"Personal Rapid Transit: The State of the Art and its Promise

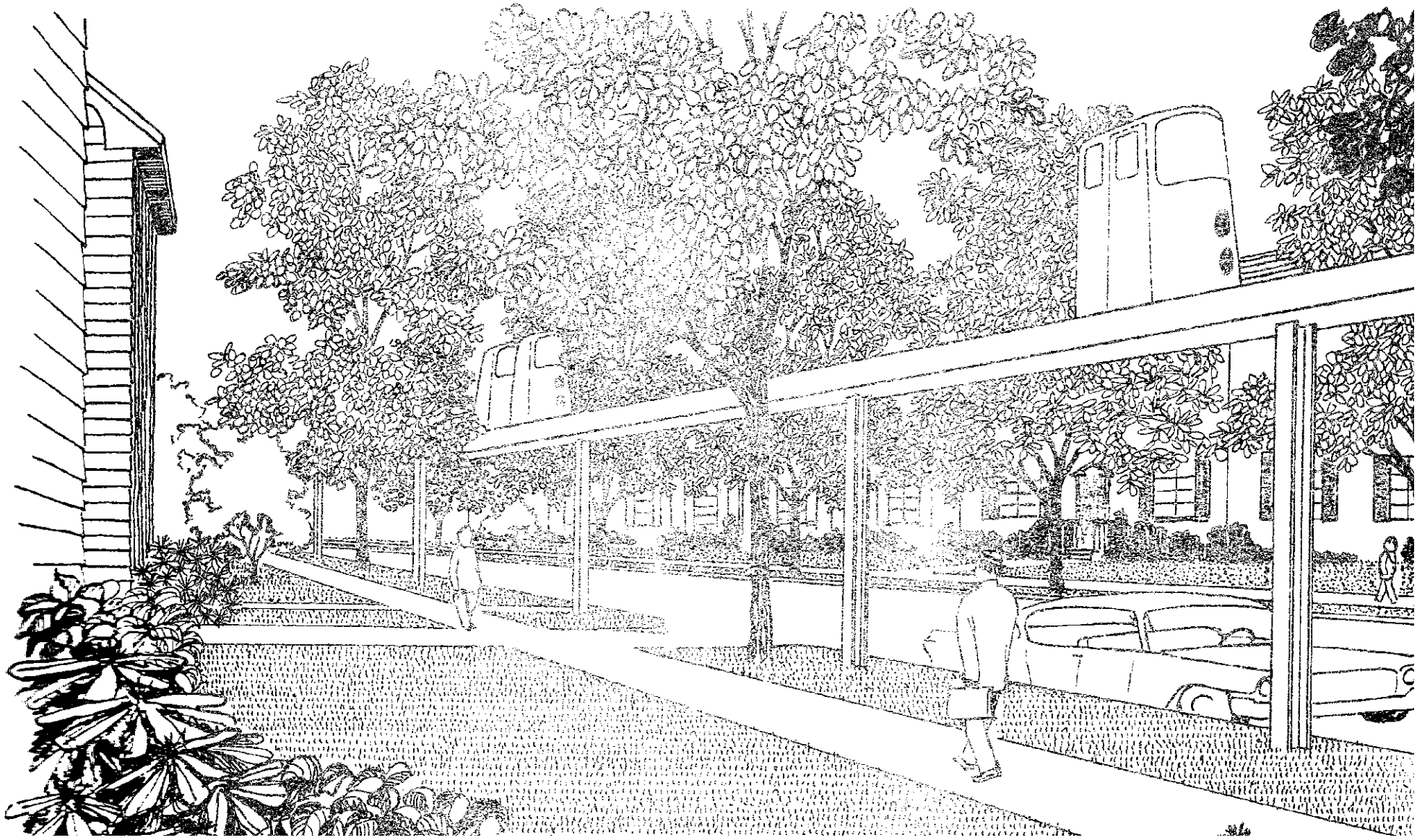
J. Edward Anderson, Ph.D., P. E.
PRT International, LLC

Former
Aeronautical Research Scientist, NACA
Manager of Space Systems, Honeywell
Professor of Mechanical Engineering
University of Minnesota & Boston University

Content of Presentation

- PRT beginnings.
- Who is involved now?
- Design process & conclusions.
- Savings in cost, land and energy.
- More benefits.
- The next step.

Simple Beginnings – Donn Fichter



Read

“Evolution of PRT”

www.prtnz.com

to appreciate the decades of work

toward a practical PRT system.

Present Status!

- Sweden has planned PRT in 59 cities.
- Korean Railroad Research Institute to develop PRT.
- Minnesota DOT held a workshop on PRT (Aug 2010
- India has announced PRT to be built in 17 cities.
- Mexico has funded PRT Program in Guadalajara.
- China to build PRT in Shanghai.
- Ithaca, NY initiates PRT Program with NYSDOT.
- Posco to build PRT system in Suncheon, Korea.
- San Jose, CA, has PRT program underway.
- ULTra PRT in service for employees Heathrow Airport.

To find better solutions, engineers must sta with a Rigorous Design Philosophy!

Professor Fritz Zwicky, Cal Tech

Morphology of Propulsive Power

This is Systems Engineering!

Understand the *Problem* and the *Requirements* for solution.

Let System Requirements dictate the technologies.

Diagram all combinations of potential solutions without prejudice and with absolute objectivity.

Thoroughly analyze analytically and experimentally all reasonable alternatives ineach combination until it is clear which best meets all technical, social, and environmental requirements.

Practice "Rules of Engineering Design," www.prtnz.com

Problems with Urban Transportatio

- Excessive congestion.
- Too much dependence on oil.
- Local, regional, international air pollution.
  Effects on the climate.
- Auto accidents. 2009: 3.9 each hour killed, 253 each hour injured.
- People who cannot or should not drive – lack of equ
- Excessive sprawl.
- Road rage.
- Transit: Large subsidies and low ridership.

How can we solve these problems?

Start with Requirements and Criteria!

Requirement – A necessary attribute

Criterion – A standard of judgment

See the paper

"An Intelligent Transportation Network System"

www.prtinternational.com

Appendix A: 37 requirements

Appendix B: 18 criteria

Appendix C: 4 courses

Our approach:

Minimize Cost per Passenger-Mile!

Develop a system-significant equation for cost per passenger-mile to clarify system characteristics that minimize it.

Conclusion:

The system that meets the requirements

while minimizing cost

also maximizes ridership

and is an optimized form of the system

generically called *Personal Rapid Transit (PRT)*

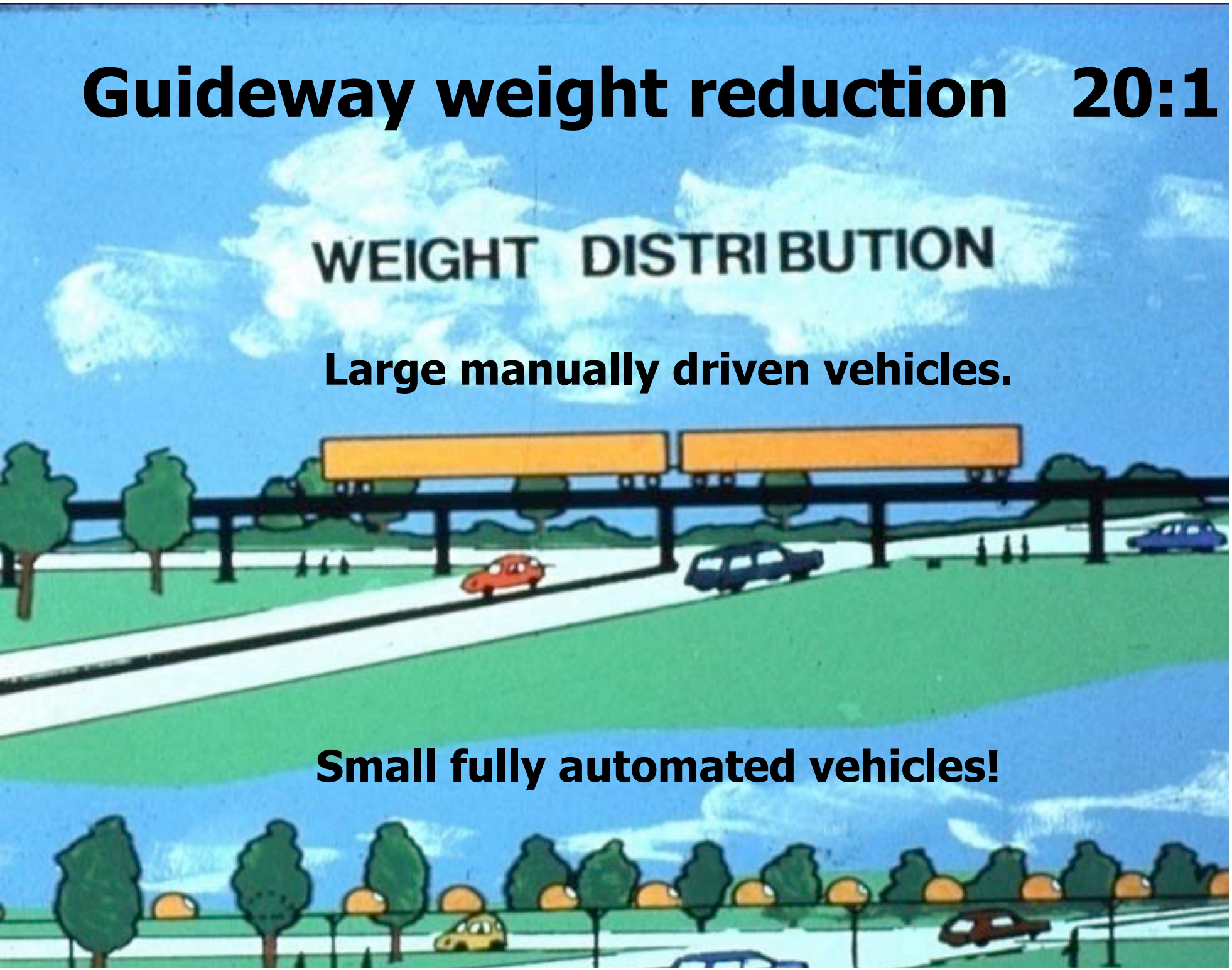
For the proof see

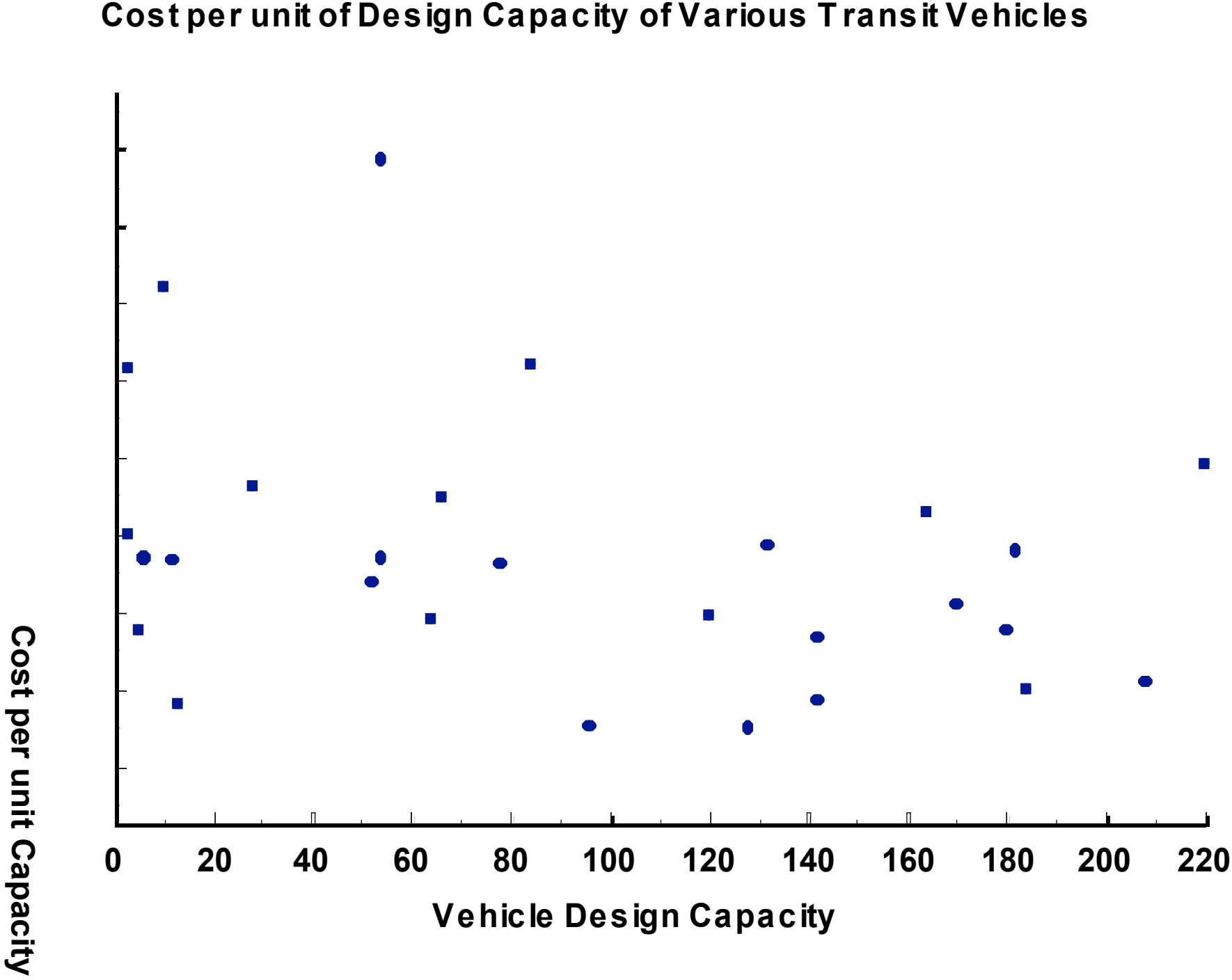
"Optimization of Transit System Characteristics,"

www.prtnz.com.

Simple logic leads to PRT:

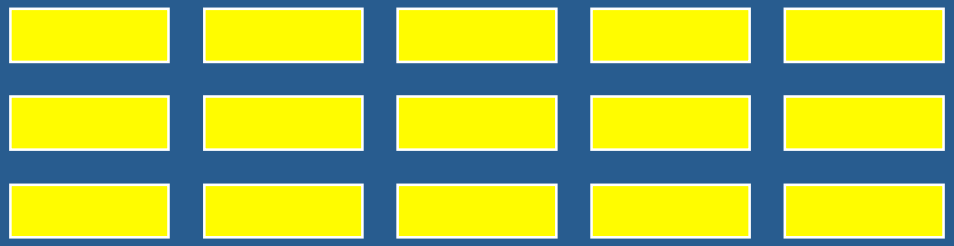
Guideway weight reduction 20:1




Cost per unit of Design Capacity of Various Transit Vehicles
Cost per unit Capacity
0
20
40
60
80
100
120
140
160
180
200
220
Vehicle Design Capacity

Fleet Cost = Cost/Vehicle Capacity
People-Carrying Capacit

Suppose 15 vehicles each averaging 10 mph provide a given people-carrying capacity.



Then 6 vehicles averaging 25 mph provide same capacity.

The average speed is highest if there are *no*

***intermediate stops,* which are not necessar**

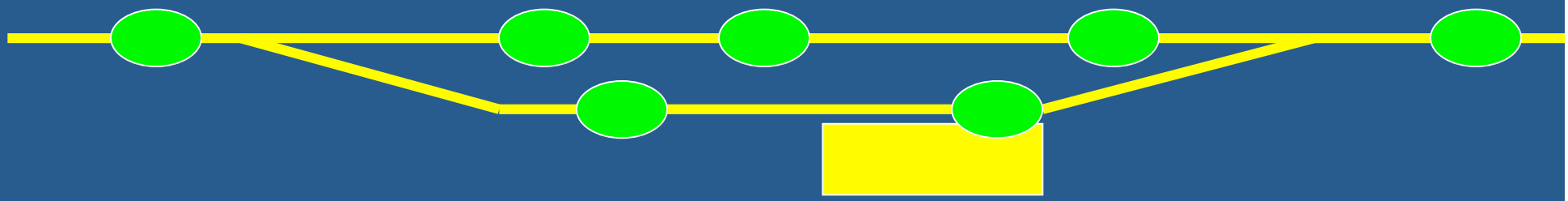
if stops are *off-line* just like on a freeway.

Conclusions:

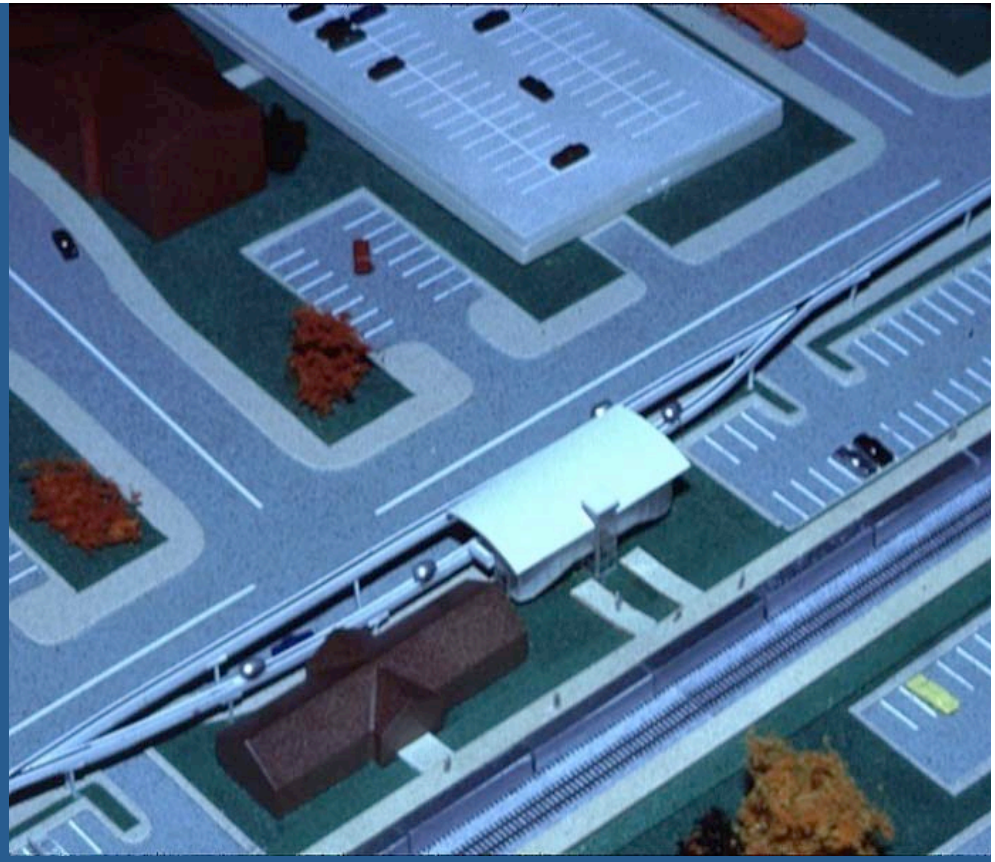
Guideway cost is minimized by minimizing vehicle weig

Vehicle fleet cost is minimized by using off-line station

This combination makes *a major breakthrough!*



Off-Line Stations are The Key Breakthrough!



- **Nonstop trips**
- **Highest average speed**
- **Minimum fleet size & cost**
- **High throughput**
- **Small vehicles**
- **Small, low-cost guideway**

Now interesting things happen:

- **Vehicles run only on demand, not on a schedule.**
- **Service is always available, the wait is short to none.**
- **Close station spacing does not decrease average speed.**
- **Stations can be sized to demand.**
- **You ride with chosen companions or alone.**

All lead to high ridership and low cost.

Tradeoff Issues:

Consider 3 of 46.

For the whole list see

http://faculty.washington.edu/jbs/itrans/

Issue: Suspension

- Air cushion
- Magnetic (maglev)
- Sled runners
- Wheels

"Maglev vs. Wheeled PRT", www.prtnz.com

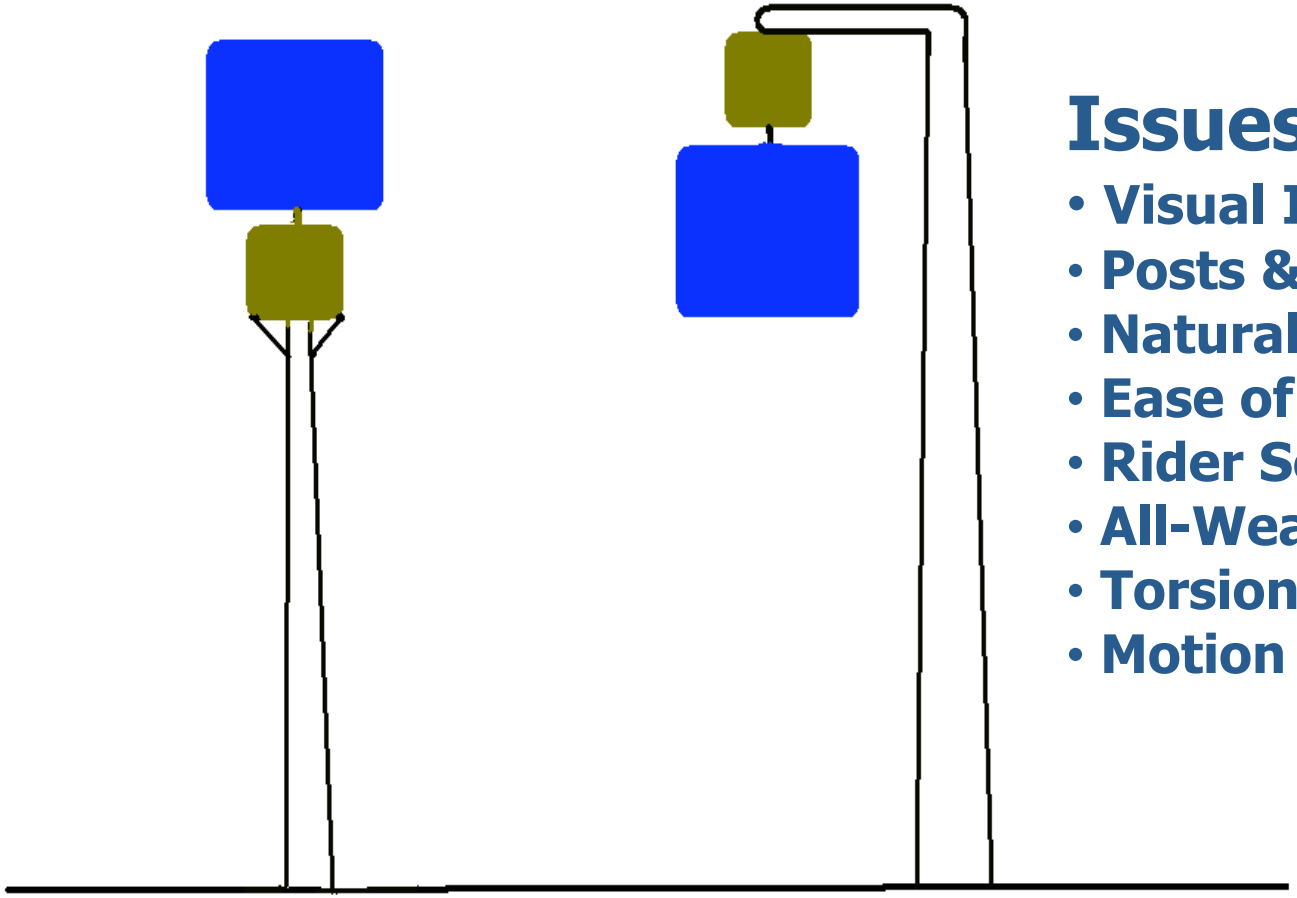
Issue: Propulsion

- Rotary motors
  - internal combustion, electric, steam
- Air
- Cables
- Linear electric motors
  - induction (LIM), synchronous (LSM)

Issues: Guideway size & cost, control flexibility, maintenance.

"Overcoming Headway Limitations in PRT,"
www.prtinternational.com

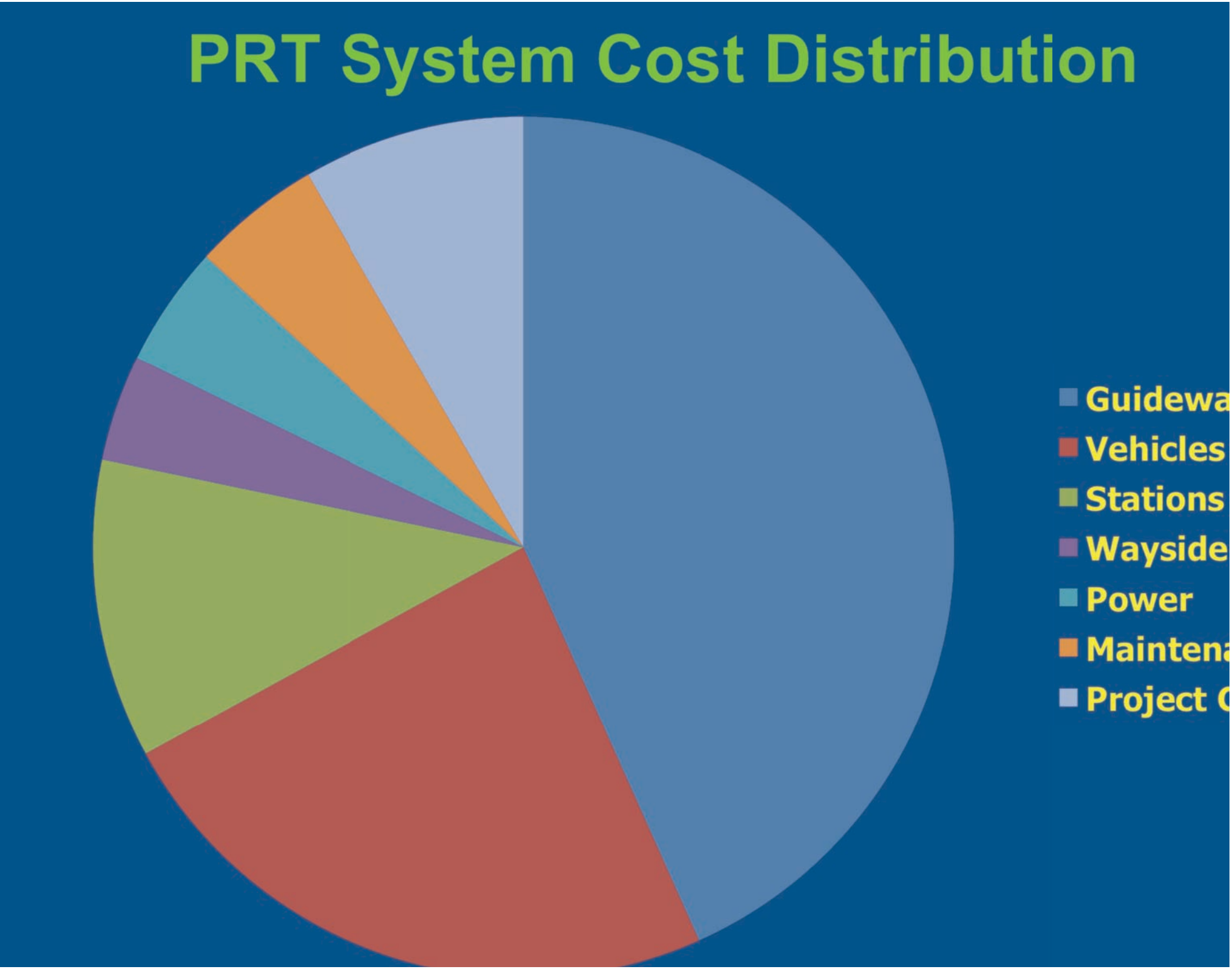
Issue: Vehicles Supported or Hung



Issues:

- Visual Impact
- Posts & Foundation Cost
- Natural Frequency
- Ease of Switching
- Rider Security
- All-Weather Operation
- Torsion in Curves
- Motion sickness

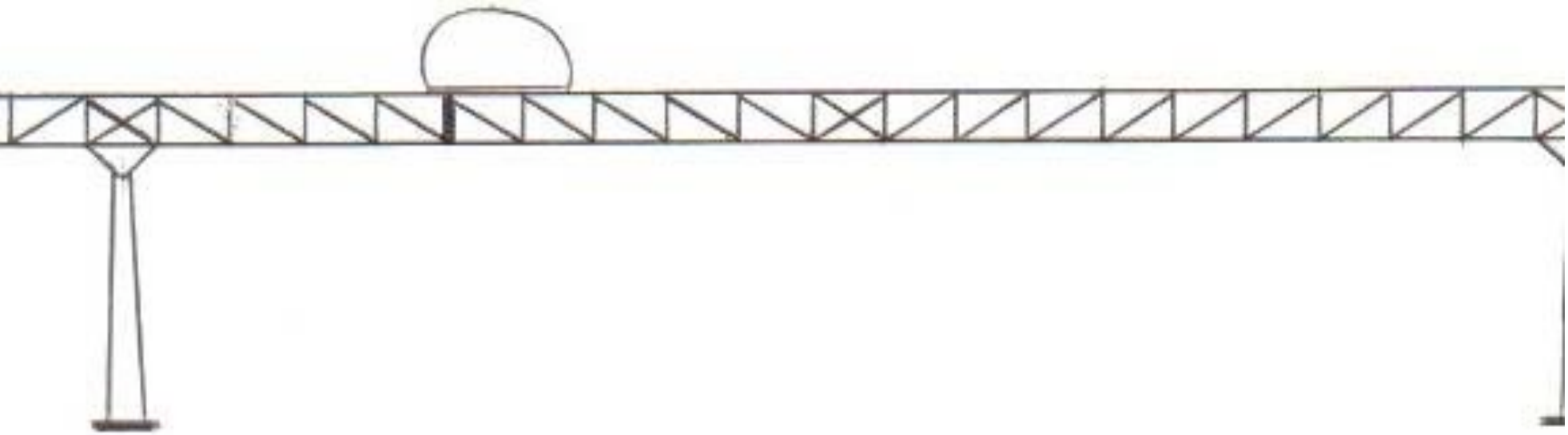
"Supported vs. Hanging Vehicles", www.prtnz.com


PRT System Cost Distribution
Guidewa
Vehicles
Stations
Wayside
Power
Maintena
Project C

Optimum Configuration

- 3′ x 3′
- No Moving Switch Parts
- All Weather
- Safe
- Smooth Ride
- Good Appearance
- Durable
- Modular
- Light Weight
- Accessible for Maintenan

Steel-truss guideway - 90-ft spans.

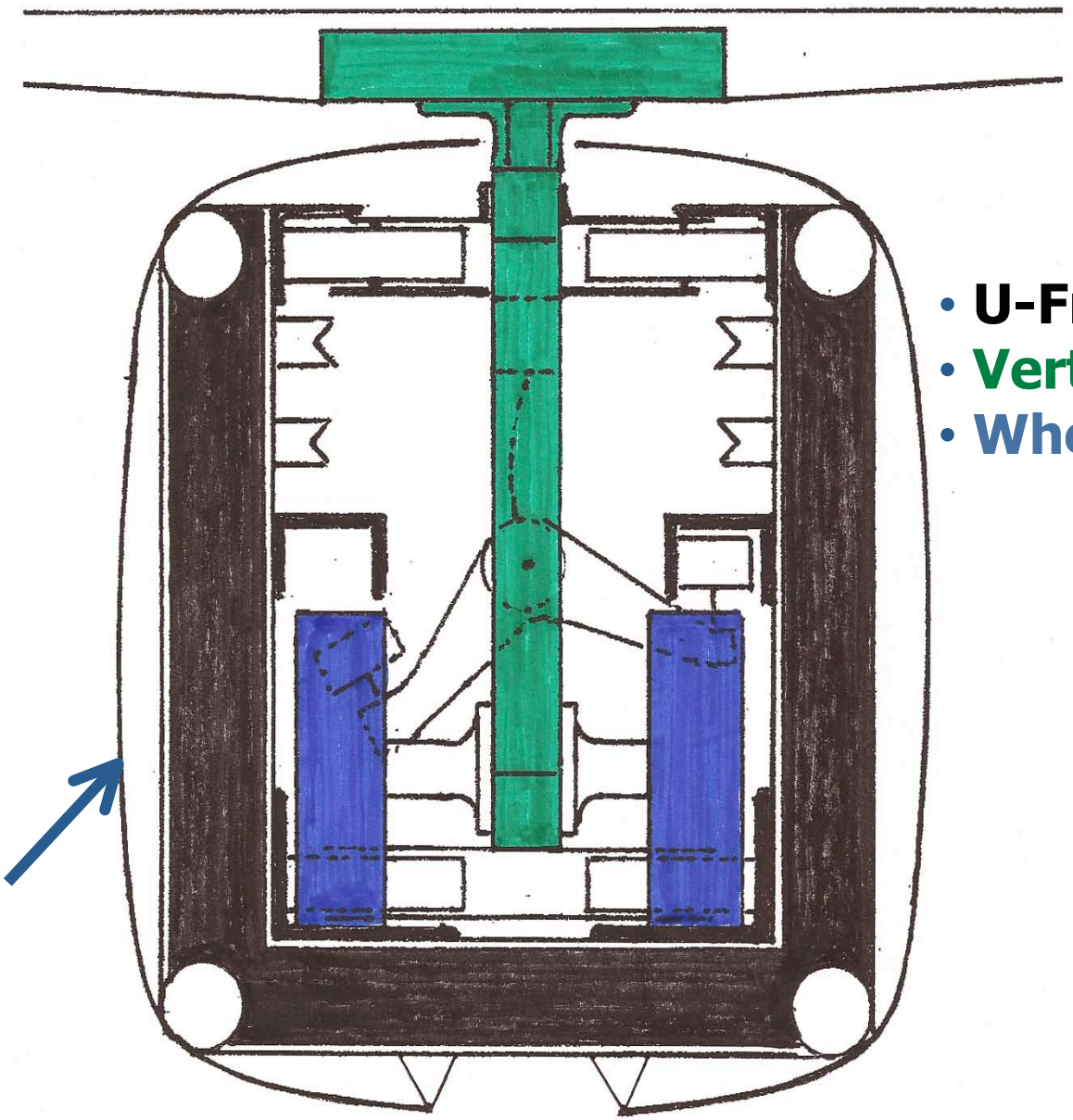


The foundations, posts, and guideway can be installed in front of a store in a day or two. Businesses are not disrupted.

Mode 1

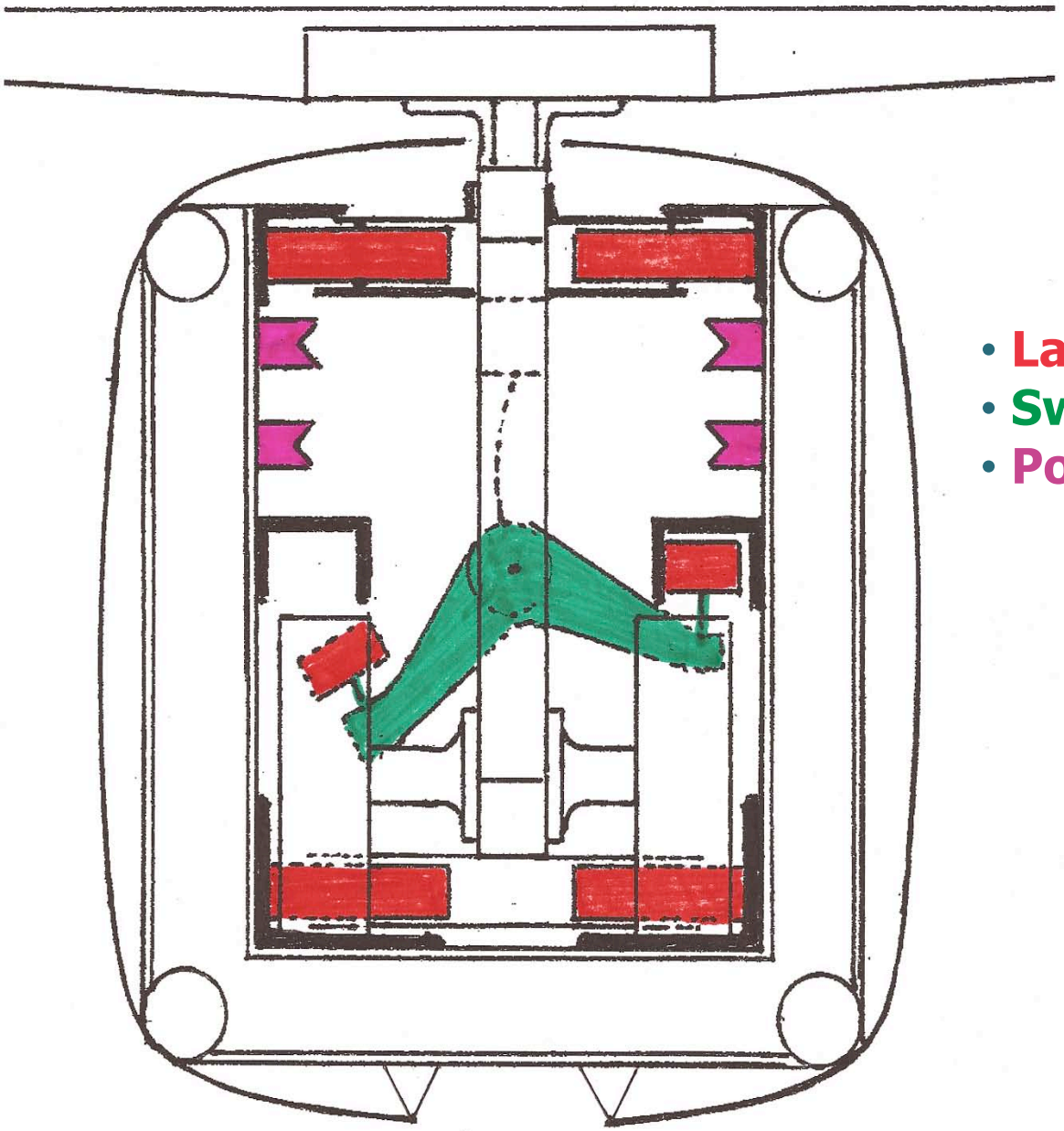
Mode 2

Mode 3



Cover

- **U-Frame**
- **Vertical Chassi**
- **Wheeled suppo**



- Lateral support
- Switch
- Power rails

"An Intelligent Transportation Network System," www.prtnz.cc

The Chassis

Covers shield from

- Sun
- Electromagnetic Radiation
- Winter night sky
- Snow & ice

- Minimize Air Drag
- Minimize Noise
- Eliminate differential thermal expansion
- Permit maintenance
- Permit customized appearance

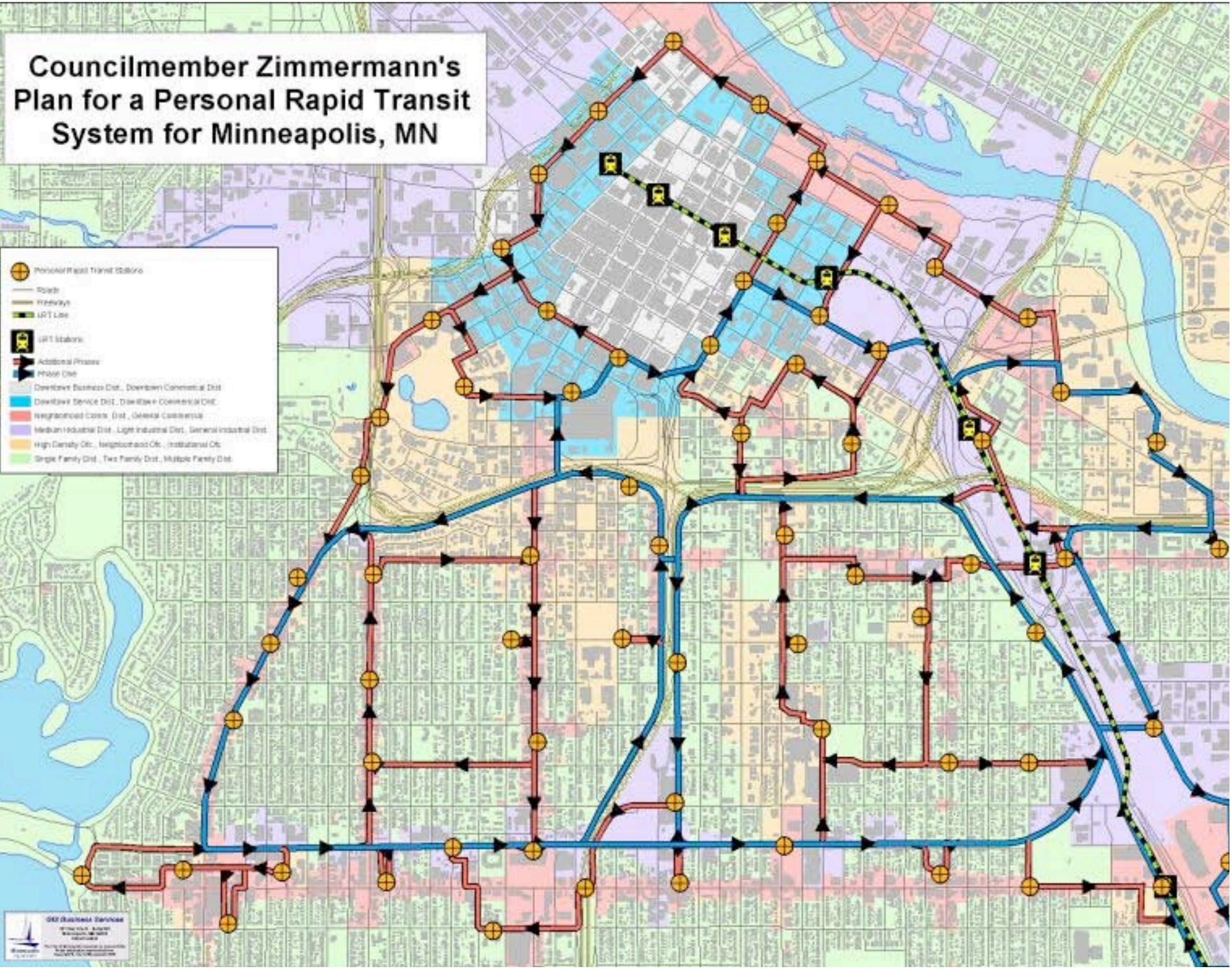
- U-shaped door permits easy entry.
- The vehicle interior is wide enough to permit wheelchair entry.
- Back seat is wide enough to accommodate three adults.
- There is room for wheelchair + attendant, or bicycle, or baby stroller, or luggage, and two fold-down seats in front

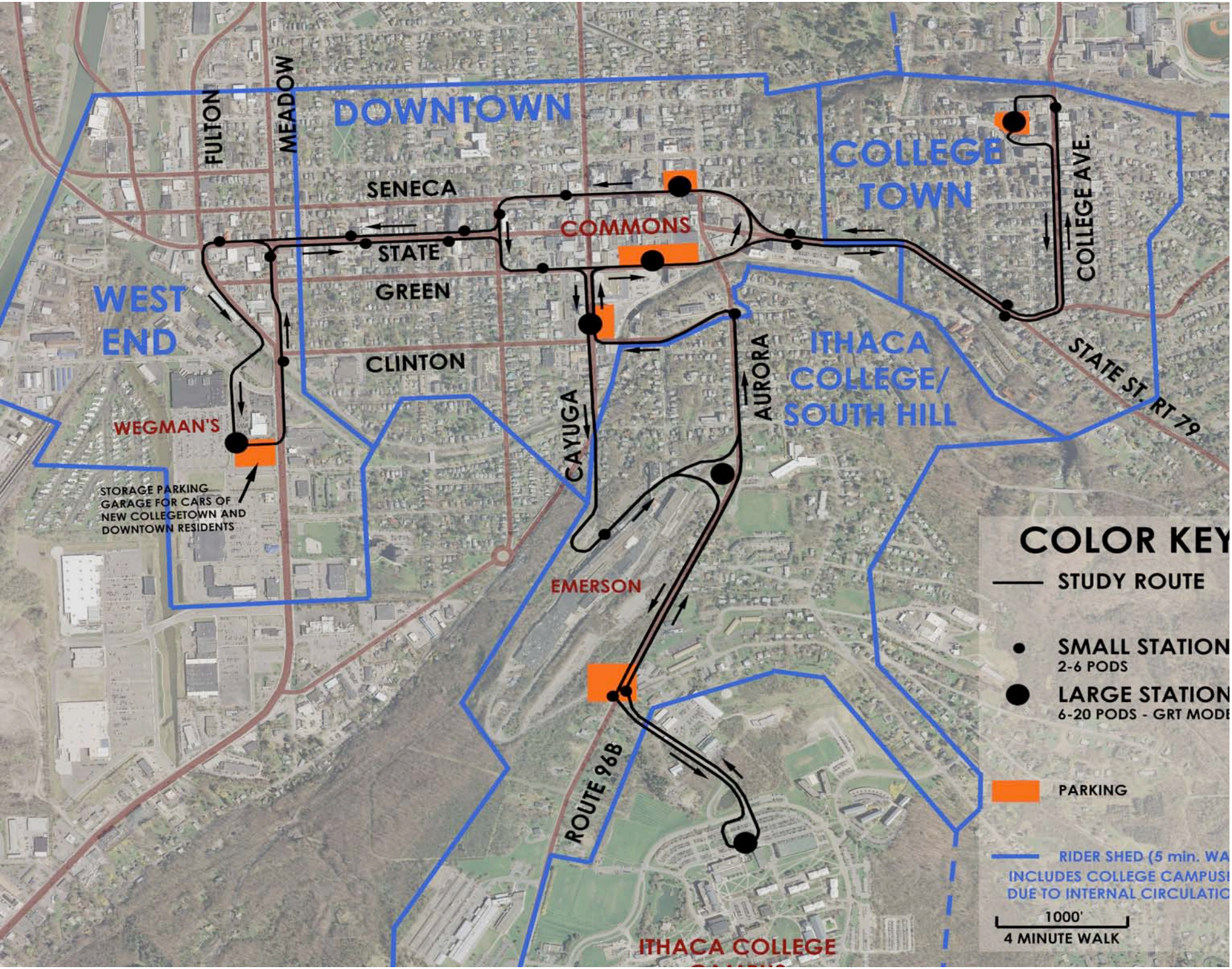
Network Layout

Highly flexible

Simple rules

"Site Planning and Network Layout"


Councilmember Zimmermann's Plan for a Personal Rapid Transit System for Minneapolis, MN
Personal Rapid Transit Stations
Roads
Freeways
LRT Line
LRT Stations
Additional Phases
Phase One
Downtown Business Dist., Downtown Commercial Dist.
Downtown Service Dist., Downtown Commercial Dist.
Neighborhood Comm. Dist., General Commercial
Medium Industrial Dist., Light Industrial Dist., General Industrial Dist.
High Density Dtc., Neighborhood Dtc., Institutional Dtc.
Single Family Dist., Two Family Dist., Multiple Family Dist.


DOWNTOWN
COLLEGE TOWN
WEST END
ITHACA COLLEGE/ SOUTH HILL
FULTON
MEADOW
SENECA
STATE
GREEN
CLINTON
COMMONS
COLLEGE AVE.
STATE ST. RT 79
AURORA
CAYUGA
WEGMAN'S
STORAGE PARKING GARAGE FOR CARS OF NEW COLLEGETOWN AND DOWNTOWN RESIDENTS
EMERSON
ROUTE 96B
ITHACA COLLEGE
COLOR KEY
STUDY ROUTE
SMALL STATION
2-6 PODS
LARGE STATION
6-20 PODS - GRT MODE
PARKING
RIDER SHED (5 min. WA
INCLUDES COLLEGE CAMPUS
DUE TO INTERNAL CIRCULATIO
1000'
4 MINUTE WALK

Control

"Overcoming Headway Limitations in PRT,"
www.prtinternational.com

How do we keep vehicles from crashing into each other?

"PRT Control," "Failure Modes and Effects Analysis," www.prtnz.com

- Computers routinely land airplanes on aircraft carrie
- We use redundancy for high reliability and safety.
- We correct speed and position every 10 milliseconds
- We measure position and speed accurately.
- Wayside zone-control computers monitor vehicles.
- Software available to control any number of vehicles precisely in networks of any size or configuration.

"Some History of PRT Simulation Programs"

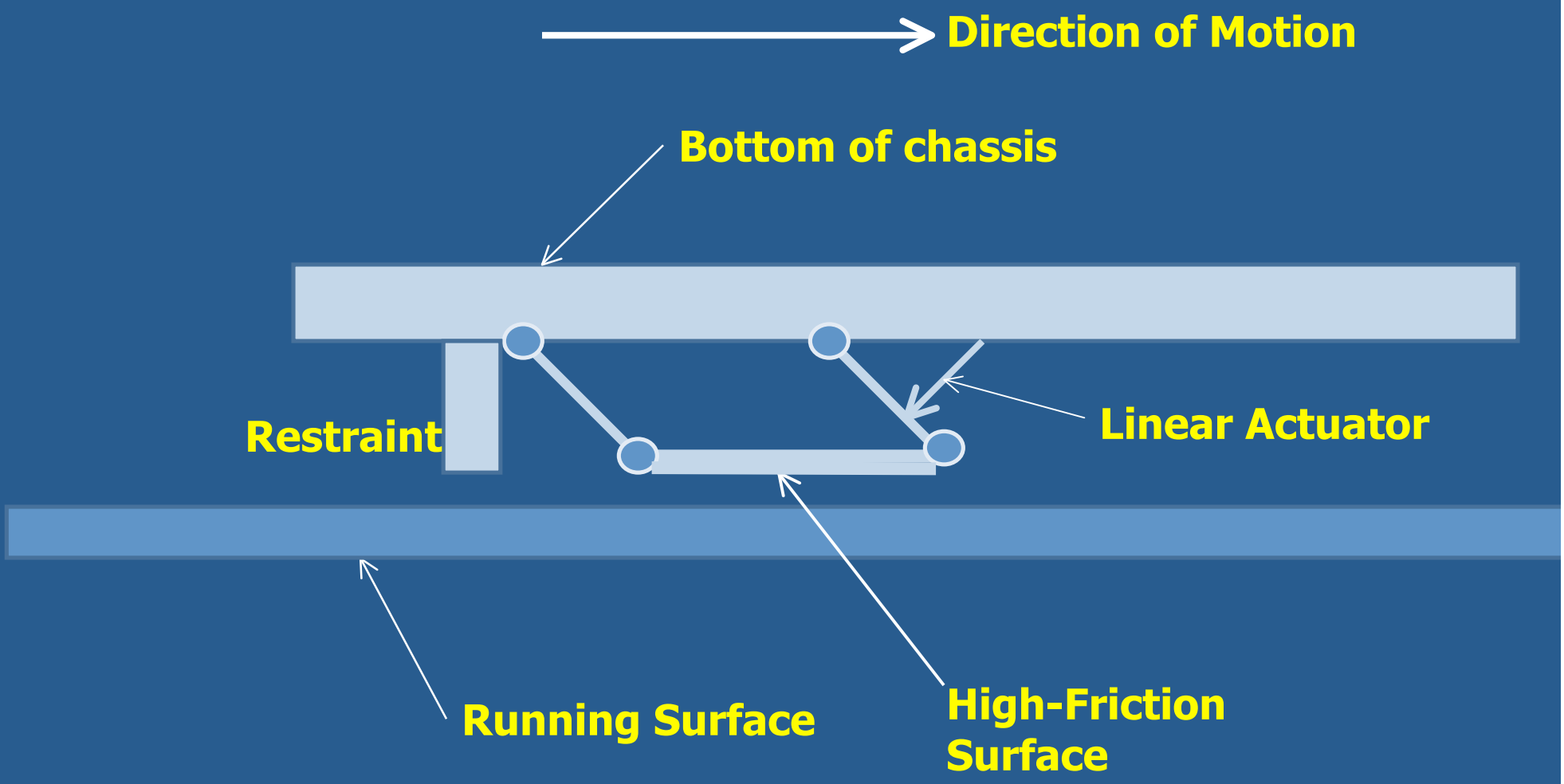
"Simulation of the operation of PRT systems"

"A Review of the State of the Art of PRT," www.prtnz.com

For safe, all-weather fractional-second headway use *Linear Electric Motors:*

- **Braking rate**
  - **Wheel braking depends on**
    - **Friction, grade, tail wind – must assume the worst case.**
  - **LEM braking independent of**
    - **Friction, grade, tail wind.**
- **Reaction time**
  - **Wheel braking > 500 milliseconds**
  - **LEM braking almost instantaneous**
- **Moving parts**
  - **Propulsion and braking through wheels: Many**
  - **LEM propulsion and braking: Fan motor only**
- **How to obtain adequate friction?**
  - **Wheel braking**
    - **Need sandpaper surface**
    - **Braking rate on dry surface too high**
    - **Tire material imbeds in surface**
  - **LEMs**
    - **Want smooth surface**
    - **Wheels only rollers – no braking through wheels**

Parking & Emergency Brake



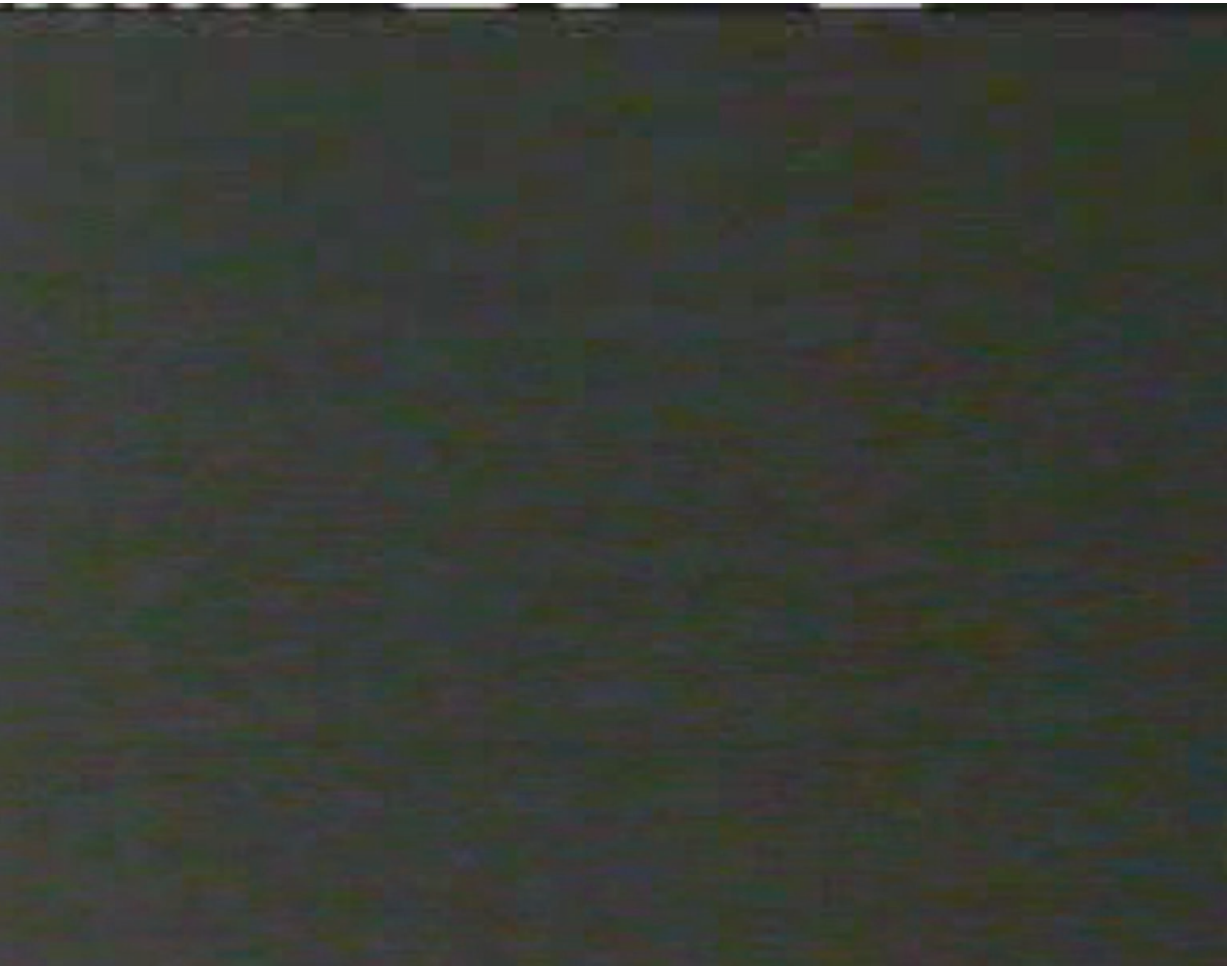
Maximum Braking Rate < 0.5g

1990's PATH Project: 60 mph on freeway near San Diego at 0.273 sec Headway.

Monitored by National Highway Traffic Safety Board

7 min video

Using the System

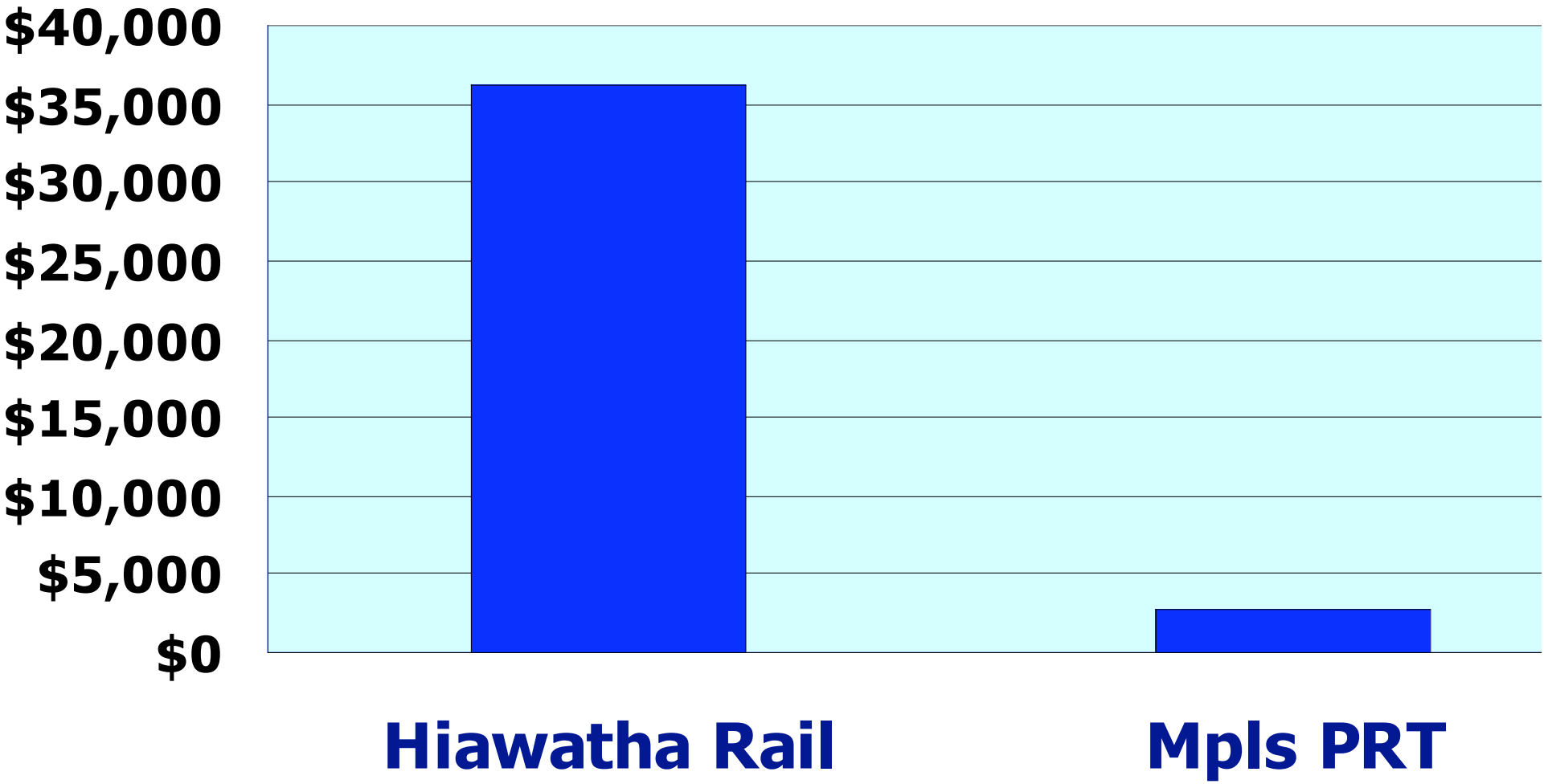


Thousands of smooth rides given at 2003 Minnesota State Fair. No Redundancy. No Failures.

Cost Savings

“Light” Rail
A transit mode f
introduced in 18

Cost per Daily Trip



Off-line stations and small vehicles attract many riders!

- Available to anyone anytime 24/7.
- No need to understand the system.
- Short walk in a wider service area.
- Short or zero wait.
- A seat for everyone.
- Ride alone or with chosen companions.
- An enjoyable, nonstop ride.
- Text message all you want!
- No transfers.
- Short, predictable trip time.
- Satisfaction by helping the environment.
- Competitive fare.

Land Savings

Freeway at Capacity

Carter : Bur

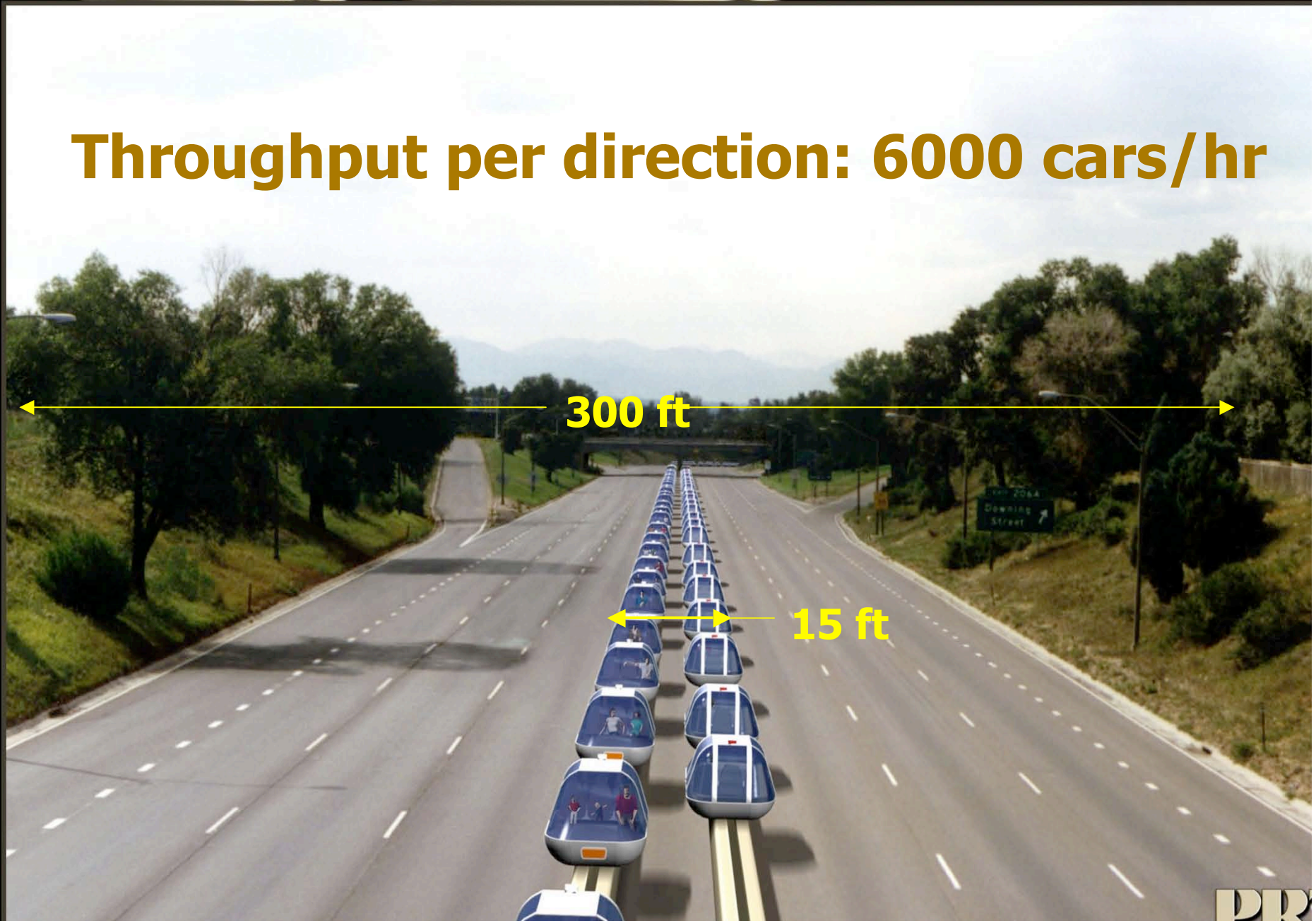
Throughput per direction: 6000 cars/hr

Vehicles Removed

PRT Passengers

Carter - Bur

Throughput per direction: 6000 cars/hr



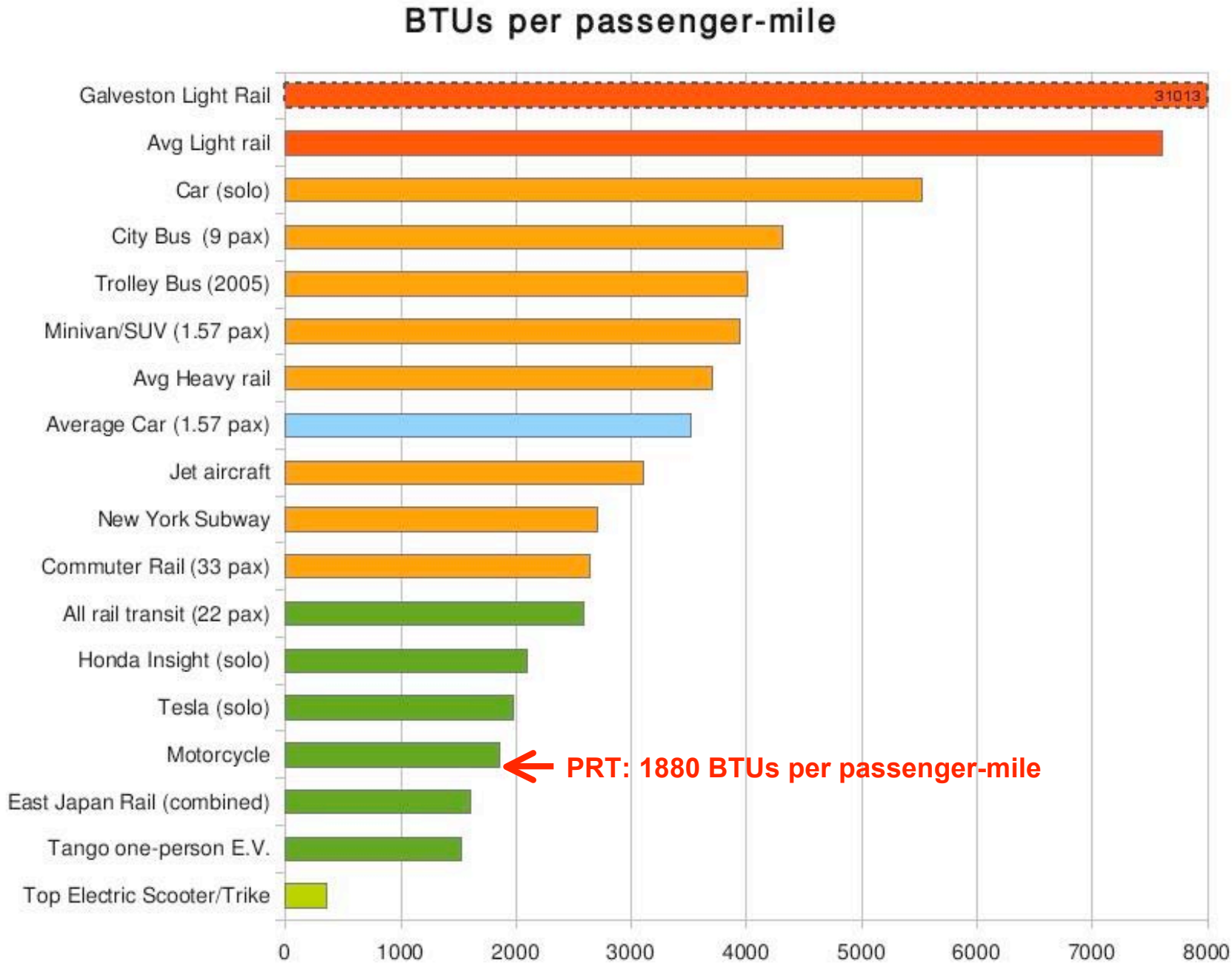
Enormous Land Savings!

- **Land required only for posts and stations,**
  only 1/5000th or 0.02% of city land.
- **Auto system requires**
  - **30% of land in residential areas**
  - **50% to 70% in downtown**
- **Land savings + high ridership permits safe, zero-pollution, energy-efficient, environmentally friendly, high-density living to an extent not possible with conventional transportation.**


A former parking lot!

Energy Savings

USA Transportation Energy Use

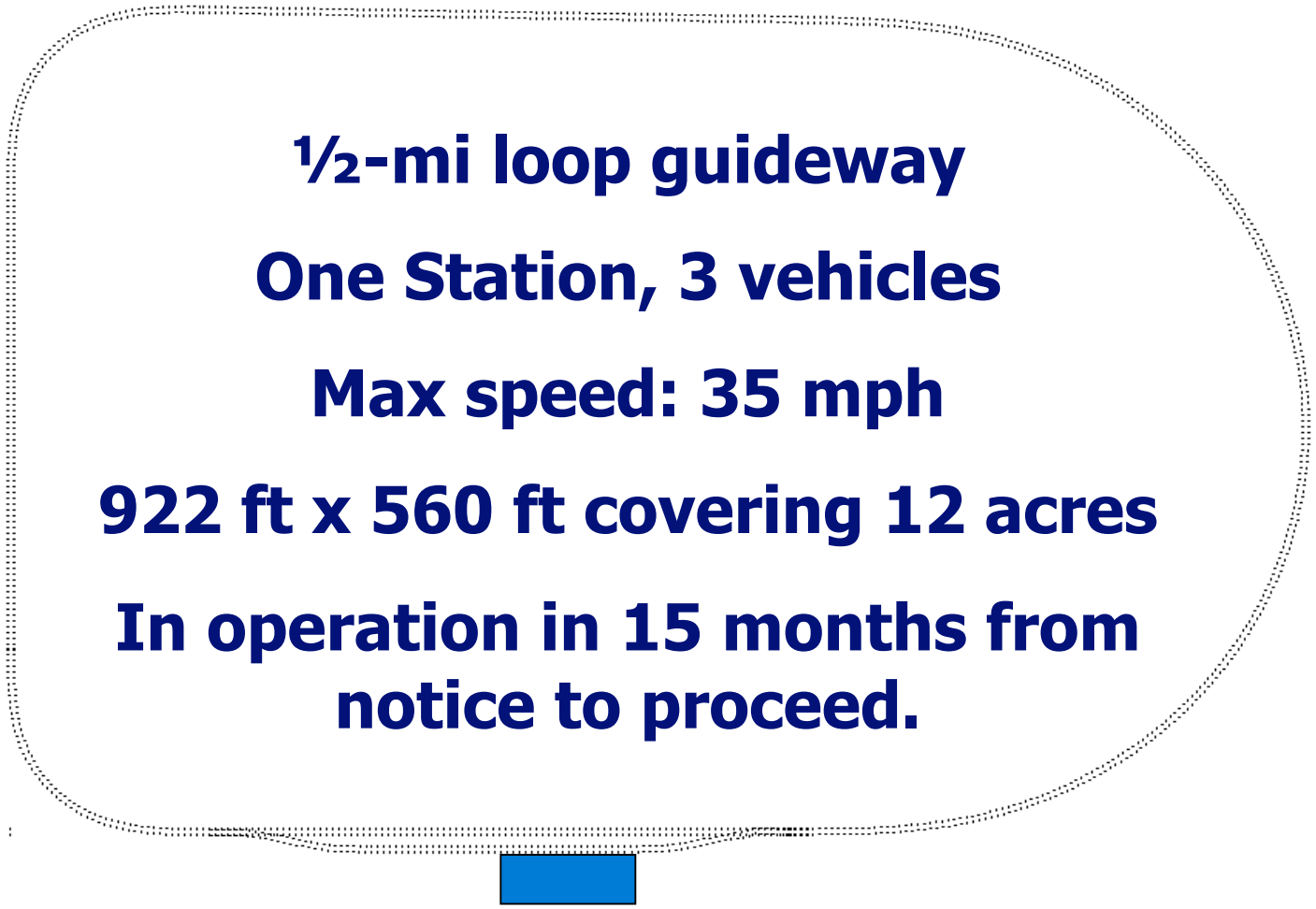


www.templetons.com/brad/transit-myth.html

More Benefits:

- Transportation without congestion.
- Electrical energy from a renewable source.
- No oil.
- No carbon dioxide.
- Accident rate < one billionth of auto system.
- Transit service for everyone.
- Contains sprawl.
- No reason for road rage.
- No public subsidy needed.
- Political support from both left and right.

The Next Step:



The Engineering Program is ready to go!

$25,000,000 for engineering, construction, installation, proof test marketing, and planning for applications.

The Engineering Tasks

1. Systems Engineering & Mgt
2. Safety & Reliability
3. Cabin
4. Chassis
5. Guideway & Posts
6. Guideway Covers
7. Control System
8. Propulsion & Braking
9. Wayside Power
10. Civil Works
11. Testing
12. Application Planning

Countries involved in Development and/or Planning of PRT:

England, Sweden, UAE, Italy, Korea, Mexico, India, China

In the USA: San Jose & Ithaca

Best independent news on PRT is found on

http://kinetic.seattle.wa.us/prt/

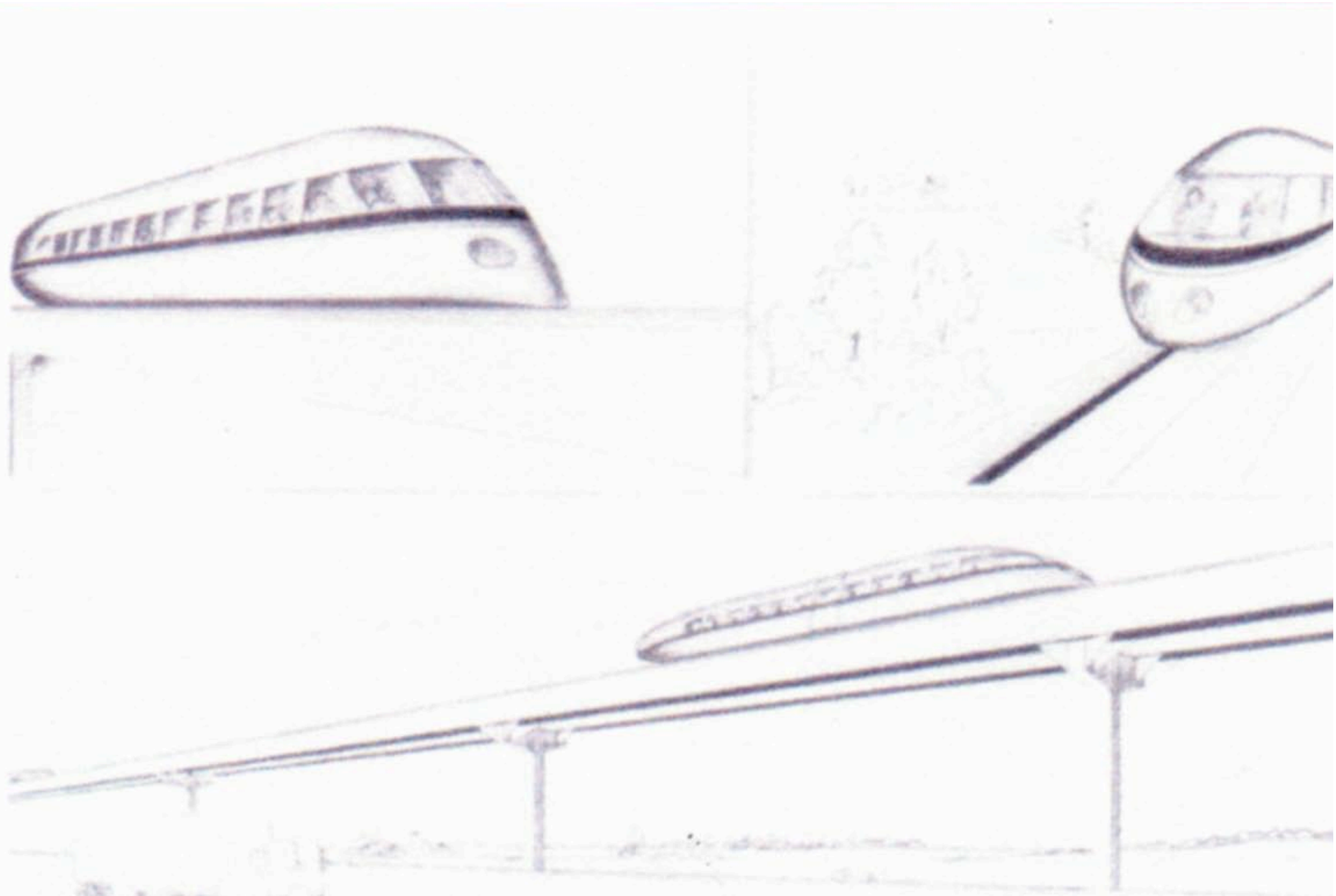
www.cprt.org

Citizens for Personal Rapid Transit

For more information:

www.prtinternational.com.

Click on "DVD" and watch a video for a more detailed Systems Engineering presentation.



150 mph intercity system. Light-weight vehicles. Off-line stations
Nonstop service between every pair of cities.
Covered truss guideway. LIM propulsion. Wheel suspension.

All Questions most Welcome!

J. Edward (Ed) Anderson, Ph.D., P. E.
(763) 586-0877
jeanderson@prtinternational.com