Causal analysis and testing

Railway Accident Investigation Seminar

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We had fundamental questions to answer …

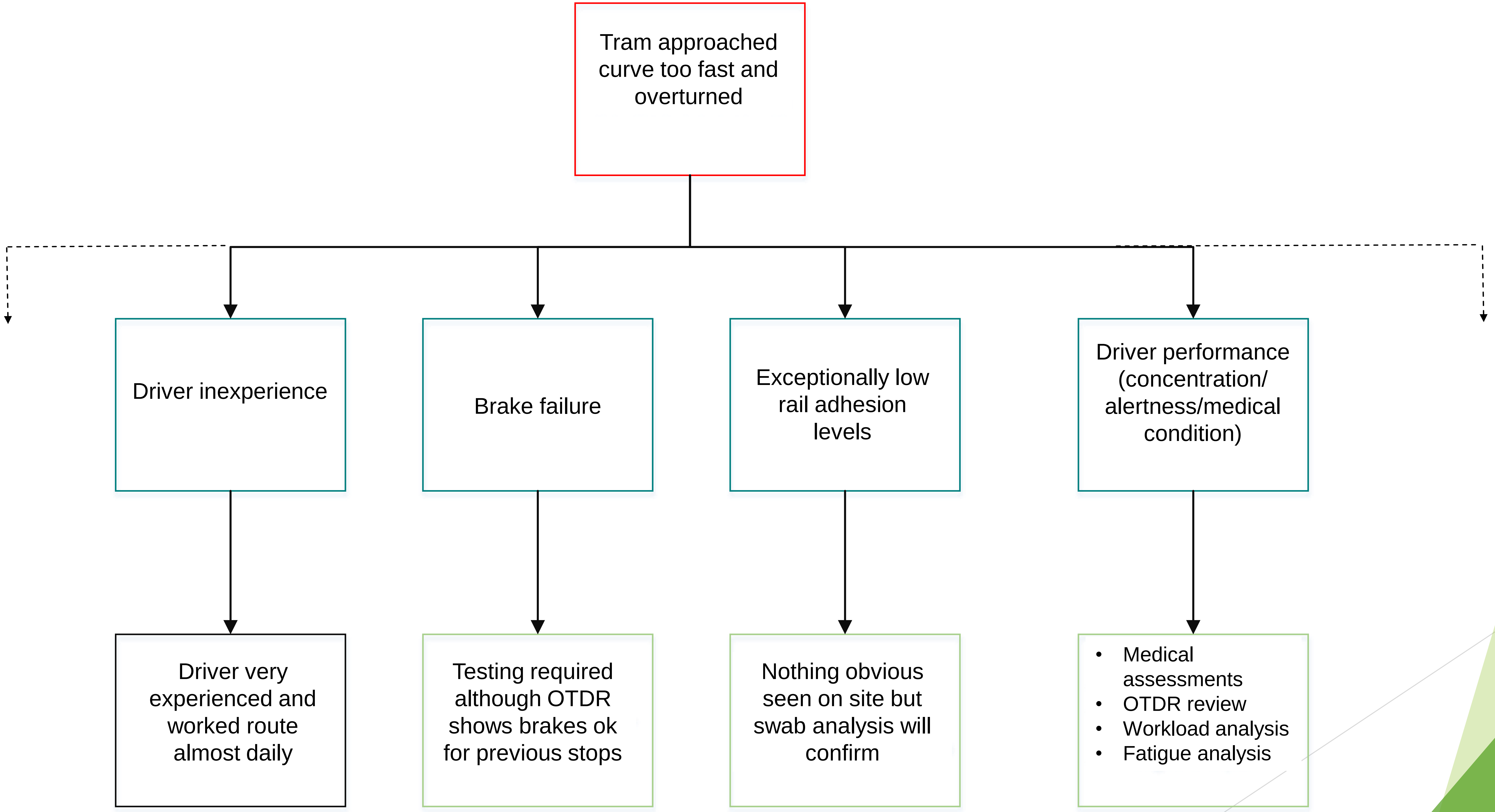
- Why was the tram travelling so fast at it entered the curve?
  - a problem with the tram?
  - driver affected by a medical condition? distracted? reckless?
  - a problem with adhesion?
  - a problem with this location?

- Why were so many people killed and seriously injured?
  - this will be discussed in a later session

Starting point

- Simple approach using why/because analysis:
  - identify possible factors that could have caused or influenced the accident:
    - malfunction of tram braking system
    - problem with tram's ability to negotiate the curve
    - driver performance/medical condition
    - malfunction of tram safety systems
    - low adhesion
  - discount factors where clear evidence they were not present:
    - collision with an object on the track
    - broken rail/serious track irregularity
    - broken axle/wheel defect/equipment fallen from tram
    - driver unfamiliarity with the curve
  - Why/because used to identify 'where to go next' and what to look for …

Why/because example



The causal analysis

- Complex investigation, but we needed to keep analysis focused and clear.
- Why/because served well for high-level overview of the accident and where to focus.
- Dynamic: updated as evidence proved/disproved factors, or where new factors emerged.
- Human performance: not just about the driver, it is also about the environment in which he worked.
- Regular investigation team review meetings to check on progress of tasks, identify potential issues/conflicts, and update the causal analysis.

Assigning work

- The initial analysis identified the areas where we needed to focus attention.
- Inspector allocated to each task.
  - strategy, implementation, deliverables

- Tasks allocated to investigation team included:
  - tram testing (strategy and implementation)
  - arranging specialist medical examinations
  - human performance: the reasons behind the actions/inactions of the tram driver
  - interrogating the tram’s data recorders
  - interrogating tram system data (loop data)

Devil in the detail

- Seriousness of the accident required in-depth testing and analysis.
  - tram testing strategy agreed with the BTP and ORR with input from tramway
  - specialist organisations used where necessary (sound levels and lighting in tunnels, speed sign and headlight testing, comparison with European tramway standards)

- Surveys to establish exact location of infrastructure features.
  - OTDR analysis
  - loop data analysis
  - scale drawing of route and location of accident.

- Model of CR400 tram and location (to scale)

- 3D model used to recreate the overturning of the tram and used as a visual aid to explain what happened.

Understanding …

- For most systems we had to gain a detailed understanding of how they worked and interacted with other systems.
- For some of the systems this meant going back to the equipment manufacturer.
- Aligning data from the tram's data recorder with the surveyed position of infrastructure on the ground was critical in identifying the tram's actual speed during the accident and exactly where the driver had operated driving controls.
- Only by clearly understanding what events happened, and where, could we begin to piece together how the tram was being driven.

Examples

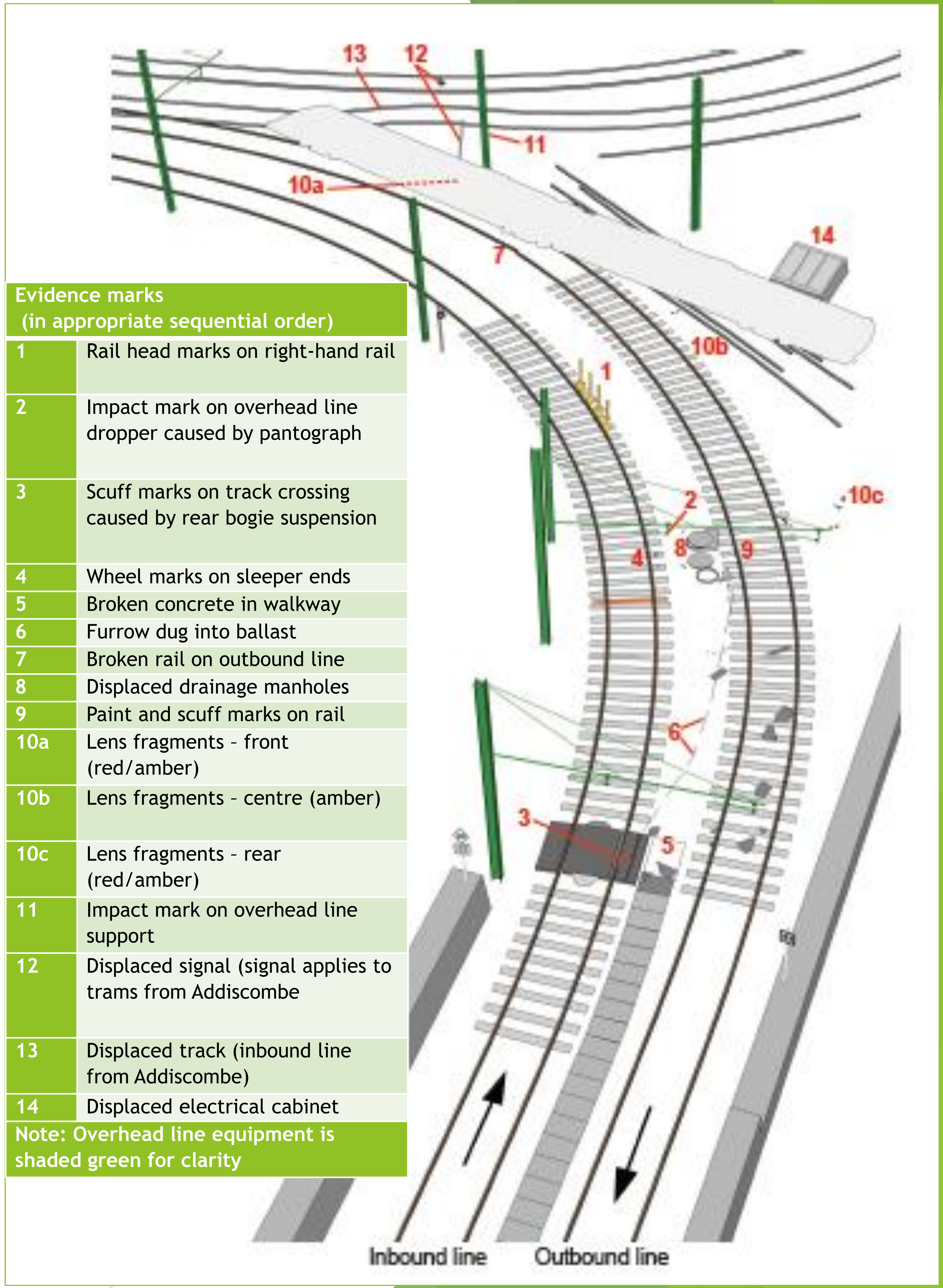
- OTDR
- modelling and surveys
- tram testing
- Loop data analysis
- intelligence gathering
- Human performance

OTDR

- Crucial to align events recorded on the tram's data recorder to where the tram was when they occurred. It was crucial to verify the accuracy of:
  - distance measured by the data recorder: wheel diameter accuracy and known points during journey (from surveys and data points from OTDR)
  - speedometer: involved OTDR testing by original manufacturer, and fitting OTDR to donor tram

- Through analysis of OTDR data we were able to establish:
  - locations where the driver operated controls, including where the driver may have tried to reorientate himself in the tunnels
  - Locations where power was selected and locations of coasting
  - braking during the journey
  - speed at key locations

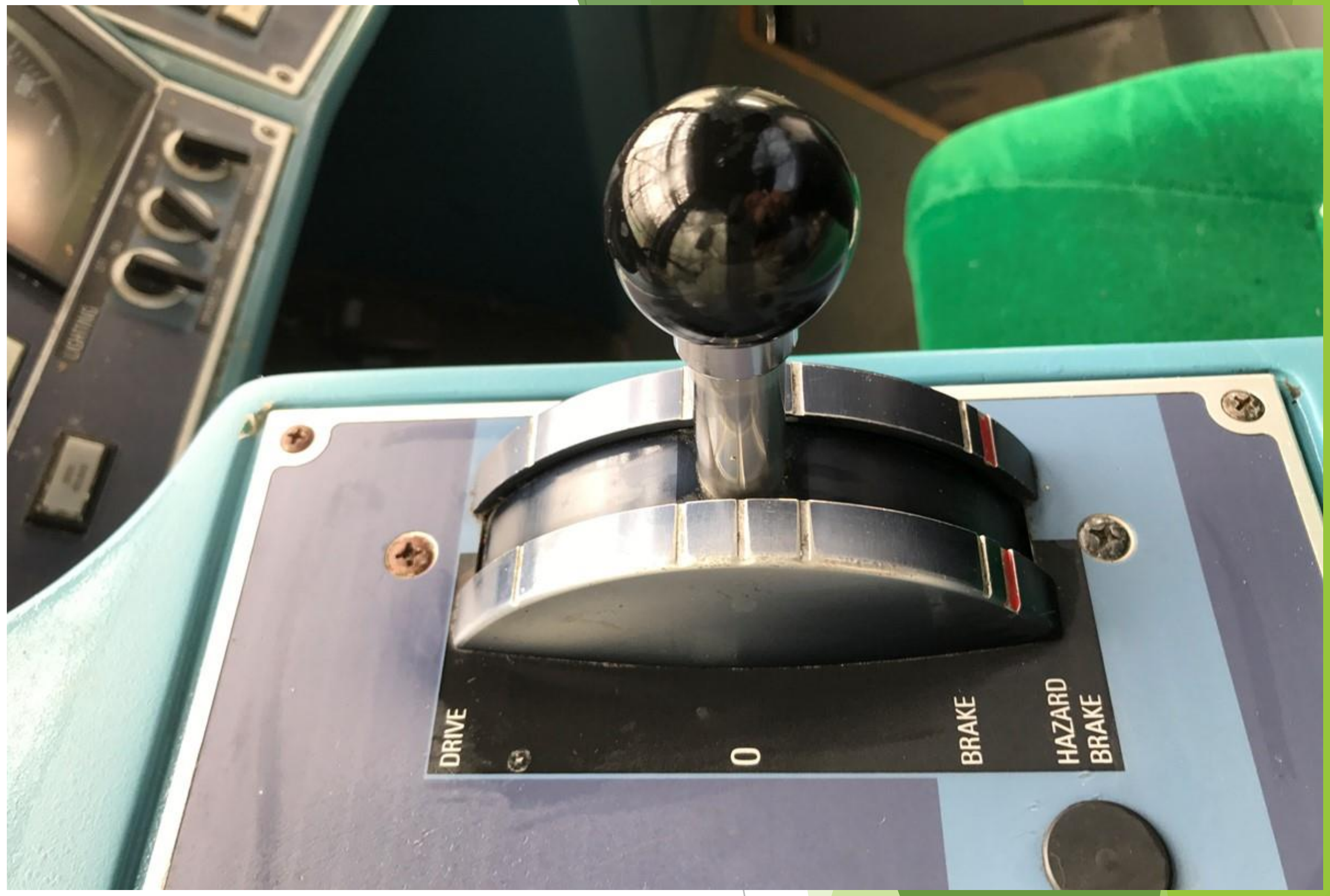
Modelling and surveys



Evidence marks (in appropriate sequential order)	
1	Rail head marks on right-hand rail
2	Impact mark on overhead line dropper caused by pantograph
3	Scuff marks on track crossing caused by rear bogie suspension
4	Wheel marks on sleeper ends
5	Broken concrete in walkway
6	Furrow dug into ballast
7	Broken rail on outbound line
8	Displaced drainage manholes
9	Paint and scuff marks on rail
10a	Lens fragments - front (red/amber)
10b	Lens fragments - centre (amber)
10c	Lens fragments - rear (red/amber)
11	Impact mark on overhead line support
12	Displaced signal (signal applies to trams from Addiscombe
13	Displaced track (inbound line from Addiscombe)
14	Displaced electrical cabinet
Note: Overhead line equipment is shaded green for clarity	

Tram testing

- Ten week programme of >220 individual tests (static)
- Dynamic brake testing with loaded tram for OTDR data analysis of braking performance
- Tram testing essential to show if:
  - brakes system functioning
  - brake controller functioning
  - dead man’s operative
  - tram able to negotiate curve



Loop data analysis

- Signal loops between the tramway rails detect the presence of trams in order to trigger operation of signals and points.
- The RAIB analysed loop data for the period from 1 January 2015 to 21 December 2016.
- Thousands of tram journeys. Complicated analysis.
- Essential to understand:
  - How many times the driver of the tram had driven the curve in the previous two year period, and his compliance with the speed limit around the curve
  - If the tram involved in previous overspeed (10 days earlier) had come close to overturning speed
  - Was there a speeding culture at this location (widely reported by passengers and media)

Intelligence gathering

- We wanted to understand how tram drivers felt about issues such as safety management, fatigue, self-reporting, their assessment of workload when driving on the tram way and any issues before at this location.

- We decided to do this using an anonymous questionnaire sent personally to every driver on the tramway.

- The RAIB recognised that there are limitations in this form of evidence gathering:
  - some of the responses may have been influenced by hindsight and actions taken by the tramway following the accident.
  - an element of self-selection in the sample of drivers, meaning that the responses might not be representative of all drivers (ie those who felt motivated to respond may have more strongly held views than others).
- The questions were designed to provide information in specific areas; they were not intended to provide an overall assessment of TOL's safety culture

Human performance

- Medical examinations:
  - doctor experienced in carrying out medical examinations of pilots involved in incidents and accidents
  - consultant neurologist
- Fatigue
  - roster pattern
  - lifestyle and sleep pattern
  - BTP technical examination of the driver’s mobile phone
- Workload
  - RAIB assessment of driver workload on the tramway
  - tram driver questionnaire results
- Influences from the environment
  - sound level tests in the tunnels
  - sighting of the speed sign
  - headlight brightness and alignment, and reflectiveness of the speed sign
  - Other visual cues available to orientate the driver

What the testing and analysis showed us

- no faults with the tram that could have either caused or contributed to the causes of the accident, and the dead man's device functioned as designed
- driver of the tram had driven the curve hundreds of times since January 2015 with no overspeeding, and no evidence of a 'speeding culture' at the location
- tram involved in previous overspeed (10 days earlier) came close to overturning speed
- no medical reason identified for the driver's loss of awareness
- Lloyd Park to Sandilands section was rated as significantly lower in terms of perceived attention demand
- 21/59 drivers had missed their normal braking point approaching the curve, with 9 drivers making hazard brake applications
- possible that the driver had become fatigued due to insufficient sleep, and may have had less sleep than normal the night before the accident
- the infrastructure approaching the curve did not contain sufficiently distinctive features to alert the driver to his position relative to the curve, or to his direction of travel in the tunnel