UNIVERSITY of DELAWARE

Overview of Track Maintenance Planning

Dr. Allan M Zarembski, PE

Professor

Director of the Railroad Engineering and Safety Program

University of Delaware

dramz@udel.edu

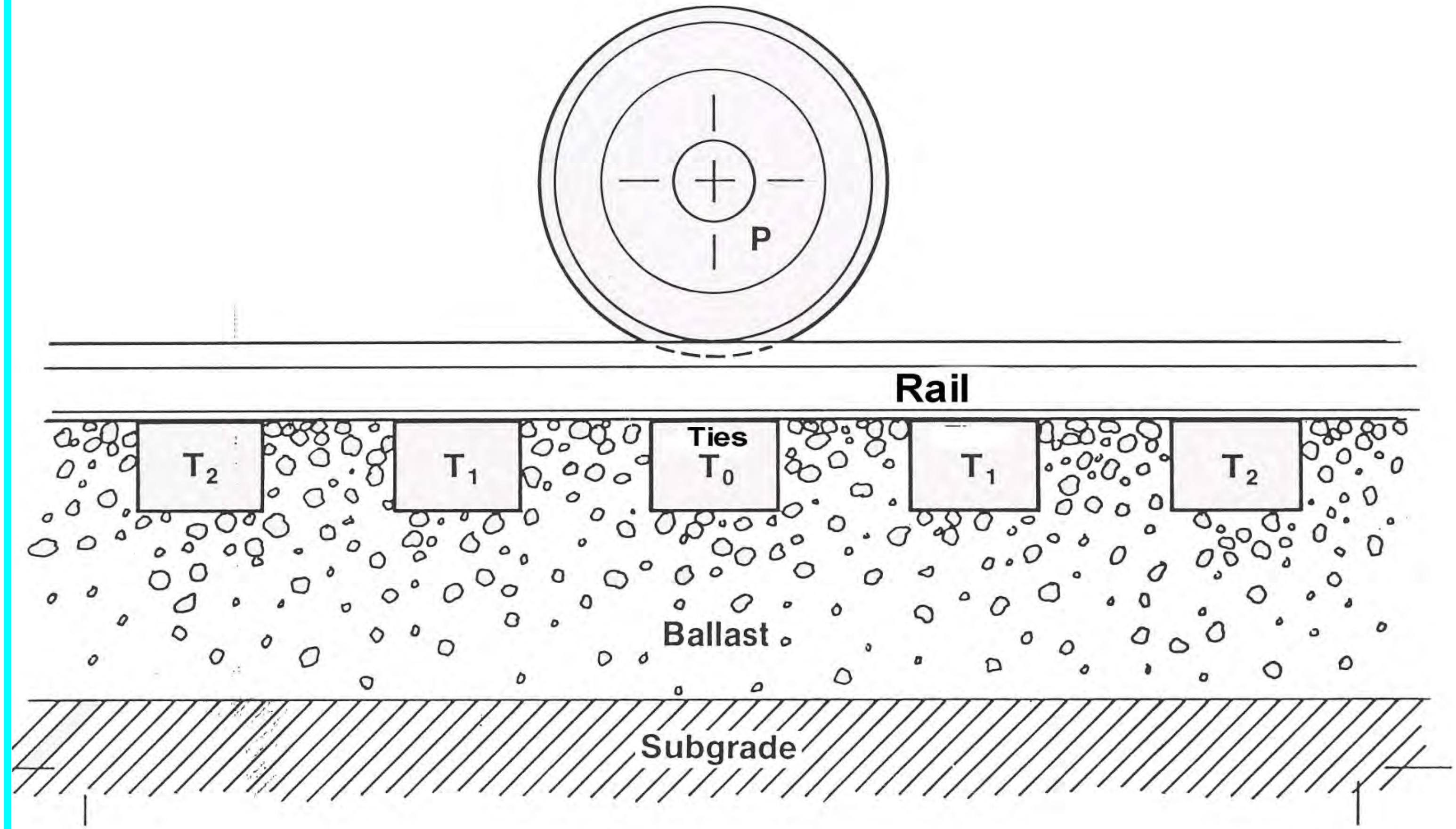
Railroad Engineering and Maintenance

- Evolution of railroad track, and key components, paralleled by evolution in railroad engineering
- Early railroad engineering focused on “building” the railroad
  - Strong emphasis on construction techniques, bridge and tunnel engineering and route alignment engineering
- Modern railroad engineering focused on improved analytical tools, better designs, and improved maintenance procedures
  - Improve track structure’s strength and ability to carry heavy loads
  - To last longer and perform more efficiently
- Dependent of traffic type and characteristics
  - Axle load, Speed, Density of traffic

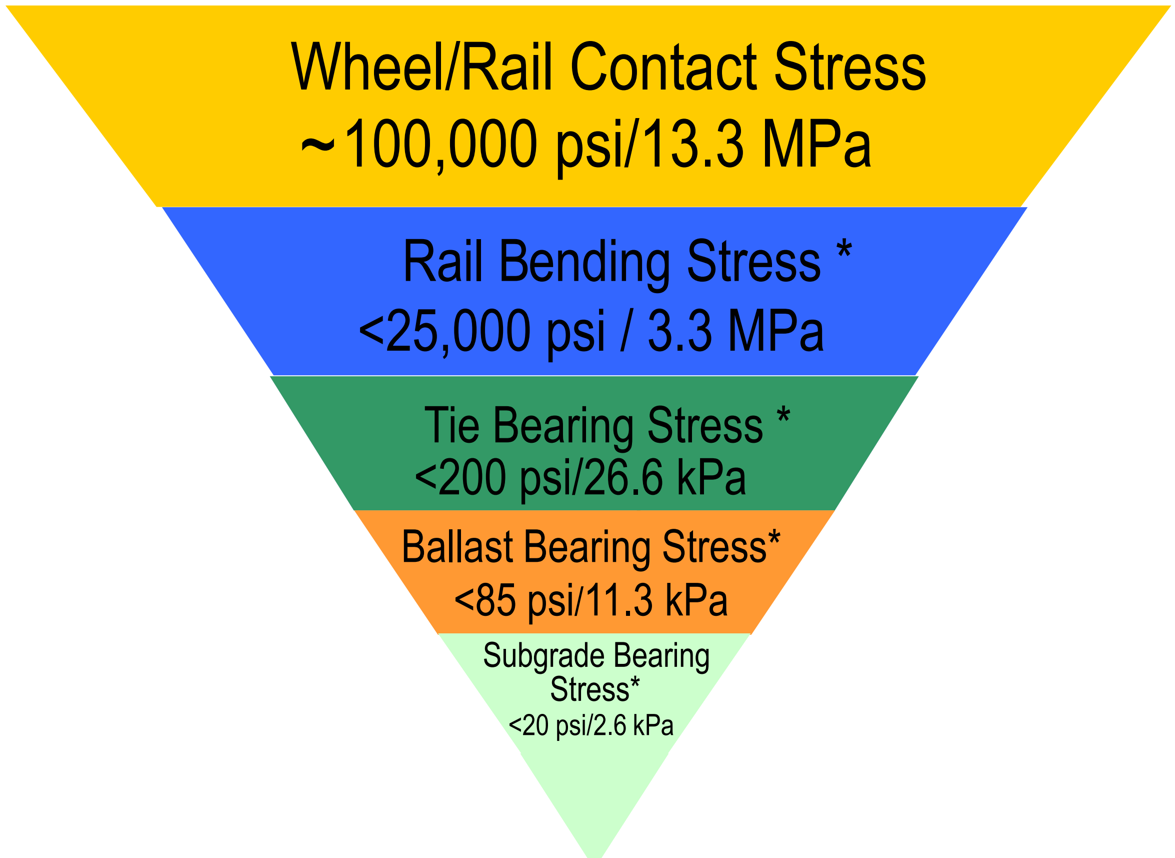
Purpose of Railroad Track Structure

- Support the loads of cars and locomotives
- Guide their movement

Function: Withstand and Distribute Loads



Pyramid of Bearing Stresses



Focus of Engineering Analysis

- Strength of the track and its components
  - Ability to resist catastrophic failure
- Ability to resist long term degradation or deterioration
  - Maintain geometric integrity
  - Reduce/control maintenance requirements over extended periods
    - Extend the life of track components
    - Reduce/control rate of track degradation
    - Identify/rectify problems before catastrophic failure

Railroad Engineering

- Current practice can be divided into two broad categories
  - Design based engineering
  - Maintenance based engineering
- Difference in focus and approach
  - Railroad design engineers primarily concerned with building new track
  - Railroad maintenance personnel being primarily concerned with maintaining existing track
    - Major focus today

Design Based Engineering:

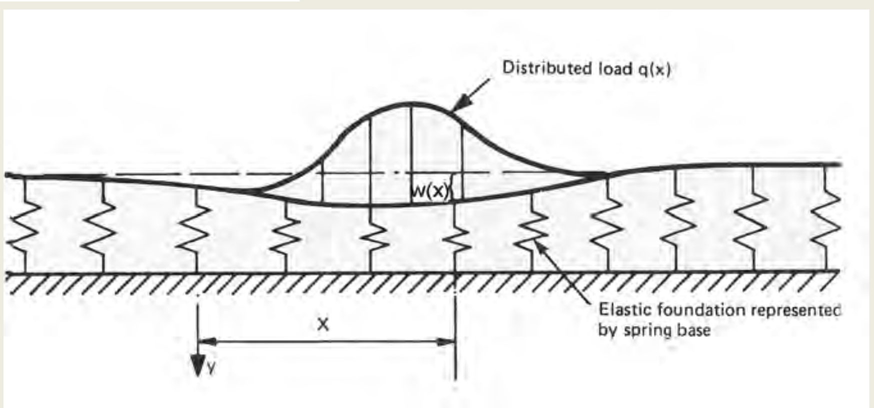
- Design based engineering concerned with track systems, subsystems, or individual components
- “Standardized” tools presented by AREMA Manual for Railroad Engineering
- “Modern” railroad engineering starts with Beam On Elastic Foundation (BOEF) theory
  - Treats track structure as rail beam sitting on a continuous linear elastic foundation (k)
    - Representing the cross-ties, ballast and subgrade
  - Calculate rail stresses and deflections
  - Tie pressures

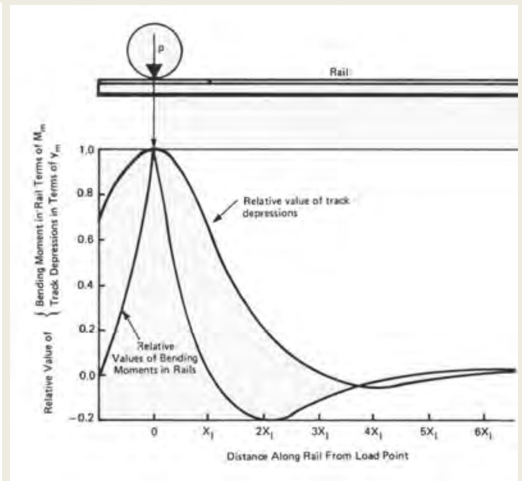
Beam on Elastic Foundation Model

$$EI\frac{d^4 w(x)}{dx^4} + kw(x) = q(x)$$

$$w(x) = \frac{P\beta}{2k} e^{-\beta x}\left[\cos(\beta x) + \sin(\beta x)\right]$$

$$M(x) = \frac{P}{4\beta} e^{-\beta x}\left[\cos(\beta x) - \sin(\beta x)\right]$$





Maintenance Based Engineering

- Maintenance based engineering is concerned with existing track and how to optimize its performance
  - long term railroad environment
  - increasing loads
- Focus is usually on specific component or subsystems
  - Different focus for HAL freight and high speed passenger
- Engineering analyses and studies in conjunction with empirical development of maintenance practices
- Maintenance engineering focus of last 40 years
  - Under heavy axle load operations, rail represents highest maintenance and replacement cost area for track structure
  - Under high speed passenger operations; track geometry represents highest maintenance cost area
- Safety is a major area of concern

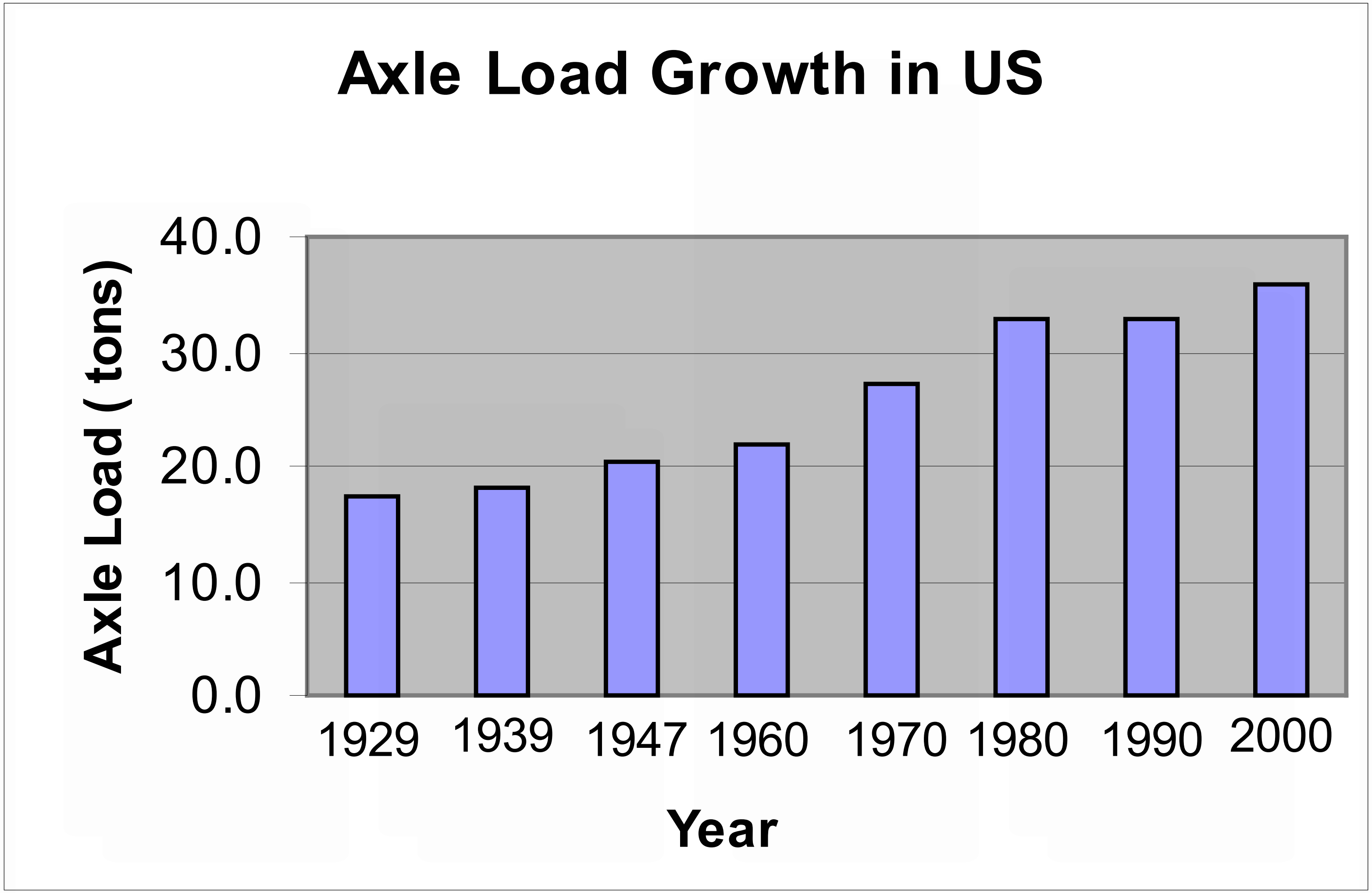
Railroad Load Environment

- Vertical Loadings
  - From railway vehicles
  - Basis for design engineering
- Lateral Loadings
  - From railway vehicles
- Longitudinal Loadings
  - From railway vehicles
  - From environment (temperature effects)

Static Wheel Loads - Worldwide

Axle Load		Gross Weight of Cars		Traffic Type
Tonnes	Tons	kN	lb.	
8	**8.8**	**310**	**70,000**	**Light Rail Transit**
12	**13.2**	**470**	**106,000**	**Heavy Rail Transit**
17	**19**	**670**	**150,000**	**Passenger**
22.5	**25**	**880**	**198,000**	**Common European Freight Limit**
25	**27.5**	**980**	**220,000**	**UK+Select European Freight**
30	**33**	**1170**	**263,000**	**BV (Sweden) limit on Ore Line**
32.5	**36**	**1270**	**286,000**	**North America Free Interchange**
36	**39**	**1400-**	**315,000-**	**Limited use in US**
41	**45**	**1600**	**360,000**	**Max in Australia Iron Ore Lines**

Dynamic loads can be 3+ times static load
Current AAR dynamic wheel load limit is 90,000 lbs (400 kN)


Axle Load Growth in US
Axle Load (tons)
40.0
30.0
20.0
10.0
0.0
1929
1939
1947
1960
1970
1980
1990
2000
Year

Heavy Axle Load Freight Train

Heavy Axle Load Track Issues

- Design of track to allow for heavy axle loads
  - Minimum grades
    - Grades < 3%
  - Elevation
    - Issue for mixed passenger and freight traffic
  - High load/stress environment
    - Rapid degradation of track components
    - Potential for catastrophic failure/derailments

- Track maintenance
  - Focus on component degradation and failure
  - Needs for long lived components
  - Need for effective maintenance planning and management

High Speed Rail

High Speed Rail

- Speed has a major effect on loading and track system requirements
- "Very" High speed rail defined as speeds greater than 180 mph
  - Highest operating speeds 350 kph (210+mph)
- High speed rail is defined at 125 to 160 mph
  - FRA Class 8
  - Highest speed in US 150 mph (Amtrak NE Corridor)
- FRA Speed categories
  - Class 5 track with passenger train speeds up to 90 mph
  - Class 6 track operating at 90 to 110 mph
  - Class 7 track operating at 110-125 mph
  - Class 8 track operating at 125-160 mph
  - Class 9 track operating at 160-220 mph

High Speed Track Issues

- Design of track to allow for higher speed passenger traffic
  - Minimum curvature
    - Curves < 2 degrees (3000 foot radius)
  - High elevation (6 inches)/ unbalance (> 4')
    - Issue for mixed passenger and freight traffic
  - Tight track geometry requirements
  - Uniform track support
  - Enhanced grade crossing protection

- Track maintenance
  - Focus on track geometry maintenance
  - Significant costs necessary to maintain track for mixed higher speed passenger and freight operations

Maintenance and Maintenance Planning

- Maintenance is primary focus of existing railway track
- Maintenance approaches
  - Interval based maintenance
    - Time
    - MGT
    - Mileage
  - Condition based maintenance
    - By component
    - By subsystem
      - Tie/fastener
    - Entire track
      - Used when train delay is critical issue
  - Scheduling and Planning key

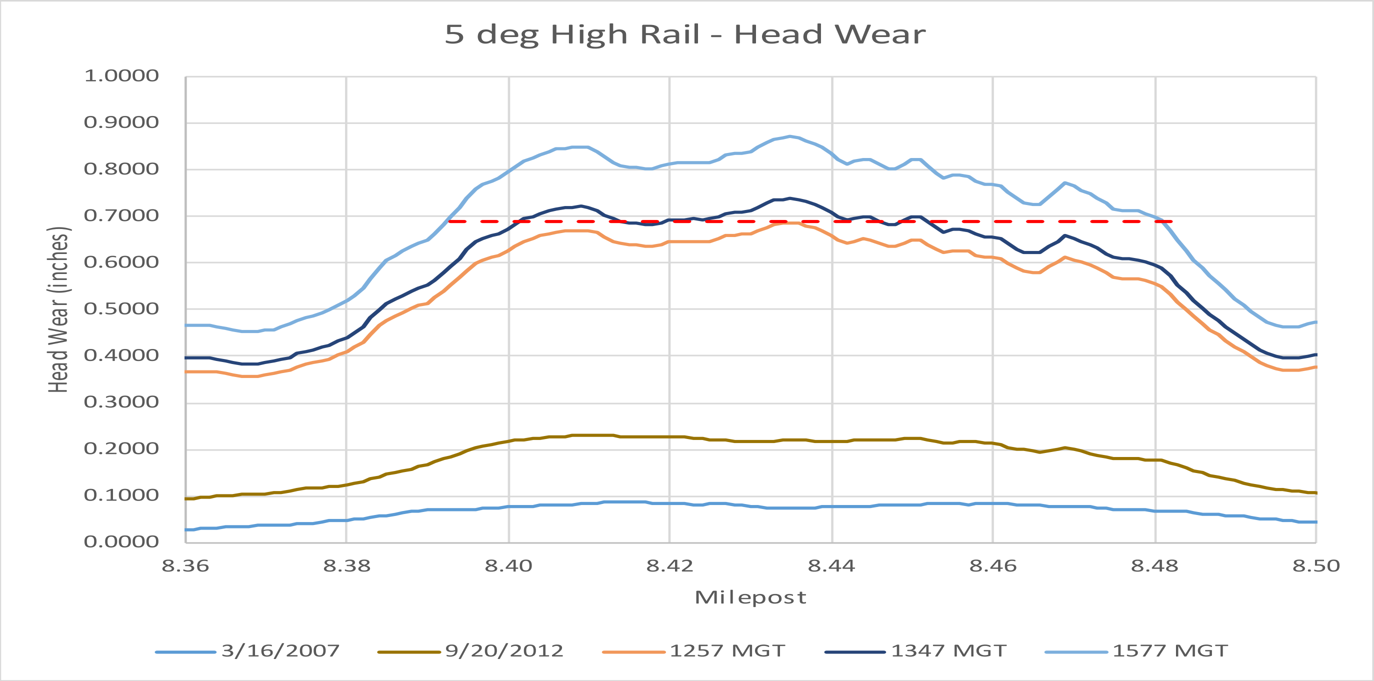
Maintenance Planning Objectives

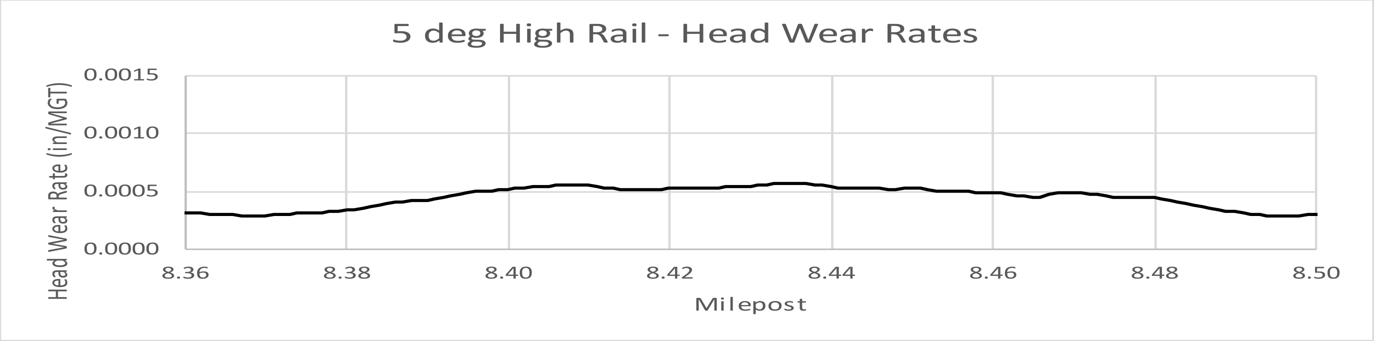
- What is in track now?
  - Data Base
  - Ongoing track inspection
- What will I need?
  - Next year (short term)
  - Two to Five years (medium term)
  - Five to Ten+ Years (long term)
- Maintenance Requirement Forecasting
  - Components (Rail, Ties, Ballast)/Dollars
- What should be done first?
  - Prioritization of needs
    - Adjust to changing budgets
  - Ability to Expand/Contract Budget
  - Decision making tools

Maintenance Planning Overview

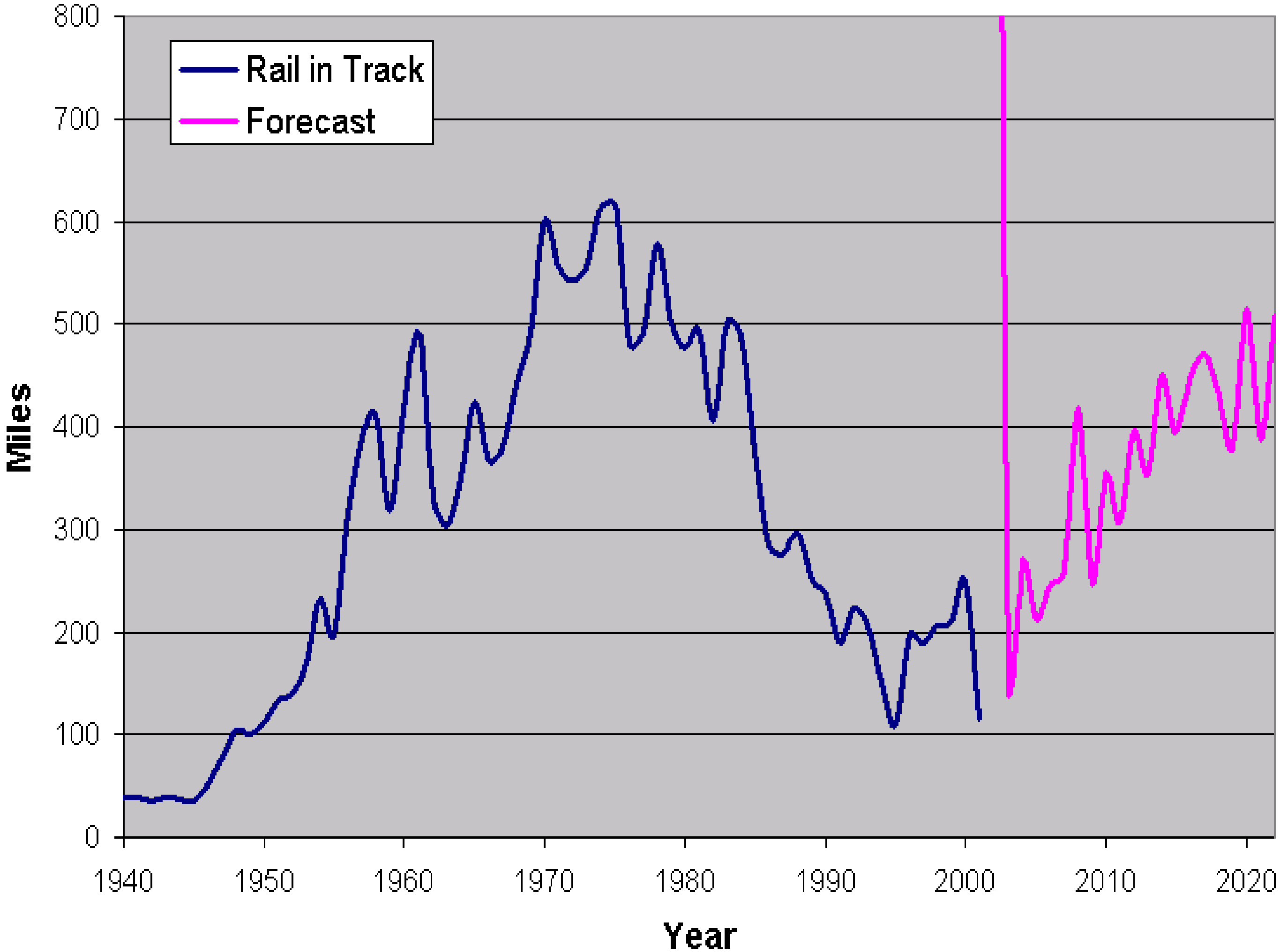
- System Condition and Defects/Exceptions
- Rail
  - Rail Replacement Forecasting
    - Fatigue Life
    - Wear Life
  - Grinding Requirements/Planning
  - Rail Test Scheduling
- Ties
  - Replacement Analysis
  - Degradation/Forecasting
- Surfacing
  - Spot Maintenance Requirements
  - Forecasting Surfacing Cycles
- Track System Approach
  - Resource Allocation

Projected Wear on 5 Degree Curve

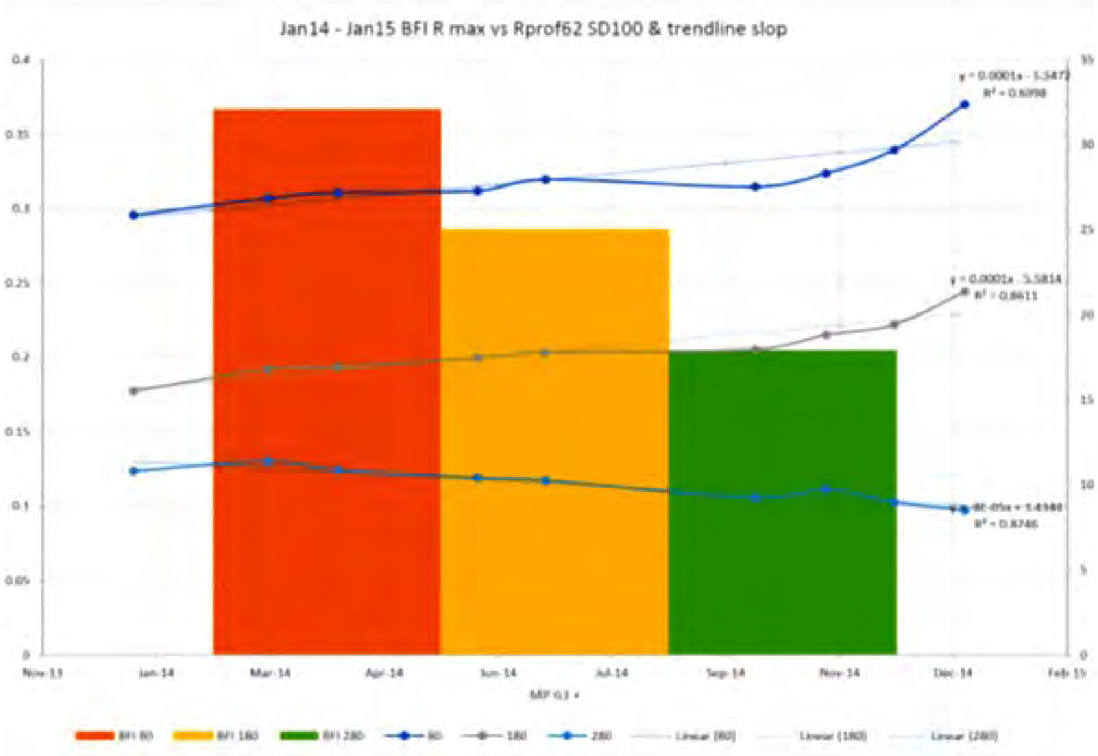




Consolidated Rail Requirement Forecast

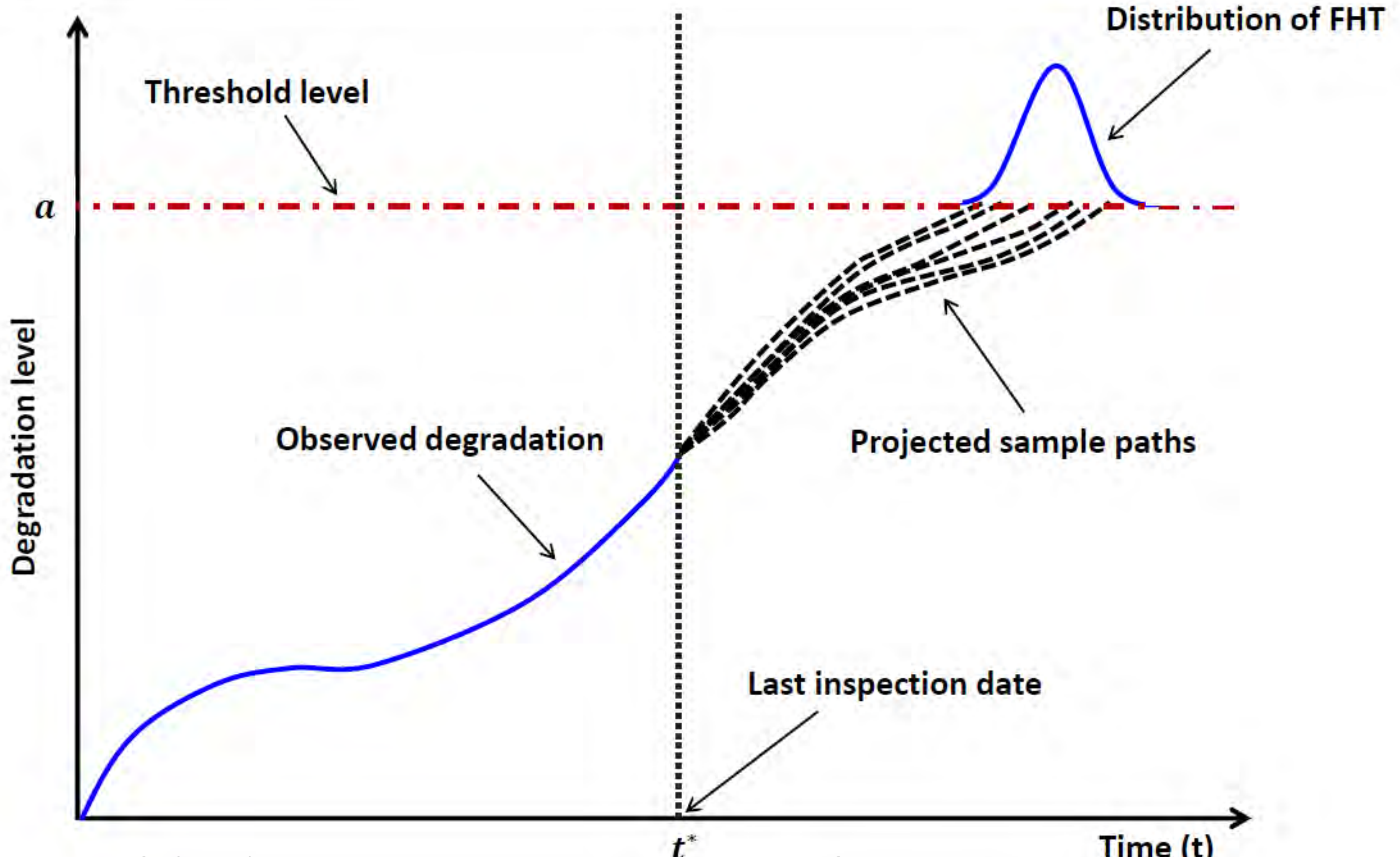


Projected Track Geometry Degradation



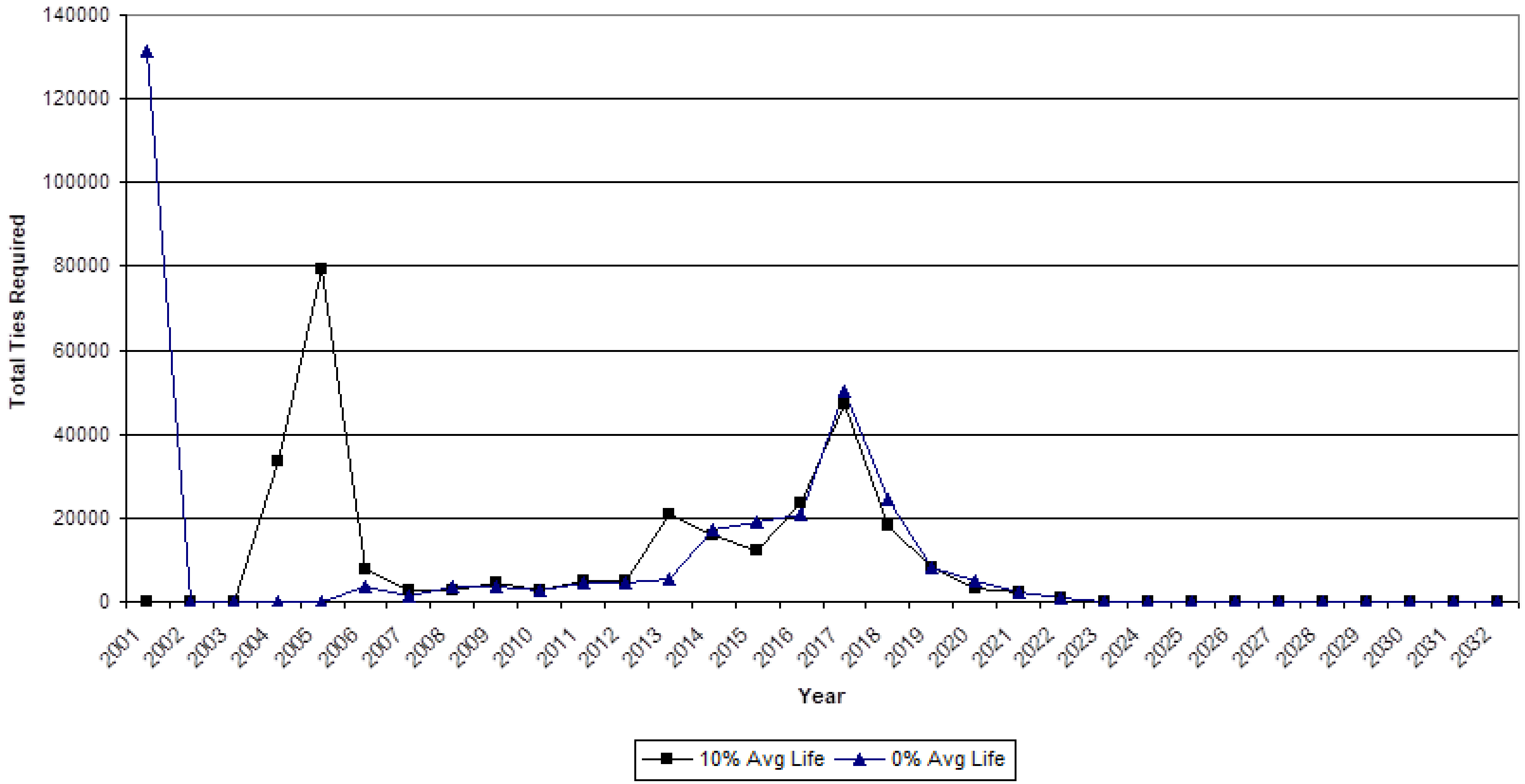
- Three track segments
  - Highly fouled (red)
  - Moderately fouled (yellow)
  - Relatively clean (green)

Data Analytics Based Geometry Forecasting Model



Galván-Núñez, S. (2017). Hybrid Bayesian-Wiener Process in Track Geometry Degradation Analysis. Ph.D. Thesis. University of Delaware.

Cross-Tie Needs Forecast



Maintenance Planning Approaches

- Traditional (“old time railroading”)
  - Visual inspection
    - Written reports from the field
  - Consolidation at headquarters and Verification
  - Determination of resource requirements
- Current
  - Extensive use of automated inspection systems
  - Continued use of visual inspection/tack inspectors
  - Analysis of exception reports
  - Use of early generation planning models
- Emerging
  - Increased reliance on automated inspection systems
  - Expanded analysis of data from inspection systems
    - Data Analytics/“Big Data”
  - New generation maintenance forecasting and planning models
  - Improved resource need forecasting and allocation

Currently Available Track Inspection Data

- – Track Inspectors (visual)
- – Track Geometry Cars
  - Manned
  - Autonomous
- – Dynamic load measurements (e.g. VTI)
- – Ride Quality (accelerometers)
- – Ultrasonic Rail Test Cars (rail Defects)
- – Rail Surface Condition Measurements/Corrugations
- – Rail Profiles/ Wear (ORIAN, LaseRail,…)
- – Tie Condition Data (e.g. Aurora)
- – Ground Penetrating Radar based Ballast condition
- – Track support/stiffness (M-Rail)
- – Automated Turnout Inspection (e.g. ASIV)

Use of Data

- Inspection data can be analyzed and compared with past and future data
- Key issue is converting "lots of data" into "information"
  - Growing use of Data Analytics ("Big Data")
- Develop degradation and forecasting models
- Develop relationship models between track components and systems
- Develop tools to help make maintenance more efficient

Use of Information

- Identify immediate maintenance needs
  - Short term maintenance
  - Safety focus
  - Extensive use of exception reports
    - Safety/maintenance thresholds
- Plan intermediate and long term maintenance requirements
  - Project track degradation
    - Develop track degradation models
  - Determine maintenance requirements
  - Develop maintenance plan

Elements of an Effective Maintenance Planning System

a) *Track Inspection Data* - both visual (subjective) and measured (objective). Track geometry, flaw detection and other inspection vehicles represent specific examples of the latter class of data.

b) *Track Data Base* - a consolidation of the track information, inspection data, maintenance history and other information into one central, accessible (computer) database.

c) *Track Deterioration Analyses* - relationships that predict the deterioration and/or failure of the key track components and subsystems, based on the information in (a) and (b).

d) *Maintenance Requirement Forecasts* - the resulting output of the track deterioration analyses applied to the track segments within the database.

e) *Policy and Controls* - guidelines that define the application of maintenance procedures to the individual maintenance requirements forecast above.

f) *Costs* - economic and financial constraints imposed upon maintenance activities.

g) *Maintenance Programs* - short-term and long-term work programs.

Summary

- Railroads are moving onto a new era of maintenance management and planning
- Increasing use of multiple inspection systems with a broad range of condition information
- Development of new generation of Data Analytic tools to convert data into useable information
- Degradation, forecasting and planning models will improve maintenance planning in the intermediate and long term
- Allow for improved maintenance practices and reduced costs