Intelligent Drive System				
		\$2,800 per Bus – 2014 Base Price	\$5,600 per Bus – 2x Base Price	\$8,400 per Bus – 3x Base Price	\$11,200 per Bus – 4x Base Price	\$14,000 per Bus – 5x Base Price
(%)	(\$)	Estimated Years to Recoup Installation Cost				
10	484.60	5.8	11.6	17.3	23.1	28.8
20	969.20	2.9	5.8	8.7	11.6	14.4
30	1,453.80	1.9	3.9	5.8	7.7	9.6
40	1,938.40	1.4	2.9	4.3	5.8	7.2
50	2,423.00	1.1	2.3	3.5	4.6	5.8
60	2,907.60	1.0	1.9	2.9	3.9	4.8
70	3,392.20	0.8	1.7	2.5	3.3	4.1
80	3,876.80	0.7	1.4	2.2	2.9	3.6
90	4,361.40	0.6	1.3	1.9	2.6	3.2

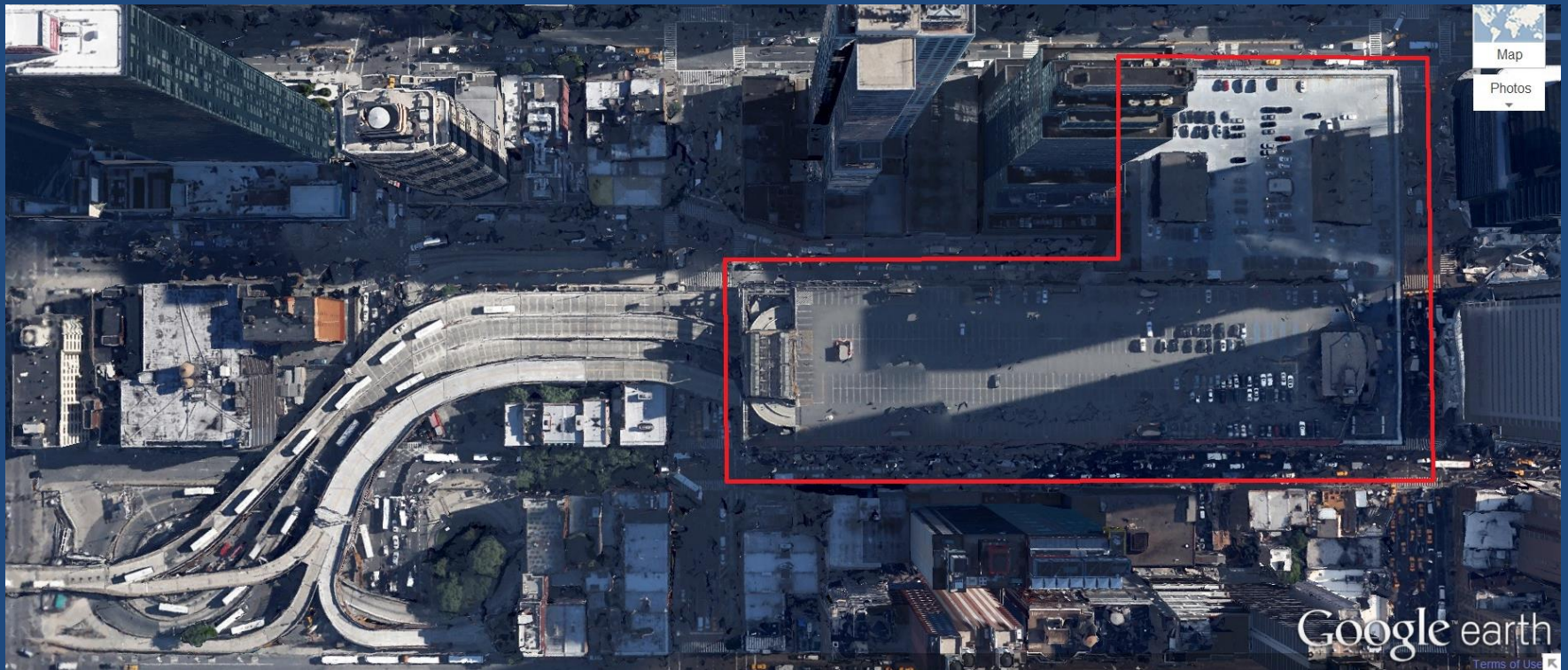
A Capacity Bonus for NJ TRANSIT Exclusive Bus Lane (XBL) to New York City

Source: Port Authority of New York and New Jersey



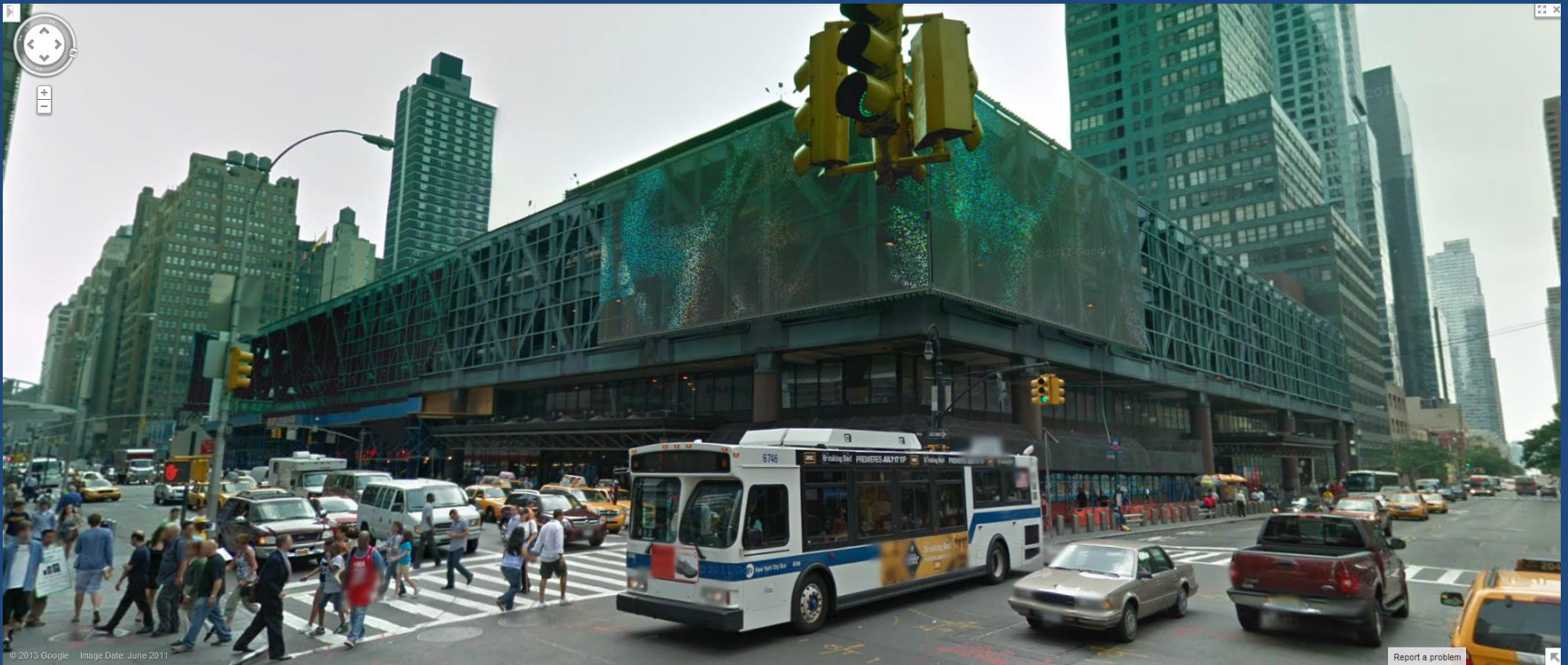
Port Authority Bus Terminal (PABT) New York City

Source: Google Earth 2013



Port Authority Bus Terminal (PABT) New York City

Source: Google Maps 2013



Increasing Bus Capacity To Mid-town Manhattan Would Involve Three Elements:

- Increasing the capacity of the PABT, particularly to accommodate outbound passengers in the PM peak*
- Increasing the capacity to feed buses into the terminal for PM outbound service, either by making bus storage space available in Manhattan or by expediting the PM eastbound flow of buses through the Lincoln Tunnel.
- Increasing the AM peak hour flow of buses through the XBL

*currently under study

Potential Increased Capacity of Exclusive Bus Lane (XBL) Using Cooperative Adaptive Cruise Control (CACC) (Assumes 45 foot (13.7 m) buses @ with 57 seats)

Average Interval Between Buses (seconds)	Average Spacing Between Buses (ft)	Average Spacing Between Buses (m)	Buses Per Hour	Additional Buses per Hour	Seated Passengers Per Hour	Increase in Seated Passengers per Hour
1	6	2	3,600	2,880	205,200	164,160
2	47	14	1,800	1,080	102,600	61,560
3	109	33	1,200	480	68,400	27,360
4	150	46	900	180	51,300	10,260
5 (Base)	212	64	720	-	41,040	-

Costs of Bus Crashes – Industry Wide

Intangible

- Human loss and suffering
- Media attention
- Good will

Tangible

- Personal injury claims
- Property damage claims
- Workers compensation
- Insurance premiums

- Vehicle repair
- Legal services
- Passenger and service delays
- Lost fare revenue
- D & A testing
- Overtime
- Sick time
- Accident investigation
- Vehicle recovery
- Hearings and discipline

NTD 2011 Bus Incidents for All Transit Agencies

Collisions	With Other Vehicle	2,693
	With Person	427
	With Fixed Object	66
	With Rail Vehicle	0
	With Bus Vehicle	46
	With Other	28
Collision Total		3,260
Fire Total		304
Security Total		403
NOC Total		5,539
Incident Total		9,506

NTD 2011 Bus Injuries and Fatalities for All Transit Agencies

		Fatalities	Injuries
Passenger		8	7,262
Rev Facility Occupant		7	2,107
Employees	Operator	3	923
	Employee	0	66
	Total Employees	3	989
Other Worker		0	3
Other	Bicyclist	4	123
	Ped in Crossing	11	109
	Ped not in Crossing	18	124
	Other Vehicle Occupant	32	1,594
	Other	4	615
	Trespasser	0	0
	Suicide	5	2
	Other Total	74	2,567
Total		92	12,928

NTD 2011 Bus Casualty and Liability Expense for All Transit Agencies

Casualty and Liability Amount	General Administration	\$432,228,288
	Vehicle Maintenance	\$50,847,722
	Sub-Total Casualty and Liability	\$483,076,010
Maximum Available Buses		59,871
Sub-Total Casualty and Liability Amount Per Bus		\$8,069

Systems Specifications and Requirements for Bus Acquisition or Retrofit to Allow for Autonomous and Connected Vehicle Technology

- **Steering**
- **Braking**
- **Throttle**
- **Transmission**
- **Engine and Drivetrain Instrumentation**
- **Sensor/Camera Locations and Connections**
- **Vehicle Area Network**
- **Communications V2V, V2I**
- **Antenna Locations**
- **Logic Unit/Mobile Data Terminal**
- **Electrical power/ conditioning**
- **Electromagnetic radiation interference**
- **Human Factors**

Need Open Architectures and Standards

- Avoid problems of legacy systems and sole source procurements
- Modular systems and components
- Standard interfaces between systems and components
- Multiple sources and innovation from vendors
- “Plug and play”

Conclusion – Next Steps

Draft Work Program - Priorities

- **Estimating benefits of adopting collision avoidance technology – analysis of collision and claims data**
- **Opportunities to enhance performance and capacity by using autonomous technology – industry collaboration**
- **Specifications and standards for new technology**
- **Prototype development**