Capacity issues resolved by modern train control systems - Lessons learned from Europe
Capacity issues and modern train control implementation in Europe

AGENDA

▪ What is capacity?
▪ Re-signaling trends in Europe for urban networks
▪ CBTC/ERTMS comparison
▪ Case studies: London, Paris, Madrid and Denmark
▪ PTC comparison
▪ ERTMS Regional
▪ Conclusion and lessons learned
TCRP Definitions:

- **Design Capacity (CD):** The maximum number of passengers past a single point in an hour, in one direction on a single track.

  \[ CD = CL \times CT \]

  - \( CD \) = design capacity (p/h);
  - \( CL \) = line capacity (trains/h); and
  - \( CT \) = train capacity (p/train).

- **The line capacity is a function of the minimum train separation and the dwell time in stations (influenced by signaling / train control)**
TCRP Definitions:

- **Achievable Capacity (CA):** The maximum number of passengers that can be carried in an hour in one direction on a single track allowing for the diversity of demand

- **CA = CD \times PHF**
  - **CA** = achievable capacity (p/h);
  - **CD** = design capacity (p/h);
  - **PHF** = peak hour factor.

- The PHF takes into account potential failures, delays and margins to recover from them
What is capacity?

Line Capacity:
- Can be measured as “throughput”: number of Trains Per Hour (TPH)
- Dimensioned by the safe braking distance of a train to stop safely before an obstacle:
  - Rolling Stock performance
  - Maximum authorized speed
  - Train detection
  - Train driver reaction to the change of the signaling status
Line Capacity improvements:

- **Worst case: Fixed Block with no cab signal**
  - Safe Braking Distance dimensioned on the worst performing train, maximum line speed, train driver reaction time.
  - Train position anywhere on the track circuit

- **Improvement: Fixed Block with cab-signal ATP**
  - Safe Braking Distance reduced by taking into account actual train speed and shorter train driver reaction time.

- **Optimum: Moving Block with positive train detection**
  - Safe Braking Distance reduced by positive train detection (more precise), actual train performance and even shorter or no train driver reaction time (ATO)
Re-signaling trends in Europe for urban rail networks

Context:

- Urban rail networks in large European cities are becoming complex
- Mix of commuter (branches) / metro (core section) types operation
- Interface with main line networks
- Different stakeholders involved
- Have to cope with significant passenger traffic increase coupled with legacy systems obsolescence
Main issues to be resolved:
• Improve performance: capacity, punctuality and reliability
• Reduce life cycle cost (especially maintenance)
• Enhance flexibility of operation
• Interoperability (main line business)

Technical solution:
• Radio based train control systems: CBTC or ERTMS

Implementation challenges:
• Acquisition and development cost
• Perceived risk is somewhat medium-high
• Interfaces with legacy signaling systems
• New or modified rules of operations (organization readiness)
CBTC and ERTMS comparison

- **CBTC and ERTMS: two different origins**
  - CBTC was developed specifically for metro / high capacity systems
  - ERTMS was developed for main lines to address railway interoperability requirements mandated by the EU

- **Similar architectures**
CBTC and ERTMS comparison

- CBTC is not a “standard” product even though often almost “off-the-shelf” – each supplier has its own proprietary solution
- ERTMS systems must comply with the Technical Specifications for Interoperability (TSI) issued by the European Railway Agency.
- ERTMS systems can be procured from different suppliers who provide fully interoperable solutions
CBTC and ERTMS comparison

**ERTMS Overview**

- Level 1: signal protection enforcement via a balise or a loop
- Level 2: safe train separation and overspeed protection via movement authorities sent by radio to onboard computer

*Train detection is still ensured via track-circuits or axle counters*
- **ERTMS Overview**
  - Level 3: is similar to ERTMS level 2 except that the train detection function does not rely on track circuits but on the position calculated by the onboard equipment.
  - Still under development (alternative version ERTMS Regional for low density lines)
CBTC and ERTMS comparison

- CBTC Overview

[Diagram showing CBTC components such as Interlocking, Zone Controller, Fixed Transmission Network, Radio, and ATS or Traffic Management System.]
# CBTC and ERTMS comparison

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CBTC</th>
<th>ERTMS Level 2</th>
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<tbody>
<tr>
<td>Architecture</td>
<td>Wayside, Onboard, radio communication, fixed transmission network and traffic control center (ATS)</td>
<td>Wayside, Onboard, radio communication, fixed transmission network</td>
</tr>
<tr>
<td>Train Detection</td>
<td>Train based</td>
<td>Track based</td>
</tr>
<tr>
<td>Radio</td>
<td>Proprietary or standard usually operating around 2.4 or 5.8 GHz</td>
<td>Standard: GSM-R</td>
</tr>
<tr>
<td>Level of Automation</td>
<td>High: ATO, UTO (driverless)</td>
<td>Manual</td>
</tr>
<tr>
<td>Headway / Capacity</td>
<td>High: 30 TPH and higher</td>
<td>Limited due to track based detection and GSM-R performance (up to 22-24 TPH)</td>
</tr>
<tr>
<td>Safety level</td>
<td>High: vital safe trains separation, continuous overspeed protection</td>
<td>High: vital safe trains separation, continuous overspeed protection</td>
</tr>
<tr>
<td>Interoperability</td>
<td>None</td>
<td>Fully interoperable</td>
</tr>
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## CBTC and ERTMS comparison

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<tr>
<td>RAM</td>
<td>High level</td>
<td>High level</td>
</tr>
<tr>
<td>Traffic regulation functions (ATS)</td>
<td>Advanced set of functionalities, included in the products.</td>
<td>Not included in the standard. Each application must interface with an existing TMS or develop its own</td>
</tr>
<tr>
<td>Maturity of products</td>
<td>High (100+ applications)</td>
<td>High (&gt;6,000 Km and 7000 Locos)</td>
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4 locations: similar issues, different solutions:

- London: Crossrail and Thameslink
- Paris: EOLE (Western extension of RER Line E)
- Madrid: Suburban network
- Denmark “Signalling Programme”
Case Studies: London

- Two concurrent projects: Crossrail (East-West) and Thameslink (North-South) with same capacity requirements in the core sections: 24 TPH
Case Studies: London

- Crossrail: decision to use CBTC with ATO for the new tunnel section (future compatibility with ERTMS L3)
Thameslink Network Rail

Infrastructure (main line): Decision to install ERTMS Level 2 With Automatic Train Operation (ATO) in Core section

Consistent with UK national strategy for ERTMS rollout
# Thameslink and Crossrail comparison

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Thameslink</th>
<th>Crossrail</th>
</tr>
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<tbody>
<tr>
<td>Characteristics of the central section</td>
<td>Existing railway, 4 km surface route, 4 stations ATO</td>
<td>New railway 21 km tunnel, 8 new stations ATO with platform screen doors</td>
</tr>
<tr>
<td>Characteristics of wider network</td>
<td>16 services (hundreds of km)</td>
<td>4 services</td>
</tr>
<tr>
<td>Central section operation and headway</td>
<td>Dedicated new fleet, 24 TPH</td>
<td>Dedicated new fleet, 24 TPH</td>
</tr>
<tr>
<td>Future headway demands</td>
<td>Not specified</td>
<td>30 TPH</td>
</tr>
<tr>
<td>Other signaling systems fitted to dedicated trains</td>
<td>AWS/TPWS</td>
<td>AWS/TPWS</td>
</tr>
<tr>
<td></td>
<td>Eventually most of the tracks will be fitted with ERTMS</td>
<td>Western branch fitted with ERTMS L2 by 2019</td>
</tr>
</tbody>
</table>
New connection of RER Line E to the west

Core section must handle 22 TPH and 28 TPH in the future

Decision: CBTC w/ ATO

Significant change of operational culture (SNCF operating Metro type system)
Charmin to Atocha high capacity tunnel

ERTMS Level 2 installed to achieve 24 TPH in the future (17 TPH actual)

All other sections equipped with ERTMS Level 1 with Level 2 upgrade planned (overall national plan to rollout ERTMS)
Denmark “Signalling Programme”

- Total replacement of all the signaling systems country-wide
- 3.2 billion Euros funded program, approved by the Danish Parliament in 2009
- ERTMS Level 2 rollout for the main lines (Fjernbane): 2020
- CBTC rollout for the Copenhagen heavy rail network (S-bane, 7 lines, 200 Km): 2018
Main objectives of the “Signalling Programme”:

- Improve punctuality and reliability of the lines (too many signaling equipment failures)
- Address obsolescence issues
- Reduce the maintenance cost for the infrastructure by at least 25% annually
- Implement new signaling with inherent capability to cope with increased capacity in the future
Denmark “Signalling Programme”

- **Key concepts to reach objectives and obtain the expected benefits:**
  - Buy proven technology (CBTC, ERTMS)
  - Procurement using Functional and Performance based specifications focused on operating needs and business requirements
  - Removal of all existing track-circuits and wayside signals
  - “Light” Fallback system using axle counters and fixed sign markers
  - Maintenance of infrastructure equipment contracted to the signaling supplier for 25 years
Context of PTC implementation is different:

- Increase safety
- Mandated by Law (so is ERTMS)
- Significant pressure on the Railroads and Suppliers to meet deadlines
- No time to take a “system approach”

In this context it is difficult to talk about a business case...
• All PTC systems must be interoperable (on an infrastructure shared by different railroads)

• The PTC system functionalities must prevent:
  • Train-to-train collisions
  • Over-speed derailments
  • Incursions into established work zone limits
  • Movement of a train through an improperly aligned wayside switch

=> In theory these requirements could be fulfilled by CBTC or ERTMS
From the FRA Report on PTC implementation issues (August 2012):
- Back-office or central level equipment for the dispatching functions
- Wayside computers
- Onboard equipment
- Data communication: the current radio technology use the 220 MHz spectrum (lower bandwidth compared to CBTC or even ERTMS GSM-R)
- GPS technology (I-ETMS) or transponders (ACSES) for the positioning function
- Implemented as an overlay to the existing signaling system (doesn’t resolve the capacity issue)
PTC Comparison – Main systems overview

- **ACSES**: Amtrak for the North-East Corridor (fulfills PTC requirements when combined with existing ATC cab-signal system)
- **ACSES-2**: Evolution of ACSES for the NEC
- **ITCS**: Amtrak Chicago-Detroit
- **ETMS/I-ETMS**: Class I Railroads solution
PTC solutions development has been led by freight and passengers railroads with the suppliers support

CBTC solutions development has been led by the suppliers to address transit operators needs

ERTMS has been developed in full collaboration by railways and suppliers
- Overlay (PTC) versus standalone train control system (CBTC/ERTMS)
- Radio link (CBTC requires more data to be transmitted quicker)
- Positioning system (CBTC requires higher accuracy due to automatic driving and short headway demands)
ERTM Regional is an adaptation of ERTMS (wayside and centralized levels)

- Low cost solution for low density line with limited signaling protection ("Dark Territory")
- Developed in collaboration with UIC / Swedish Transport Authority
- First commercial application in Sweden since February 2012 (Västerdal pilot line – 143 Km)
ERTMS Regional: architecture
ERTMS Regional: Key Concepts

- Positive train detection (no track circuits)
- Use of virtual fixed blocks for train tracking
- Centralized and integrated interlocking and Radio Block Center for ATP functions with few object controllers in the field controlled via radio link
- Centralized dispatch and field control from a TCC
- Train integrity function performed by an onboard device
- Onboard equipment using the conventional ERTMS equipment (EVC and GSM-R)
ERTMS Regional: Key Concepts

- Infrastructure cost lower than full ERTMS solution
- Significant reduction in wayside equipment
- Elimination of local control
- Stand-alone system allowing to improve capacity if needed
- Fully interoperable with onboard ERTMS
Conclusions and Lessons Learned

- CBTC remain the first choice for capacity requirements higher than 24 TPH and for metro type applications
- ERTMS with ATO can compete with CBTC for certain applications (convergence?)
- Choice of signaling goes beyond the capacity issue:
  - Life Cycle Cost reduction
  - Obsolescence
  - Other performance requirements: punctuality and reliability
  - Interoperability
Conclusions and Lessons Learned

**System approach for PTC (post-2015):**

- Define common high level set of functional requirements
- Focus on the business and operational requirements: let the supplier design the solutions
- PTC is focused on safety, but what about capacity, operations enhancement, automation, high speed?
- Define a standalone system (not as an overlay)
THANKS!