Towards Automatic Train Operation (ATO) for long distance services:
State-of-the-art and challenges
Some definitions concerning the level of automation (GoA: Grade of Automation)

GoA0: Everything is managed by the driver. No supervision (by ex. Tramway)

GoA1: Everything is managed by the driver. Partial or Full supervision
(ATO: Automatic Train Protection)
Sometimes: speed cruise control devices

GoA2: Driver is in the cab but normally doesn't drive between stops. Full supervision
(ATO/SATO or ATO/STO: Semi-Automatic Train Operation)

GoA3: No Driver. Full Supervision
A staff member watch the door closure and could sometimes move slowly
the train in degraded operating conditions
(ATO/DTO: Automatic Train Operation / Driverless Train Operation)

GoA4: No Driver. Full Supervision
No staff
(ATO/UTO: Automatic Train Operation / Unattended Train Operation)
**State-of-the-art**

- **CBTC**: Communication Based Train Control
- **ATS**: Automatic Train Supervision System
- **ATP**: Automatic Train Protection System
- **ATO**: Automatic Train Operation System

**Challenges GoA2**

- **ATP + ATO**
- **ATS**
- **CBTC**
  - Inside City Proprietary solution

**Challenges GoA4**

- **Outside City**
  - ETCS_L0 (Proprietary solution)
  - ETCS_L2 (European solution)
- **Inside City**
  - European solution

**Crossrail**

**Thameslink**

**TMS**: Traffic Management System
Main Goal: **Capacity increase** in the city central section where bottlenecks are at station entries

**Dual system** (for ex. Crossrail project: ETCS_L2 - **CBTC** - ETCS_L0)

- **GoA1 + CBTC**
- **CBTC**
- **GoA1 + CBTC**

Outside(GoA1)  **T**  Central Section  **T**  Outside(GoA1)

(\(\text{GoA1-4 - ATO over ETCS available}\))

**ETCS Only** (for ex. Thameslink project: ETCS_L2 +ETCS_L0/1/2)

- **GoA1 + GoA2**
- **GoA1 + GoA2**
- **GoA1 + GoA2**

Outside(GoA1)  Central Section  Outside(GoA1)

\(\text{(GoA1-4 - ATO over ETCS available)}\)

**State-of-the-art**
Crossrail 'outer'
- Signalling condition
- Interlocking alterability
- Control alterability
- AC immunisation
- Performance
- GW-ATP
- TSI

Crossrail 'inner'
- Interlocking capacity
- Control centre capacity
- ATP to Heathrow
- Performance
- GW-ATP
- TSI

Central Section

North Eastern Section
- Capacity (18tph)
- Performance (RAM)
- Compliance

CROSSRAIL

Western Section
- ATO system
- Traffic Management
- Performance/Capacity (24tph)
- Interfaces

South Eastern Section
- Immunisation (AC/DC)
Lateral Signalisation
(ATP: AWS/TPWS)

CBTC

GEML: CBTC - AWS/TPWS  ETCS_L0

CROSSRAIL

© NR-2015
Every 2½ minutes

Every 2 minutes in case of recovery service !?

ATO over ETCS (Packet 44)
**ETCS+ATO**: Use of the multi-purpose ETCS Packet 44
Possible use with ETCS_L1 FS (with GSM-R) or ETCS_L2 FS

If the goal is to increase capacity in bottleneck then the use of **ETCS_L2** (shorter fixed block sections than with ETCS_L1) is efficient

Siemens/Alstom/Invensys/NR: *ATO with ETCS Data Flows and Data Packets (2011):*
- **Segment Profile**: Real time update of infrastructure data
- **Journey Profile**: Real time update of timing points
  (timing point main types: departure/passing/arrival)

---

**In 2011, a timing point is only** a three-dimensional entity: type, location and time *(but not speed)*
Capacity with a CBTC system or with ETCS_L2 + ATO:
Only slight differences

\( D_{\text{max/min}} \): max/min distance between the safe rear end of a train and the NV_MAL of the following train
[hypothesis: Immediate and continue update of train locations. No specific Danger Point (DP)]

L: Section Length
CAM: Collision Avoidance Margin
RbM: Rollingback Margin
V_MAL: Vital Movement Authority Limit
NV_MAL: Non-Vital Movement Authority Limit

<table>
<thead>
<tr>
<th>Examples</th>
<th>CBTC Strategy</th>
<th>( D_{\text{min}} )</th>
<th>( D_{\text{max}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paris M14</td>
<td>Fixed / Fixed</td>
<td>CAM+RbM</td>
<td>L+CAM+RbM</td>
</tr>
<tr>
<td>Paris M1</td>
<td>Moving / Fixed</td>
<td>CAM+RbM</td>
<td>L</td>
</tr>
<tr>
<td>Lyon Ligne D</td>
<td>Moving / Moving</td>
<td>CAM+RbM</td>
<td>CAM+RbM</td>
</tr>
</tbody>
</table>
# State-of-the-Art Summary:

<table>
<thead>
<tr>
<th>System/Project Name</th>
<th>Inside City</th>
<th>Outside City</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise speed keeper</td>
<td>GoA_1</td>
<td>GoA_1</td>
<td>Long distance / HSL</td>
</tr>
<tr>
<td>Cruise speed controller</td>
<td>---</td>
<td>GoA_1</td>
<td>Freight(TripOptimizer) / HSL</td>
</tr>
<tr>
<td>Crossrail</td>
<td>GoA_4-CBTC</td>
<td>GoA_1</td>
<td>Outside City: ETCS_L0/L2</td>
</tr>
<tr>
<td>Thameslink (2018)</td>
<td>GoA_4-ETCS</td>
<td>GoA_1</td>
<td>Outside City: ETCS_L0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System/Project Name</th>
<th>ATO and TMS</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long distance passenger service</td>
<td>Not connected</td>
<td>Driving comfort / Punctuality</td>
</tr>
<tr>
<td>TripOptimizer (Freight)</td>
<td>Connected or not</td>
<td>Energy saving</td>
</tr>
<tr>
<td>Crossrail</td>
<td>Connected in city center</td>
<td>Bottleneck capacity</td>
</tr>
<tr>
<td>Thameslink (2018)</td>
<td>Connected in city center</td>
<td>Bottleneck capacity</td>
</tr>
</tbody>
</table>
Mastering and planning the ERTMS/ETCS Long-Term Evolution

Baseline 3

Version 3.3.0

Version 3.4.0

Version x.y.0

Baseline ?

GoA2

2013

2014

2015

2016

2017

2022

2012

Train Interface FFFIS

ATO Specifications (GoA2)

DMI-EVC FFFIS

ATO GoAx

Improved Key Management

Packet based Euroradio I/F

IP Coms and bearer independency

Shift2Rail

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ERTMS Users Group

ERA – 2016:
GoA2 in 2018/2019
GoA3: long term
Challenge GoA2_A: How to keep self-motivated and skilled drivers?
- To spend more time in driving simulators

Challenge GoA2_B: ETCS-ATO Interface standardization
- To develop Form Fit Function Interface Specifications (FFFIS)

Challenge GoA2_C: ETCS-ATO Improvement
- To add speed in the timing point features

ETCS-GoA_2: let's go!
Challenge GoA3/4_A: **Supervision of the train working order**
- To add more sensors and to correlate their results

Challenge GoA3/4_B: **Cross-check of outside aspects of trains**
- To film and analyse train videos
- To develop trackside more sophisticated and more numerous devices in the context of the global Wayside Train Monitoring System (WTMS)

Challenge GoA3/4_C: **Obstacle on the track visually detected**
- To film and analyse in real time train video looking ahead

Challenge GoA4_D: **Running “On Sight” (OS), under “Staff Responsibility” (SR) or “Shunting” (SH) modes**
- To film and analyse in real time train video looking ahead
- To use a telecontrol system
To resume

GoA2 over ETCS: let's go!

- ATS
  - Automatic Train Supervision
  - Coordinates train movements
- ETCS trackside
  - European Train Control System
  - Provides safe movement authorities
  - ATS – ATO communications are via ETCS and GSM-R radio
- ETCS onboard
  - European Train Control System
  - Ensures safe train movements
- ATO
  - Automatic Train Operation
  - Ensures optimum train movements

GoA4 over ETCS: for tomorrow!

Thank you for your attention
Fig. 7: Components for automated rail traffic ("KOMPAS" research project)
Capacity with a CBTC system or with ETCS_L2 + ATO: Only slight differences

**Time-minimum** train run
(very simplified)
Les domaines avec cantons virtuels fixes purs et canton tampon

FU-EBD:
Enveloppe des vitesses maximales pouvant être atteintes en cas de déclenchements du Freinage d'Urgence (FU) [EBD: Emergency Brake Deceleration]

MR: Marge de Recul
MAC: Marge d'AntiCollision [CAM: Collision Avoidance Margin]
CAB: CAB signaling
D: Distance entre NV_MAL et V_MAL

MA: Marge Amont

NV-MAL:
Non-Vital Movement Authority Limit, appelée parfois EoA: End of Authority

Consigne de vitesse

V-MAL: Vital Movement Authority Limit, appelée parfois SvL (Supervised Location)

Déplacements simultanés de FU-EBD et Consigne par libération de cantons virtuels fixes
Les domaines avec cantons virtuels fixes purs **sans** canton tampon

**Déplacements simultanés de FU-EBD et Consigne par libération de cantons virtuels fixes (translations par sauts)** [p.ex. Paris – Ligne M_14]
Les domaines avec cantons virtuels dynamiques et fixes (mixtes)

Déplacement continu de FU-EBD et par libération de cantons virtuels fixes pour Consigne [p.ex. Paris – Ligne M_1, Barcelona – Ligne M_9]
Les domaines avec cantons virtuels dynamiques

Déplacements continus de FU-EBD et Consigne [p.ex. Lyon – Ligne D]