William W. Hay Railroad Engineering Seminar

“Moving Towards High Speed Rail”

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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

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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
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

Travel Time (hours)

Market Share (%)
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
Also operated world wide
- 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)
“Hotter” colors indicate deeper ballast and deformed subgrade surface
GPR Complemented by Geometry Data

Growing ballast pocket

Geometry Roughness, Track 1

Combined GPR and LIDAR (FliMap)

MP 20 + 4600’ cross section

Surface Topography from FliMap data

Subgrade Surface from GPR data
Barrier Removal – Track Structure
Barrier Removal - Track Structure
Barrier Removal - Track Structure

Engineering

- **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)
Track Structure – Special Trackwork

Still Needed

– Better transition in track support modulus
– Better sensors for signal integrity
– Better power mechanisms for switch
Miter Rails – Old Style AMS
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
Miter Rails – Rider II

Engineering
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
Geometry - Track Quality

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

Percent Exceeding:
- 50% Exceeding
- 10% Exceeding

MCO (in.)

Safe Reliable Economical Smart
Geometry – Higher Speed Rail

- 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

Tracker Distance (feet)

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

Alignment Error Before TLM July 2010

Alignment Error After TLM and Filtered Error July 2010

Location of Hit

Direction of Travel

Safe Reliable Economical Smart
Geometry – Solution Window

Direction of Travel

Alignment error extends past the 21 switch and into and past the 32 switch

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
Geometry – Use of TGCS

MP 90.0 Trk 2, Alignment Error

Alignment Error Before TGCS

Alignment Error After TGCS
No ARMS Hits since being tamped with TGCS
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!