William W. Hay Railroad Engineering Seminar

“Moving Towards High Speed Rail”

David E. Staplin, P.E.
Deputy Chief Engineer, Track Amtrak

Date: Friday, October 25, 2013 at Noon
Time: Lunch Available 11:45, Seminar Begins 12:15
Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

Sponsored by
Moving Towards High Speed Rail

The William Hay Lecture UIUC

David E. Staplin
Deputy Chief Engineer – Track
October 25, 2013
Topics to be Discussed

- Remembering those who got us to where we are
- The State of Amtrak
- Approaches to Intercity Passenger Rail
- Higher Speed Rail
- Removing Engineering Barriers to Higher Speed Rail
Remembering…

Dr. Hay

The “Great Generation” of Railroaders

- Tom Hutcheson, SCL
- Ben Gordon, Bob Smith, Bruce Willbrant, PC/Conrail
- Bill Autry, Herb Web, ATSF
- Harry Williamson, Harry Berkshire, SP
- Walter Simpson, Hubert Rose, Southern
- Lucien Durham, George Janosko, N&W
- Bob Brown, UP
- Don Bertel, MP
- Don Sartore, CB&Q, BN
- Vin Terrill, B&M
- Mike Rougas, B&LE
The State of Amtrak

Amtrak System Map

500 Miles

Safe Reliable Economical Smart
Amtrak Has Just Closed Fiscal 2013

- System ridership – 31.6 million, up about 1% over 2012
  - In spite of several major service disruptions
  - Revenue growth exceeded ridership – 4%
  - Increased in 10 of the last 11 years
  - Amtrak’s ridership exceeded by only five airlines

- Ridership by business line (2012 numbers)
  - NEC – Approx 12 million, up 46% from 1998
  - Short Corridors – Approx 15 million, up nearly 100% from 1998
  - Long Haul Trains – Approx 4.5 million, up 20% from 1998

- Financial performance
  - Farebox recovery is 81% on train ops, 88% on all operations
  - Debt has been pared from $3.9 billion (2002) to $1.4 billion, a reduction of 64%
Approaches to Intercity Rail

- Traditional intercity rail, maximum speed generally 79 MPH
- Higher Speed Rail 80 to 125 MPH
  - Limited by FRA
  - Practical limit of 110 MPH account of diesel performance
- Amtrak’s NEC 125 MPH to 150 MPH
- True high speed rail (10 MPH above whatever Amtrak’s best is at the time)
Passenger Trains at Any Speed

Impact of Rail Travel Time on Market Share vs. Air

![Graph showing the impact of rail travel time on market share compared to air travel. The x-axis represents travel time in hours, ranging from 1 to 5, while the y-axis represents market share in percentage, ranging from 120% to 0%. The graph shows a downward trend as travel time increases.]
Traditional Intercity Rail

- It’s what we’ve been doing since the days when passenger trains were privately operated by freight carriers
- Technology is mature
- Regulation is simple, except for new PTC mandate
- Issues between freight and passenger interests
  - Line capacity issues well understood
  - Track standards between modern freight needs (HAL) and passenger are pretty much the same
High Speed Rail

- Accepted world-wide
- Technology is mature
  - Differs somewhat between country
  - Rolling stock and infrastructure are designed as a system
- Doesn’t mix with freight
  - To justify HSR, high traffic densities are needed
  - High traffic densities mean short headways between trains
  - No room between HSR trains for freight as we know it in North America
    - Example:
      - 200 MPH train covers 50 miles in 15 minutes
      - 50 MPH freight train covers 50 miles in 60 minutes
      - Freight eats 4 to 5 HSR slots
      - Generally, lines shut at night for maintenance
Higher Speed Rail

- Also operated worldwide
  - The routes are sometimes called “Classic Lines”
  - Provide service to more intermediate points than HSR
  - Investment in these lines has slowed or stopped to pay for HSR

- US was heading in this direction before World War II
  - Railroads needed something to counter increased auto use
  - World War II stopped it to focus on war effort
  - After WW II governments focus on highways and airports

- Technology
  - Rolling stock is mature but not made in the US
  - Clock stopped on the infrastructure about 1950

- Can mix with freight
What Does This Mean to the Engineer?

- **Traditional Passenger Rail**
  - Get an AREMA Manual
  - Dust off your Hay textbook, earlier edition

- **HSR** – buy it from its owners and import it
  - Comes complete as long as different systems aren’t mixed
  - Biggest challenge is probably in regulations and environmental permitting

- **Higher Speed Rail**
  - Put on your thinking caps – none of the above quite fit
  - Challenge “standards” until you either prove them to be correct OR prove them to be unfounded and change them
  - Must be able to mix the new and the old
Higher Speed Rail, a Good Choice?

- While it’s clear that HSR will work in the US, the barriers to building it are substantial.

- Higher Speed Rail can develop passenger markets:
  - Clearly is already based on Amtrak ridership trends
  - Can pave the way for true HSR

- Investment costs likely to be an order of magnitude lower than true HSR.

- Possible to do now on freight lines especially those with low traffic densities:
  - Capacity is not so much an issue
  - Freight can operate as an incremental user, increasing viability.
Higher Speed Rail – Already Happening

- Chicago Hub has large opportunity with Higher Speed Rail
  - Now in development
    - Chicago to St. Louis
    - Chicago to Detroit
  - In limbo but likely viable
    - Chicago to Madison and possibly Twin Cities
  - Other lines fit the model
    - Chicago to Iowa
    - Chicago to Indianapolis, Cincinnati and maybe Louisville
    - Others?

- East
  - New Haven to Springfield
  - New York to Albany and beyond
Incremental Development Possible

- Do improvements while still operating service
- Can operate on conventional track structures
- Large property takings not usually required
- Environmental permitting is simpler
- PTC can be developed in conjunction with existing signal systems
- Highway grade crossings can be addressed on a risk basis
- Attack slower running areas with finite work packages
- Share rolling stock with other lines
Incremental Development

- Increased ridership comes through
  - Reduction of run times
    - Elimination/Improvement of slow running areas
    - Curve modifications
    - Higher cant deficiency for passenger
    - Track improvement
  - Increased frequency
    - Capacity Improvements, extension/creation of double track
    - Better over-the-road times make faster equipment turns possible
  - Better rolling stock
    - Comfort
    - Features (wifi, power outlets, etc.)

- As fully developed, may make the case for true HSR
Higher Speed Rail Approaches

- Chicago/St. Louis - High investment on the head end
  - Completely new track structure
    - Concrete ties
    - New CWR in place of older CWR
    - Ballast cleaning/replacement
  - Capacity built for intermodal trains in the future
  - Dispatching and ownership stay with freight railroad

- Detroit/Chicago – Lower investment on the head end
  - Track stabilization emphasized
    - Stay with wood ties
    - Old CWR, some non-control cooled
    - Limestone ballast foundation
  - Capacity improvement only for local freight auto traffic
  - Ownership and dispatching in public’s hands
Approaches – Pluses and Minuses

- **Chicago to St. Louis**
  - Should lower costs downstream for maintenance
  - Doing improvements up front may reduce later service disruption
  - Federal funding usually not available on Illinois scale
  - Freight ownership means service changes reopen negotiations

- **Chicago to Detroit**
  - Public ownership facilitates
    - Control of standards
    - Control dispatching
    - Control level of service
  - States not equipped to manage railroads
  - States don’t have funding mechanisms in place for annual expenditures, but PRIIA has forced them to think about the issue
Barrier Removal for Passenger Service

- Much work ahead for railway engineering community
- Problems and solutions have freight benefit spillover and vice versa
- Specific examples, but list is by no means exhaustive
  - Improved roadbed
  - Improved track substructure
  - Improved track structure
  - Improved special track work
  - Improved track geometry
    - Safety
    - Ride comfort
Old roadbeds not built to current standards
- Original goal of railroads
  - Get line open to produce revenues
  - Fix later as financials strength improved
  - Financial weakness since Depression means the “later” never came on some lines

Application of current standards in developing passenger lines not always feasible
- Right-of-way limitations
- Environmental limitations

Need to engineer the problem on a “section by section” basis
Barrier Removal - Roadbed

- Will not support modern slopes
  - Right-of-way width
  - Wetland delineation
- No room for maintenance road
• Same issues in cuts with the additional problem of having adequate drainage ditches
• Solutions tailored to the situation
  • Will change frequently
  • Limited ditch width may require buried pipe to get capacity

• Provide access for people on foot
Roadbed Analysis - LIDAR
The granular layer thicknesses typically specified for new track construction aren’t compatible with old roadbeds.

- Restoring track by adding new cross section on old bed:
  - Track winds up being a lot higher than existing tracks
  - No roadbed width to hold bottom width of section (15 feet)
- The excavation to “nestle” the granular layer cross section into an old roadbed creates significant:
  - Creates a very large volume of material
  - Disposal costs of materials are huge if they cannot be reused

Granular layer analysis needs to used to address trade-offs:

- With strong subgrade, may be able to reduce thicknesses
- May be able to reuse old materials
Roadbed Drainage

Bathtub effect, retained water
Roadbed Drainage - Remediation

Existing Conditions

Clean Shoulder to Longitudinal Sub-Drain, Open Ditch or Fill Slope

After Remediation

New Track

Provide adequate depth for pipe to have proper longitudinal slope

Longitudinal sub-drain, as needed to drain ROW
Old roadbeds are a very large challenge
  – Good ride quality requires uniform track modulus/settlement
  – Economical maintenance requires control of track deflection
  – Old roadbeds are seldom uniform

Tools to characterize subgrade
  – GPR
  – LIDAR
  – Falling weight deflectometer
  – Cone penetrometer
Track Substructure Analysis (GPR)
GPR Indicates Ballast Pocket

“Hotter” colors indicate deeper ballast and deformed subgrade surface.
GPR Complemented by Geometry Data

Growing ballast pocket

Geometry Roughness, Track 1

8/2007
4/2005
4/2003
4/2002
5/2001
Combined GPR and LIDAR (FliMap)

MP 20 + 4600’ cross section

Surface Topography from FliMap data

Subgrade Surface from GPR data
Substructure Remediation

Existing Conditions

After Remediation
Barrier Removal – Track Structure
Barrier Removal - Track Structure

- **Rail** – Generally a good news story
  - Sections available are very good – well engineered
  - Straightness has improved over the years, still has some upward potential
  - Increased lengths coming available reduces weld tolerance issues

- **Ties** – Could use research help (Preach to choir)
  - 110 MPH can be accommodated on wood ties
  - 125 MPH is probably the time to require concrete
    - Concrete design needs a “physic”
    - Fasteners as well
    - Benefits of under tie pads

- **Ballast** – existing research pointed in right direction

- **Special track work** – Needs help
Track Structure – Special Trackwork
Track Structure – Special Trackwork

- Things that are fixed
  - Hollow steel ties for switch rods – better for tamping
  - Removed ¼ inch rise of switch point over stock rail
    - ZU-160 rail section permits positive hold down on stock rail
    - Improved maintenance practices
  - Improved heel compromise connection between rail sections
  - Rollers for switch point to eliminate lubricant

- In the works
  - Better geometry for higher speeds
  - More conformal contact for switch points
  - Probable return to slip joint in moveable point frog (MPF)
Still Needed

- Better transition in track support modulus
- Better sensors for signal integrity
- Better power mechanisms for switch
Track Structure – Special Trackwork

Safe  Reliable  Economical  Smart
Miter Rails – Failure of AMS at Nan
Miter Rails – Failure of AMS at Nan
Miter Rails – New Riders for Nan
Miter Rails – New Riders for Nan
Miter Rails – Rider I

Safe Reliable Economical Smart
Miter Rails – Rider II
Analysis of true vehicle behavior versus reliance on pre-existing standards

- Problem
  - Poor vehicle behavior possible on track with geometry variations at one-half of safety standards
  - Variations are not usually detectable by eye
  - Root cause not always evident from raw geometry car data
  - Variations are also not “seen” by tamper referencing systems

- Tools
  - Well calibrated vehicle track interaction (VTI) models can replicate problem
  - Filtered geometry car data can help analyst “see” the problem

- Problem usually rolling stock specific
Distribution of LProf 124 MCO w/ & w/o XL Error for Open Track Between Baldwin & Hook Interlockings on AP Line, Track 3

- 50% Exceeding
- 10% Exceeding
Distribution of Prof124 Data for Average of Baltimore Sub & Adams Sub Open Track Section Used by Acela

- **Average for all of Adams Sub. Open Track Blocks**
- **Average for all of Baltimore Sub. Open Track Blocks**

50% Exceeding

10% Exceeding

MCO (in.)

Percent Exceeding
HSR uses survey equipment to direct tampers
- Lines surfaced to original “design” via field installed references
- Principle reference is part of catenary system
- Systems are expensive to install and operate
- Very effective

Freight and traditional passenger ops have relied on
- Internal reference systems on tampers
- Sometimes aided by field measurements
- Effective for freight speeds

Higher speed rail can afford neither
- HSR model would drive costs out the roof
- Short chord internal reference systems inadequate for harmonics related to higher speeds
Geometry – Diagnosis and Control

- Geometry car data is used to diagnose issues
  - Filters often necessary to “see” patterns
  - Can “see” before and after

- Amtrak has worked with a replacement system for tamper software (TGCS)
  - Developed by British Rail Research
  - Designed to integrate chord measurements into longer wavelength data
  - Currently installed on three tampers

- Results in solving individual cases have been very good
  - Works on both profile and alignment
  - Does not require external references other than fixed curve points
Geometry – Space Curve Data

- Left Rail Space Curve
- Right Rail Space Curve

Left & Right Profile Space Curve Error (in.)

Track Footage
Geometry – Filtered Cyclic Error

Error Amplitude (inches)

320 feet

170 feet

Track Distance (feet)

Acela Coach @ MP 123.7, T3
Acela PC @ MP 127.0, T2

Safe Reliable Economical Smart
Geometry - Ride Quality Problem

• Point Interlocking
  • Near Baltimore
  • Located at MP 90.2 on track 2

• ARMS (ride quality) hits are carbody lateral peak to peak

• Different tampers sent to fix the problem, to no avail

• Hits result from long wavelength track cyclic error
Geometry – Filtered Error MP 90.2

Location of Hit

Direction of Travel

Alignment Error Before TLM and Filter

Alignment Error After TLM and Filter

Safe Reliable Economical Smart
Geometry – Solution Window

**Standard Method**
- Measure and tamp through 21 switch
- Tamper only recognizes part of the error, and cuts down peak slightly

**Improved Method**
- Measure and tamp from 89+5000 to 90+1200
- Tamper is able to view alignment error and correct it

Alignment error extends past the 21 switch and into and past the 32 switch
Geometry – Use of TGCS

Alignment Error Before TGCS

Alignment Error After TGCS

MP 90.0 Trk 2, Alignment Error
Distance [m]

Parameters
Before
After

Safe Reliable Economical Smart
Geometry – History of RMS MP 90.2

No ARMS Hits since being tamped with TGCS


0  20  40  60  80  100  120  140
Point Track 2, Versines and Throws

- Alignment error or throws (mm)
- TGCS Throws
- AGGS Throws
- Horizontal Versines

Zero on y-axis = Track Centerline
Positive value on y – axis = Error or throw to the left (mm)
Negative value on y – axis = Error or throw to the right (mm)
Geometry – Lessons Learned

- Ride comfort issues develop before safety limits in geometry.
- Raw geometry car output does not necessarily highlight cyclic problems.
  - Must use filters to show cycles.
  - Filters show extent of problem.
- Tamper control systems do not economically capture long wave feature.
  - Will look over a length of 150 meters (400 plus feet).
  - Assumes long windows allow large throws.
  - Will want to align track to error instead of parent alignment.
  - Operators rightly limit throws.
- Better software needed.
Advice for Young Engineers...

- Take back the “process”
  - Engineers are being marginalized by professional planners
  - Staplin’s Law of Projects – Progress is proportional to one over process

- Engineers must be
  - on top of the technical game
  - articulate
  - able to explain trade-offs to non-technical people

- Treat your profession as you would citizenship
  - Be active in professional associations
  - Payback is far more than the effort
Moving Towards Higher Speed Rail

Thanks for your attention!