Corporate Background

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Global and Local Partners

- Plateway works in close collaboration with several leading local and global partners
  - SMA and Partners Zurich
  - OpenTrack GmbH
  - Savannah Simulations
  - IFB Dresden
  - LIFT Trieste
Corporate Background

- Plateway has worked throughout Australia and New Zealand.
- Plateway’s core business has grown from a railway infrastructure management capability focusing on process redesign.
- Plateway has since expanded to a much wider total rail systems capability.
- Clients include rail operators, network owners and increasingly, rail customers.
Simulation Tools

Why Simulate?

• Computer simulation allows a virtual reconstruction of complex systems both natural and man made.

• Takes into account the combined effect of all known variables and uncertainties.

• Very cheap means of obtaining experience.

• Unexpected problems and conflicts within a system can be detected and solved.
Simulation Tools

Why Simulate?

• Test Sensitivity of System Performance to inputs such as rollingstock, passenger patronage, freight volume, infrastructure configuration (track, signals), system reliability, access policy.
• Obtain stakeholder buy in.
• Communicate awareness of system drivers.
• Inputs to downstream processes.
Benefits of Simulation

- More control of modelling parameters.
- Reduces risk.
- Reduce project lengths.
- Visual representation which flowcharts and spreadsheets do not have.
- Reduce design errors in the preliminary stages.
- Can help decide project feasibility.
- All benefits can reduce costs.
## Types of Computer Simulation

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Features</th>
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<tbody>
<tr>
<td>Dynamic simulations</td>
<td>Models changes in a system in response to a defined input signal.</td>
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<tr>
<td>Stochastic models</td>
<td>Uses random number generators to model chance or random events.</td>
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<tr>
<td>Discrete event simulation</td>
<td>Manages events in time- the computer simulates a queue of events in the order in which they occur.</td>
</tr>
<tr>
<td>Continuous dynamic simulation</td>
<td>Solves differential equations and uses the solution to change the simulation.</td>
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</tbody>
</table>

A dynamic simulation could be achieved by altering train arrival times to see which combinations may cause a problem.

Problems

- There may be combinations that can either not occur or are extremely likely to occur in reality.
Reading Train Graphs

Signal: BS038 - Cleveland

Time

Locations

Slope of graph line shows train speed- the steeper the line the quicker the train
Dynamic Simulation
Could be achieved by describing train run times as a statistical distribution.

Problems

- The statistical distribution does not calculate actual train performance.
- Maybe incorrect relationships between cause and effect.
- Major problems if outliers are not analysed and treated correctly.
Benefits of Stochastic Models

• Modeling should be based on a range of outcomes.

• On time running is defined relative to that range i.e. about threading the train path through a series of nodes within an allowable band rather than an absolute value.

• Measure the expected reliability of a timetable change.
Stochastic models
Discrete event simulations are generally based on the response of a service based system (say the operation of a bank) to a defined event such as a queue.

Problems

• The cause of queuing is not identified.
Continuous Dynamic Simulation

Uses equations which describe the physical processes involved to generate a simulation.

Problems

- Complicated code required which solves multiple ordinary differential equations. Requires a large amount of computing power.
<table>
<thead>
<tr>
<th>Railway/metro companies, railway administrations</th>
<th>Consultancies</th>
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<tr>
<td><img src="image1" alt="Images of railway companies and organizations" /></td>
<td><img src="image2" alt="Images of consultancies" /></td>
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<tr>
<td>Universities and research institutes</td>
<td>Railway supply industry / maglev industry</td>
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<td><img src="image3" alt="Images of universities and research institutions" /></td>
<td><img src="image4" alt="Images of railway supply and maglev industry" /></td>
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May 2012

- 248 OpenTrack licenses have been sold to 164 Companies and Institutes in 33 countries.

September 2010

- OpenTrack had issued 150 licences to 80 different holders within 22 countries.
OpenTrack Calculation Algorithm

The calculation engine in OpenTrack uses the equations of motion to calculate each train's acceleration, speed, and position at a given point in time.

Force = mass x acceleration.

To move a train, the power unit has to apply a net tractive effort to overcome the resisting forces.

So the acceleration becomes:

Acceleration = $\frac{\text{Net tractive effort}}{\text{mass}}$
The “resisting” forces considered in the OpenTrack calculation include:

- power unit losses
- rolling resistance
- the track gradient over the train length
- the track curvature over the train length
To perform the calculation OpenTrack needs a reference set of data. This includes:

Traction unit characteristics including a speed vs. tractive effort curve.

Environmental conditions, how slippery the rail is.
Assumed train braking performance.

- Increasingly modern systems blend air and electric (dynamic) braking.
- Blending is computer controlled and dependent on environmental conditions as well as individual driving style.
OpenTrack Input Data

- Railway curves, grades and line speeds.
OpenTrack Input Data

- Signaling layouts and interlocking functionality.

Source: RailCorp Network Documentation
Once the net force available for traction has been calculated, the computer applies differential calculus to the acceleration using the Euler method to calculate the speed of the train and then again to calculate the train's position.

\[
v(t) = v(t - \Delta t) + \Delta t \cdot \frac{dv}{dt}(t - \Delta t) ; \quad v(t_0) = v_0
\]
The Euler method is an approximation but **computers cannot solve differential equations.**

The accuracy of the approximation improves with decreasing the time interval used in the calculation.
OpenTrack Calculation Algorithm

- The acceleration and speed are also adjusted as a result of the signaling system inputs.
- Other defined “events” which are triggered by distance may include station stops, changes in train loading and direction.
- Once the computer has finished the calculations for each time interval the computer starts again for the next increment.
- The method uncorrected will generally produce the “best performance” possible. For use in practical applications this is always down rated.
The basic electrical Ohms law relationship is a major factor in deciding the parameters for the chosen system.

Voltage \( (U) = \text{current (I) \times Impedance (Z)} \)

The losses in the conductors can be given by \( P = I^2 Z \)

So the higher the voltage, the lower the current and the lower the system losses.
In an AC system the impedance to the flow of current is a function of:

- The resistance.
- Magnetic coupling between the supply and return side conductors.
- Capacitive coupling is a component of impedance but not a major influence in traction supply systems. It does however generate interference.
Resistance to the flow of current is a function of:

- Conductor size.
- Conductor material.
- Conductor temperature.
- Conductor length - in a traction supply the distance of the train to the supply point.
- Component wear (of contact wire and rails)
Why simulate the traction power supply?

- To determine the line voltage at the pantograph and the resulting impact on train performance.
- To determine the influence of the network structure on electrical load distribution.
- To size equipment such as cable, transformers, rectifiers.
- Some energy suppliers have constraints on the ability of the network to cope with regenerated energy under different network switching conditions.
The power supply system influences the resultant energy consumption and costs as well as train performance. 

**Simulation of these dynamic processes enables:**

- Energy consumption analysis and prognosis.
- Design and rating verification of the electrical installations.
- Electromagnetic field studies.
Energy consumption simulation for electrical railway systems is a factor of:

- Whether the train is powering or braking.
- The throttle setting and required traction power.
- The position of the trains within the network.
- The configuration and capability of the power supply system.

All of this information is needed at exactly the same time.
Traction Power Supply Simulation

Older simulation products compromised on:

- the complexity of the rail operation (only able to simulate a small number of trains).
- the detail of traction unit performance under degraded line conditions and feedback into the simulation.
- the detail of the electrical network.
Traction Power Supply Simulation

Railway Operation Simulation

**OPENTRACK**
Uses calculus to calculate the position, speed, acceleration and resulting power demand of every train in the network

“Co-Simulation”

ATM - Advanced Train Module
Locomotives adjust performance in response to available power supply

PSC Power Supply Calculation
Uses calculus to solve Ohm’s Law to calculate current, voltage, resistance.

Propulsion Technology
Power Supply System
Structure of OPN
Traction Power Supply Simulation

Power Supply Network Structure (2 AC 25 kV ~ 50 / 60 Hz)

Power Grid Connection
3 AC 110 / 220 kV

Substation

Autotransformer
AT1

Autotransformer
AT2

Autotransformer
AT3

25 kV

-25 kV

OC S

Rails
Negative Feeder
Earth
Data Input

- Electrical network structure (feeding sections, feeding points, switch state) in congruence to the track topology.
- Electrical characteristics of the feeding power grid.
- Electrical characteristics of the substations.
- Electrical characteristics of the conductors (cables, Catenary wires, tracks, rails).
- Electrical characteristics rail-to-earth.
Data Input

• Modelling of additional power consumers (e.g. switch heaters).
• Loading capacity (conductors, converters, transformers).
• Protection settings.
Traction Power Supply Simulation

Catenary Arrangement and Conductor Model

CL TRACK

SH = 1600

CWH = 5300

TOR

CWH Contact wire height
SH System height

Negative Feeder
Return conductor
Messenger wire
Contact wire

„Slice“
Traction Power Supply Simulation

Catenary Arrangement and Conductor Model

Slice n

material, diameter

\((x_1, y_1)\)

electro-magnetic coupling effects

\((0, 0)\)
Traction Power Supply Simulation

Sequence of Slices

- Slice 0
  - Node
  - Section
- Slice 1
  - Connector
- Slice 2
  - Negative Feeder
  - OCS
  - Rail
  - Conductor
  - Earth

Position

$x_0$, $x_1$, $x_2$
Traction Power Supply Simulation

**openPowerNet** tool development

- Developed by IFB Dresden to work with a commercial rail network simulator.
- Initial deployment on high speed network in the Netherlands
- Then used to simulate the operation of the Zurich tramways and trolley bus system.
Traction Power Supply Simulation

License sold to the Fourth Railway Survey and Design Institute in China.

Used for design verification for High Speed and Metro projects.

openPowerNet tool development
Cleveland Line Proof of Concept

- QR required comfort that the power supply simulation would produce data which could be used with confidence for future network design and analysis.

- Proof of Concept involved a series of instrumented single train runs and logging the performance of a traction sub station over five days and comparing the measured results with the simulated results.

- First time this has been done for a 25 kV AC urban rail network.
Cleveland Line Proof of Concept

- Measured voltage at each end and at Lytton Junction substation.
- The energy consumption was measured at the feeding location.
Cleveland Line Proof of Concept

- Part of the Brisbane suburban railway network.
- Runs east from Park Road station on the south of the river for 32 km to Cleveland.
- Line contains single and double sections.
- Fifteen peak hour services every weekday.

Cleveland Line Proof of Concept

Potential Variables

- Driving style.
- Interpretation of running rules and driver’s instruction manual.
- Use of different rollingstock types each with different performance characteristics.
- Daily timetable variations.
- System feeding.
Single Train Run Results

H816 SMU 289 from PKR to CNV
PKR - HMM

Graph showing various parameters over time.
Single Train Run Results

Issues

- Sometimes the simulation output and measurement are calculating different things.
- The trains position had to be adjusted based on the AWS magnets as the traction / braking systems included controlled wheel slip which reduced odometer accuracy.
- The difficulty in simulating the blended braking is apparent.
- Even with a substantial performance derating, the simulation powers and brakes far harder than the human driver.
Cleveland Line Proof of Concept

- To enable the simulated and measured results to be compared the timetable had to be adjusted to account for actual train running.
- The global performance factor was adjusted to provide an average of how the trains were being driven.
To show the way that the OpenTrack performance change from 97% to 90% Impacts on the simulation; for the Tuesday operation both diagrams are presented.
Actual Timetable – Tue 31\textsuperscript{st} Jan
Performance Setting 97%
Actual Timetable – Tue 31\textsuperscript{st} Jan

Performance Setting 90%
Network Simulation Results

Train Graph with indicated Pantograph Voltage
monday peak (AdAd421Afe000)
Cleveland Line Proof of Concept

Results

• Extremely good correlation between single train simulations and measured values.

• The morning peak simulations were within the acceptance criteria.

• The results illustrated a very different electrical performance of assets at each end of the line.
For further details please see:

http://www.openpowernet.de

http://www.opentrack.ch/opentrack/opentrack_e/opentrack_e.html