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

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Content of Presentation

- PRT beginnings.
- Who is involved now?
- Design process & conclusions.
- Savings in cost, land and energy.
- More benefits.
- The next step.
Read “Evolution of PRT” at www.prt.nz.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 start 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 in each combination until it is clear which best meets all technical, social, and environmental requirements.

Problems with Urban Transportation

- 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 equity.
- 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)*.

Simple logic leads to PRT:
Guideway weight reduction 20:1

Large manually driven vehicles.

Small fully automated vehicles!
Cost per unit of Design Capacity of Various Transit Vehicles
Fleet Cost = Cost/Vehicle Capacity

People-Carrying Capacity

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

Conclusions:
Guideway cost is minimized by minimizing vehicle weight.
Vehicle fleet cost is minimized by using off-line stations.
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/ittrans/
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
Optimum Configuration

- 3′ x 3′
- No Moving Switch Parts
- All Weather
- Safe
- Smooth Ride
- Good Appearance
- Durable
- Modular
- Light Weight
- Accessible for Maintenance
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.
- U-Frame
- Vertical Chassis
- Wheeled support

Cover
An Intelligent Transportation Network System,

- Lateral support
- Switch
- Power rails

“An Intelligent Transportation Network System,” www.prtnz.cc
The Chassis
We call our system an "Intelligent Transportation-Network System" (ITNS).

The Generic Name "Personal Rapid Transit" (PRT) 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
Our design won competitions in Chicago, SeaTac & Cincinnati.

- 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
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 carriers.
- 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

Direction of Motion

Bottom of chassis

Restraint

Linear Actuator

Running Surface

High-Friction Surface

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
Cost Savings
“Light” Rail
A transit mode first introduced in 1886.
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
Throughput per direction: 6000 cars/hr
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

BTUs per passenger-mile

- Galveston Light Rail: 31013 BTUs per passenger-mile
- Avg Light rail
- Car (solo)
- City Bus (9 pax)
- Trolley Bus (2005)
- Minivan/SUV (1.57 pax)
- Avg Heavy rail
- Average Car (1.57 pax)
- Jet aircraft
- New York Subway
- Commuter Rail (33 pax)
- All rail transit (22 pax)
- Honda Insight (solo)
- Tesla (solo)
- Motorcycle
- East Japan Rail (combined)
- Tango one-person E.V.
- Top Electric Scooter/Trike

PRT: 1880 BTUs per passenger-mile

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:
$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:
Click on “DVD” and watch a video for a more detailed Systems Engineering presentation.
Nonstop service between every pair of cities.
Covered truss guideway. LIM propulsion. Wheel suspension.
All Questions most Welcome!

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