Envisioning Autonomous Vehicle Pathways through the Lens of Air Transportation Planning

Megan Ryerson
Assistant Professor

Department of City and Regional Planning
Department of Electrical and Systems Engineering
University of Pennsylvania
Autonomous vehicles

- Vehicle-to-vehicle communication and situational awareness
- Programmed decisions based on standards rather than human decisions based on guidance
- Travelers cede control to the vehicle
- Diverse vehicle fleet with varying performance standards
Numerous car manufacturers, Google, and CMU have autonomous vehicles in various stages of testing
  – CMU Cadillac drove a congressman and the PA DOT Secretary on a 33 mile fully autonomous trip in September 2013 including highways and parking areas

 Autonomous vehicles are coming....
  – Dr. Raj Rajkumar (CMU/Penn UTC director), Nissan, and others estimate these vehicles will be on the road by 2020
  – Google has asserted the time to market is 3-5 years
  – Some experts disagree with this timeframe

 ....But do we want them? And how should we prepare?
  – Experts agree that the policy and legal barriers are at this point the most significant
### Public benefits & private benefits

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Source: The Eno Foundation, Preparing a Nation for Autonomous Vehicles (2013)

These are aviation fatality rates of about 1%
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If this is something we want, how might we regulate and plan to ensure safety, efficiency, livability, environmental stewardship, and our other goals?

- Safety regulation and managing public perception
- Intercity transportation infrastructure planning

*Source: The Eno Foundation, Preparing a Nation for Autonomous Vehicles (2013)*
Aviation is statistically the safest mode of transportation, yet public interest polls continue to show the auto is perceived as the safest.
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People – dispatchers, the traveling public, policymakers – place a high probability on unlikely events out of their control leading to behaviors and decisions that are costly and possibly dangerous.
Aviation system planning safety responses

- Public response to a safety event
- Over-estimation of necessary infrastructure
- Over-fueling flights in the flight planning process
Flight planning

• Flight dispatchers
  – Airline employees, responsible for planning and monitoring all flights for an airline
  – Act as point of contact for pilots during flight
    • Coordinate between groups for maintenance issues
    • Speak with air traffic control and airport personnel
  – Determine characteristics of flight plan
    • Actual routing from origin to destination
    • How much fuel to load, including extra fuel for contingencies
• **Mission fuel**: Choose a route (econ, other alternative route) and calculate necessary fuel

• **Federal Aviation Regulations (FAR) Reserve Fuel**: Fuel to hold for 30 minutes plus fuel to fly to an alternate airport (under specific wx conditions)

• **Contingencies**
  – Alternate airport fuel
  – Contingency fuel
Flight planning basics: Statistical contingency fuel (SCF) for domestic flights
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Dispatchers routinely load significantly more than was needed historically.
Behind the behavior of fueling

- **Dispatcher beliefs**
  - On a peer-to-peer basis, a diversion is seen as a safety failure rather than a fact of the system
  - Think a bit of extra fuel is “cheap insurance”
  - Job description is to be safe and efficient, and they err on the side of safety
  - Significant variation across dispatchers from conservative to aggressive loading practices

- **Dispatcher distrust of technology**
  - Indeed the airline’s ability to estimate mission fuel correctly varies across aircraft type and is poor for pre-merger aircraft
  - Concern that the flight management system doesn’t possess the necessary situational awareness
What is the cost to carry “additional” fuel?
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What is “additional” fuel?

**Domestic**
Any fuel above SCF 99 + 25% of fuel loaded for alternates

**International**
Any fuel above the notional SCF 99
What is the cost to carry “additional” fuel?

What is “additional” fuel?

What is the burn attributed with carrying this “additional” fuel?
Dataset for analysis

- All domestic and international flights for a year (mid-July 2012 to mid-July 2013)
- Flight statistics
- Fueling information (mission fuel, reserve fuel, tankering fuel, contingency fuel, alternate fuel, suggested contingency fuel from SCF95/SCF99, Target Gate Arrival Fuel)
- Actual weather at the time of schedule arrival (not forecast)
- Delta’s cost-to-carry factors

All Flights:
All flights from mid July 2012-mid July

All Flights with no Destination WX:
ALL flights with NO destination weather at the scheduled arrival time (flights that are scheduled to arrive during a thunderstorm, snowstorm, low ceiling and visibility, or IFR conditions are eliminated from the dataset)
Cost to carry results

- 42.5-45 million gallons per year ≈ $128-135 million per year

- 250 dispatchers responsible for all fuel loading decisions: that’s $550,000 per dispatcher!

- Very significant when compared with other big-ticket initiatives
Takeaways for autonomous vehicle planning

- We find dispersed decision makers – from dispatchers to drivers to policymakers – trade-off safety and efficiency in different ways
  - Possibility for large variations in autonomous vehicle safety policy on a state by state basis
  - Implications for manufacturers and vehicle costs as well as barriers to national policies

- We find that variability in vehicle performance leads to planning for the lowest common denominator
  - Possibly leading to conservative policies such as separation requirements

- We review how placing a high probability on infrequent events leads to dangerous decisions and possibly unnecessary infrastructure
  - Possibility of favoring new infrastructure development over efficient utilization of existing infrastructure for autonomous vehicles
    - Dedicated streets
    - New highway lanes just for autonomous vehicles
  - Possibility of autonomous vehicles policy being shaped by the first incident
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Notional cost(time) and distance trade-offs

How will autonomous vehicles change intercity mode share, and how should that impact intercity transportation infrastructure planning?
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Distance

Generalized cost

Partially Autonomous

Auto
Train
Aircraft

Distance a
Distance b
Distance

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Short connection flights and point to point flights

Distance a, Distance b, Distance

Partially Autonomous

Fully Autonomous

Auto
Train
Aircraft
The future of short haul transportation – is autonomous vehicles?

• There are system motivations to reduce short haul service
  – ATM side, “A blip is a blip”
  – Passengers find connections as onerous as flight time
  – For airlines, short-haul services are very costly comparatively, particularly as fuel prices increase

• Could we reduce short-haul air service, and how might that impact capacity planning?
Case study: San Francisco on June 25, 2008

Queuing diagram, SFO arrivals
Case study: San Francisco on June 25, 2008

Queuing diagram, SFO arrivals

Time impacts of eliminating short-haul flights, by cut-off distance
What does this mean for airport planning?

• We might be able to derive major airport capacity benefits with autonomous vehicles... *if* the carriers decide to leave the market

• Airlines currently offer short-haul services for numerous reasons
  – Network completeness and to serve *connecting* passengers
  – Market share and competitive presence

• Airlines will only exit a market if it makes business sense to do so
Airline response to competition

Boston to NYC O-D Air Passengers

- OD Passengers
- Connecting Passengers

Bar chart showing the number of OD and connecting passengers from Boston to NYC from 1993 to 2010.
Airline response to competition

• How are rail investments incorporated into airport capacity plans?

• How are policies to keep seats per operation high or other demand management policies evaluated in airport capacity plans?
The process through which we plan airport infrastructure is the NEPA process
  – Purpose and need
  – Alternatives to the preferred action
  – Environmental consequences of feasible alternatives

Review of 13 EIS documents
  – 10 airport capacity enhancement EIS documents for major airports since 2000
  – 3 HSR development EIS documents

Results of the review
  – Demand management was not retained for evaluation in the EISs reviewed
  – HSR was not retained for evaluation in the aviation EISs reviewed
  – Aviation was retained only in the CA HSR EIS for review
Federal modal agency boosterism leads to signing off on modally restrictive purpose and need statements

- **Chicago**: “The purpose of the proposed Chicago to St. Louis HSR Corridor Program is to enhance the passenger transportation network in the Chicago to St. Louis HSR Corridor by improving high speed passenger rail service, resulting in a more balanced use of different corridor travel options by diverting trips made by automobile and air to rail.”

- **Philadelphia**: The purpose of the Capacity Enhancement Program is to enhance airport capacity in order to accommodate current and future aviation demand in the Philadelphia Metropolitan Area during all weather conditions.

- Local urban boosterism

- Lack of understanding of multi-modal interactions

- Lack of planning urgency for modes that are not “fiscally constrained”
A way ahead for autonomous vehicles

• Autonomous vehicles present a way to greatly enhance the productivity of our existing infrastructure

• It is possible that overcautious safety regulations and the current environmental planning process will prevent this
  – Encourage additional capacity building
  – Reduce the efficiencies gained from existing infrastructure

• Autonomous vehicles are a radical new mode, they might just be what we – policymakers and the public – need to radically change mindsets
  – Ambitious marketing campaigns about safety
  – New structures within the environmental planning process to allow for multi-modal analysis
**Airport EIS Purpose and Need Excerpt**

**Washington, Dulles:** “The purpose of the project, from the Federal perspective, is to support the development of IAD such that it will safely accommodate the projected future aviation activity demand levels, without that aviation activity incurring unacceptable levels of aircraft operational delay, thereby causing resultant delays throughout the National Airspace System.”

**Ft. Lauderdale, Florida:** “The purpose of the proposed action is to provide sufficient capacity for existing and forecast demand at FLL with an acceptable level of delay.”

**Philadelphia:** The purpose of the Capacity Enhancement Program is to enhance airport capacity in order to accommodate current and future aviation demand in the Philadelphia Metropolitan Area during all weather conditions.

**HSR EIS Purpose and Need Excerpt**

**Chicago:** “The purpose of the proposed Chicago to St. Louis HSR Corridor Program is to enhance the passenger transportation network in the Chicago to St. Louis HSR Corridor by improving high speed passenger rail service, resulting in a more balanced use of different corridor travel options by diverting trips made by automobile and air to rail.”

**Florida:** “The purpose of FHSR is to enhance intercity passenger mobility in Florida by expanding passenger transportation capacity and providing an alternative to highway and air travel.”

**California:** “The purpose of the proposed High Speed Train system is to provide a reliable mode of travel, which links the major metropolitan areas of the state, and delivers predictable and consistent travel times. A further objective is to provide an interface with commercial airports, mass transit and the highway network and relieve capacity constraints of the existing transportation system as increases in intercity travel demand in California occur, in a manner sensitive to and protective of California’s unique natural resources.”
Towards autonomous vehicle futures

• Safety
  – Perception of safety
  – Safety regulation

• Infrastructure for intercity transportation
  – Mode shifting
  – Infrastructure planning
Final thoughts

Situational awareness, separation, vehicle to vehicle communication, and best equipped best served

Routing and options for re-routing

Planning a large scale dispersed system with local, state, Federal, and private interests
Study of the current and future safety levels of the North Airfield of LAX with the status-quo configuration and alternative configurations (Barnett et al., 2010)

- Status quo: Chance of fatal accident is once every 200 years, or one death per 150 million passengers
- Moving Runway 24R
  - 100 feet north: 40% increased safety over the status quo
  - 340 feet north: 55% increased safety over the status quo
  - 340 feet south: 50% increased safety over the status quo

Result:
- “The Panel does not see a compelling case on safety grounds alone for reconfiguring the North Airfield.”
- FAA condemns the report and urges Los Angeles with the following: “Everything possible must be done to make the north airfield as safe as it can be.”
- Millions of federal and local dollars for reconfiguration, current preferred alternative is moving 24R 400 feet north
Perception of Safety Post Disaster

- Statistically significant increase in traffic accidents after September 2001
- ~350 lost lives on the roads due to Americans avoiding flying

Source: Gigerenzer, 2004

Fig. 1. Number of fatal traffic accidents in the United States in 1996 through 2000 versus 2001. The gray line represents the means for the years 1996 through 2000, the vertical black bars indicate the highest and lowest values for those years, and the black squares indicate the values for 2001.
Flight planning basics: Statistical contingency fuel (SCF) for international flights

LHR-ATL

Notional “SCF 99”
Flight planning basics: Statistical contingency fuel (SCF) for international flights

Flights above this amount are expecting to burn significantly less than they are carrying

Notional “SCF 99”