Accident Precursor Monitoring in Metro Railways

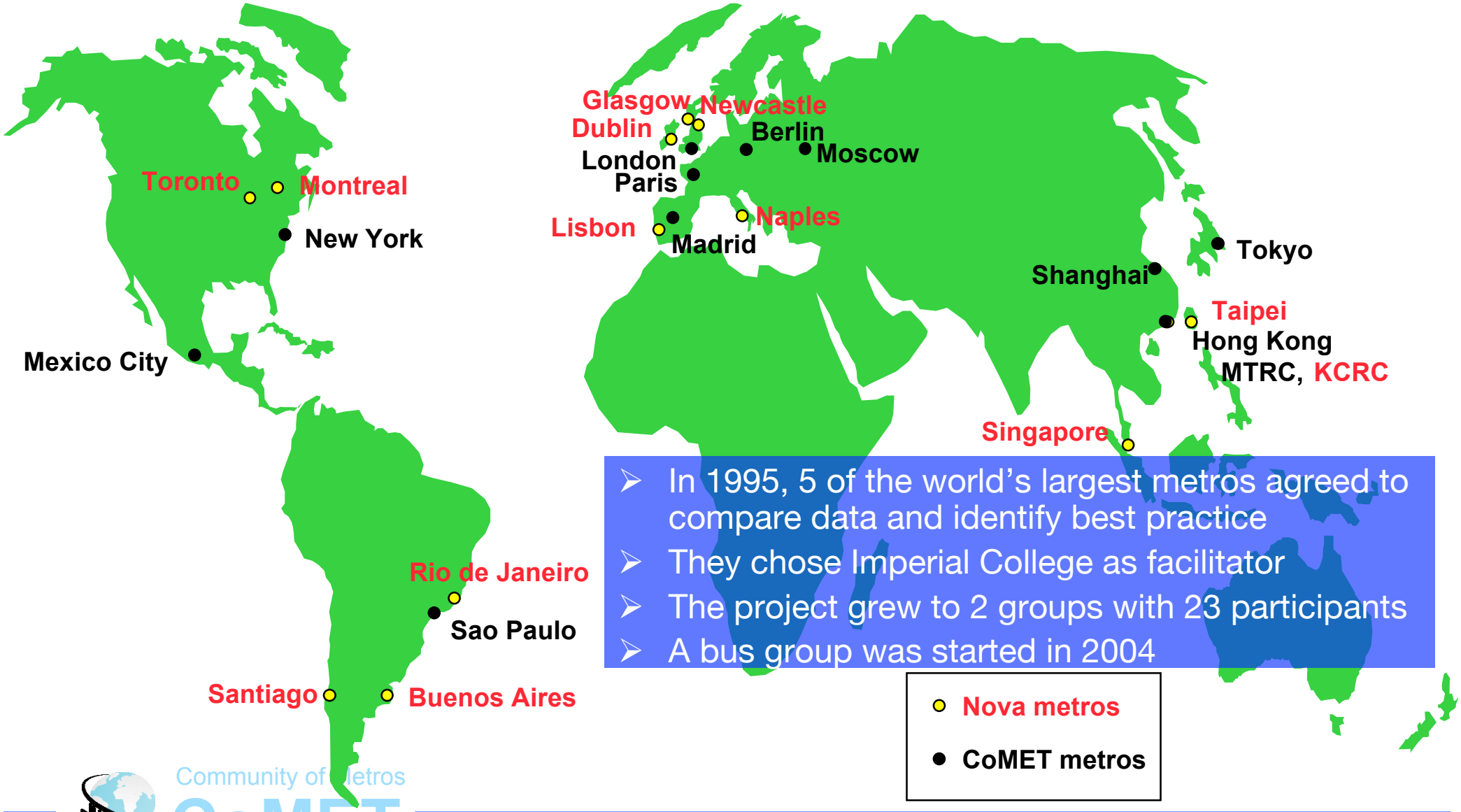
Workshop on accident/ incident precursor analysis in air transport and railways

Imperial College, 9 February 2006

Community of Metros

CoMET

The data and sponsors: the CoMET and Nova groups



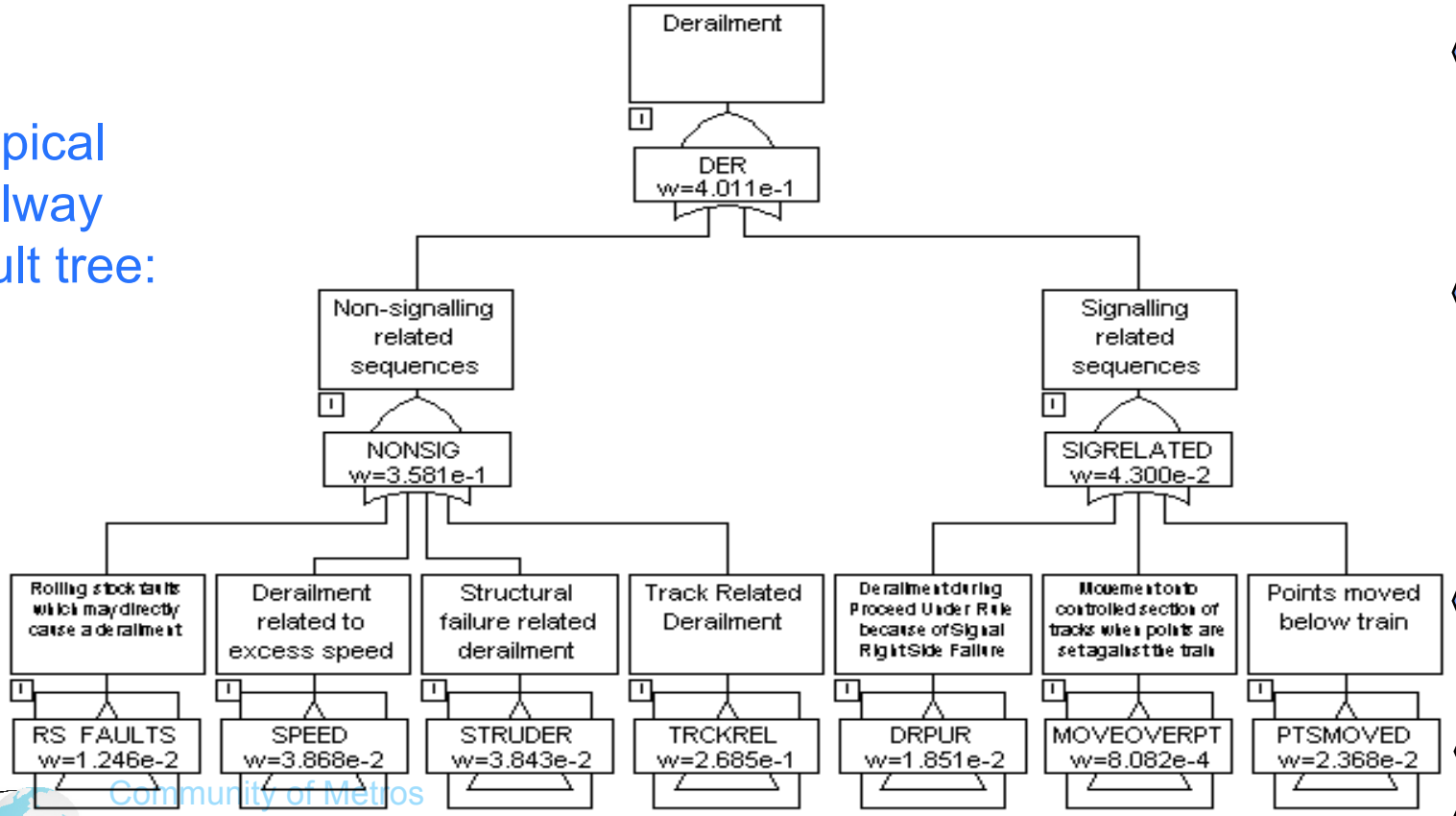
- In 1995, 5 of the world's largest metros agreed to compare data and identify best practice
- They chose Imperial College as facilitator
- The project grew to 2 groups with 23 participants
- A bus group was started in 2004

Community of Metros
CoMET

Accident Precursor Modelling in Railways - Definitions

- A statistical model to monitor changes in the underlying level of risk, related to precursors: events or conditions that can cause risk to increase
- Top Event: a hazardous event that can be the direct cause of an accident
- Accident: an event leading to injury, death or major material damage

Typical railway fault tree:



Top event

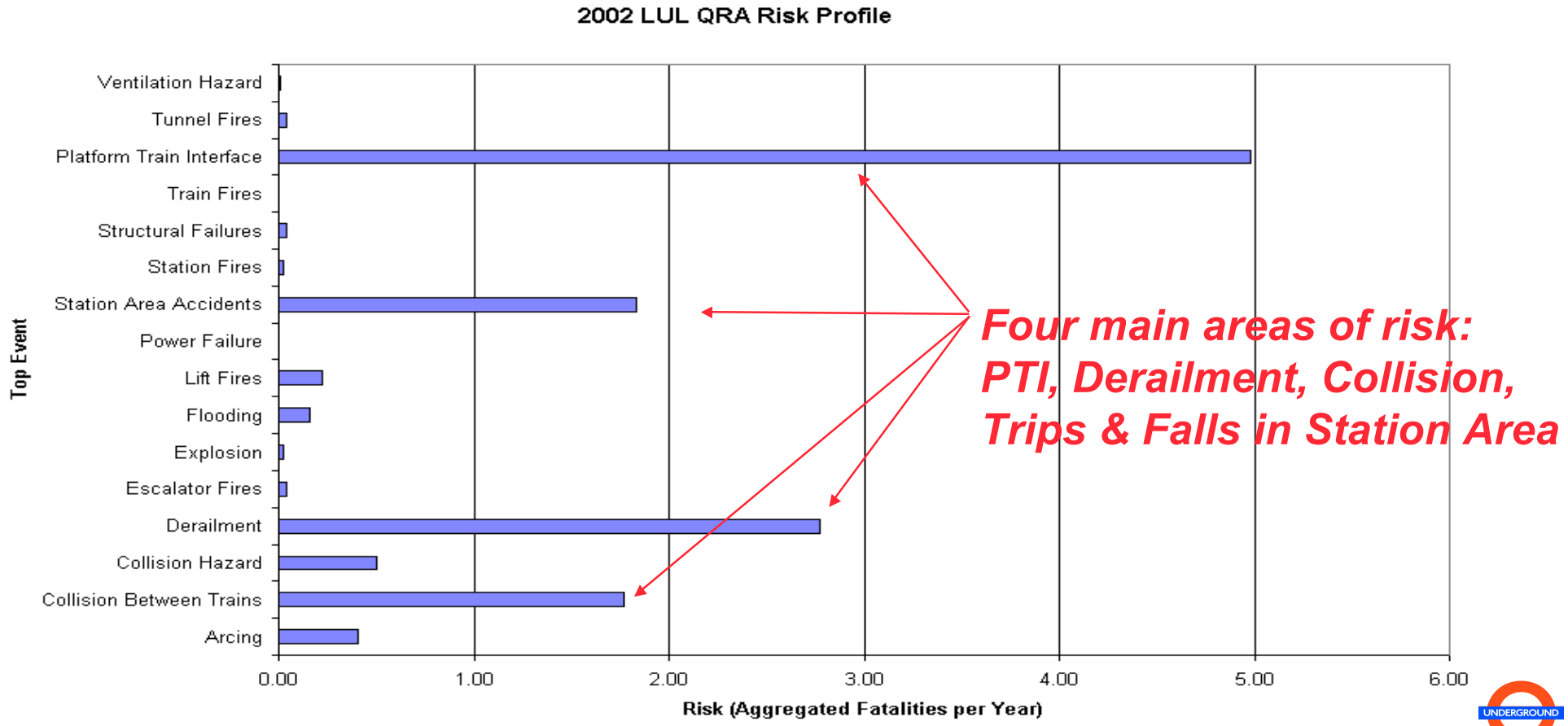
Precursor Category

Direct precursor

Indirect & Root Cause (not shown)

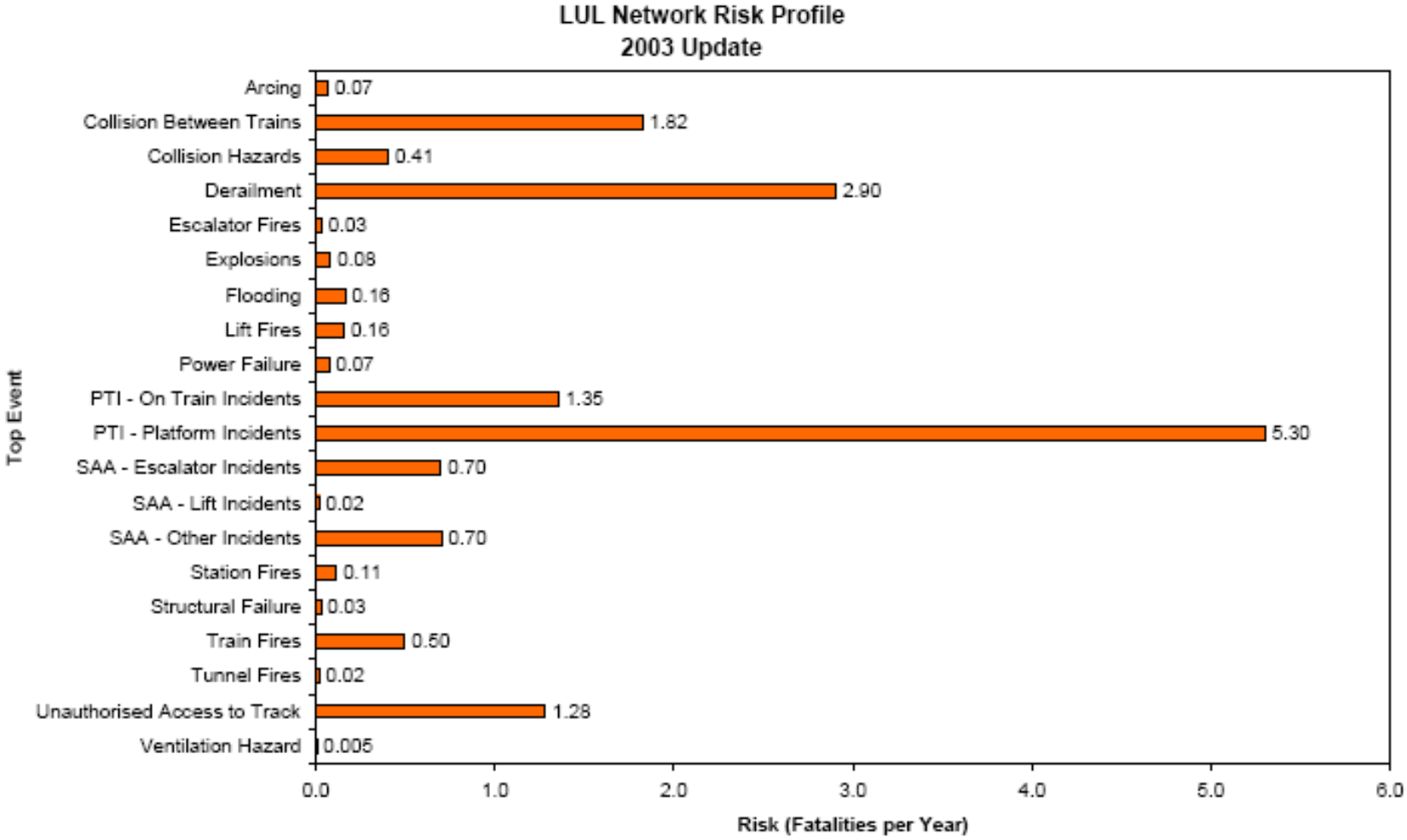
Use of results - example of 2002 data in London

- Prioritise investment & management attention on top risk events / areas
  - input to design of new assets, maintenance levels / special measures
- Measure performance, modify safety improvement programme as needed:
  - value of fatalities avoided used to justify expenditure



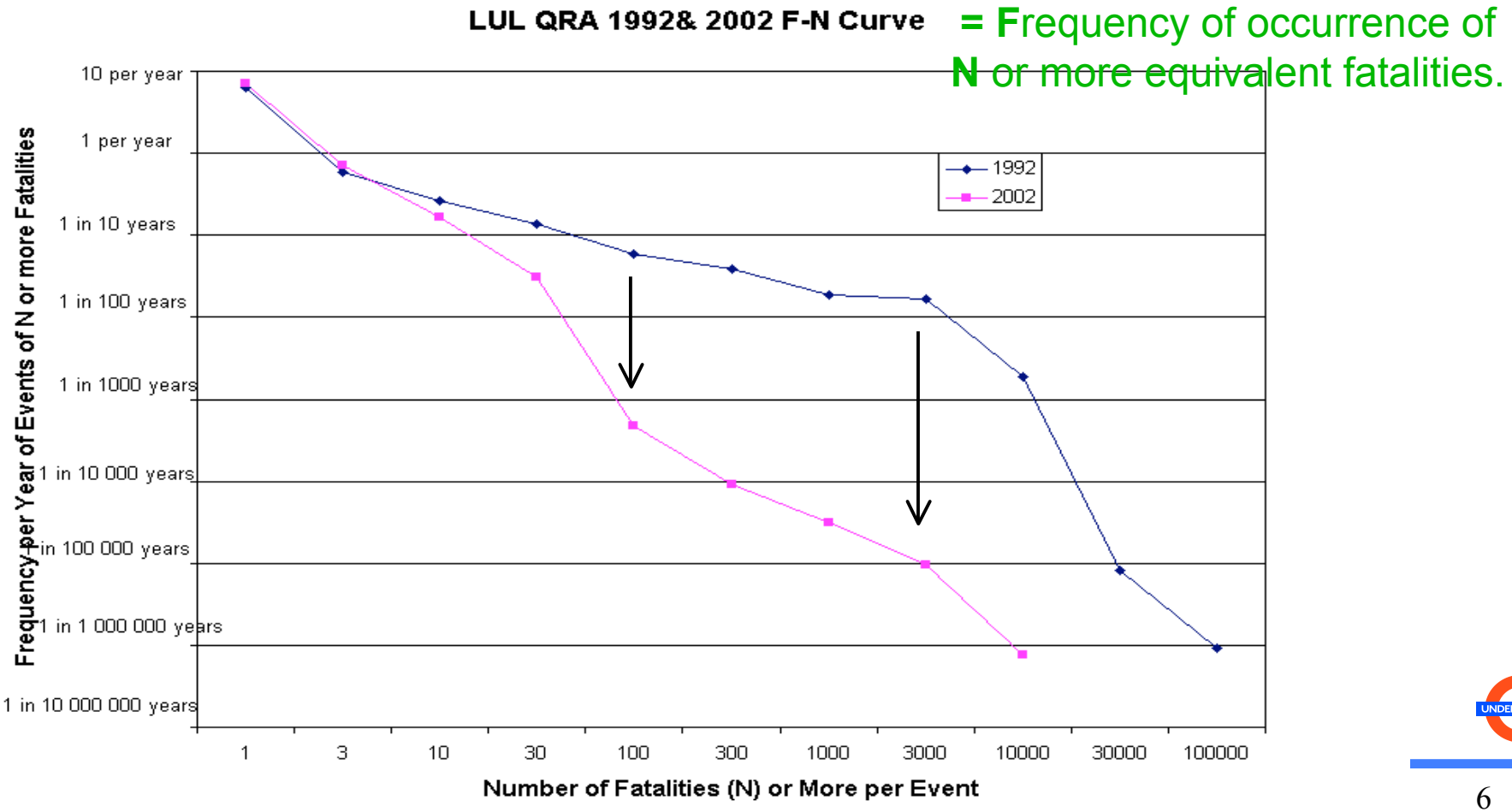
Use of results - example of 2003 data in London

- The risk profile categories can be broken down further to address high priority issues such as unauthorised access to track, one of RATP'S biggest problems
- Progress in mitigation is clearly demonstrable, such as here with arcing



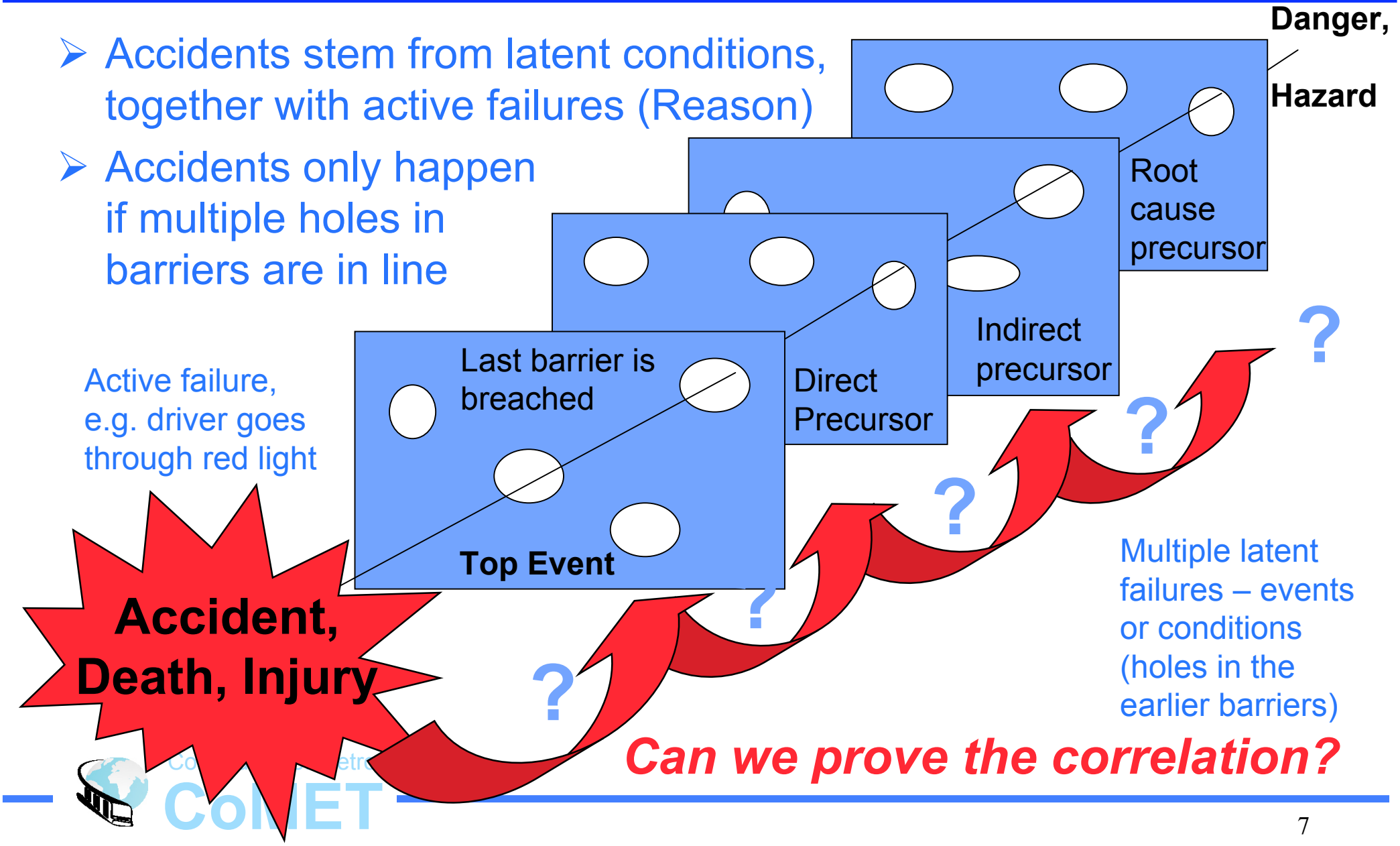
Proof of effectiveness – catastrophe risk reduced in London

- Risk reduction led by precursor model has shifted the curve down & left.
- An 3,000 fatality incident was likely every 100 years – now every 100,000
- One with 100 fatalities was likely every 30 years – now every 3,000 years



Defence in Depth – Protection against Impact of Precursors

- Accidents stem from latent conditions, together with active failures (Reason)
- Accidents only happen if multiple holes in barriers are in line



Can we prove the correlation?

Methodology: 1. Top events list by cause of danger agreed

Proposed Top Event

1. Derailment
2. Electrocution
3. Collision
4. Platform/train interface (or passenger-train interface)
5. Crushing/entrapment
6. Fire
7. Heat exhaustion
8. Asphyxiation
9. Poisoning
10. Explosion
11. Puncture wounds/violence
12. Trips & falls
13. Flooding
14. Panic

Comparison with national rail model:

CoMET / Nova metro model:

- 14 events
  - by cause of danger
- 27 precursors
  - more for derailment and collision than any other events

UK RSSB model:

- 120 “hazardous events”
- 800 precursors arranged into
  - 84 main precursors
    - 34 SPADS*
    - 50 other
  - 6 groups, 20 sub-groups

*SPAD: Signal Passed at Danger

2. Precursors were chosen based on participants' judgement

- Considered to be only those that contribute the most to increase in risk
  - And where data is available on a comparable basis
- The list will be changed if anyone can show that others are better

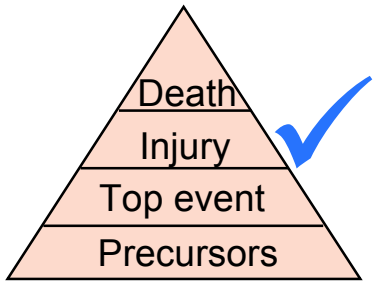
No	Precursor
1	Manual (degraded) operation
2	SPADs (Signals Passed At Danger)
3	Signal failure
4	Person on platform caught in train doors
5	Person hit by train
6	Fall between train and platform
7	Fall onto track (no train present)
8	Trespass
9	Congestion
10	Falls on escalators due to lack of care or drunkenness
11	Falls on escalators due to bulky baggage
12	Falls on escalators due to other reasons
13	Falls on stairs - all reasons

No	Precursor
14	Passenger carrying dangerous / flammable goods
15	Acts of vandalism
16	Substantial objects on track
17	Exceeding speed limits
18	Failure of smoke extraction fans
19	Smoke on train
20	Smoke in station
21	Smoke on track
22	Arcing
23	Broken / cracked rail / other serious rail defect
24	Loss of brake function
25	Station totally closed
26	Station access closed
27	Loss of station lighting

Findings and conclusions from overall statistics

- More Precursors=>more Top Events=>more Injuries
  - R^2=0.85 for Top Events (TEs), R^2=0.76 for injuries
  - F-test, t-stat are significant: relationship is proven and meaningful

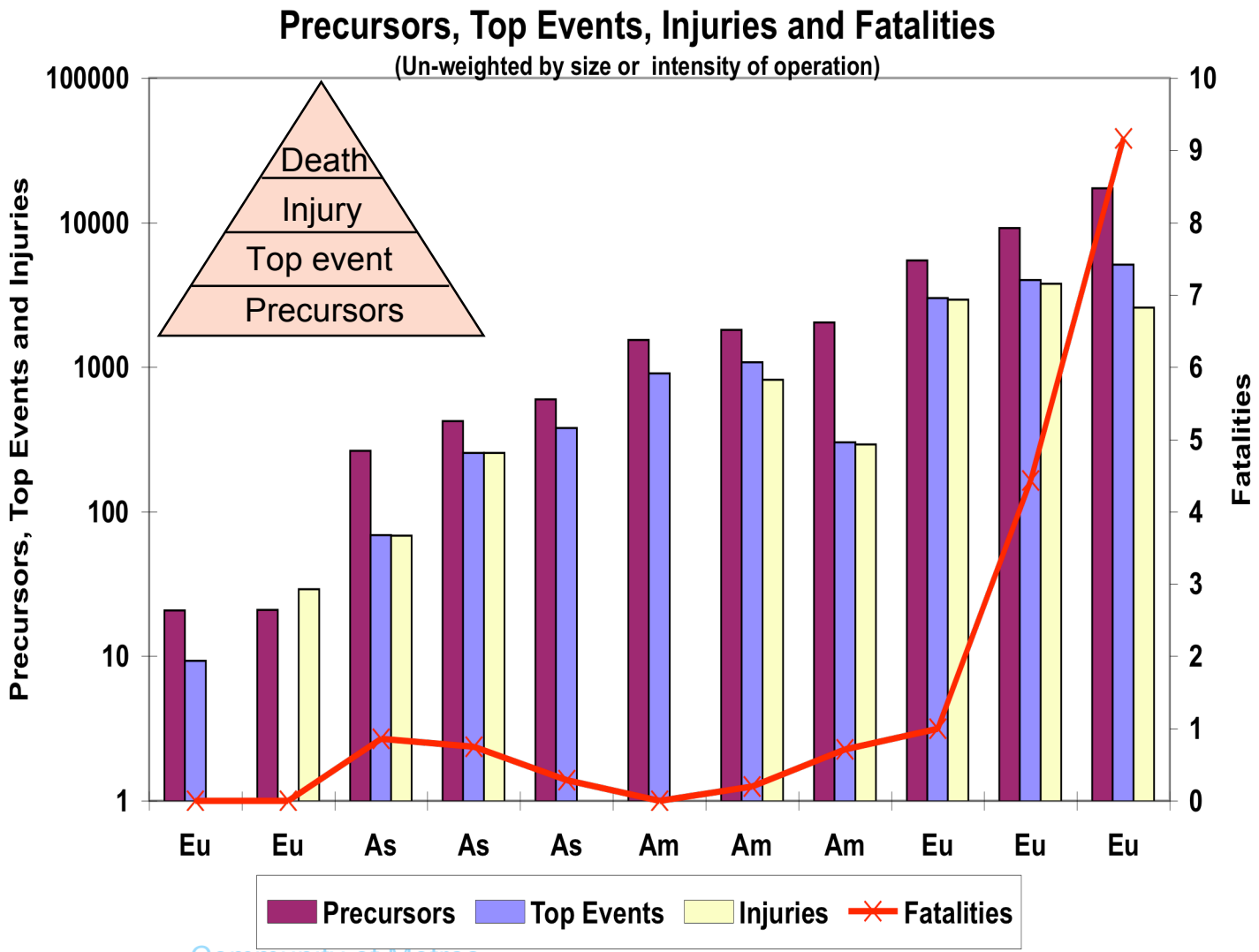
=> Monitoring & reducing precursor incidence is worth while



- This is fully confirmed for collisions, derailments, fires etc., but there are still certain limitations:
  - Ratios are variable: over time, between metros, between TE categories
  - There are no “true” Precursors for trips and falls or PTI*, since P≈TE≈I
  - Where metros have a more complete set of scenarios / fault trees, they *should* have a higher ratio of precursors to top events and injuries
- The cause and effect chain is not proven for fatalities
  - This is probably due to lack of enough data (only 3-4 years)

*Platform-Train Interface or Passenger-Train Interface

More precursors *do* mean more top events and injuries



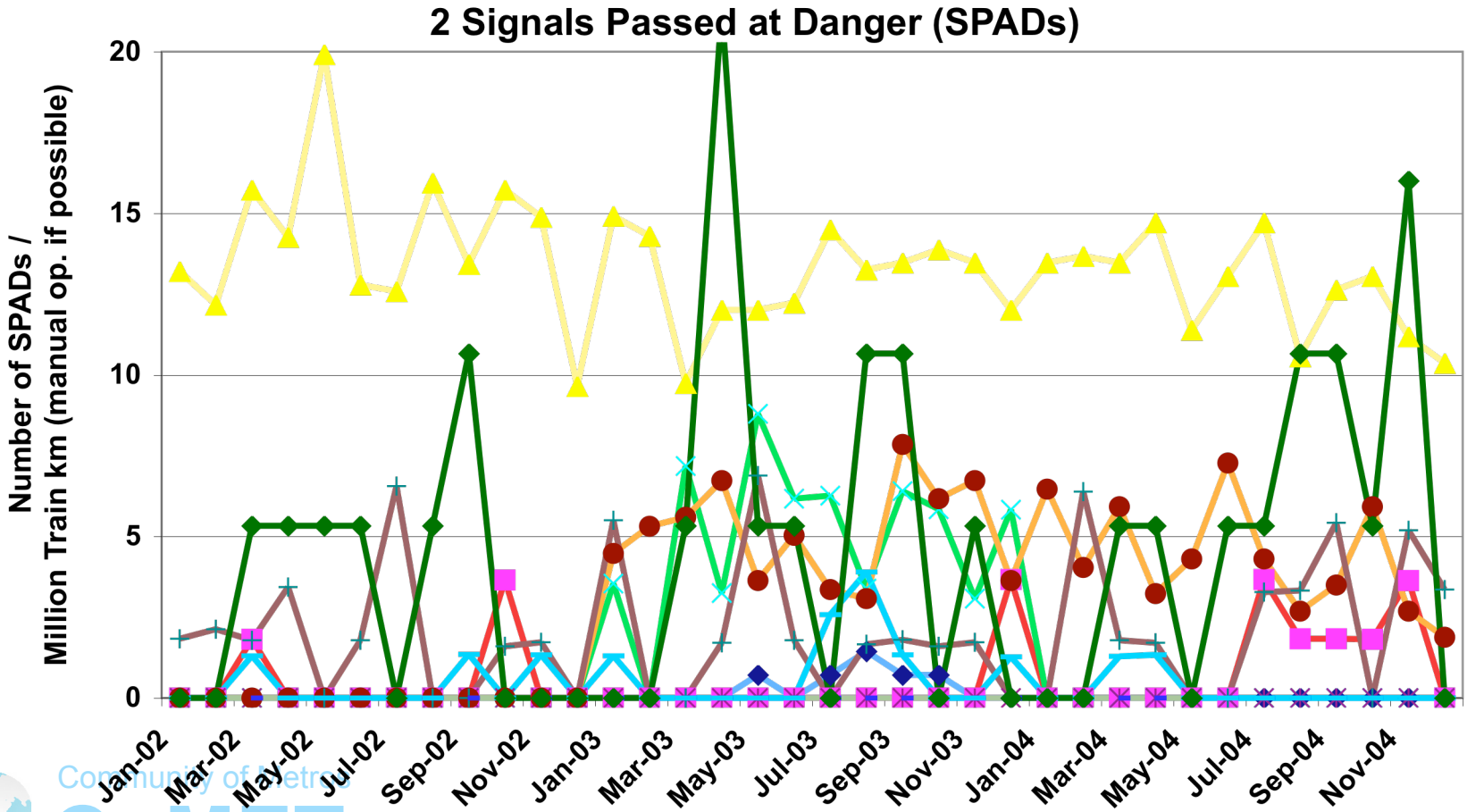
- Top events and injuries **do** correlate positively with precursors
- Deaths **do not** conform to the pyramid hypothesis
  - Only 3-4 years data shown here
  - Too few deaths for statistics to be at all significant
- This establishes the triangle or pyramid - it does not consider if metros' performance is good or not

Conclusions from precursor comparisons

- Most precursor rates are of a similar order of magnitude
  - This indicates comparability
  - Permits identification of significant differences and trends
  - Some provide input for copying good practice elsewhere
  - Long time series (3 years or more) are essential to identify trends
- This provides the statistics to ground QRA models in reality
- These comparisons have already enabled improvements
  - Understanding the environment better
  - Providing added justification for investments that reduce risk
  - Setting the direction for investment
  - Providing the spur for further study and action
  - RATP is now changing the way in which it collects station-related data

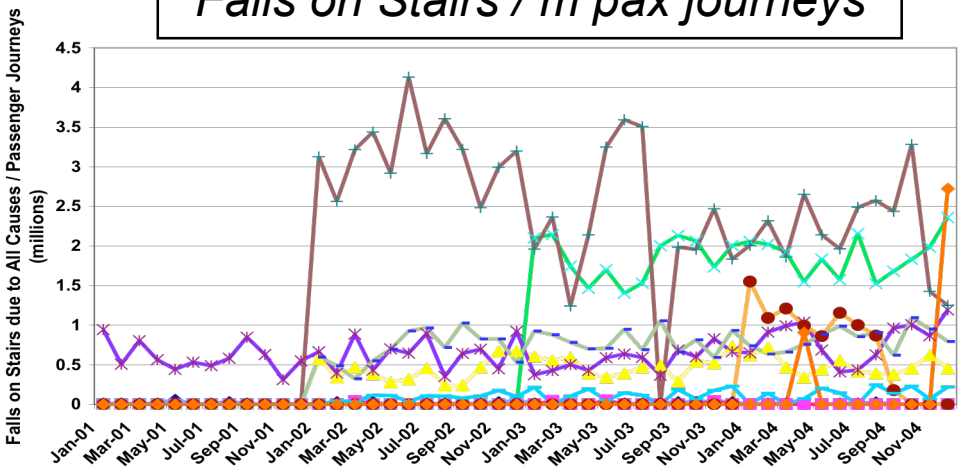
Identifying if better practice is achievable

- The yellow coloured metro is clearly much worse than others - due to poor technology
- The green one shows quite good but variable performance, with similar technology
- The blue metro clearly demonstrates best practice - ***and*** the right technology



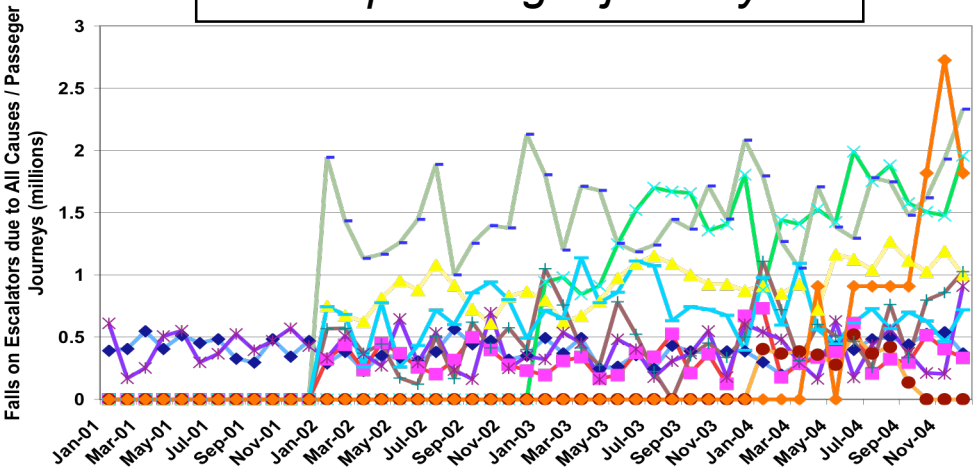
Differences in environment or performance?

Falls on Stairs / m pax journeys

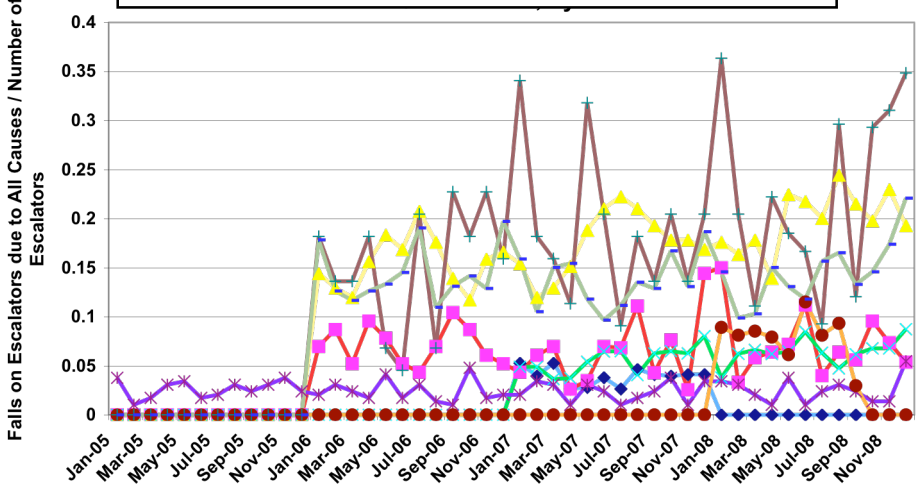


- Factors outside management control?
  - Number of deep level stations
  - Stair:Escalator ratio
  - People using escalators
  - Surfaces and width of stairs
- Different denominators can indicate different levels of performance

Falls on Escalators / m passenger journeys

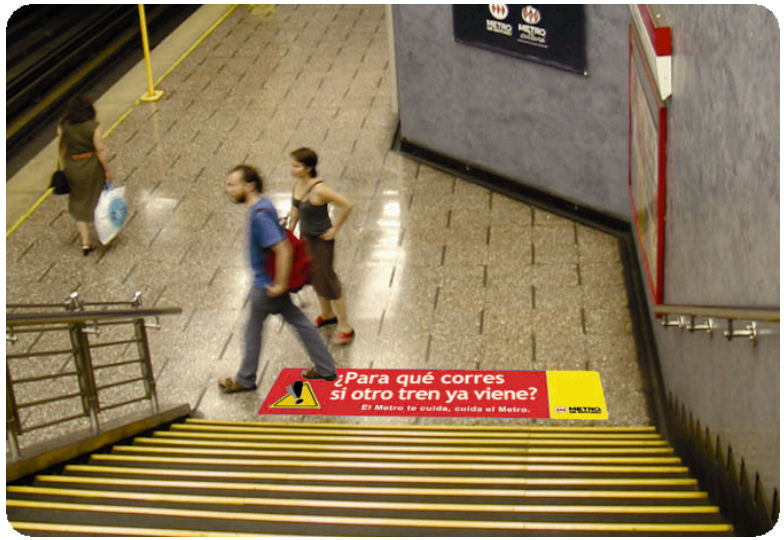


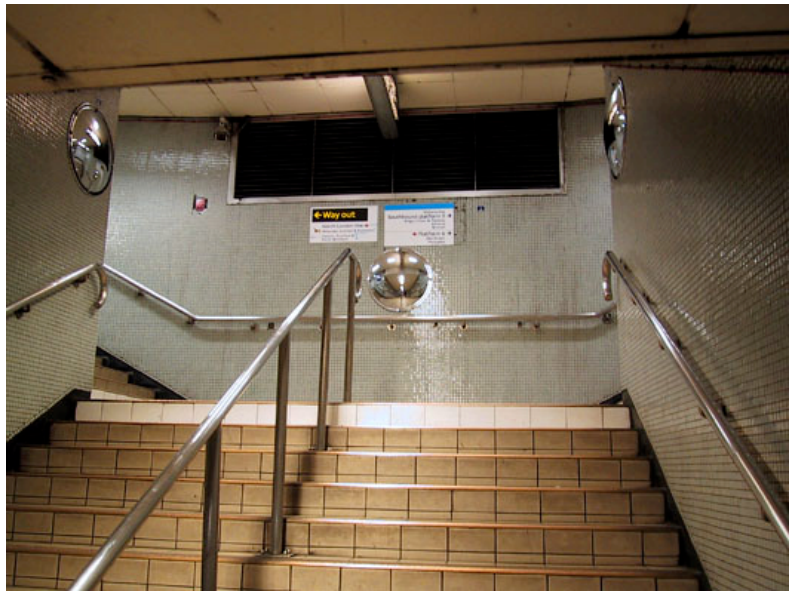
Falls on Escalators / number of escalators



Passenger Behaviour is not outside management control!

- Wide stairs make falls more likely
- Clear indication of step edge helps
- London improved safety greatly by putting hand rails up the centre
- Poster campaign " be careful"
- Madrid changed stair surfaces from marble to non-slip in new stations





Benefits from precursors - learning from others

- Performance difference are always worth investigating –
  - Why does that metro perform better than us?
- Environmental factors are almost always one reason –
  - But they can sometimes be changed
- Best practice will NOT be the only reason for differences –
  - But it may be ONE of the reasons - if so, it can usually be emulated
- Metros are looking at best performers to see what to copy
  - Use direct bilateral contacts to shorten lines of communication
  - A solution to vandalism that has now been copied
  - Three methods of preventing trespassers
  - Controls to reduce SPADs
  - London's good practice with stairs that others can copy

Overall conclusions and recommendations

- The more who collect data, the better the statistics
- Use longer time series - it reveals trends invisible over 1 year
- Monitor only precursors that make the most difference to risk
  - Test whether QRA fault and event trees are correctly calibrated
  - Modify the precursor list as incidence and impact changes
- Distinguish between cause - effect precursors and indicators of risk level
- Undertake action plans to reduce precursor incidence, BUT:
- Do NOT use reduction of precursors as a target for those responsible for reporting data - or all you achieve is to destroy the truth!