OPERATING ECONOMICS OF AUTONOMOUS LONG-HAUL TRUCKS

Dale Lewis

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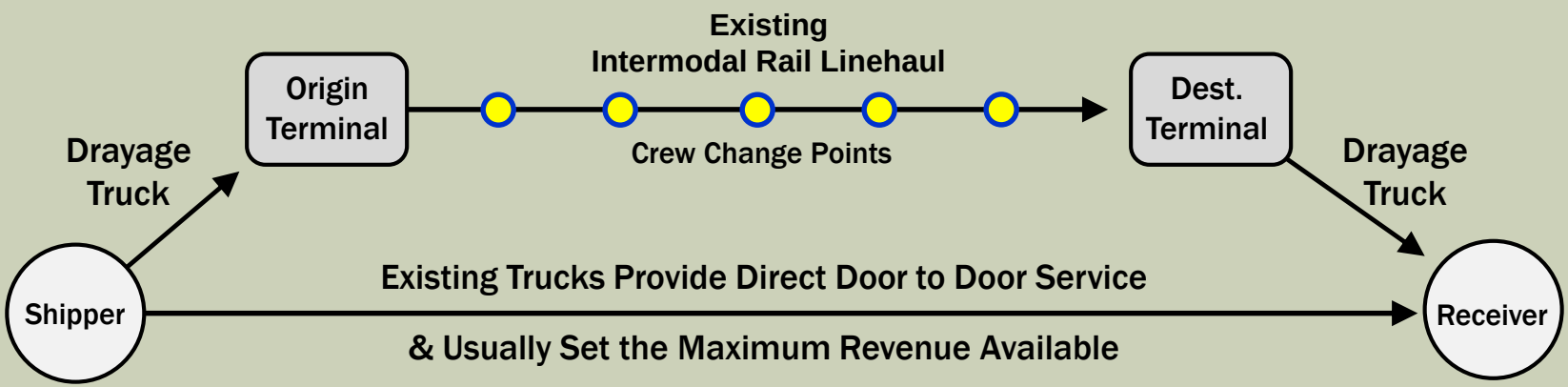
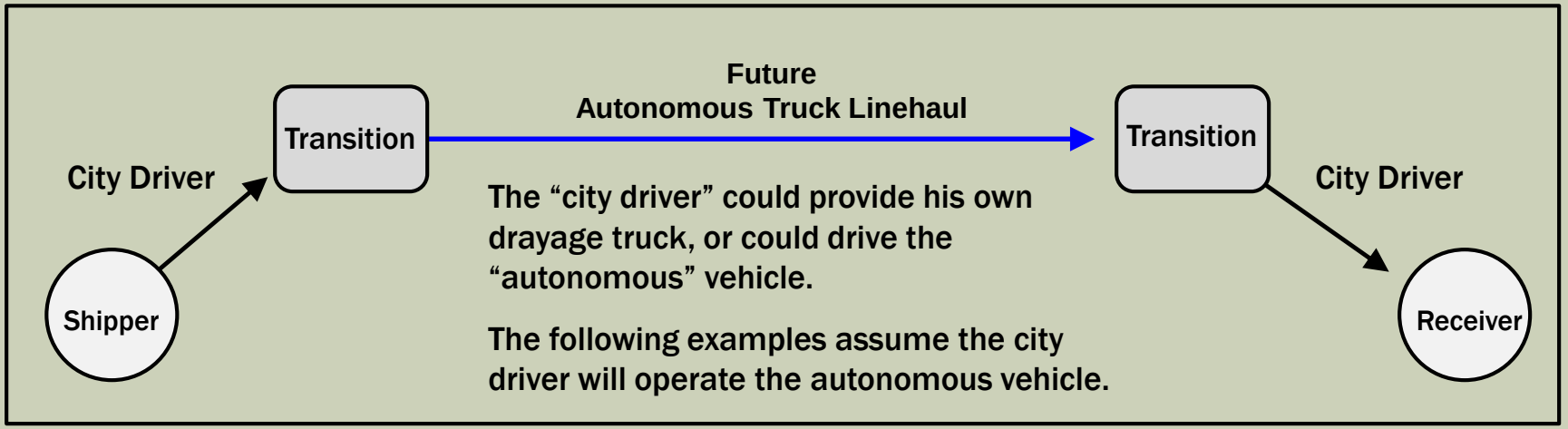
LONG-HAUL TRUCK AUTOMATION QUESTIONS

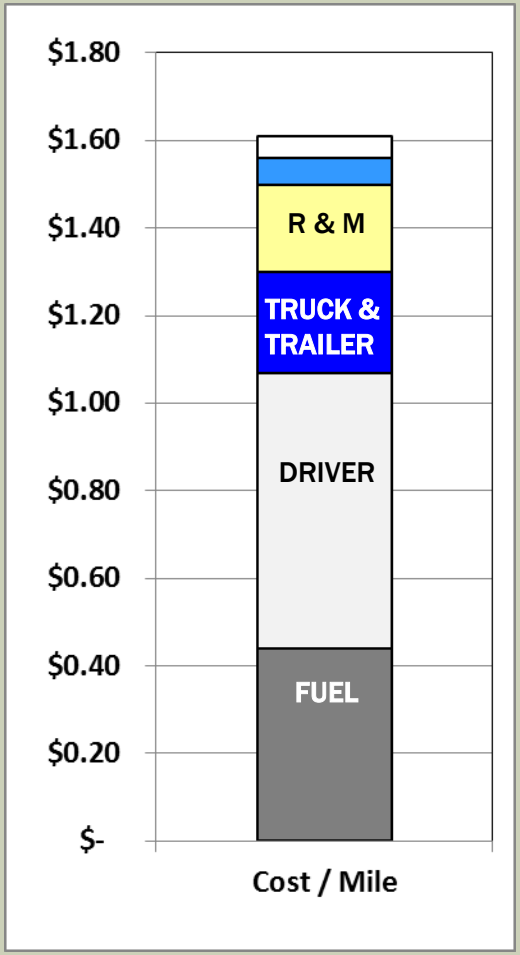
- What private dollars are in play? What are the public impacts? What is the cost impact on delivered retail goods?
- How would it work? Is there a range of reasonable operating assumptions under which autonomous trucks are economically feasible?
  - Assumption 1: Levels 1 & 2 (Driver Assist) happens soon
  - Assumption 2: Level 4 (Autonomous Linehaul) several years later
- Where would you start? Private fleet? For hire?
- Is there enough lane-specific freight available to make the economic case for several thousand automated trucks?
- Are the private economics so strong that we should work through the public safety, emissions, infrastructure and regulatory issues?

AUTONOMOUS TRUCKS COULD OPERATE IN A "TERMINAL TO TERMINAL" MODEL



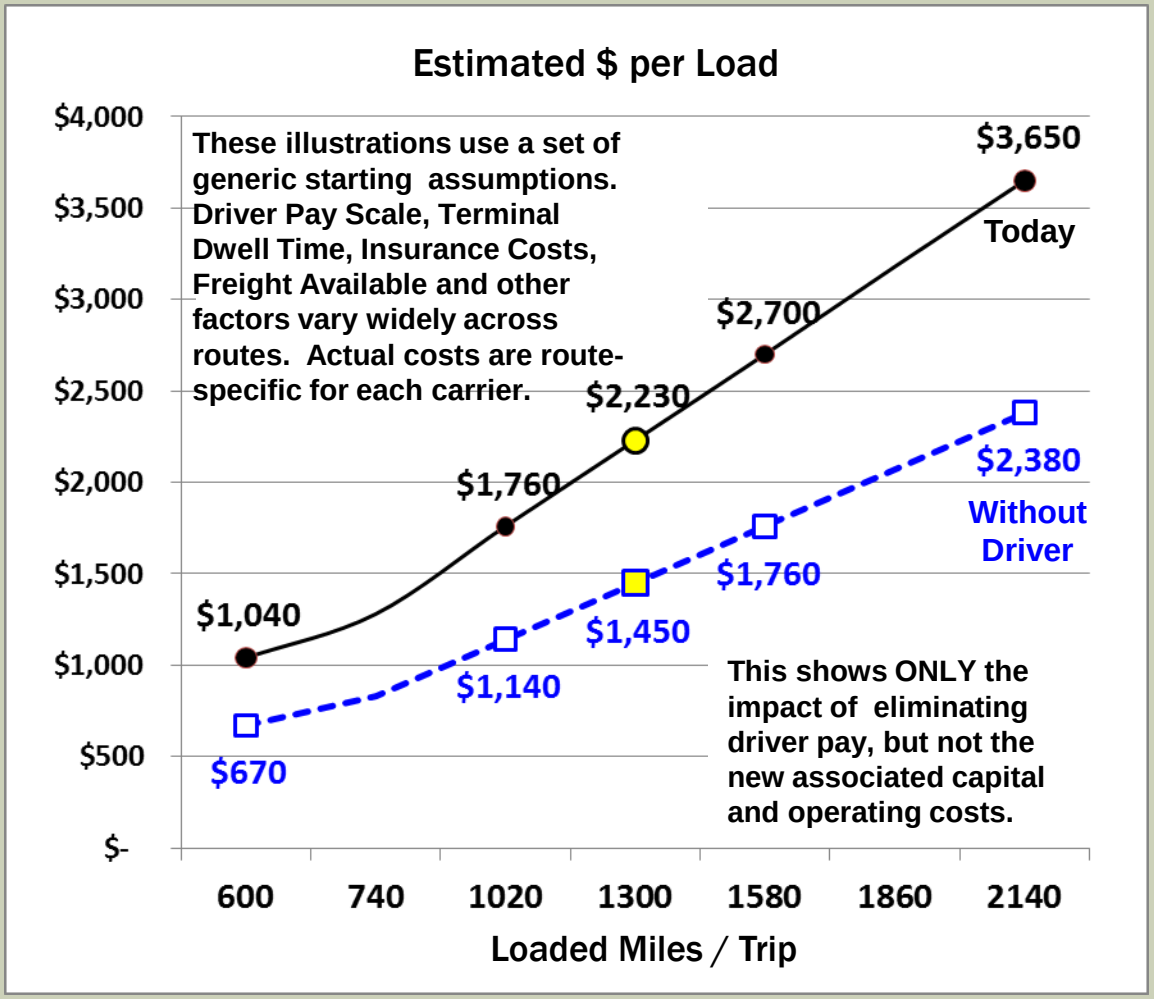


THERE ARE BOTH BIG POSITIVES AND BIG CHALLENGES



- Private Gains
  - Avoided Linehaul Driver Pay
  - More Operating Hours per Day
  - More Operating Days per Year
  - Improved Fuel Efficiency
  - Increased Ratio of Loaded Miles
  - Lower Costs of Insurance / Risk
- Public Impacts
  - Reduced Transportation Compensation
  - Reduced Highway Maintenance Funds
  - Potential Mode-Shift Emissions Increases
  - Additional Safety Infrastructure Needs
  - Small Consumer Cost Reductions
  - New Regulatory Framework Needed

AVOIDING OPERATING PAYROLLS WOULD HAVE A MAJOR IMPACT ON COSTS

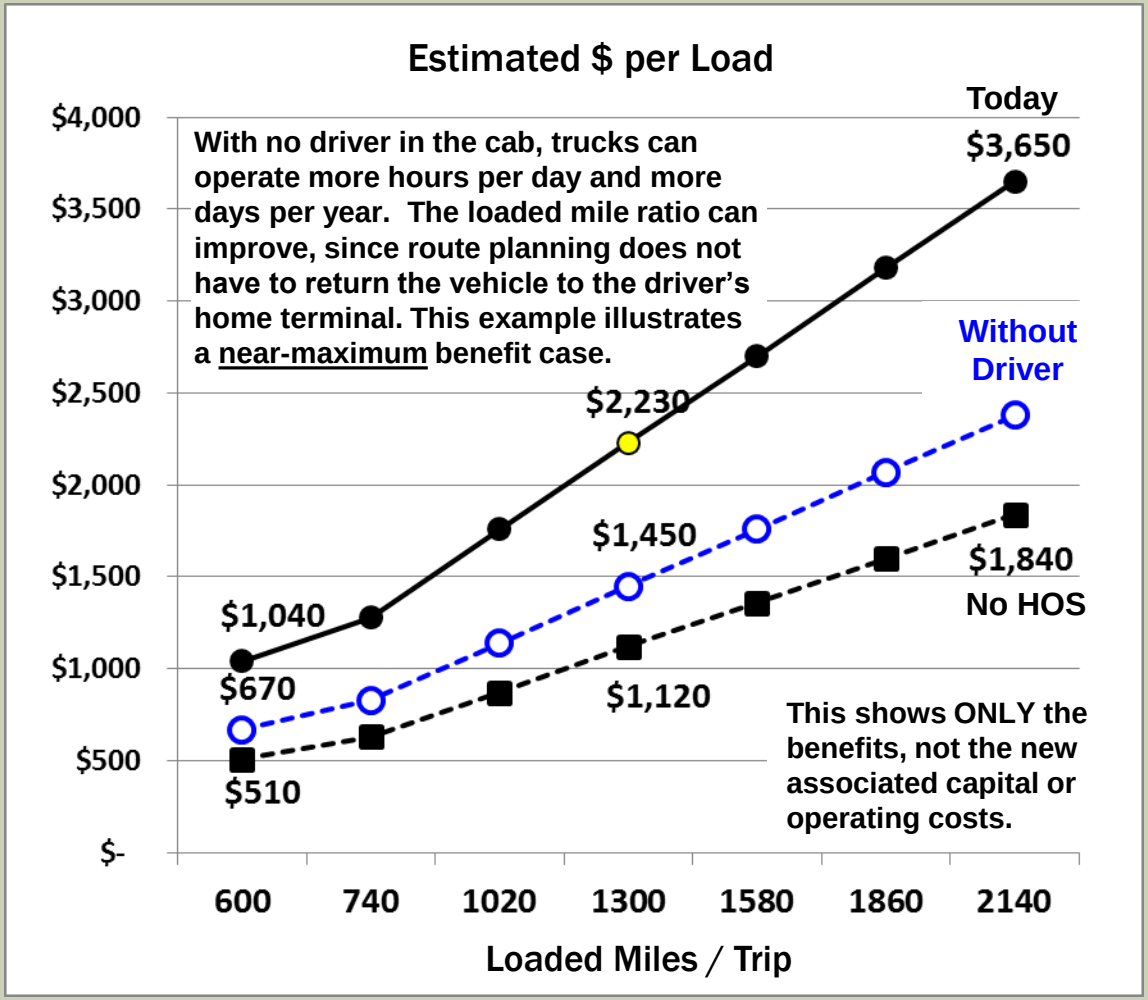


Mid-Range Assumptions

Truck & Route:
$150,000 Truck (Level 0)
$3.00/Gal Diesel
7.2 MPG
70% Loaded Miles
119,000 Miles/Year
800,000 Mile Limit
6.8 Year Truck Life
$0.06 / Mile Insurance

Driver Pay:
$50,000 per year
270 Days in service
2,100 On Duty Hrs/Yr
14 Hour Days
11 Hours Driving
1 Hour Rest
10 Hours Sleep

HOS AND ROUTING CHANGES CAN DRIVE UP PRODUCTION PER TRUCK



Mid-Range Assumptions

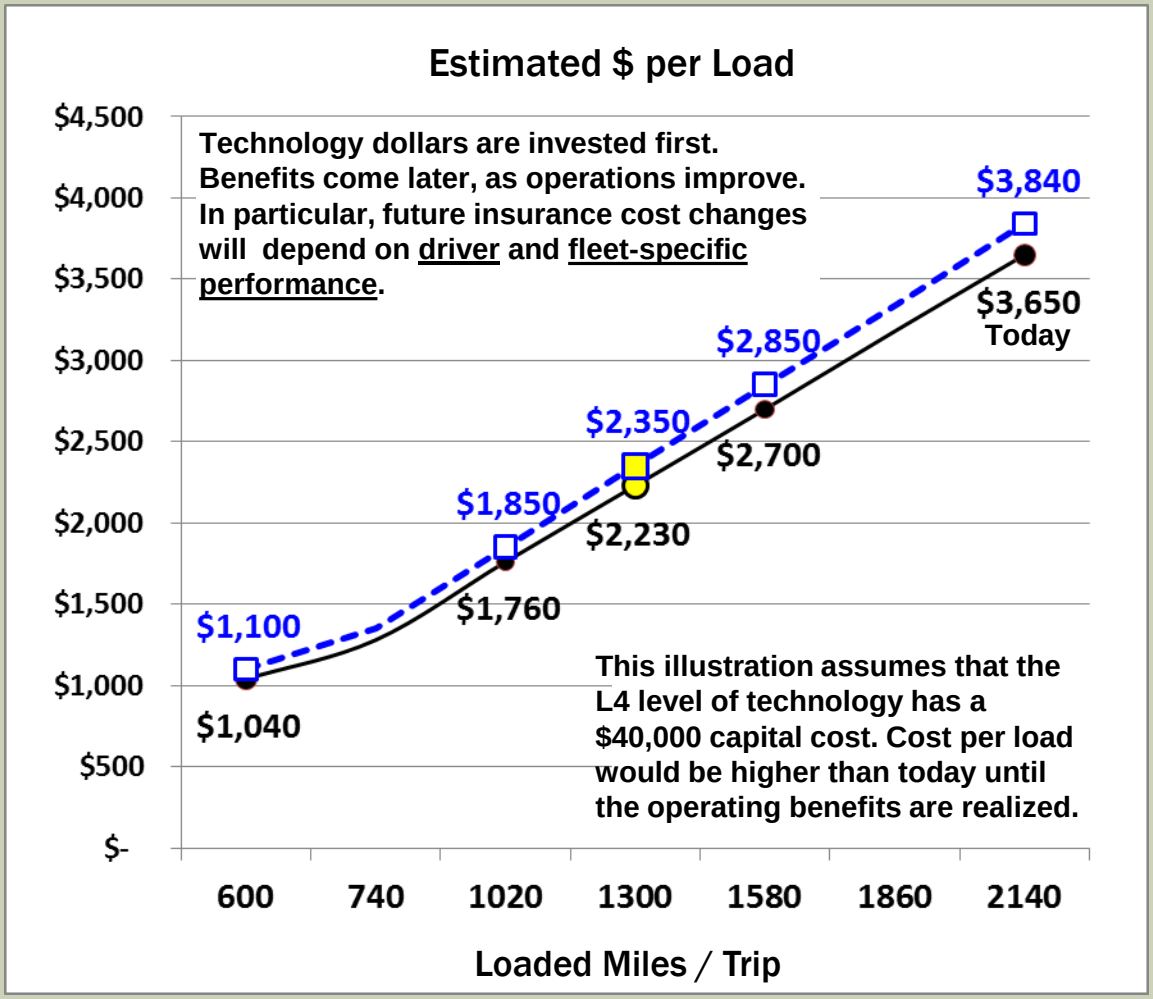
Truck & Route:

$150,000 Truck $3.00/Gal Diesel
8.2 MPG
75% Loaded Miles
426,000 Miles/Year
800,000 Mile Limit
1.9 Year Truck Life
$0.04 /Mile Insurance

Driver Pay:

$50,000 per year
350 Days in service
20 Hour Days
20 Hours Driving
0 Hour Rest
0 Hours Sleep

INITIALLY, THE TECHNOLOGY WOULD SUPPORT TODAY'S DRIVERS

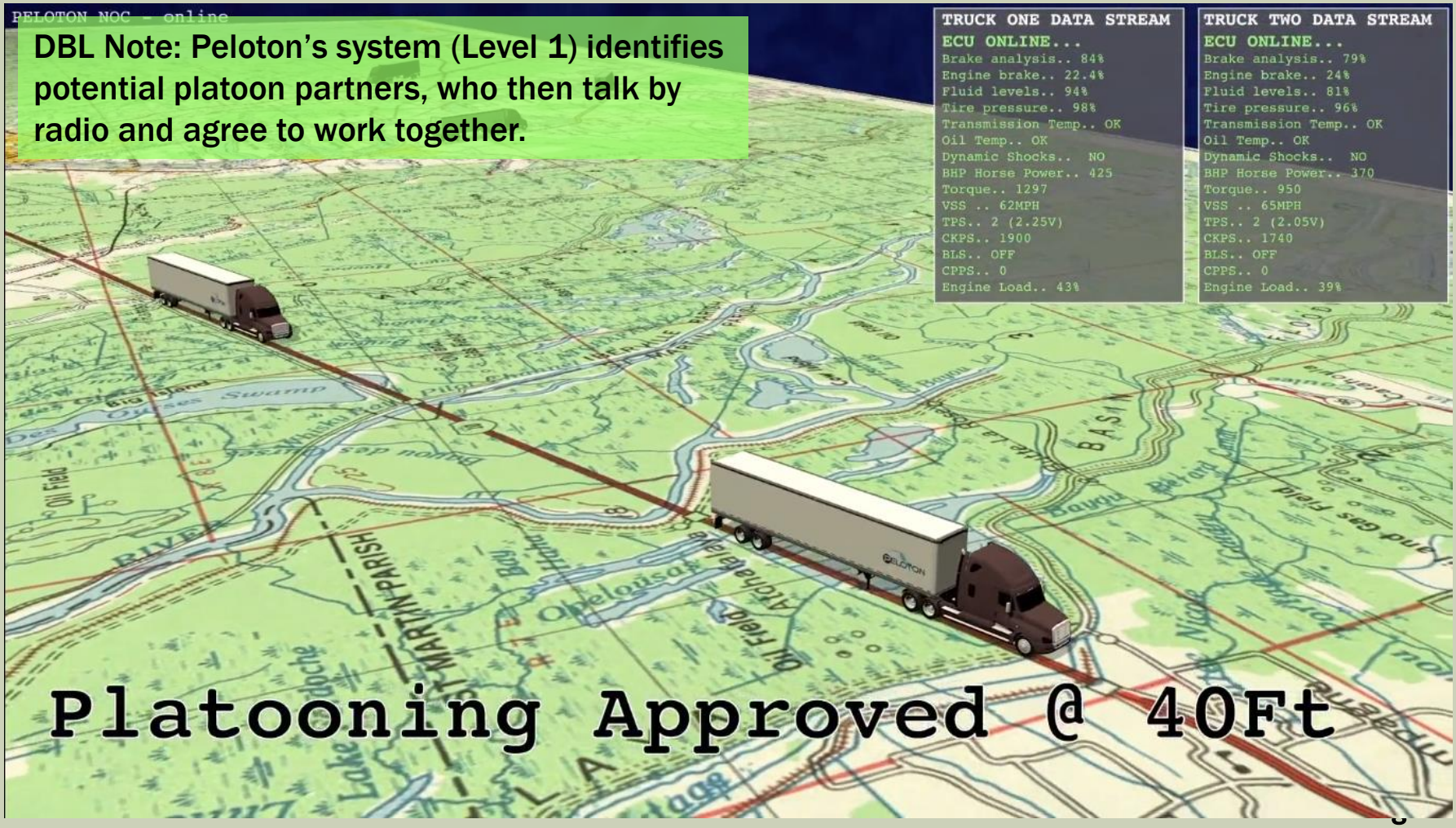


Mid-Range Assumptions

Truck & Route:
$190,000 Truck (L4)
$3.00/Gal Diesel
7.2 MPG
70% Loaded Miles
119,000 Miles/Year
800,000 Mile Limit
6.8 Year Truck Life
$0.06 / Mile Insurance

Driver Pay:
$50,000 per year
270 Days in service
2,100 On Duty Hrs/Yr
14 Hour Days
11 Hours Driving
1 Hour Rest
10 Hours Sleep

PLATOONING IS ONE TECHNOLOGY STEP



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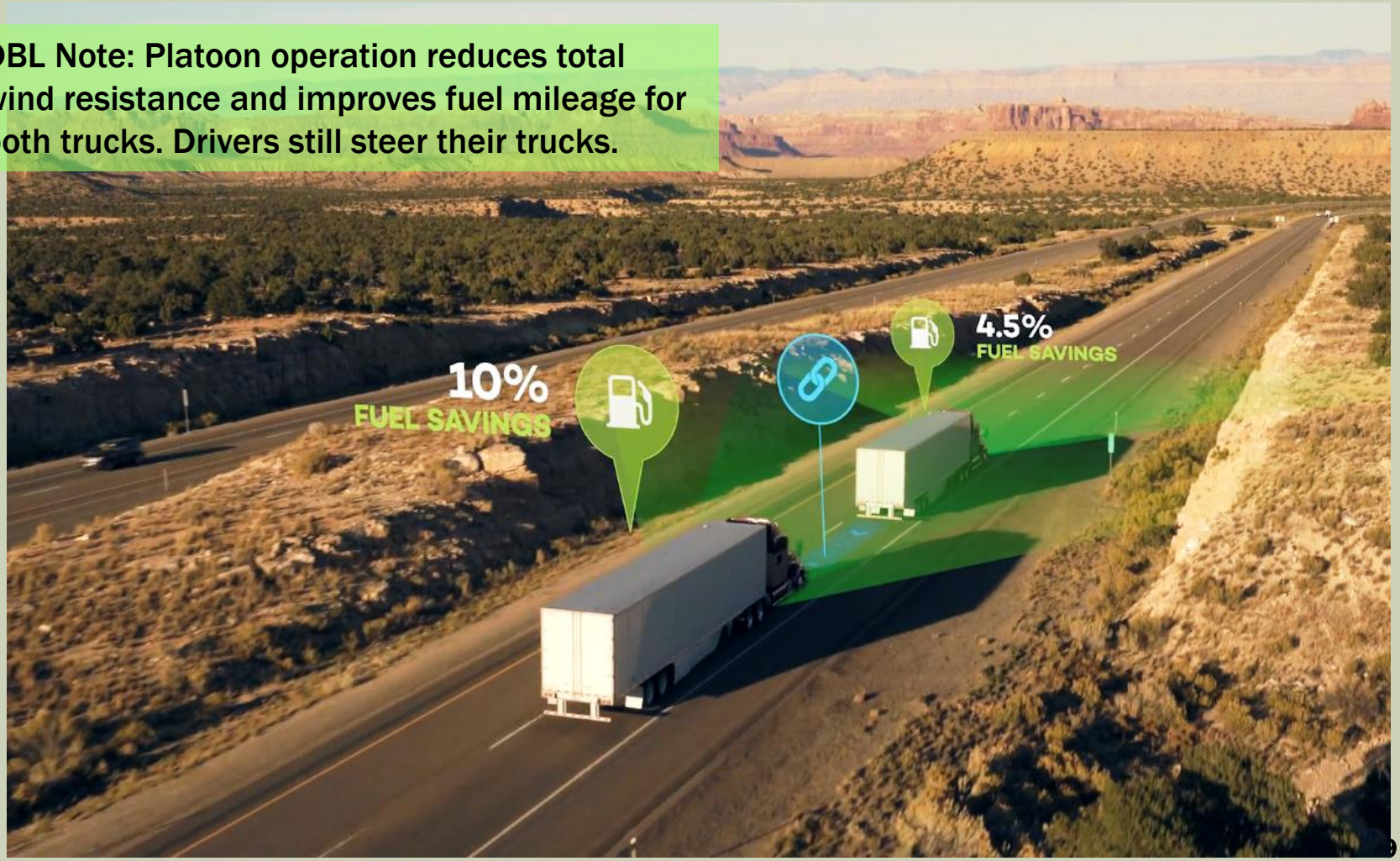
PLATOONING IS ONE TECHNOLOGY STEP

DBL Note: Platoon operation reduces total wind resistance and improves fuel mileage for both trucks. Drivers still steer their trucks.



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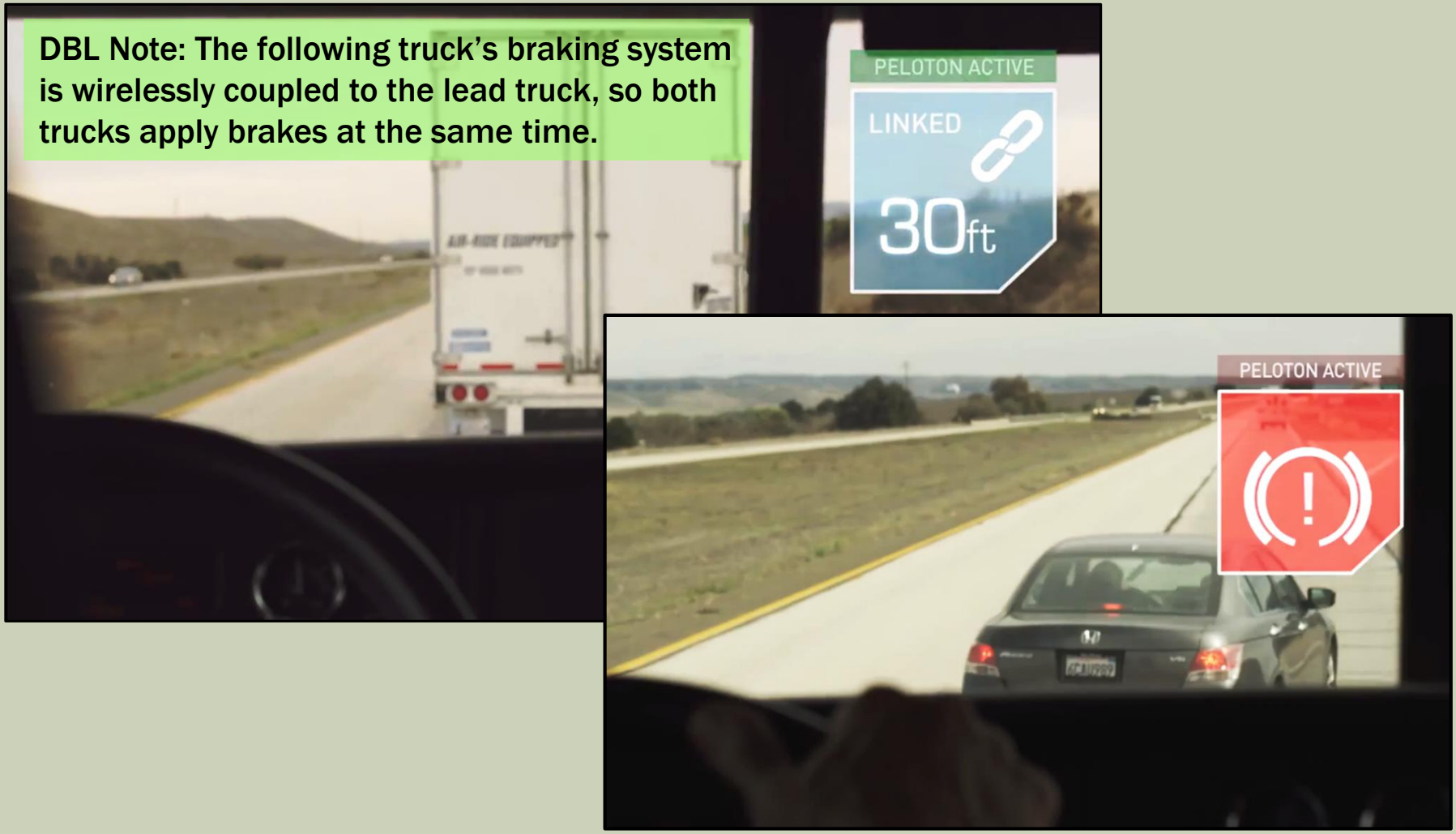

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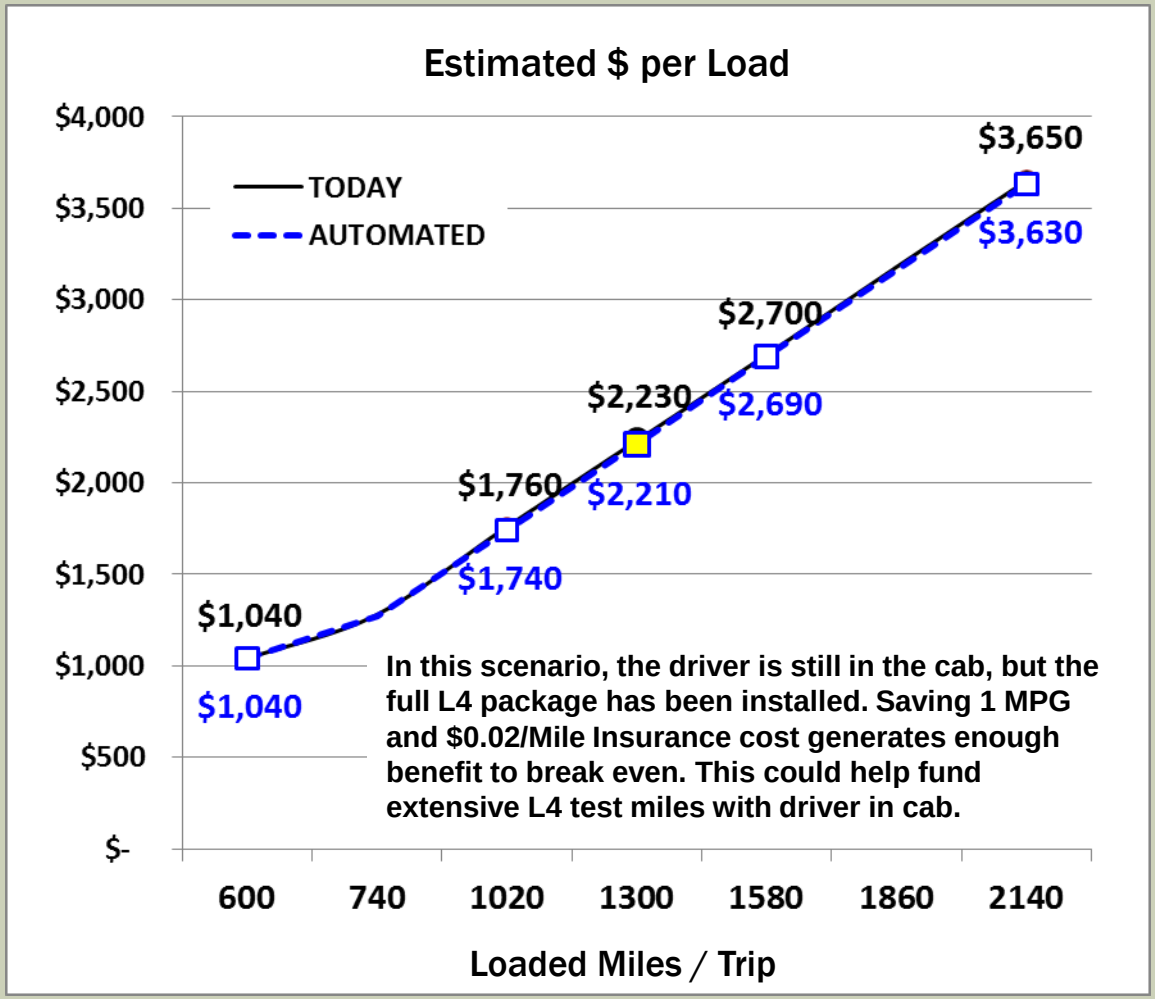
FUEL & INSURANCE COST REDUCTIONS COULD OFFSET LARGE TECHNOLOGY COSTS

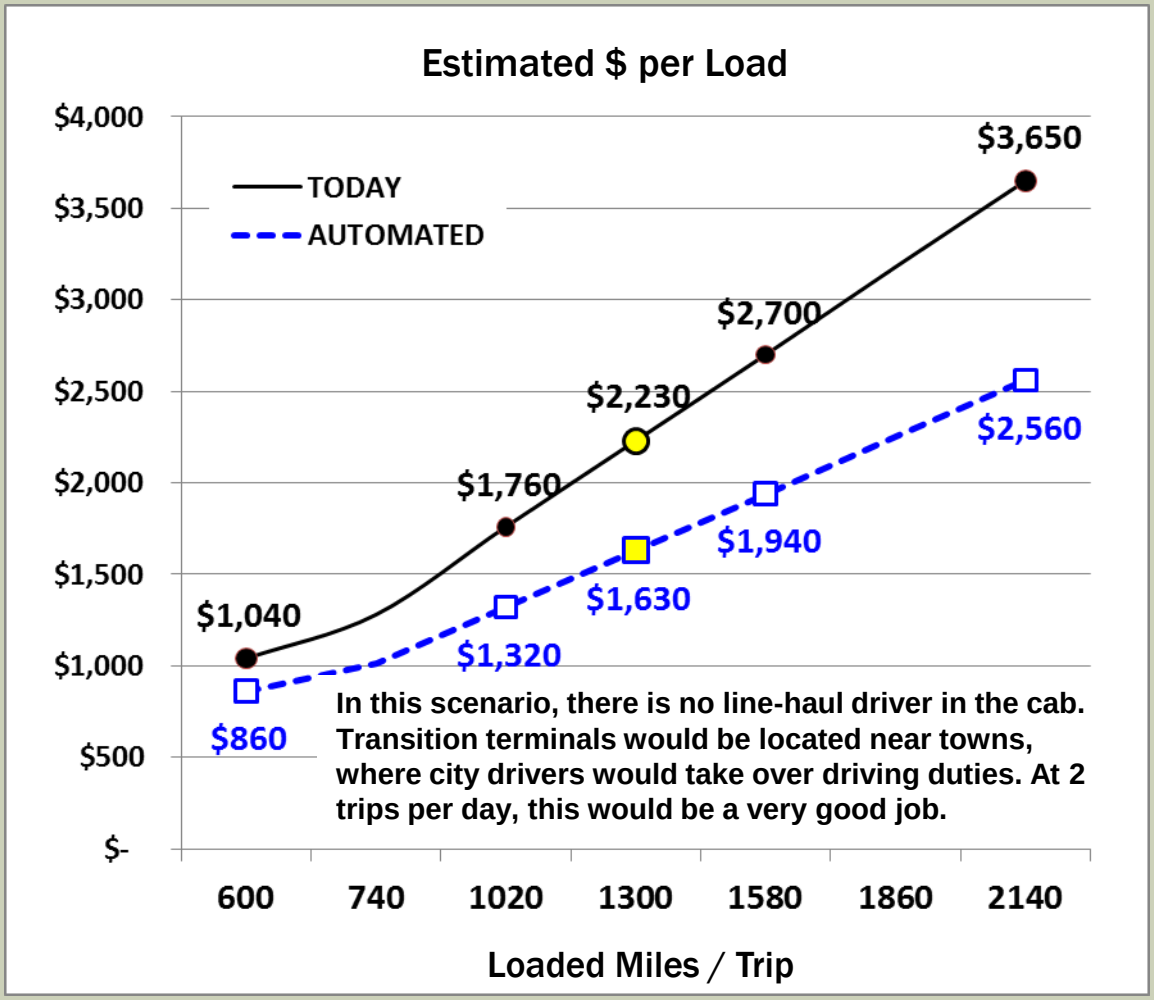


Mid-Range Assumptions

Truck & Route:
$190,000 Truck (L4)
$3.00/Gal Diesel
8.2 MPG(1 MPG Better)
70% Loaded Miles
119,000 Miles/Year
800,000 Mile Limit
6.8 Year Truck Life
$0.02/Mile Ins Savings

Driver Pay:
$50,000 per year
270 Days in service
2,100 On Duty Hrs/Yr
14 Hour Days
11 Hours Driving
1 Hour Rest
10 Hours Sleep

AUTONOMOUS OPERATIONS COULD BE SUPPORTED BY CITY DRIVERS



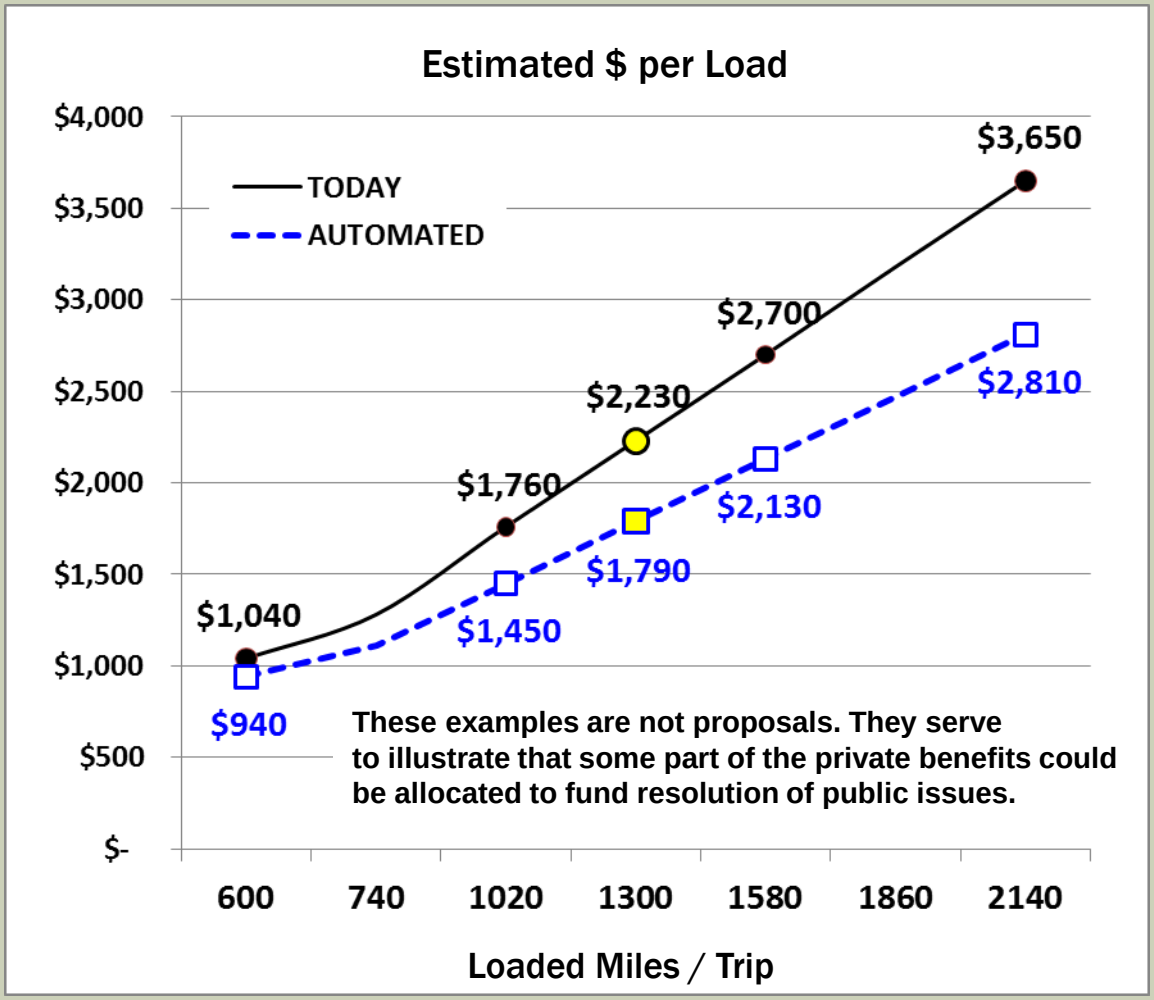
This view includes:

All benefits from HOS changes, fuel use, improved empty ratio and lower insurance costs.

This view adds:

- $200 “City Drivers” for each load
- $50,000 per year Linehaul Monitors, who provide remote oversight of the move on the line of road (each monitor observes 3 loads)

CAPITAL CHARGES AND VEHICLE TAXES COULD HELP OFFSET PUBLIC IMPACTS



This view adds:

- A $0.24 per gallon fuel tax
- A one-time $25,000 capital charge per truck

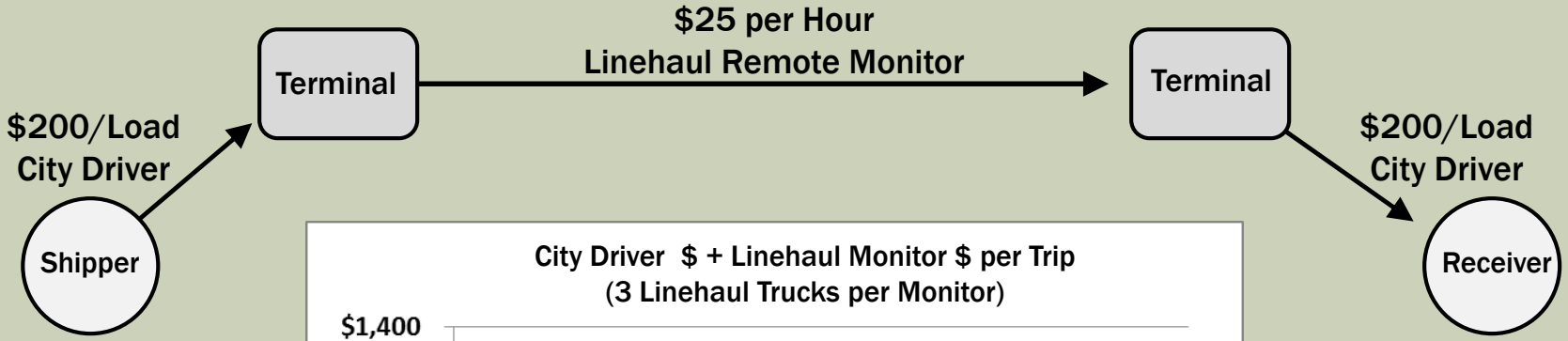
Note: A "$ per Ton Mile" tax could be used instead of a fuel tax.

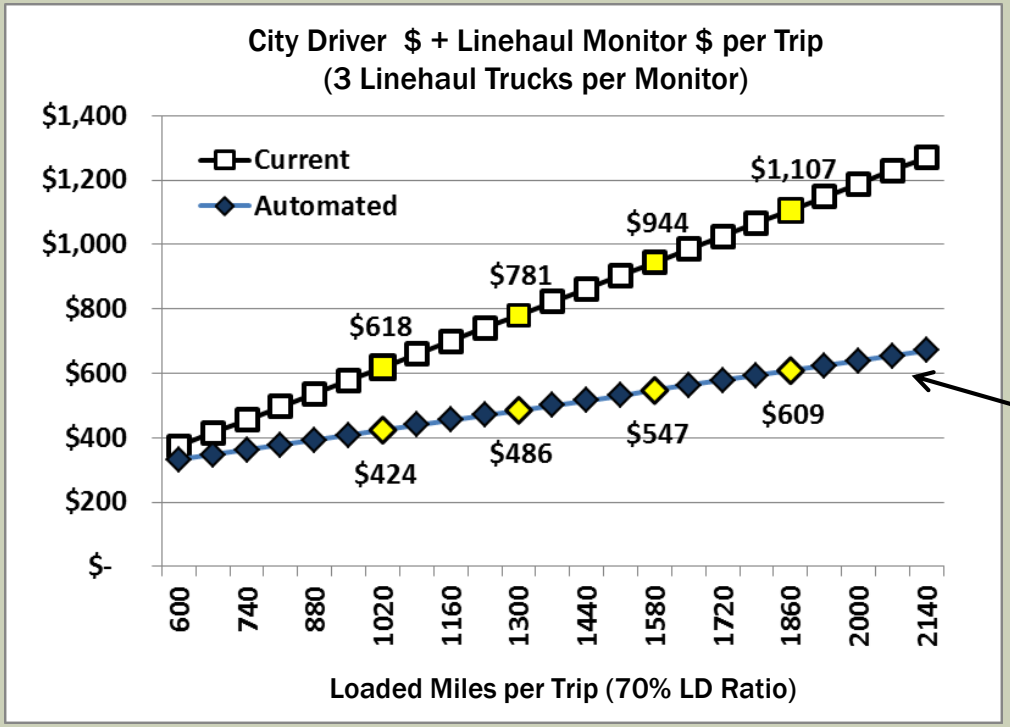
These funds could be used to:

- Create spatial or temporal separation between cars and trucks
- Create incentives intended to lower carbon footprint
- Reduce the funding gap on failing infrastructure

Transportation Payroll Impact: Total operating dollars decline.

TOTAL "OPERATING PAY" PER LOAD WOULD GO DOWN WITH L4 AUTOMATION

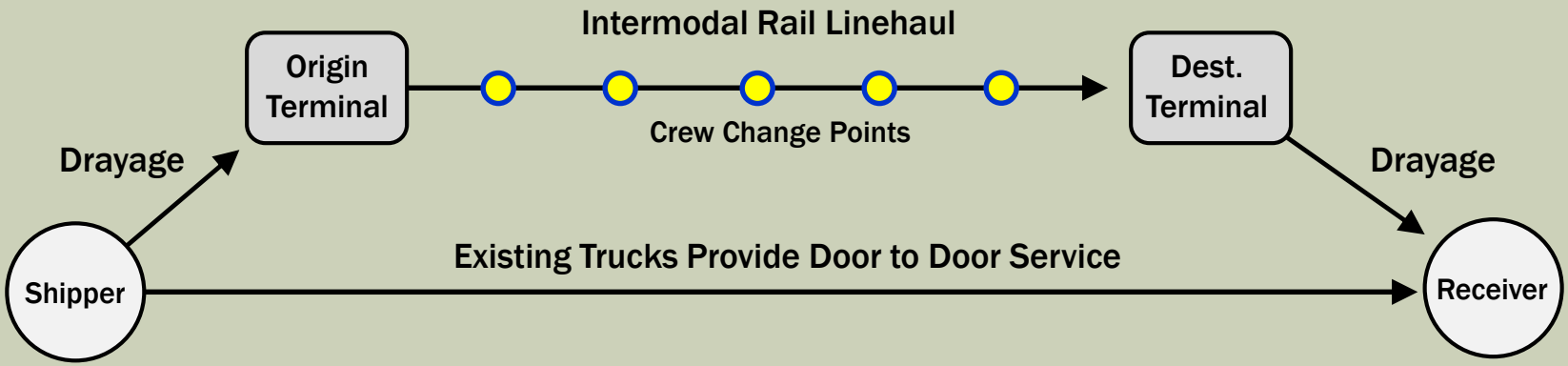




"Operating Pay" per load using city drivers at $200 per load, along with a linehaul monitor being paid $25 per hour, watching 3 trucks.

POTENTIAL LOADS: INTERMODAL CONVERSION?

EXISTING INTERMODAL FREIGHT IS ONE POTENTIAL SOURCE OF VOLUME



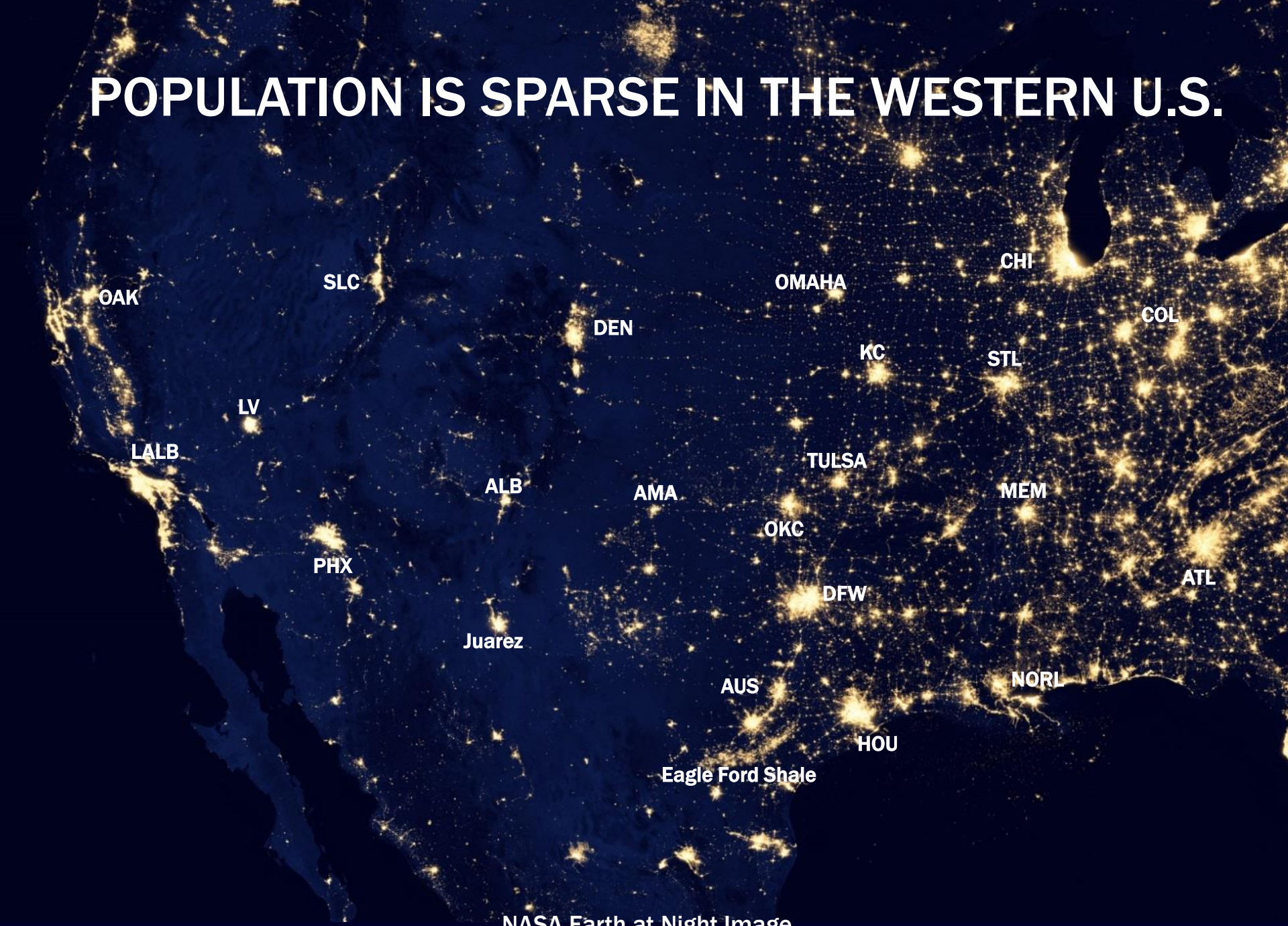
U.S. Intermodal Moves Handled (M)

Railroad	2016	2017
CSX	2.77	2.84
NSC	3.87	4.07
UPRR	3.26	3.28
BNSF	4.95	5.25
KCS	0.24	0.26
Total	15.09	15.71

Intermodal Rail

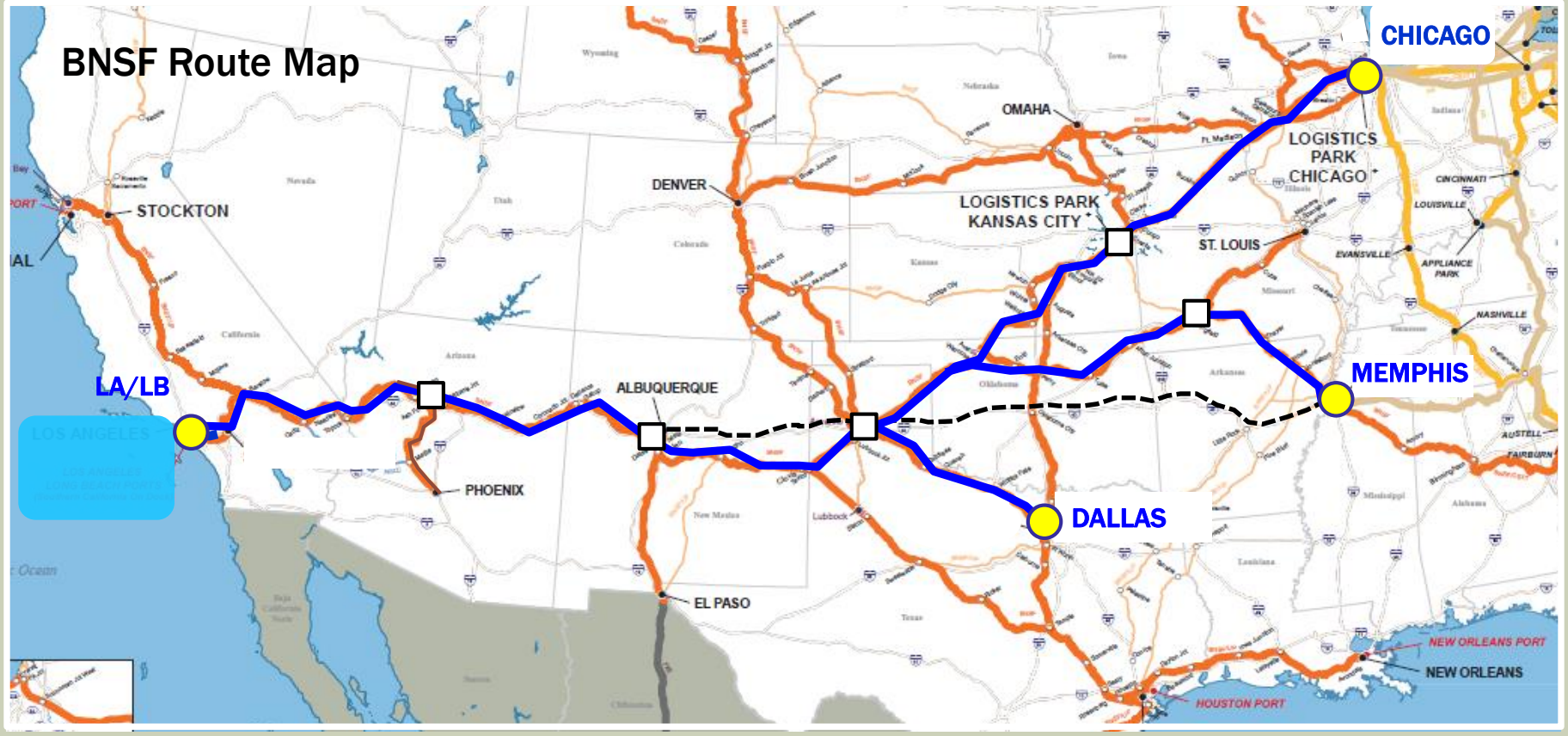
- **U.S. handles over 15 M of the 18 M North American intermodal loads**
- **Truck competition sets the revenue, velocity and reliability limits**
- **Door to door rail service is not feasible, so final-mile moves are handled by Class 8 trucks, which serve multiple customers each day**

POPULATION IS SPARSE IN THE WESTERN U.S.



NASA Earth at Night Image

RAILROADS OFFER LONG-HAUL INTERMODAL SERVICE IN THESE AREAS

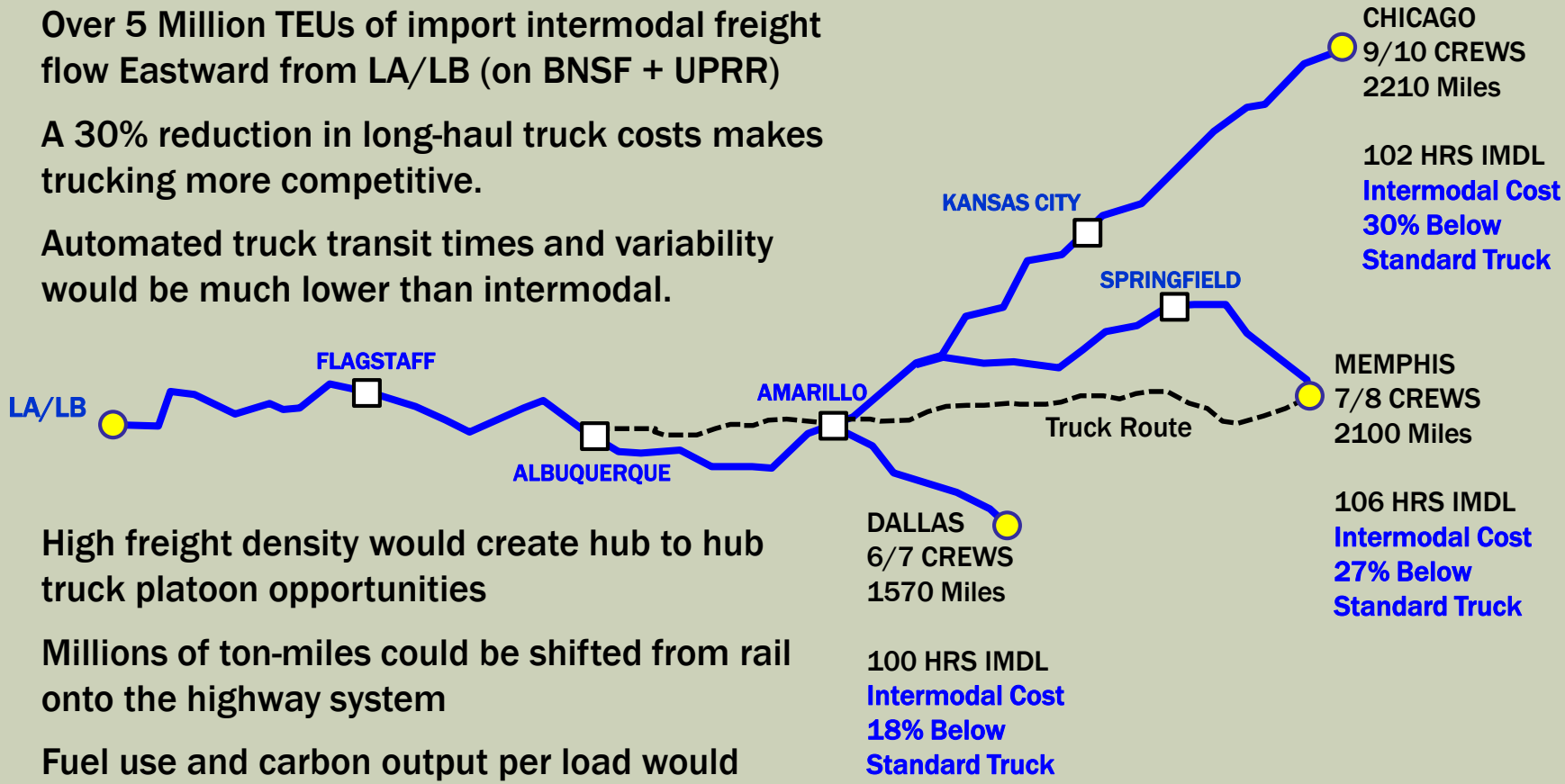


LOS ANGELES to MEMPHIS
RAIL 2,100 Miles, 90 to 106 Hours
TRUCK 1,850 Miles, 55 to 65 Hours

LOS ANGELES to CHICAGO
RAIL 2,210 Miles, 100 to 105 Hours
TRUCK 2,030 Miles, 60 to 70 Hours

AUTOMATION COULD LOWER DIRECT COSTS TO NEAR-INTERMODAL LEVELS

- Over 5 Million TEUs of import intermodal freight flow Eastward from LA/LB (on BNSF + UPRR)
- A 30% reduction in long-haul truck costs makes trucking more competitive.
- Automated truck transit times and variability would be much lower than intermodal.



- High freight density would create hub to hub truck platoon opportunities
- Millions of ton-miles could be shifted from rail onto the highway system
- Fuel use and carbon output per load would more than double in a shift to trucks

MODE CHOICES ARE MADE BY 3PLS AND MAJOR TRUCKING COMPANIES

J B Hunt Photos

J. B. Hunt Operations

2017	IMDL	PVT	TRUCK
Loads (Millions)	2.00	2.58	0.37
Ld Miles (Millions)	3,362	458	161
Avg Haul (Miles)	1,681	178	435
Share of Loads	40%	52%	8%
Share of Miles	84%	12%	4%

Note: 2010 was J. B. Hunt's first year to move 1 Million intermodal loads.

- Both modes are well understood, and choices can change week to week
- Shipper relationships are THE key

CONSUMER IMPACT:
ENOUGH TO SPUR RETAIL SALES?

A LESS THAN 1% IMPACT ON RETAIL PRICES IS LIKELY FOR MANY GOODS

- **A 53 ft container can carry a wide range of consumer goods**

Item	Price Each	Cu Ft Each	Container Value *
Dewalt Deluxe Comp Miter Saw	$474	8.4	$193,000
Hunter Economy Fan	$99	2.3	$152,000
GE 2.0 Cu Ft Microwave	$169	5.1	$115,000
GE Washing Machine	$561	19.4	$97,000
1 Patio Table Metal Frame	$248	10.8	$79,000
GE 27" Electric Dryer	$389	17.1	$77,000
225 FT Capacity Hose Reel	$40	1.9	$65,000
2 Patio Chairs Metal Frame	$200	23.5	$30,000

In Addition to Transport Costs:

A consistent 1 day reduction of transit time is worth about $50 in reduced inventory costs for a container with $115,000 of cargo.

This would be less than $0.10 saved on an individual microwave at a 15% interest rate.

- **A $400 to $800 reduction in truck costs on a $115,000 load yields 0.3% to 0.7% in potential savings on consumer goods ($800 / $115,000 = 0.7%)**

* Example only. Containers normally move a mix of items.

SUMMARY

- Early adoption, using Levels 1 and 2, starts with fuel economy and safety improvements, with human drivers in control.
- At Level 4, decline in linehaul driver income would be larger than the “safety monitor” and “city driver” payroll dollars gained.
- Retail value impact is potentially less than 1% per load.
- Carbon emissions would increase by more than 100% on loads converted from intermodal to automated trucks. Loads converted from intermodal would add stress to the highway system.
- At the individual carrier level, autonomous Level 4 long-haul appears to be economically feasible, even after:
  - Paying linehaul monitors to track vehicles on the line of road
  - Using city drivers for the first and last miles
  - Replacing trucks after 3 years or less in service
  - Funding some level of infrastructure and emissions costs

APPENDIX

NHTSA AUTOMATION LEVEL DESCRIPTIONS

HTTPS://WWW.NHTSA.GOV/TECHNOLOGY-INNOVATION/AUTOMATED-VEHICLES-SAFETY#ISSUE-ROAD-SELF-DRIVING

- **Level 0 - The human driver does all the driving.**
- **Level 1 - An advanced driver assistance system (ADAS) on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously.**
- **Level 2 - An advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The human driver must continue to pay full attention ("monitor the driving environment") at all times and perform the rest of the driving task.**
- **Level 3 - An Automated Driving System (ADS) on the vehicle can itself perform all aspects of the driving task under some circumstances. In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task.**
- **Level 4 - An Automated Driving System (ADS) on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The human need not pay attention in those circumstances.**
- **Level 5 - An Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.**

OVER 8 MILLION TEUS MOVE EAST BY RAIL FROM WEST COAST PORTS