Rethinking Transportation 2020-2030
Disruption, Implications & Choices

American Public Transportation Association
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A STROLL DOWN Memory Lane
Where is the car?
Where is the horse?
What is a Disruption?

WHEN A NEW PRODUCT OR SERVICE HELPS create a new market

AND significantly weaken, transform, or destroy an existing product, market category / industry
FAST FORWARD TO 1985

Image: GMAuthority.com
AT&T hired McKinsey & Co to forecast cell phone adoption by the year 2000.

**THEIR (15-YEAR) PREDICTION**

900,000

**THE ACTUAL Year 2000 NUMBER WAS**

109 million

They were off by a factor of:

120x

AT&T Disrupted - while $$ Trillions Created

- AT&T’s landline telephony market was disrupted
- It missed out on multi-trillion dollar opportunities!

Sources: Subscriber Data : CTIA Companies: Company Stock date source: Yahoo!
It’s usually the ‘experts’, ‘insiders’ & mainstream analysts who dismiss Disruptive Opportunities

“There's no chance that the iPhone is going to get any significant market share. No chance....”

Steve Ballmer, CEO Microsoft, 2007

“The iPhone's impact will be minimal. It will only appeal to a few gadget freaks. Nokia and Motorola have nothing to worry about.”

Bloomberg Analyst, 2007

“It's important that [Internet] expectations aren’t cranked too high. The total number of users is still very small...”

Bill Gates, CEO Microsoft, 1994

Image Source: Forbes
FAST FORWARD TO 2000
Kodak FY 2000: Record Results

- FY **2000** Financial Results:
  - Revenues: $14 B
  - Operating Earnings: $2.2 B
  - Net Profits: $1.4 B

- "Picture-taking at an all-time high worldwide:" (1)
  - Record # of Pictures taken: 80 billion.
  - Record # of Prints ordered: 100 billion.

- 2012 - Kodak Filed for **Bankruptcy Protection**

"A great brand, a great balance sheet, cash flow. This is a very smart time to be in the picture business"

Daniel Carp, CEO, Kodak
Letter to Investors, FY 2000

(1) Kodak, Annual Report 2000, Letter to Investors,
Sources: Data and Image: Kodak
Why do smart people at smart organizations consistently fail to anticipate or lead Market Disruptions?
Technology Cost Curves

- # of transistors doubles (roughly) every two years.
- Annual improvement rate ~41.4%
- Exponential growth in # of transistors

Technology Cost Curves
Technologies Improving at different rates

- **Data Storage** – Kryder’s Law
  - Hard Disk $/bit down *50% every 18 months*

- **Digital Imaging** – Hendy’s Law
  - Pixels per $ - *59% / year*

- **Network Capacity** – Butter’s Law of Photonics
  - The $ cost of transmitting a bit decreased by *50% every 9 months*

- **Li-iOn Batteries**
  - $/kWh *20% per year*
Technology Convergence
Convergence 2007 - Smartphone

- Technology convergence in 2007 to make the smartphone possible
  - Data Storage – Kryder’s Law
    - Hard Disk $ cost per bit down 50% every 18 months
  - Digital Imaging – Hendy’s Law
    - Pixels per $ - 59% / year
  - Network Capacity – Butter’s Law of Photonics
    - The $ cost of transmitting a bit decreases by 50% every 9 months
  - Touchscreen, Li-ion batteries, computing, sensors...

Key Technologies
2017 - Key Technologies

1. Sensors / Internet of Things
2. Artificial Intelligence / Machine Learning
3. Robotics
4. Solar PV
5. Batteries
6. 3D Printing
7. 3D Visualization
8. Mobile Internet & Cloud
9. Big Data / Open Data
10. Unmanned Aerial Vehicles / Nano Satellites
11. Blockchain
Exponential Market Adoption S-Curve
Tech adoption is not linear but follows an exponential S-Curve.
Car market share (passenger miles) – 20 years to 95%!

- Car market share (passenger miles): from 11% (tipping point) to 81% in 10 years!

Despite:

- Building two whole new industries (auto and oil) from scratch – from extraction to production to retail
- Building a new road infrastructure from scratch
- Training a whole generation of workers in brand new skills (complex operation of machines, maintenance…)
- Inventing new industrial processes (assembly line…)
- Inventing new business models (car loans…)
- Fighting World War I
Tech adoption S-Curves are getting even more exponential! Accelerating!
Technology Adoption S-Curves vs Linear Forecasts

- Tech adoption S-Curves: feedback loops, exponential growth, tipping points, network effects, business model innovation, tech cost curves...
Mainstream Forecasts: **Linear – despite evidence**

- Mainstream Forecasts:
  - Linear
  - Backwards-looking
  - Siloed

- They don’t take into account
  - Technology cost curves
  - Product Innovation
  - Business Model Innovation
  - Reality: evidence of exponential nature of technology adoption
A business model innovation is a new way of creating and capturing value within a value network that is enabled by technology convergence.
Business Model Innovation: Ride-Hailing (Uber, Didi, Lyft, Ola, Gett...)

- **Uber Bookings > US Taxi Industry Revenues** (2016)
- **San Francisco** - Uber & Lyft are **20% of all VMTs** (2017) (2)
- **NYC** - Ride-Hailing = **500,000 rides/day** vs MTA Buses = **2.4m rides/day** (2016) (1) (3)
"The shift toward a new driving economy might already be taking hold: An Ipsos/Reuters survey showed that, of the people who traded in their cars, about 10 percent weren’t replacing them. They were switching to car-sharing and ride-hailing.

The survey also showed that 39 percent of Americans had used ride services and that 27 percent of that group did so at least several times per week. That’s a groundswell
Business Model Innovation: AirBnb
Marketplace Broker
Business Model Disruption

Business Model Innovation is as important & disruptive as Technology Innovation.
CLEAN DISRUPTION OF ENERGY & TRANSPORTATION

1. Batteries
2. Electric Vehicles
3. Autonomous Vehicles
4. Ride-Hailing
Li-ion Battery costs dropping exponentially

- Laptop Li-ion battery costs dropped ~14% per year over 15 years. (1)

- Investments in battery tech increasing dramatically:
  - 3 multi-trillion $ industries investing:
    1. IT/ Electronics
    2. Automotive
    3. Energy

- 2010-2014, battery costs dropped at ~16%/year → ACCELERATION
Projected cost of Li-ion Battery $/kWh (CD: 2014)

Clean Disruption (2014) Assumption: 16% /year Technology Cost Curve

Source: Clean Disruption
Investments in Battery Megafactories increasing

- **20 Li-iOn Megafactories** in the pipeline to come online by 2021 totaling **325 GWh** (1)

- **In 2014 there were just 3** (in the 2021 pipeline) totaling **50 GWh** (2)

- **Samsung SDI**, **Dyson**, LG Chem, Total, Bosch, Boston Power, BYD, TDK, Apple, Nissan, Daimler, VW, etc.

- **Tesla** may **Triple** expected output to 105 GWh (cells) / 150 GWh (packs) (4)

**Tech Cost Curve has accelerated to ~20% (2010-2016)**

Sources: (1) Reuters, (2) (3) Benchmark Minerals (4) Electrek
National Renewable Energy Lab (NREL) study of 10,000 utility rate plans: more than a quarter of U.S. businesses could cut power bills if they installed batteries to reduce peak energy demand. (1)

Companies with Demand Charges > $15/kW can benefit…including more than one million customers in Georgia, Colorado, Michigan, Texas, Florida and New England.
DYSON to Develop Electric Car

Vacuum maker Dyson to invest £2.5 billion to develop an electric car to go on sale 2020.

Last year the Dyson announced £1 bn investment in battery technology after acquiring solid-state battery maker Sakti3 for $90m, which “developed a battery breakthrough”\(^{(1)}\)
The Electric Vehicle Disruption
IS THE ELECTRIC VEHICLE Disruptive?

(You always need to ask)
1. Electric Motor - 5X more Energy Efficient

Energy Efficiency

- Internal Combustion Engine: 17 - 21%
- Electric Motor: 90 - 95%

Sources: ICE - DOE, EM Wikipedia, Image Sources: ICE - Tony Seba, Electric - BradMerritt.com

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2. EVs are **10X** cheaper to charge/fuel

- It costs **$15,000** to fill up a (gas) Jeep Liberty over **five years** (Consumer Reports)
- An **Electric** Jeep Liberty would cost **$1,565** in electricity
- Improvements in software and power electronics to increase this >10X

**Assumptions:**
- 12,000 miles/year
- Tesla Roadster: 4.6 miles per kWh.
- Avg retail electricity in the U.S.: 12 ¢/kWh
- 5 year-cost = (60,000 miles * 0.12 $/kWh) / 4.6 miles/kWh = $1,565.
3. EVs: 10X cheaper to Maintain

ICE (Gas) Vehicle

- 2,000+ moving parts (1)

Electric Vehicle (EV)

- 18 moving parts (1)

- EVs 100X fewer parts

- Tesla: Infinite Mile Warranty! (2)

Transmission, driveshaft, clutch, valves, differentials, pistons, gears, carburetors, crankshafts...

Source: (1) Baron Funds, (2) Tesla Blog
• EV powertrains last 500,000 miles (800,000 Km)
• Tesla (& others) building 1,000,000-mile (1.6m Km) Powertrain
• That's 5x-7x ICE vehicles (1)
“University Student team builds EV that breaks world acceleration record (0-100 Km/h in 1.51 sec) beats the $1m Porsche 918 Spyder (2.2 sec)” (1)
6- EVs Can Provide Services to Grid

- An **EV can power avg American home for ~2 days**

- With Vehicle-to-Grid (V2G) tech EVs can provide the grid with ancillary services that can **generate $revenue$ for the EV owner.**

- **EVs > than cars - EVs = Batteries / Power Plants on Wheels** – can be used as dynamic, modular, scalable & reliable grid resource.
Anticipating Disruption from Above – Electric Vehicles

Cost of EV with 200-mile (320 Km) range

2014 Assumptions:
- 4 miles/kWh,
- 50kWh batteries,
- 16% yearly battery cost improvement,
- EV Cost = 3X battery

ICE "Affordable SUV": $35-$40K
Avg ICE Car in US: $33K
Avg Low-end ICE car US: $22K

Source: Clean Disruption © Tony Seba
Tesla Model 3 – Record Single-Day Sales for any Product of Any Kind Ever!

Tesla Model 3

$ 35,000+ Unsubsidized

Autopilot (semi-autonomous)

215-mile range

0-60mph in < 6 secs

Market reaction:

180,000 cars ordered / reserved first 24h!

>$6.3b pipeline first 24h!

Biggest Crowdfunding Event in History: $500m & counting!

Sources: Tesla

Image: Tesla
The Autonomous Vehicle Disruption

Photo: Waymo
Alphabet Launches Taxi Service With No Human Drivers

November 7th, 2017
Corporate Working on Autonomous Vehicles
TESLA TO TRANSITION TO LEVEL 5 - FULLY SELF-DRIVING - 2019


Elon Musk: "From Parking Lot in California to Parking Lot in New York without touching controls by Dec 2017." (2) April 2017

"Level 5 Autonomy in two years [2019]. " (2)
Autonomous Vehicles = Computer on Wheels

ALL YOU NEED is ONE Platform to Achieve LEVEL 4-5

- Computer Platforms = network effects
- Winners Take All: only two O/S Survive (PC, Smartphone, Tablets...)

Image: © Copyright Tony Seba
WHAT ABOUT THE **COST** of Autonomous Vehicles?
What an autonomous car sees
Technology Cost Curves
Exponential Technologies: Machine Vision (LIDAR Sensors)

2012
Google announced that the cost of technology in its self-driving car was ~$150k
LIDAR Sensor (for Machine Vision) was $70k

By the end of 2013
The next generation LIDAR was $10k

By Oct 2014
A SV Startup company announced LIDAR for $1k
LIDAR: From $70,000 to $250

2015 GEN 1 LIDAR: $1,000
2017 GEN 2 SOLID STATE LIDAR: $250
GEN 3 (POSTAGE STAMP): $90

Sources: Quanergy, Clean Disruption
Autonomous Electric Vehicle (A-EV)

Where are the 5 LIDAR Sensors?
Autonomous Vehicles = Computer on Wheels

WHAT IS THE Cost Curve of Computing Power TO PROCESS SENSOR INPUT?
Year 2000: World’s 1st 1-TeraFlops Computer

ASCI RED - Sandia National Labs

- Space = 1,600 sq ft (150 m²)
- Power Consumption = 850 kW
- Cost = $46 million

Image: Extreme Tech
Exponential Tech Improvement: GPU NVIDIA Drive™ PX

Dual Drive PX 2 GPU Platform

8 TFlops

- Power Consumption = 250 W
  3,400x improvement

Cost = ~$600
  ~653,000x improvement

✓ Drive PX™ Pegasus (mid-2018): 320 TOPS
✓ 25 companies developing level 5 AVs (1)
  Built-in Deep Learning Software

NVIDIA CEO Jen-Hsun Huang

Image and Data Sources: NVIDIA

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Product Innovation – Autonomous Anything on Wheels!

- Not just substitution of existing modes of transportation.
- Self-Driving **delivery units, tractors, buses, trucks, wheelchairs...**
- Impact on logistics, retail, food, mail, health care...

Photo: Tony Seba

Self-driving Scooter at SMART MIT
Disruption Accelerators

Open Access Technology Development
Open access to technology and capital lowers costs, increases the speed of product development, and lowers barriers to entry.

Examples: open source, open knowledge, open APIs, crowdfunding

Conceptual Innovations
New concepts, methods, models, frameworks, and software architectures that enable totally new ways of doing things.

Examples: TCP/IP, blockchain
Waymo’s (fka Google) physical cars have driven **3.5 million miles** on public roads in **8 years**. (2)

Waymo has **25,000 self-driving cars** driving **8 million miles/day** (2.5 billion miles/year) within its **Carcraft simulation** software. (1)

Carcraft can simulate hundreds/thousands of variations of situations that might even be impossible to encounter in the ‘real world’.
High Definition 3D Mapping & Localization --> L4/L5

ALL YOU NEED is ONE Platform to Achieve LEVEL 4–5

Image: Source © Copyright DeepMap

Computer Platforms = network effects
Winners Take All: only two O/S Survive (PC, Smartphone, Tablets...
Cool! I can __ [Facebook, Twitter, Instagram] __ 

and also __ [WhatsApp, LinkedIn, WeChat] __

while NOT driving!

BUT WHERE’S THE Big Bang Disruption?
The Disruption of Transportation 2020-2030
Cars: Huge Waste of Space and Money

- Cars = 2^{nd} largest Capital Expense
  - Avg. new car costs = $33k

- Cars are parked 96\% of the time! (1)

- 4\% Asset Utilization is a disruption waiting to happen!
Transportation As A Service (TaaS)
On Demand + Autonomous + Electric Vehicle Tech: Convergence of Technology & Business Model Innovation

Source: Rethinking Transportation
TaaS - Transportation-as-a-Service: On Demand, Autonomous, Electric (AEV)

- Transport As A Service (TaaS)
  - Ride-Hailing (on demand) biz model
  - Electric Vehicle tech
  - Autonomous Vehicle tech

- Driving time goes from 4% to 40%
- Vehicle Asset Utilization goes UP 10X
- Cars can drive 100,000 miles/year (up from 10k miles/yr)
Why Electric Vehicles?

FLEET Choice: A-EV far cheaper than A-ICE


- TaaS companies that use A-ICE will have to
  - Switch to A-EVs, or
  - Go bankrupt
Transportation As A Service (TaaS)

On Demand

Autonomous Electric Vehicles (AEVs)

Owned by Fleets not individuals
TaaS: 4x-10x Cheaper than IO Vehicles

Source: (1) Clean Disruption
Source: Rethinking Transportation
95% of Passenger Miles TaaS (AEV) by 2030
Implications:
End of ICEV & IO
U.S Vehicle Fleet Shrinks by 80%
Annual Demand for New Vehicles Shrinks by 70%
Implications: Disruption of Oil Industry
Global Oil Demand Peaks at 100mpd 2020
Drops to 70mpd 2030

Source: (1) Clean Disruption
Source: Rethinking Transportation
Global Equilibrium Cash Cost ~ US$ 25.4/bbl with 70mbpd demand
Up to 70% of Deepwater Oil, Shale Oil, Oil Sands Uncommercial = Stranded Assets

- **Oil sands**
- **Offshore midwater**
- **Offshore deepwater**
- **Offshore shelf**
- **Shale/tight oil**
- **Conventional onshore**

**Diagram:**

- **Commercial**
- **Uncommercial**

**Source:** Rethinking Transportation
Implications: Financial, Social, Environmental, Geopolitical
TaaS Disruption Implications
Financial & Social

▶ Financial
▶ Saving per Household: $5,600+ / yr
▶ U.S. Disposable Income increase by $1 Trillion / year
▶ Productivity increase of $1 Trillion / yr - time freed from driving

▶ Social: Increased mobility for all
▶ Elderly / Pensioners
▶ Disabled
▶ Young
▶ Poor, Unemployed, Underemployed

Source: RethinkX
TaaS Disruption Implications
Environmental & Geopolitical

- **Environmental**
  - 80% decrease energy consumption
  - 90% decrease in CO2 emissions
  - Decreased use of **materials** (20 vs 2000 & 200k vs 500k)

- **Geopolitical**
  - Oil Energy Independence
  - Foreign Policy: energy security less critical
TaaS Disruption - Parking Obsolete: 80%+ Vacant
TaaS Disruption Implications - Auto Industry

- Parking -> Real Estate
- Roads / Infrastructure
  - Car Insurance
  - Car Financing
  - Repair & Maintenance Shops
  - Dealerships
  - Materials - Mining
  - Shipping

Source: Rethinking Transportation
Back to the Future
On the Cusp of the Fastest, Deepest, Most Consequential Disruption of Energy & Transportation in History

We are here

2018

2030
This is NOT an Energy Transition
This is a Technology Disruption
Thank You!
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