William W. Hay Railroad Engineering Seminar

“Railroad Capacity Analytics at CSX”

Date: Friday, August 29, 2014
Time: Seminar Begins 12:15
Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

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Sponsored by
Railroad Capacity Analytics at CSX

W.W. Hay Railroad Engineering Seminar
August 29th 2014
CSX is defined by its network

- The CSX network serves the U.S. east of the Mississippi River
- Reaches nearly two-thirds of the nation’s population
- Core Routes
  - I-90 Corridor
  - I-95 Corridor
  - Southeastern Corridor
CSX is committed to reinvesting in its network / resources

CSX Historical Capital Expenditures (In Billions)
Network Planning’s role is critical to company success

- Network Planning…
  - Identifies where to add capacity to accommodate future growth
  - Ensures infrastructure can support and sustain high level of service
  - Improve efficiency of capital spending

Network Planning makes sure that the network is in the **right place**, with the **right capabilities**, to serve the **right markets**
Network Planning uses a multi-step approach to manage network capability

- Monitor current service levels
  - Is there a problem?

- Determine root cause of disruptions
  - Is the problem operational or infrastructure?

- Analyze alternatives
  - What are possible solutions?

- Calculate best investment decision
  - Which alternative provides the best financial return?

Simulation Tools
Analytics
Simulation models continue to be a key component of capacity analysis

- **Rail Traffic Controller (RTC)**
  - line-of-road simulation tool
  - off-the-shelf

- **Hump Yard Simulation System (HYSS)**
  - hump yard simulation tool
  - custom-built for each location

- **AnyLogic**
  - off-the-shelf tool platform
  - used for a variety of projects
Network Modeling was looking for a better way to evaluate network performance

- Wanted to:
  - Understand trade-off between service and volume
  - Use actual data to determine LOR capacity
  - Calculate capacity on double track

- Sam Sogin proposed using traffic theory in thesis.

- Decided to investigate use of density as a service metric

Density is a key component of traffic theory

- Speed drops linearly with density
- “Flow” (i.e. volume) increases linearly with density when well under capacity
- Less flow improvement with incremental density when close to capacity
- When already congested, flow decreases with increasing density
Density and velocity are strongly correlated at a system level.

- Density measures the congestion on our network.
- Density is strongly correlated to velocity, both in theory*, and in data.

* Garber and Hoel; Traffic and Highway Engineering

However, not actionable at a system level.
Density can be calculated by individual track segment

Density can be calculated using already commonly used measures:

\[
\text{Density} = \frac{\text{Volume}}{\text{Velocity}} = \frac{\text{Trains per Day}}{\text{Mile per Hour}} \times \frac{\text{Hour}}{\text{Day}} \times \frac{\text{Trains}}{\text{Mile}}
\]

Density measures how many trains occupy a segment

- All else equal, higher density for a given volume equals lower speed, longer asset turn times, and reduced service levels
Density/volume chart provides insight into capacity & service

- There is a “perfect day” curve, at which operational performance is limited by infrastructure
  - Curve represents maximum velocity that can be achieved with existing infrastructure at any given volume

- Helps bring visual clarity to infrastructure capability of a given segment
  - Capability is reached when additional trains only add more congestion, with very little improvement to throughput

- Can also get a sense of velocity on each day from the chart
  - Velocity is the slope of the line to each daily point
Single and double track segments have different curves

Volume versus Density on Single Track

Volume versus Density on Double Track

Density, trains per mile

Volume, trains per day

Volume, trains per day

Density, trains per mile
Also provides visibility to reliability and operational risk

- For a given volume of trains, there is a range of congestion
  - Impossible to always be on the perfect day curve... stuff happens that will slow down trains

- The range of congestion gets wider as a segment volume gets closer to infrastructure capability
  - Reliability declines
  - Increased risk to network fluidity
Yards have a similar relationship to density in Little’s Law

**Little’s Law**

“under steady state conditions, the average number of items in a queuing system equals the average rate at which items arrive multiplied by the average time that an item spends in the system.”

\[ \text{Inventory} = \text{Arrival Rate} \times \text{Waiting Time} \]

\[ \text{Cars} = \frac{\text{Cars}}{\text{Hour}} \times \text{Hours} \]

\[ \text{Density} = \frac{\text{Volume}}{\text{1/Velocity}} \]
There are many implications of understanding density

- Provides framework to better understand reliability, customer service and day-to-day railroad operations

- Allows quantification of:
  - Impact of disruptions
  - Inherent risk of running near capacity

- Shifts the debate from capacity… to risk / variability
  - Line of road has more risk when:
    - Running at when higher volumes
    - Increased train mix / priorities
    - Fewer resources
    - Constrained yards
Illinois Interns helped progress work in Network Planning

- **2010 - Sam Sogin**
  - Helped build RTC infrastructure to increase speed of modeling

- **2012 - Kathryn Born**
  - Studied train lengths on key subdivision to evaluate “ideal” train length based on sidings lengths

- **2013 - Ivan Atanassov**
  - Completed capacity study of key subdivision on where to add capacity to meet future capacity demands

- **2014 - Chen-Yu Lin, Jesus Aguilar & Mei-Cheng Shih**
  - Helped expand understanding and analysis using density
Chen-Yu built density dashboard in Tableau

- Greatly increases analytical ability to monitor and diagnose segment performance
Jesus built tool to find equation of “Perfect Day” curve

- Allowed for development of “Performance Index” to measure how well a segment is performing against ideal.
Mei-Cheng tested different methodologies of using RTC to match actual densities

- Improved understanding of how to best use and validate current simulation models
CSX must continue to invest in capacity research

- Offers insight into capacity questions
- Develops new methodologies with existing tool sets
- Educates future employees

*Partnership with researchers will be critical to ensure that the improvement in our tools and methodologies keeps pace with the increasing complexity of the industry*
Relentless pursuit of excellence . . .