
Encouraging Successful Technology Transition

Presentation to NAS Performance Workshop

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with thanks to Dr. Karen Marais, Norma Campos, Jenny Hu

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Why Technology Transition is Hard

- Aviation stakeholders
 - Multiple independent – yet interdependent – stakeholders
 - Mix of commercial, private, public, and government
 - Differing motivations (profit, safety, etc.)
- Technology
 - Expensive
 - Takes a long time to deploy; long in-service times
 - Technology changes faster than it can be deployed
- System attributes
 - Network externalities
 - Free-rider problems
 - Market failures
- Multiple stakeholders must change concurrently in a coordinated fashion to achieve real system-wide benefits

Motivation

- Past performance gains in the NAS achieved by actions of a single or few stakeholder(s)
- Unlikely to continue to be the case
- Need to understand how to think about complex interdependent technology transitions in a multi-stakeholder context over long periods of time

**Central Research Question:
How can aircraft operators be
encouraged to adopt new technologies?**

ADS-B Out Example

Incentivize users to equip early with ADS-B

2008

2014

2020

- NPRM for ADS-B Out
- Ground infrastructure contract awarded to ITT

Segment 2:
NAS-wide deployment
of ADS-B ground
infrastructure

ADS-B Out
Equipage
Required

Segment 1:

- TIS-B, FIS-B deployment
- Airspace Trials

Presentation Agenda

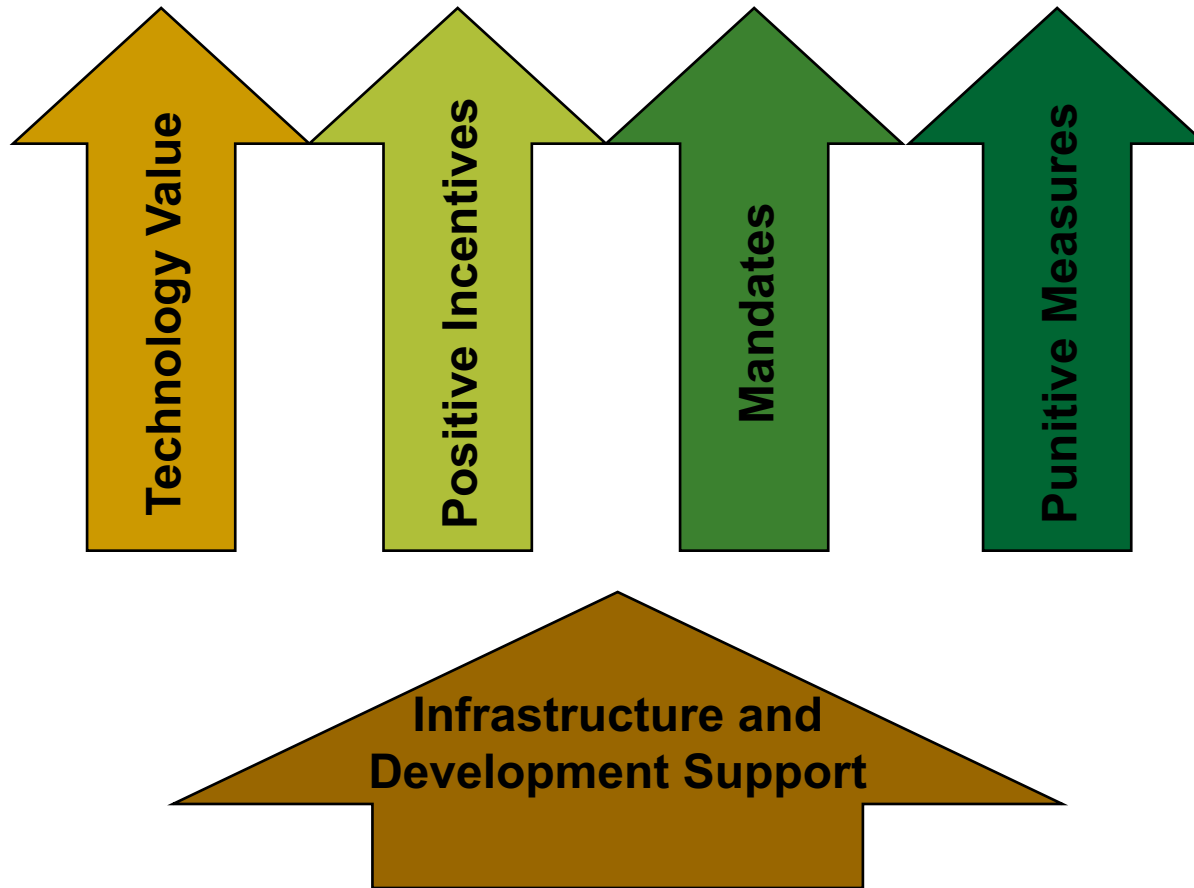
- Technology transition policy levers
 - Determinants of equipage value
 - Strategy preferences depends on equipage situation – need to segment incentive strategies
- Three approaches to analyzing challenges with technology transitions
 - Value analysis approach
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 - Cost – benefit time lag problems
 - Network effects approach
 - Game theoretic approach
- Epilogue: The case for change is more than ROI

Why Policy Levers are Needed

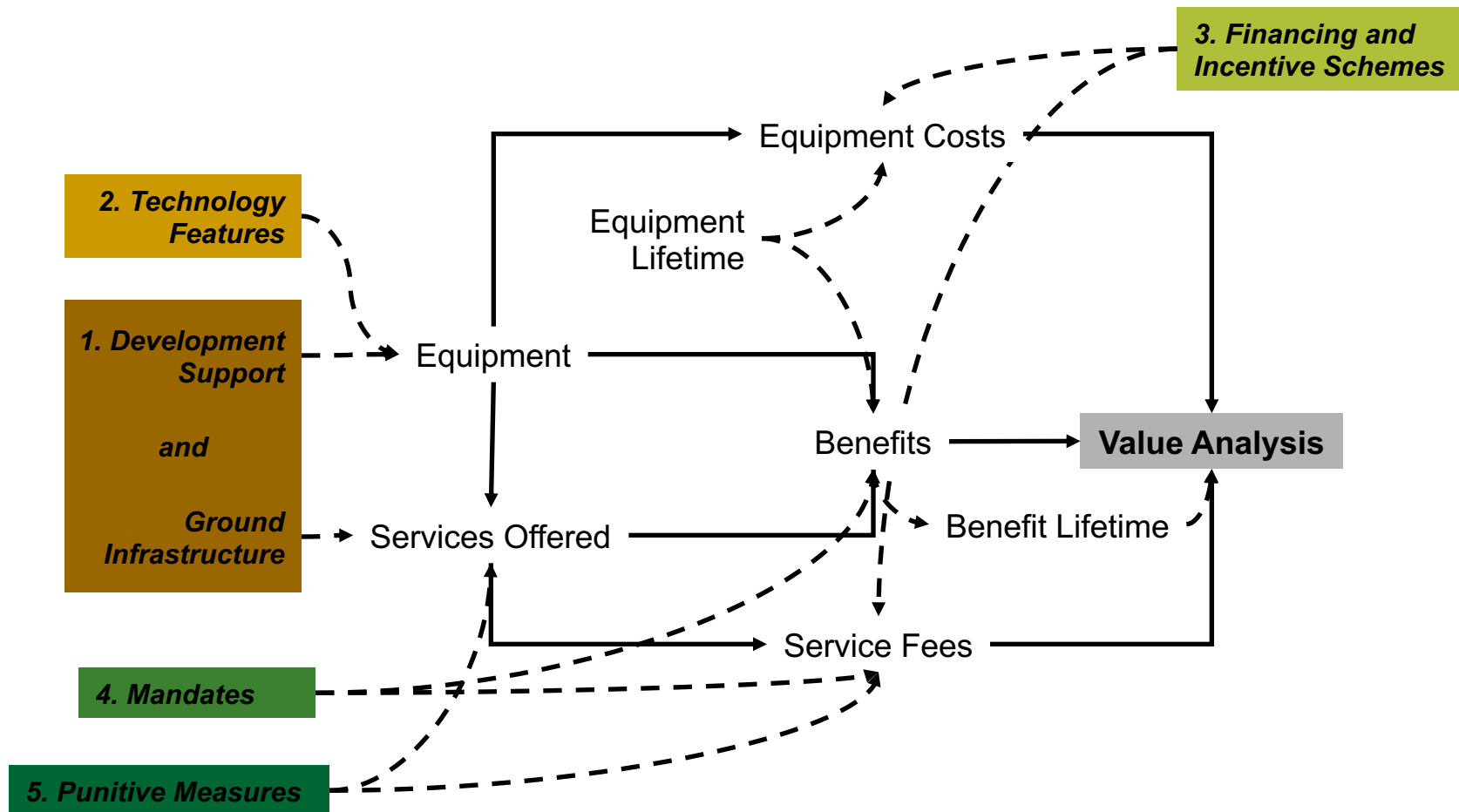
- Reduce value imbalances and uncertainties
- Remedy various market failures inherent in network markets
- Overcome stakeholder reluctance
- Stakeholders reluctant if:
 - Costs are high
 - Perception that benefits are limited, doubtful, may be delayed, short-lived, or free rider option
- Stakeholders enthusiastic if:
 - Costs are low relative to benefits
 - Perception that benefits are pervasive, rapid, clear, long-lived, no free rider option
- Focusing on aircraft operators, as frequent limiting factor on successful technology transitions

Five Policy Levers

Successful Technology Transition

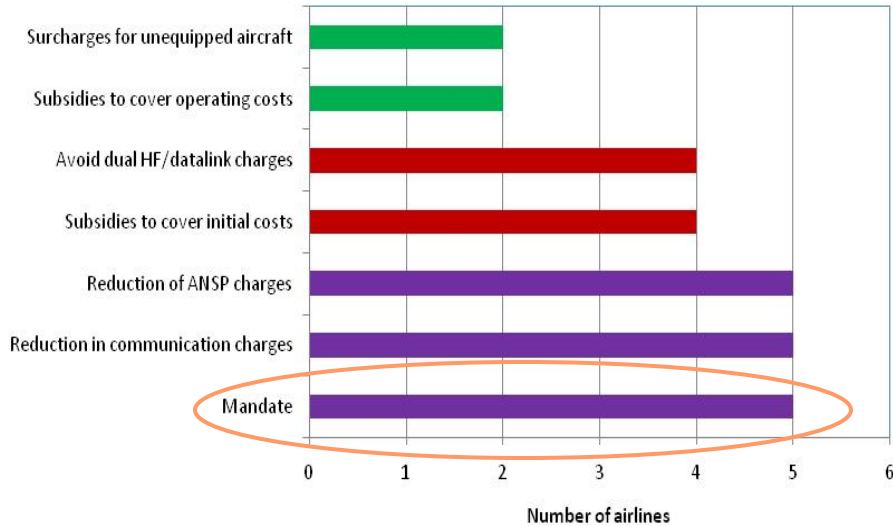


Value Determinants of Adopting Equipage and Effects of Policy Levers

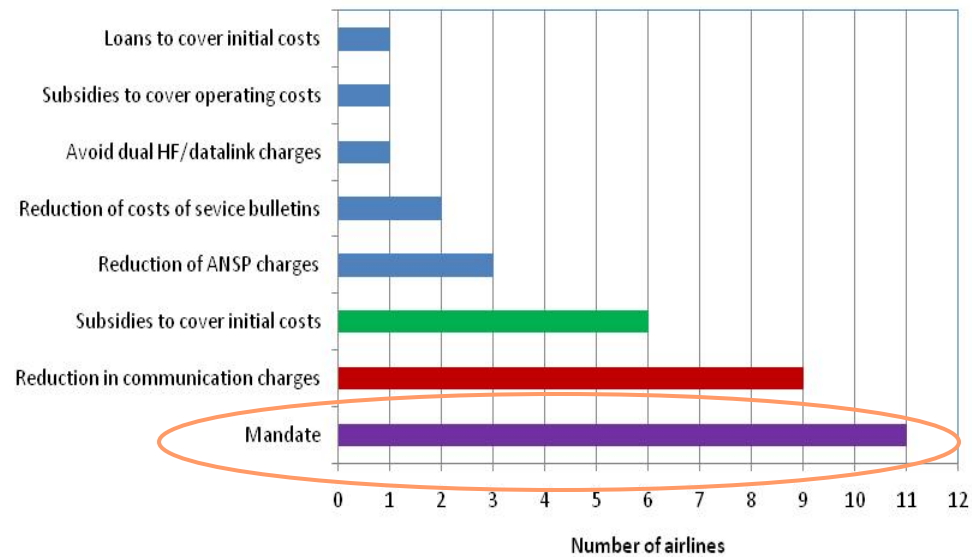


Argument for Segmenting Incentives

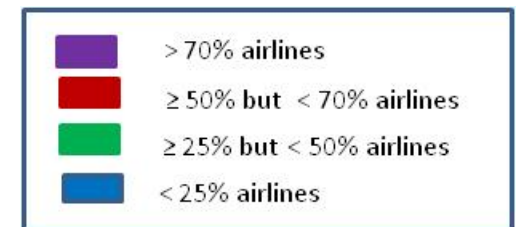
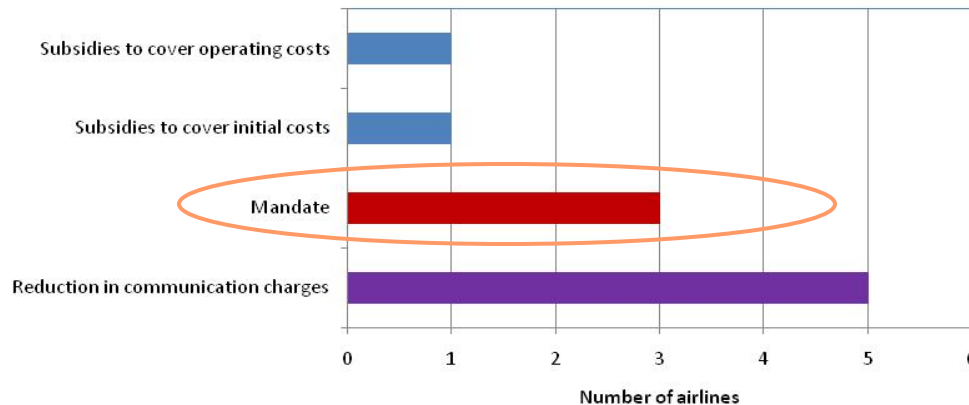
Strategies according to airlines 100% equipped with FANS-1/A (7 total)



Strategies according to airlines partially equipped with FANS-1/A (14 total)



Strategies according to airlines that are not equipped with FANS-1/A (6 total)



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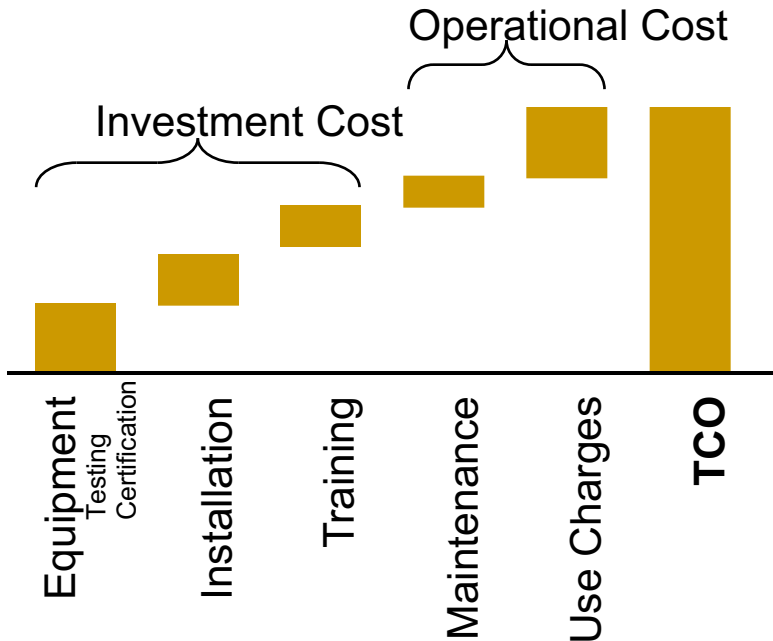
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Value Analysis Approach

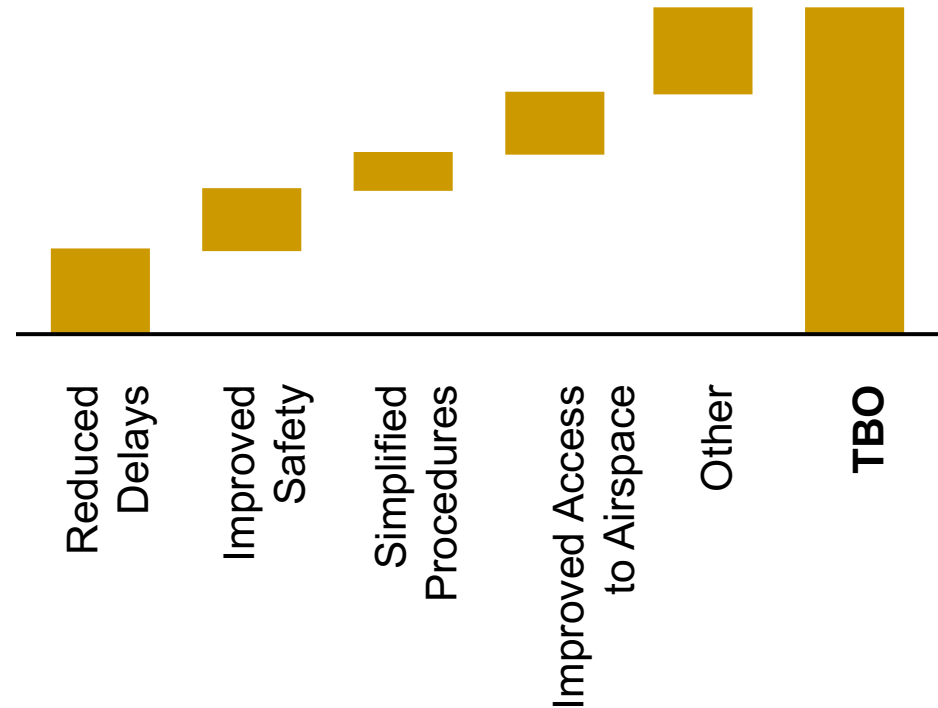
Broadly Examine Costs and Benefits

Value = (Benefits / Costs)

Total Costs Example

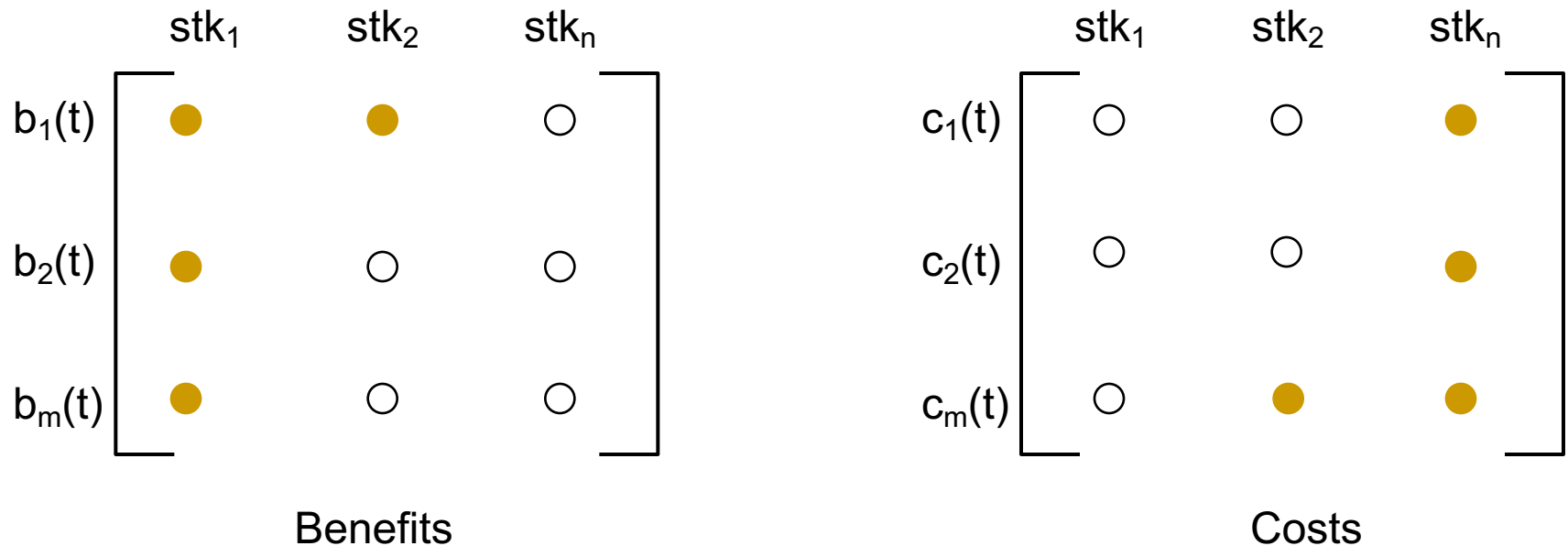


Total Benefits Example



Value Distribution

- How are costs and benefits distributed between stakeholders?



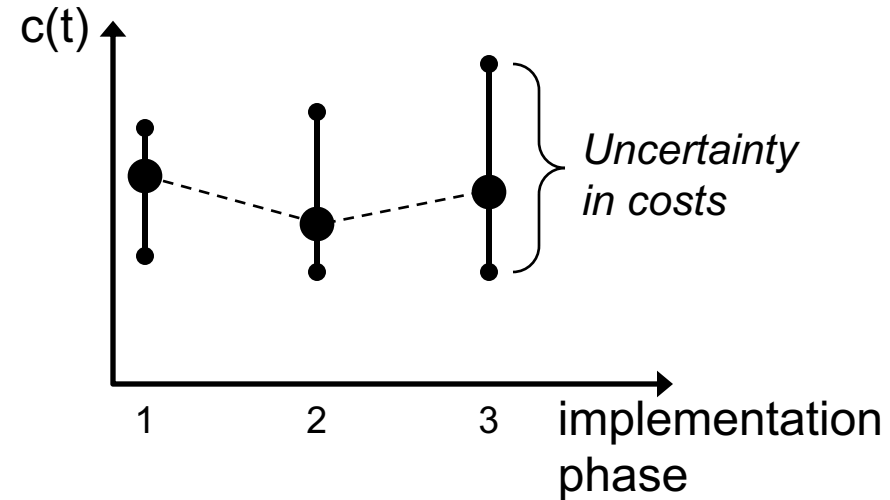
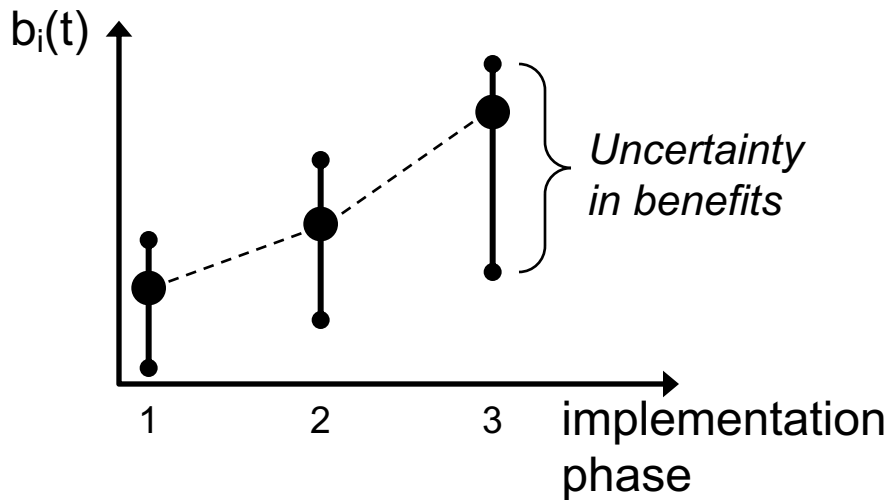
Looking at costs and benefits in this way can reveal imbalances in how they are distributed

ADS-B Stakeholder Benefit and Cost Distribution



Time-Phased Value Analysis

- Show how costs & benefits accrue over **implementation phases** for different stakeholders
- Identify cost and benefit **realization risks**

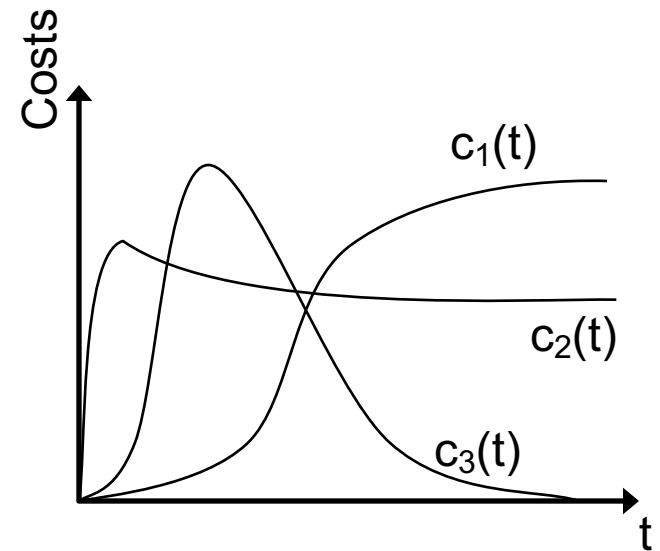
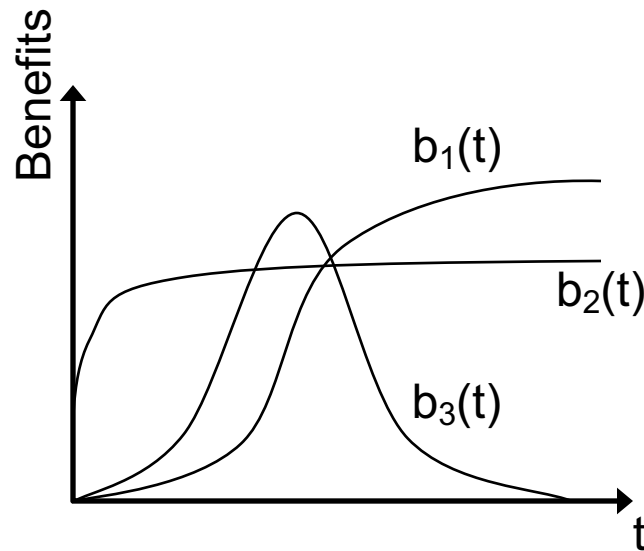


Positive long-term NPV necessary but may not be sufficient

- Time to positive ROI excessive
- Uncertainty in costs/benefits excessive

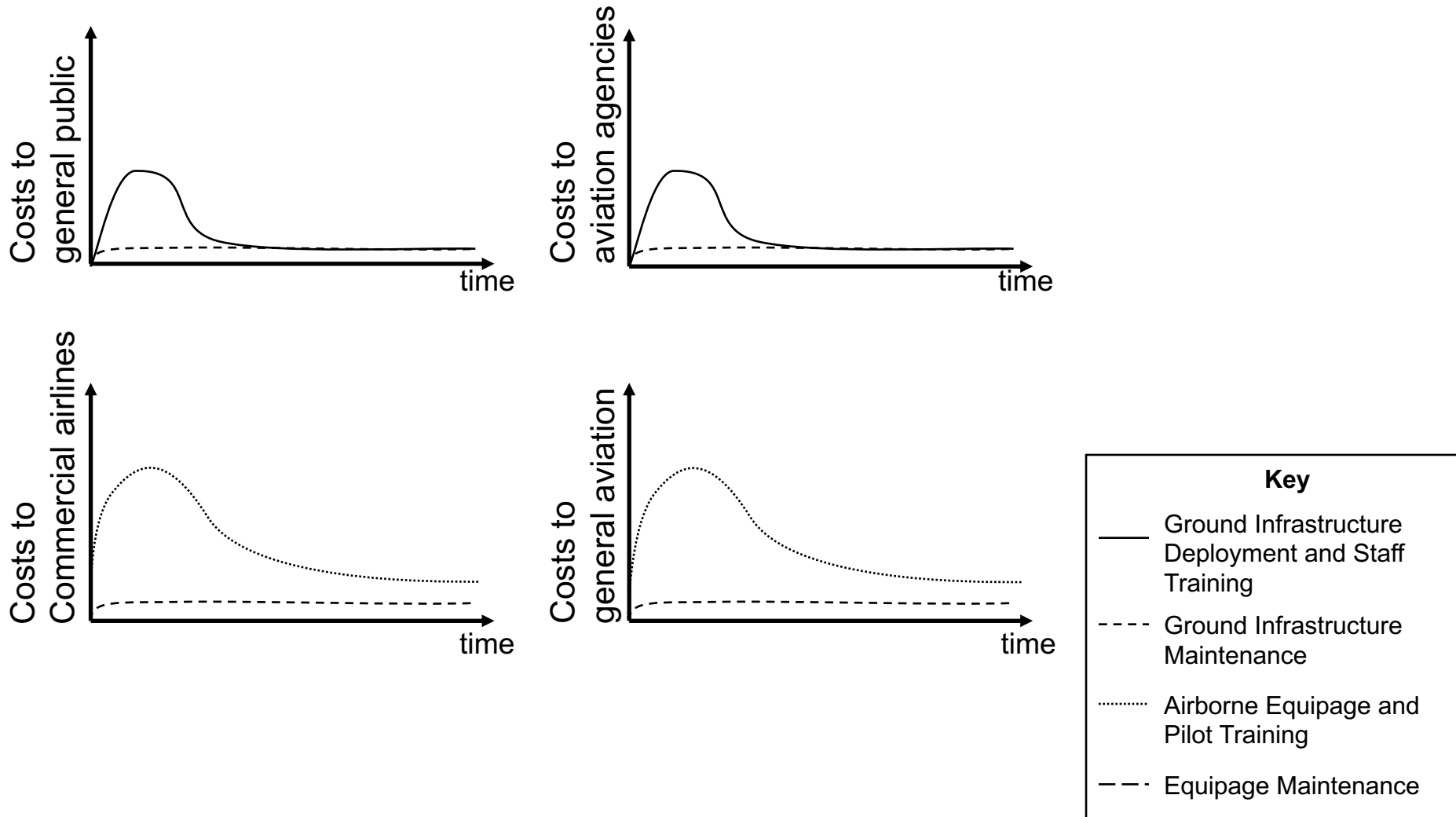
Value Over Time

- How are costs and benefits distributed over time?

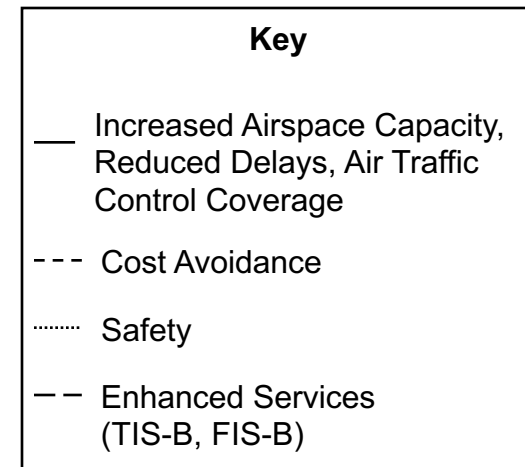
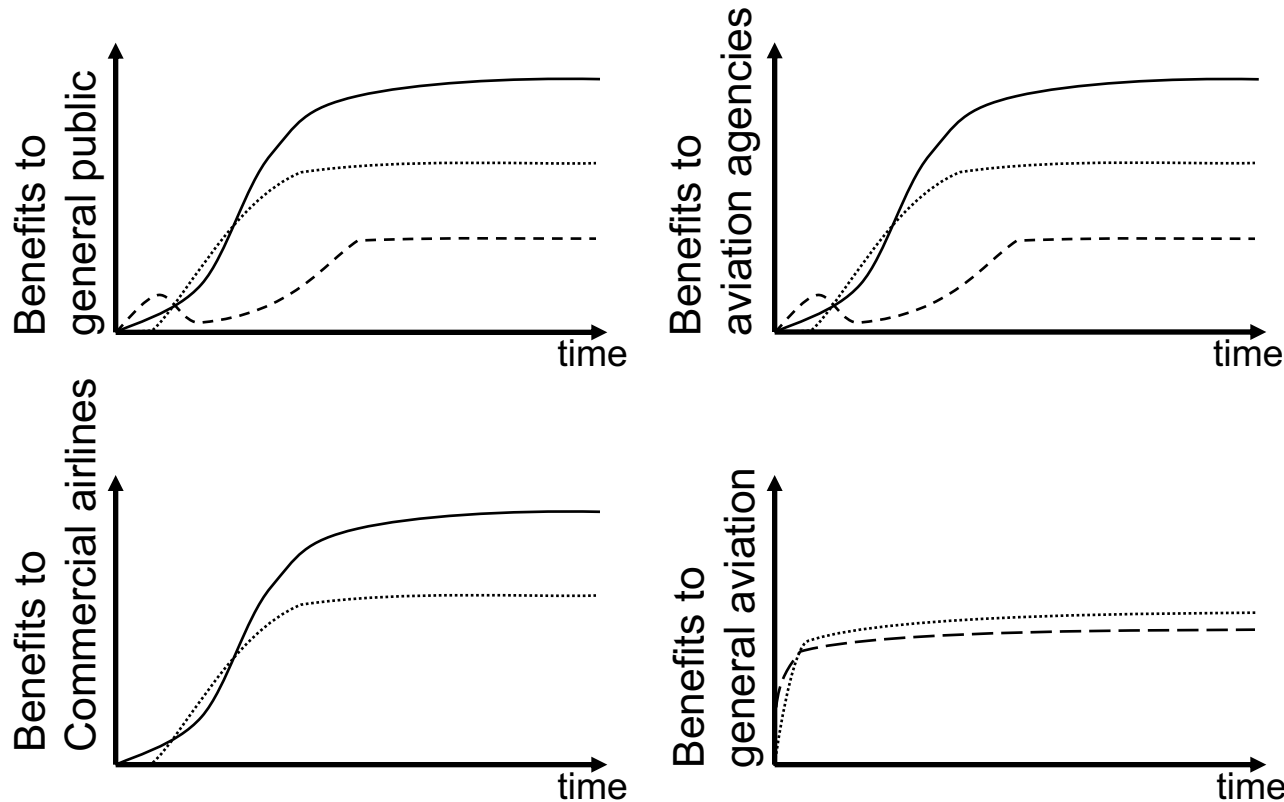


- Consider different types of cost
 - E.g., installation, training, operation

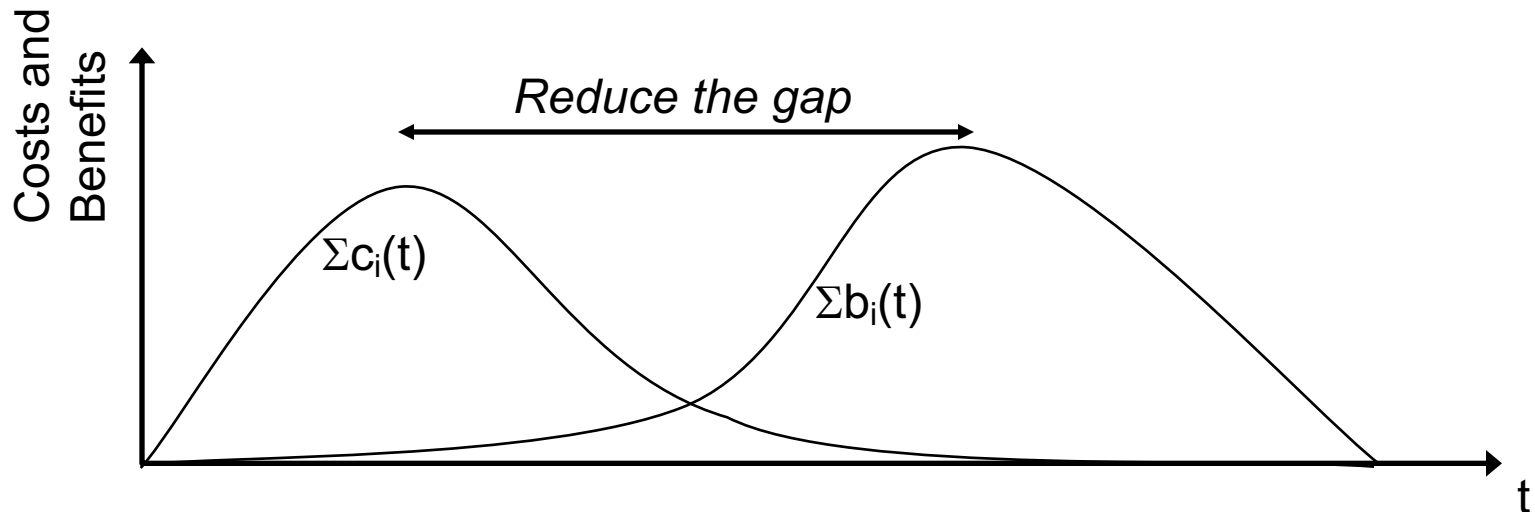
ADS-B Cost Distribution Over Time



ADS-B Benefit Distribution Over Time

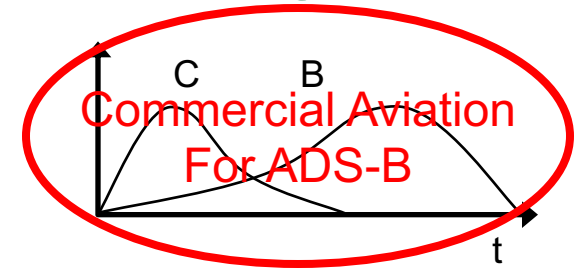
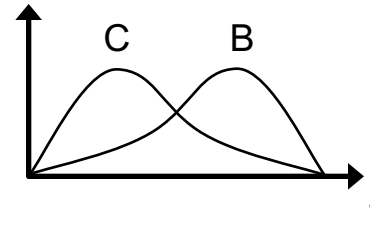
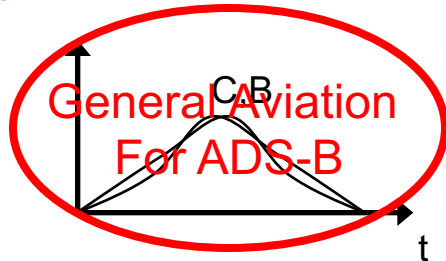


Accelerating Benefits and Delaying Costs Addresses Time-phased Value Distribution



- Investment more attractive if benefits more quickly realized
- Positive NPV over short term is better, especially when costs are high
- Delay costs
 - Aviation agency pays for initial installations, provides discounts
- Accelerate benefits
 - Rapid ground equipment deployment when ground equipment required
 - Coordinated effort across airlines when strong network effects

Policy Levers Selection for Value Timing

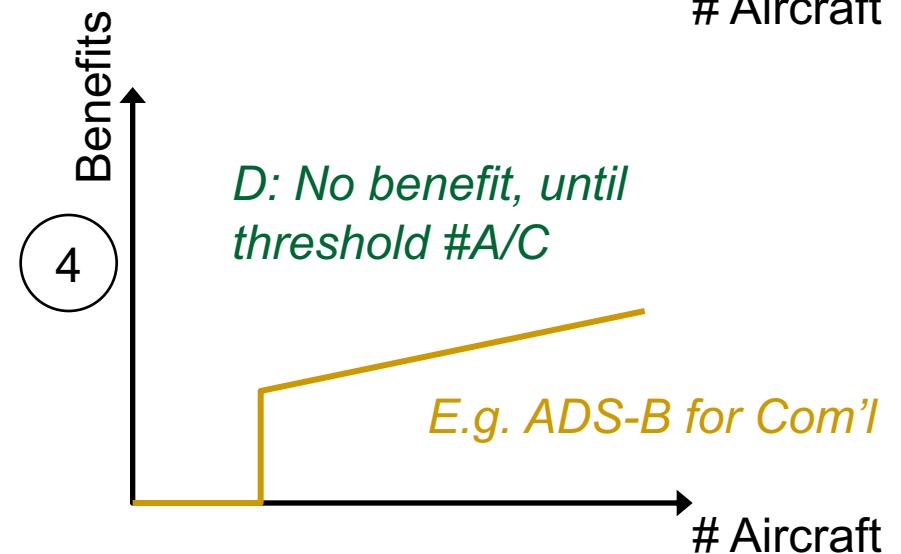
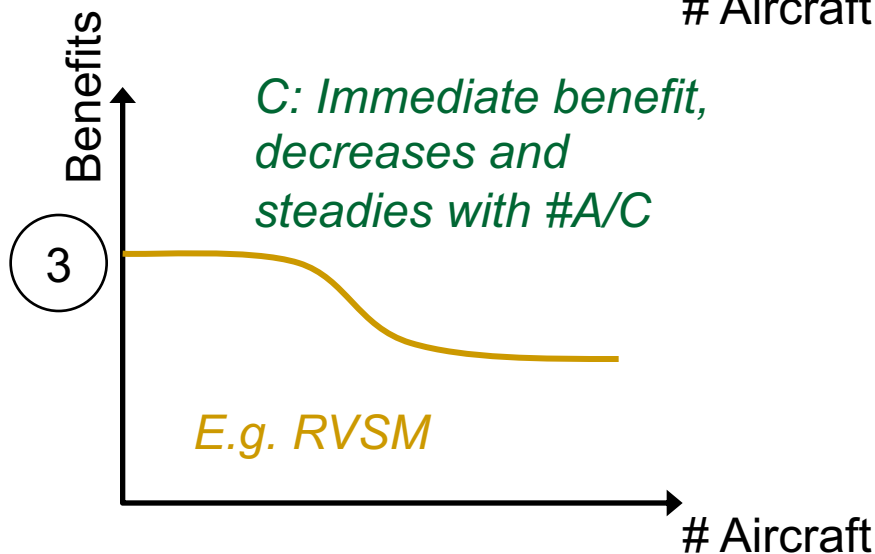
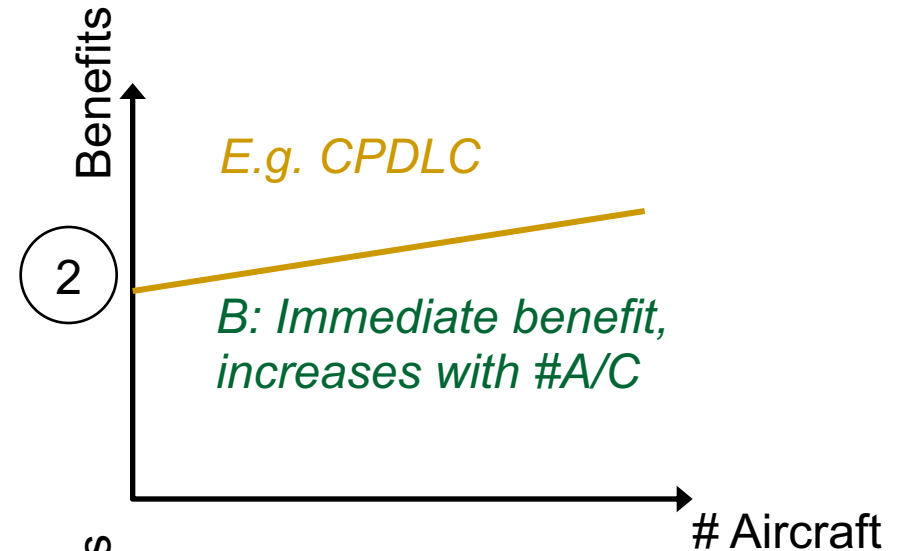
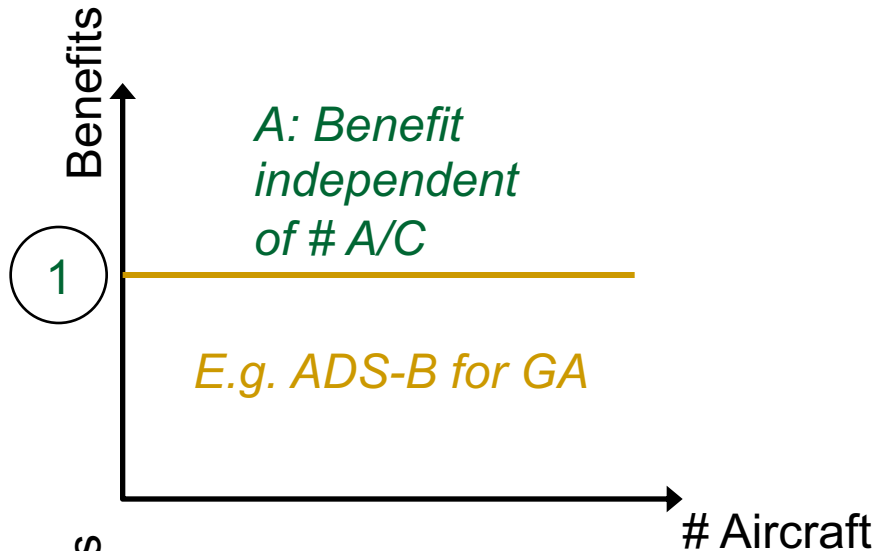


Timing	Costs and benefits coincide	Costs precede benefits	Long delay to benefits
Scenario Examples	Individual adoptions provide benefits.	Benefits realized only when other A/C equipped. Delays in ground infrastructure deployment.	Benefits realized only when <i>many</i> other A/C equipped. Long delays to ground infrastructure deployment.
Strategies	Significant benefits realized concurrently with costs provides incentive to aircraft operators to invest. When short-term benefits are smaller than costs, positive incentives may be needed to improve the value case.	May be possible to make ROI cases based on operational benefits of technology without resorting to positive incentives such as discounts and financing schemes.	Pioneer schemes, positive incentives, and mandates. Strong incentives and aid schemes in addition to technology benefit are needed to mitigate the slow ROI.
Comments	Great situation, but rarely occurs.	More realistic scenario.	When benefits take this long to realize it may be a signal that the proposed technology solution is not appropriate.

Network Effects Approach

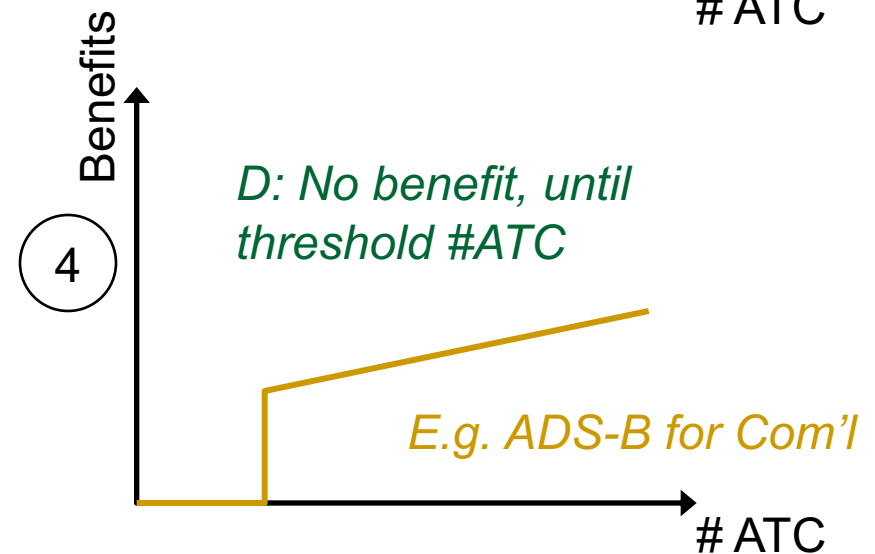
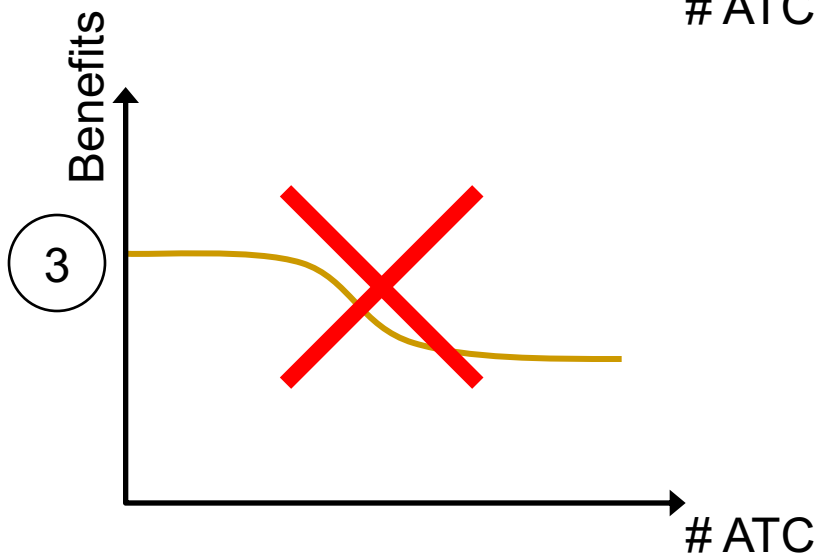
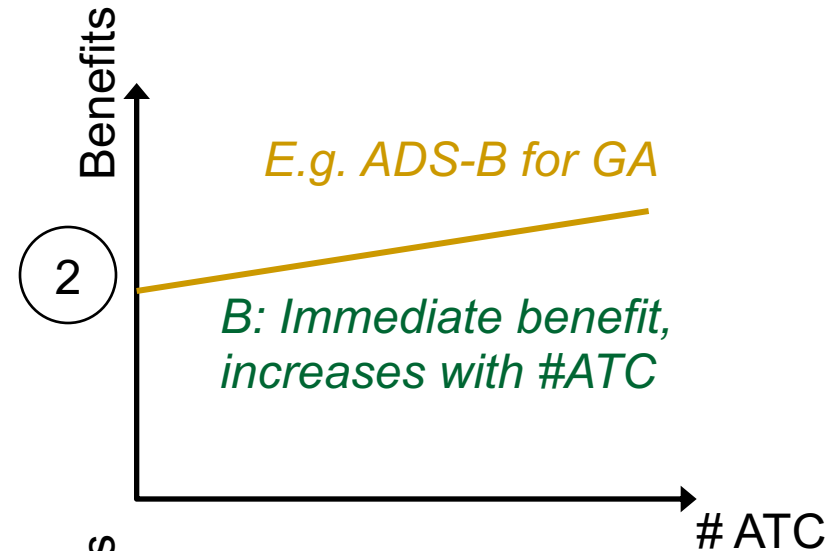
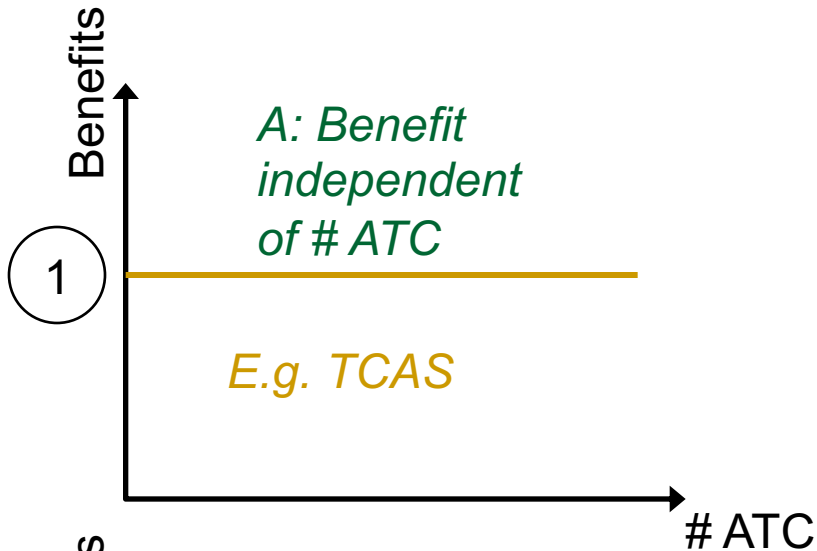
Benefit Network Effects, #A/C

Benefits may of course increase/decrease non-linearly, shape of curves illustrative only

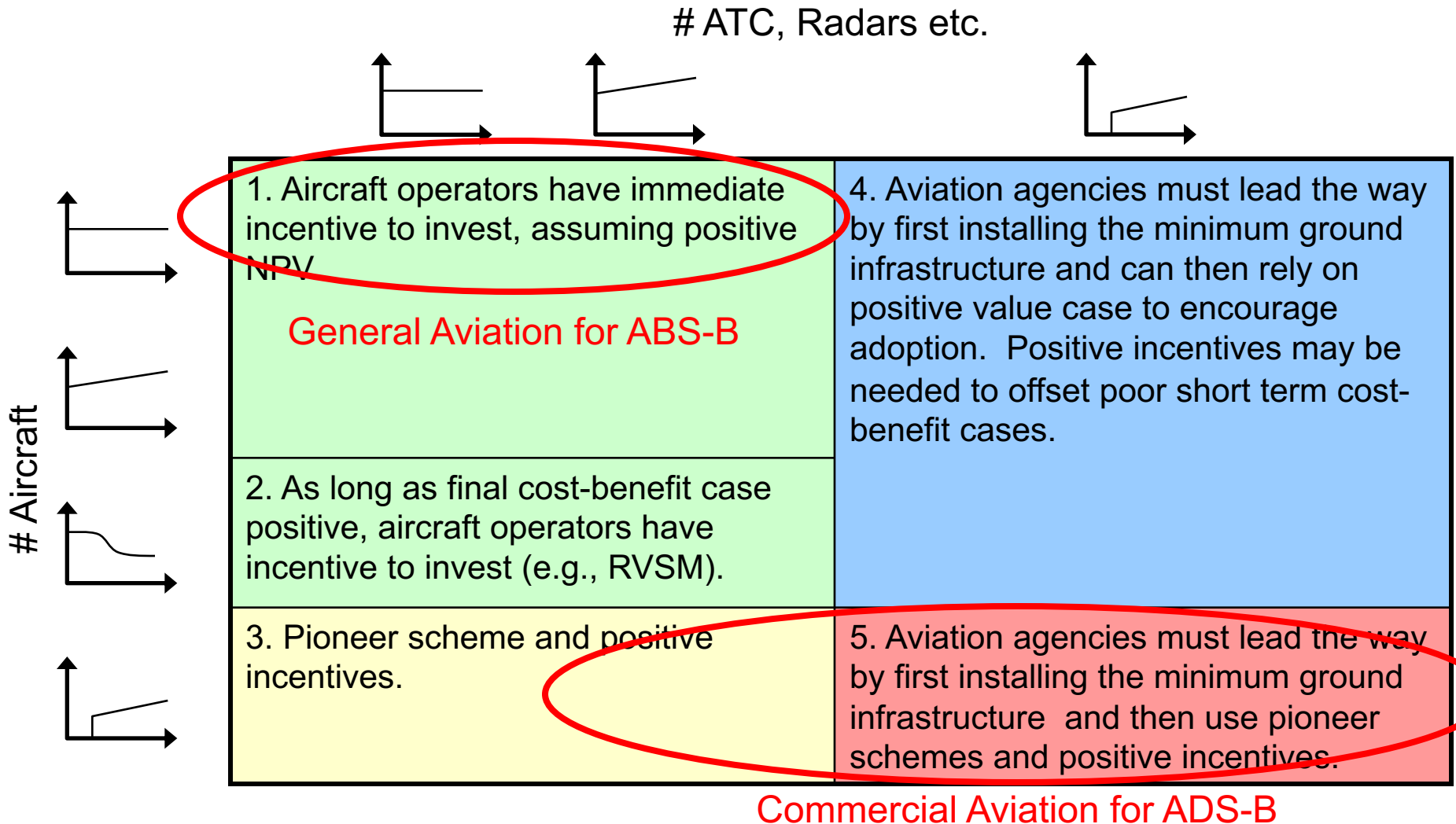


Benefit Network Effects, #ATC

Benefits may of course increase/decrease non-linearly, shape of curves illustrative only



Best Leverage Strategies for Different Network Effects



Game Theory Approach

Games and Findings

1

		Airline 2	
		Equip	Don't Equip
Airline 1	Equip	$P-C+\epsilon+\gamma$	$P-C$
	Don't Equip	ϵ	0

Public Goods Market Failure

Airline to Airline Game

2

		Major Carrier	
		Equip	Don't Equip
Other Users	Equip	$P_{GA}-C_{GA}+\epsilon_{AC}+\gamma$	$P_{GA}-C_{GA}$
	Don't Equip	ϵ	0

Asymmetry of Costs, Benefits, and Information

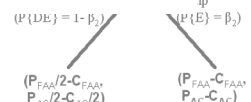
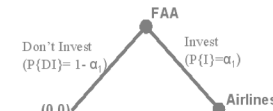
Major Carriers to Other Airspace Users Game

3

		Airlines	
		Equip	Don't Equip
FAA / ATC	Equip	$P_{ATC}-C_{ATC}$	$-C_{ATC}$
	Don't Equip	ϵ	0

Asymmetry of Costs and Benefits, Risk Dominance, Institutional Failures

Major Airlines to FAA Game (Static and Dynamic)



Assumptions:

- Free market conditions
- No bargaining or side payments, so no coalitions in airline to airline game
- Groups act as coalitions in major carriers to other airspace users and major airlines to FAA games

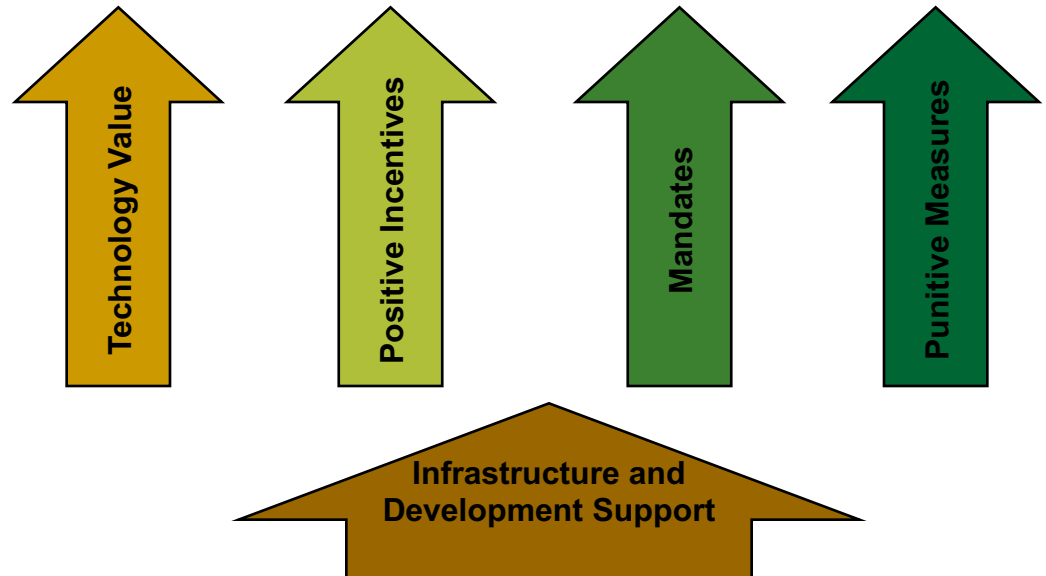
Using Policy Levers to Address Market Failures

Market Failures:

- Public Goods Market Failure
- Asymmetry of Costs and Benefits
- Asymmetry of Information
- Risk Dominance
- Organizational Process Difficulties
- Pressure on Government Budgets

Potential Policies to Address Market Failures:

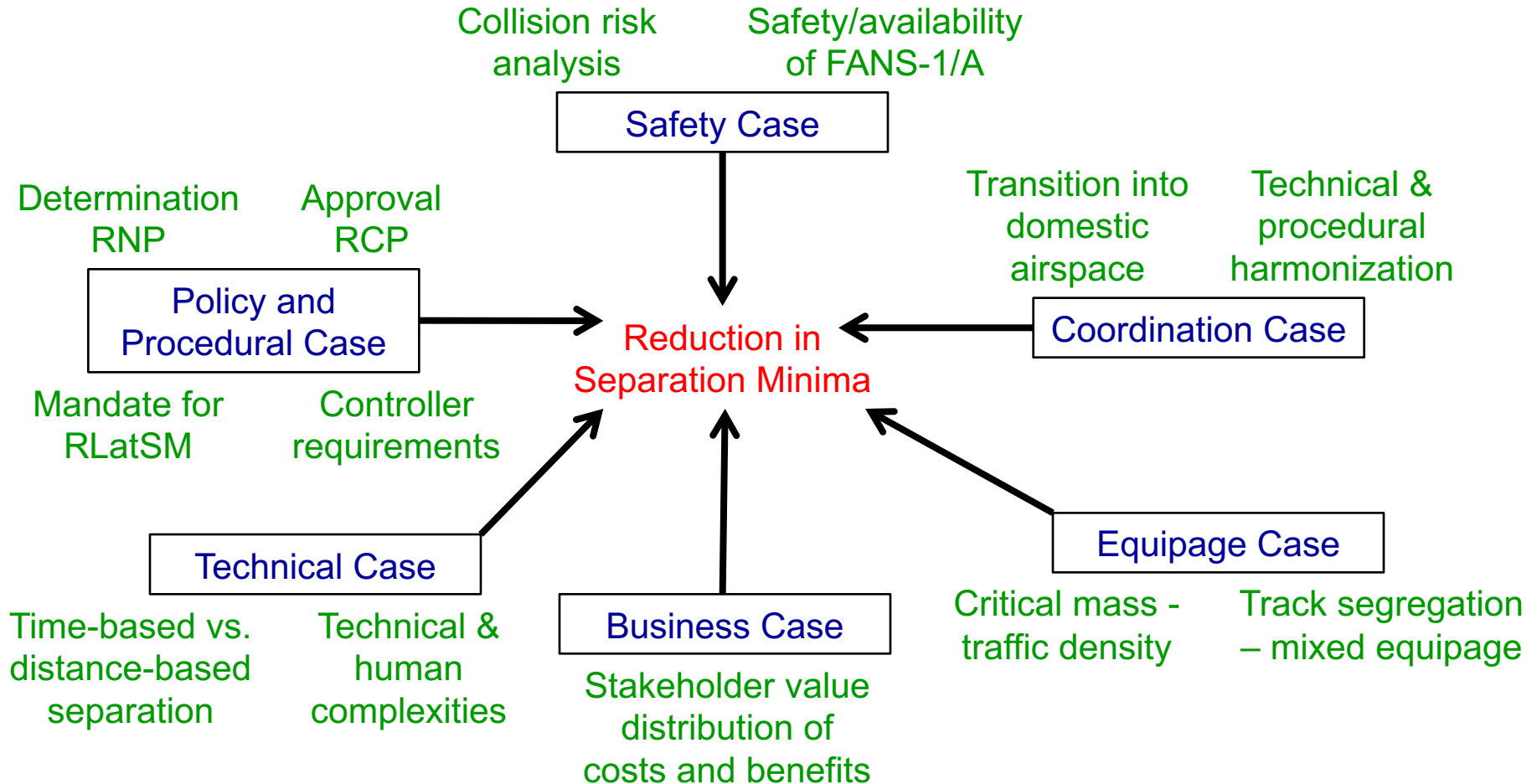
- Accelerate high benefit applications
- Trials
- Cash
- Tax credits
- Preferential treatment
- Guaranteed benefits
- Accelerate mandate
- Mandate for select airspace
- Taxes
- Exclusionary airspace



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Delivering Value is More Than Balancing Costs and Benefits



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