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Improving railway safety: Global metro railways' precursor and safety maturity performance

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Overview of Presentation

- Introduction
- Aim of research - definitions
- Accident Precursor Monitoring - Results
- Safety Maturity - Results
- Conclusions

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Introduction

- Railways constitute an important means of transport around the world
- The safety of railway operations is very important – both passengers and politicians expect a level of safety much higher than that of road traffic
- Fatal railway accidents occur rarely so some railways identify changes in safety levels from injuries and accident precursors or near misses
- CoMET is a benchmarking consortium of 12 of the largest metro systems from around the world. Nova is a similar consortium of 14 smaller metros
- Since 2002, many CoMET & Nova members have participated in a risk management programme including accident precursor monitoring, which provides the statistical basis for this study

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Aim of research

To improve safety of metros by:

- Analyzing and defining the potential correlation between precursors, top events, injuries and fatalities
- Communicating some of the methods and best practices by which metros have succeeded in reducing the frequency of accident precursors and injuries
- Developing and testing a new safety maturity model that describes a set of actions and policies that will result in less injuries and deaths

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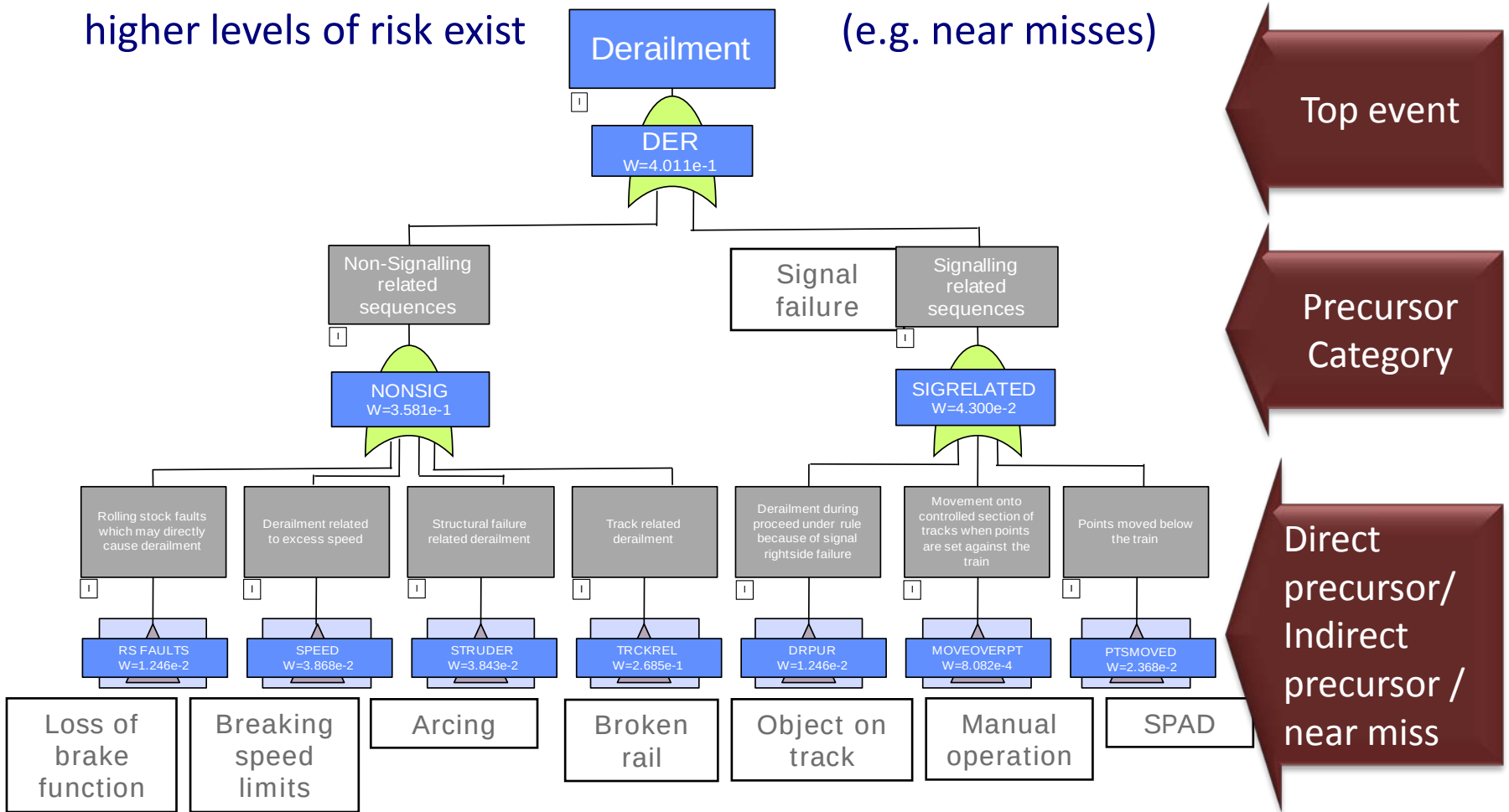
What are precursors & top events?

- Top events: serious incidents that may result in injury or death
- Precursors: events or conditions that may cause top events ***or*** indicate that higher levels of risk exist (e.g. near misses)



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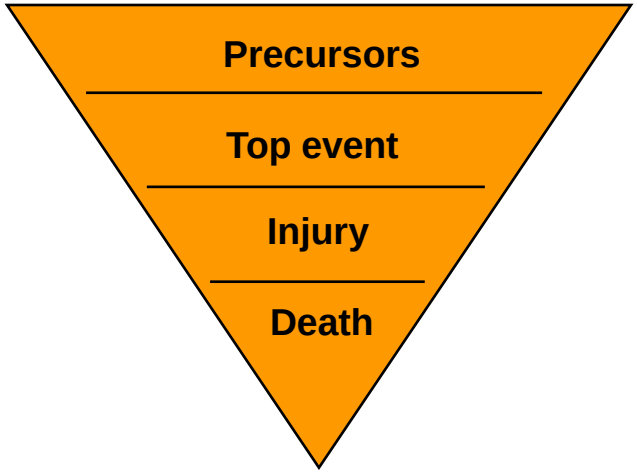
Accident Precursor Monitoring (APM)

Goals:

- To verify whether the probability of more serious incidents and accidents may be reduced by lowering precursor frequency following the idea of the reverse pyramid



- To share practices, actions or measures can be taken in order to improve safety

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Definitions

- Accident: *any unplanned event that results in injury or ill-health to people, or damages equipment, property or materials….where there was a risk of harm*

- Precursor: *an event or condition that may cause a top event **or** that may indicate that higher levels of risk exist (e.g. near misses or actions taken **because of** risk)*

- Top Event: *a serious incident that may be the immediate cause of a death or injury*

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Definitions

- Minor injury: *an injury that does not fulfil the criteria for a major injury (e.g. when a passenger is injured but is not taken to hospital). In the case of an employee or contractor, an injury that prevents the person from working for over three days but still does not fulfil the criteria for a major injury*

- Major injury: *an amputation of a limb, a fracture or dislocation, internal injuries, loss of an eye, burns or other injury of a kind which results in an immediate admission to hospital following the accident for observation or treatment*

- Fatality: *any death that occurs on a metro's property or as a result of an event that took place on a metro property*

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Precursor categories and Precursors

27 precursors are monitored and divided into 6 main categories to address different types of precursors in different ways

Precursor Categories	Precursors in each category
Human Performance-operator & maintainer	Broken wheels &/or axles on RS, Cracked rail / other serious rail defect, Exceeding speed limits, SPADs
Technical failures	Arcing, Broken rail, Broken wheels &/or axles on RS, Cracked rail / other serious rail defect, Loss of brake function, Loss of station lighting, Manual (degraded) operation, Person on platform caught in train doors, Right side signal failures, Wrong side signal failures
Passengers	Congestion, Fall between platform and train, Fall onto track, Falls on escalators – all reasons, Falls on escalators due to bulky items, Falls on escalators due to drunkenness, Falls on stairs – all reasons, Person hit by train, Passenger carrying dangerous / flammable goods
Fire	Smoke in station, Smoke on track, Smoke on train
Malicious or illegal action	Act of vandalism, *Passenger carrying dangerous/ flammable goods,* Trespass, Substantial objects on track
Management policy	Station access closed, Station totally closed

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Precursors and Top Events interconnection

The 27 precursors are connected to 14 monitored top events, for example

Top Event	Precursors (Approximate Assignment to Top Event)
Derailment	Manual operation, SPADs, Signal failure, Broken Rail, Object on track, Excess speed, Loss of brake function
Electrocution	Arcing
Collision	See derailment (A collision between a train and a person is treated as a PTI incident-see next category)
Passenger/ Train interface (PTI)	Caught in train doors, Hit by train, Fall between platform & train, Fall on track (no train present), Congestion
Crushing/ Entrapment	See derailment, plus Station totally closed, , Station access closed
Fire	Smoke in train, on track, in station, Arcing
Heat exhaustion	Congestion, Station access closed
Asphyxiation	See Fire, Heat exhaustion

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Participating metros

17 out of 26 CoMET and Nova metros sent data for the period 2002 - 2008

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Methodology

- 17 metros participated over the period 2002-2008
- Data were analysed on a yearly and monthly basis
- Several different denominators are used for different precursor categories as appropriate for each
- To adjust for metros that did not provide a full set of precursors the following equation was used

$$P_A = \frac{P}{\left(\frac{O}{O_{max}}\right)}$$

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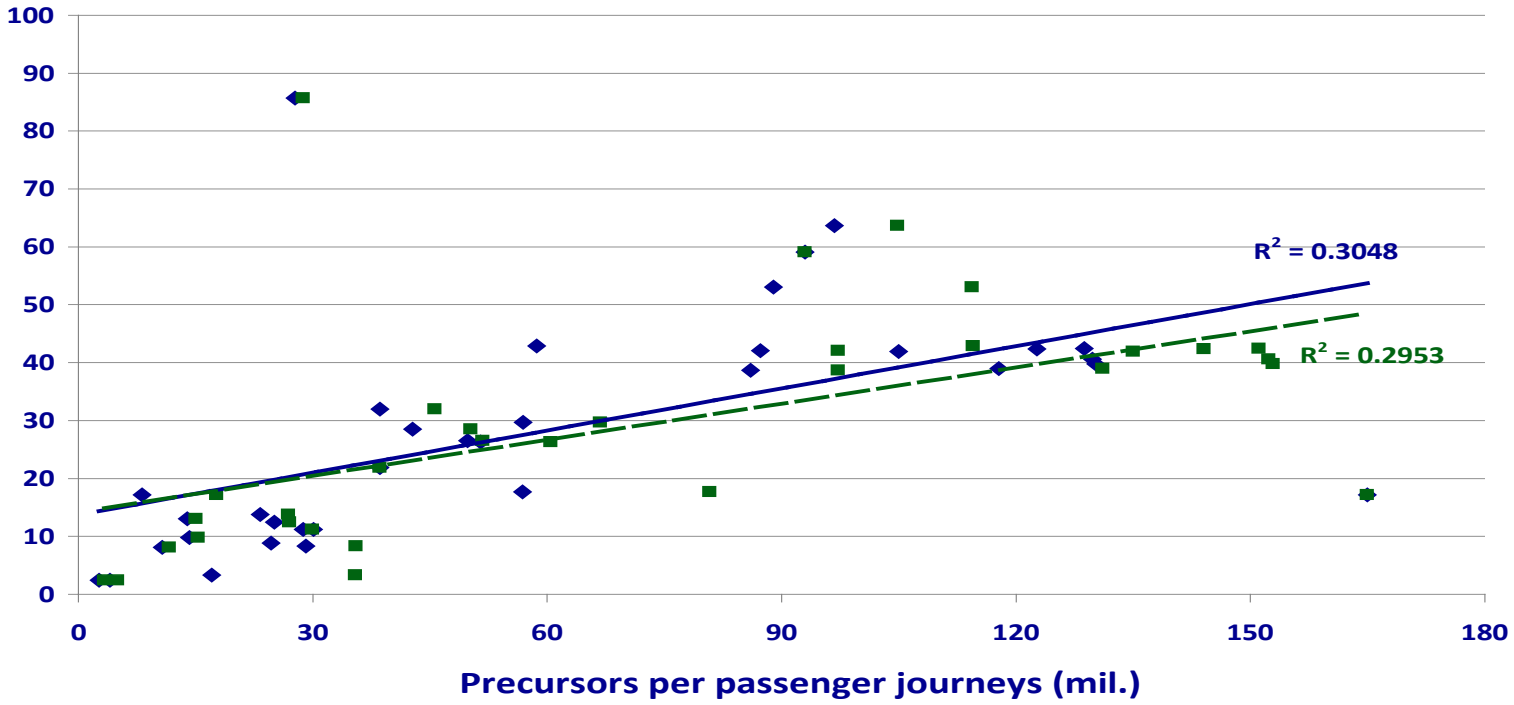
Results

Injuries correlated with precursors & adjusted precursors (precursor numbers divided by passenger journeys)



Sample: 45

Correlation coefficient: 0.749, 0.714

Significance: 0.000 (0.01 level)

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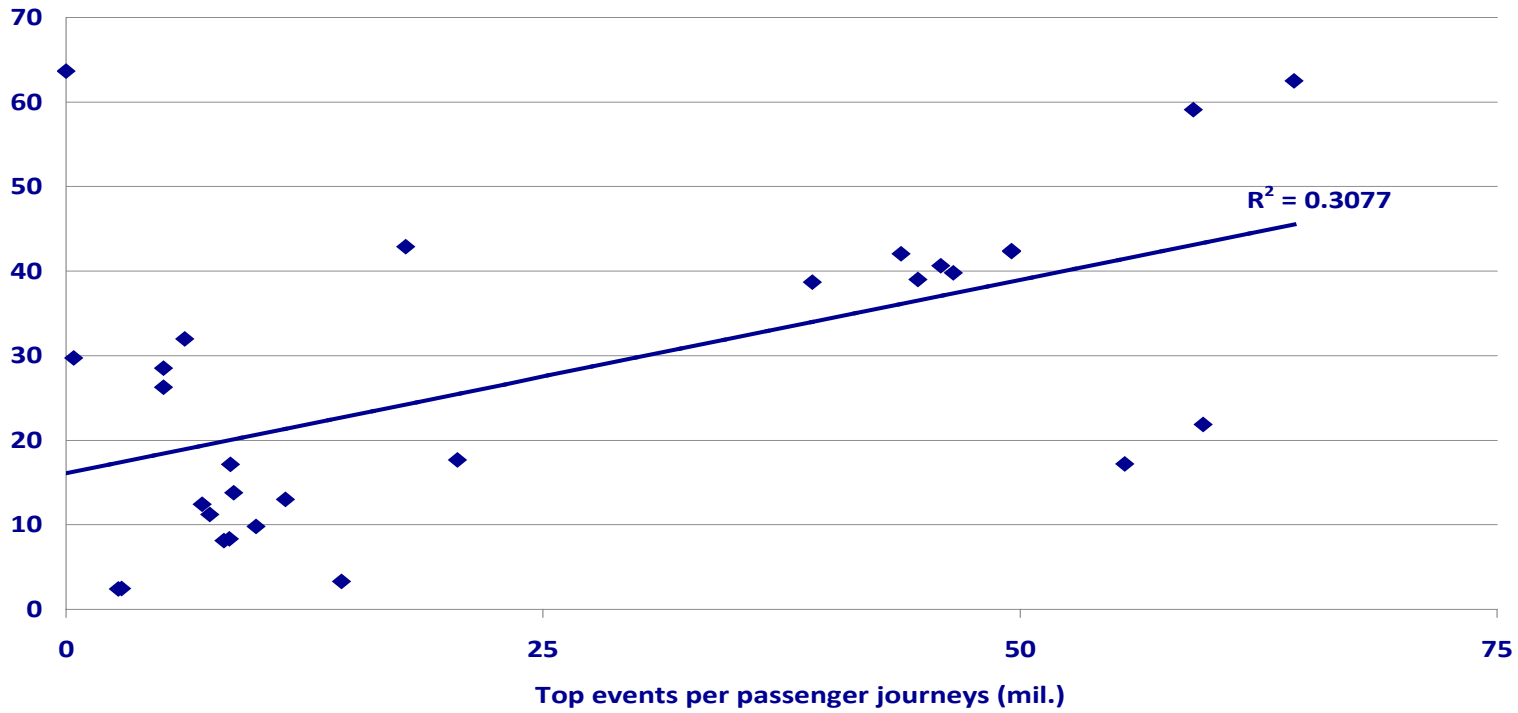
Results

Injuries correlated with top events



Sample: 41

Correlation coefficient: 0.355

Significance: 0.001 (0.01 level)

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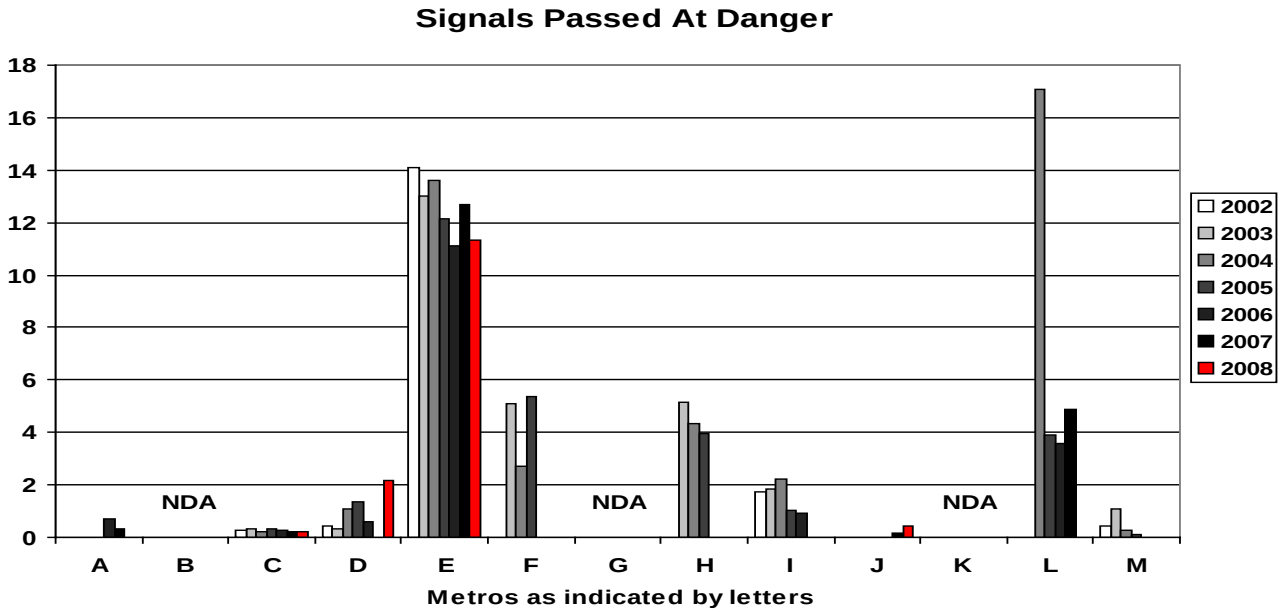
Precursor patterns and improvements by category

Human performance - operator and maintainer



Improvements due to:

- Quality of SPAD investigations
- Development of revised signal sighting training course
- Analysis of causes and effects of fatigue on train operators' performance

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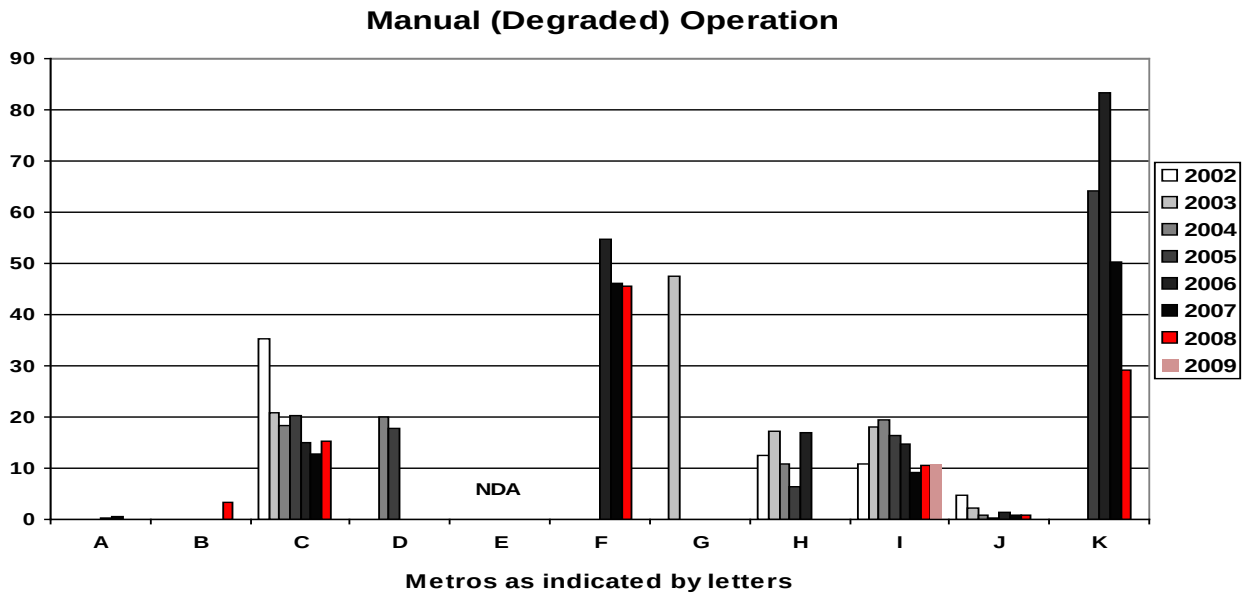
Precursor patterns and improvements by category

Technical Failures



Improvements due to:

- Reduction in the freedom given to train drivers to elect to drive in manual mode
- Relocating on board signalling system equipment

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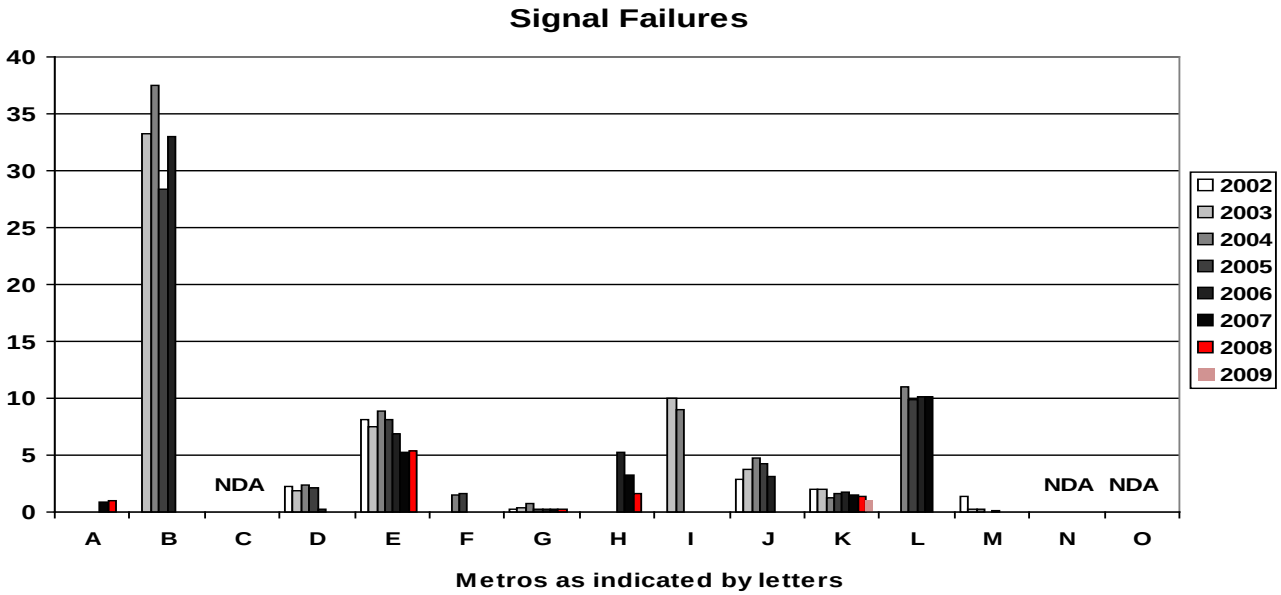
Precursor patterns and improvements by category

Technical Failures



Improvements due to:

- Track replacement programmes and improvement of maintenance procedures (increased use of risk-based maintenance scheduling)
- Thorough cleaning of tunnel led to reduction of false track circuit occupation

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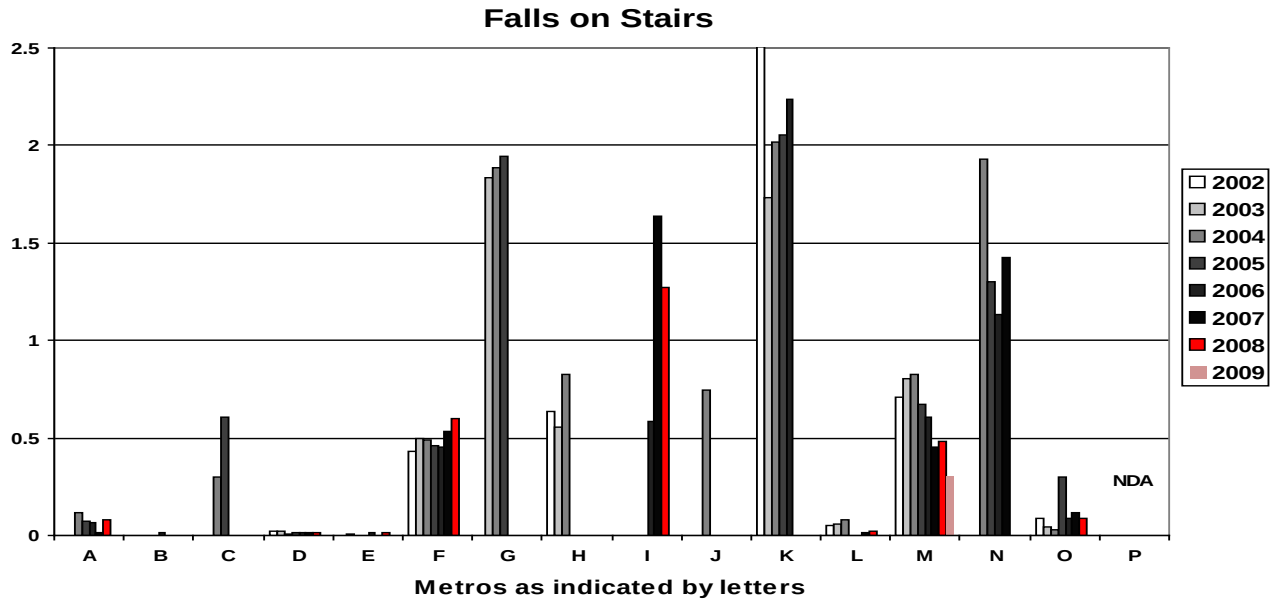
Precursor patterns and improvements by category

Passengers



Improvements due to:

- Installation of central handrails
- Successful poster campaigns
- Encouraging vulnerable passengers, such as the elderly and women with children, to take elevators rather than stairs or escalators

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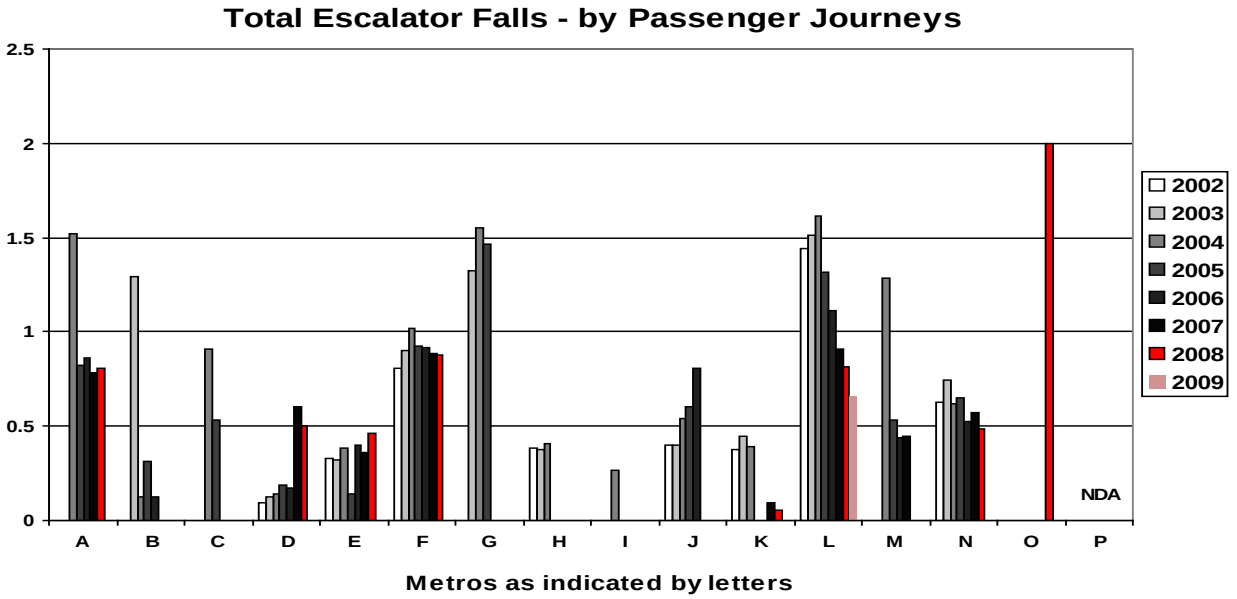
Precursor patterns and improvements by category

Passengers



Improvements due to:

- Station staff warning escalator staff about passengers that would need assistance on their arrival there
- Successful poster campaigns
- Encouraging vulnerable passengers, such as the elderly and women with children, to take elevators rather than stairs or

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Safety Maturity Model

- Monitoring precursors is only one way of measuring safety levels and improving safety – but it should form part of a comprehensive approach
- The safety maturity model is an initial attempt at defining in a more comprehensive way the features that define the safest metros and to describe a pathway to success
- The criteria in the proposed safety maturity model may not yet be fully comprehensive – further refinement / completion may be justified

Safety Maturity Model

Why is a new safety maturity model needed?

Previous models:

- Concentrate exclusive on behavioral and cultural issues
- Insufficient to explain major differences in the safety of metro railways
- Do not address the majority of accident precursors or top events

New model is based on:

- Capability Maturity Model (CMM)
- Safety leadership incorporated in the model using the International Safety Rating System (IRSC)

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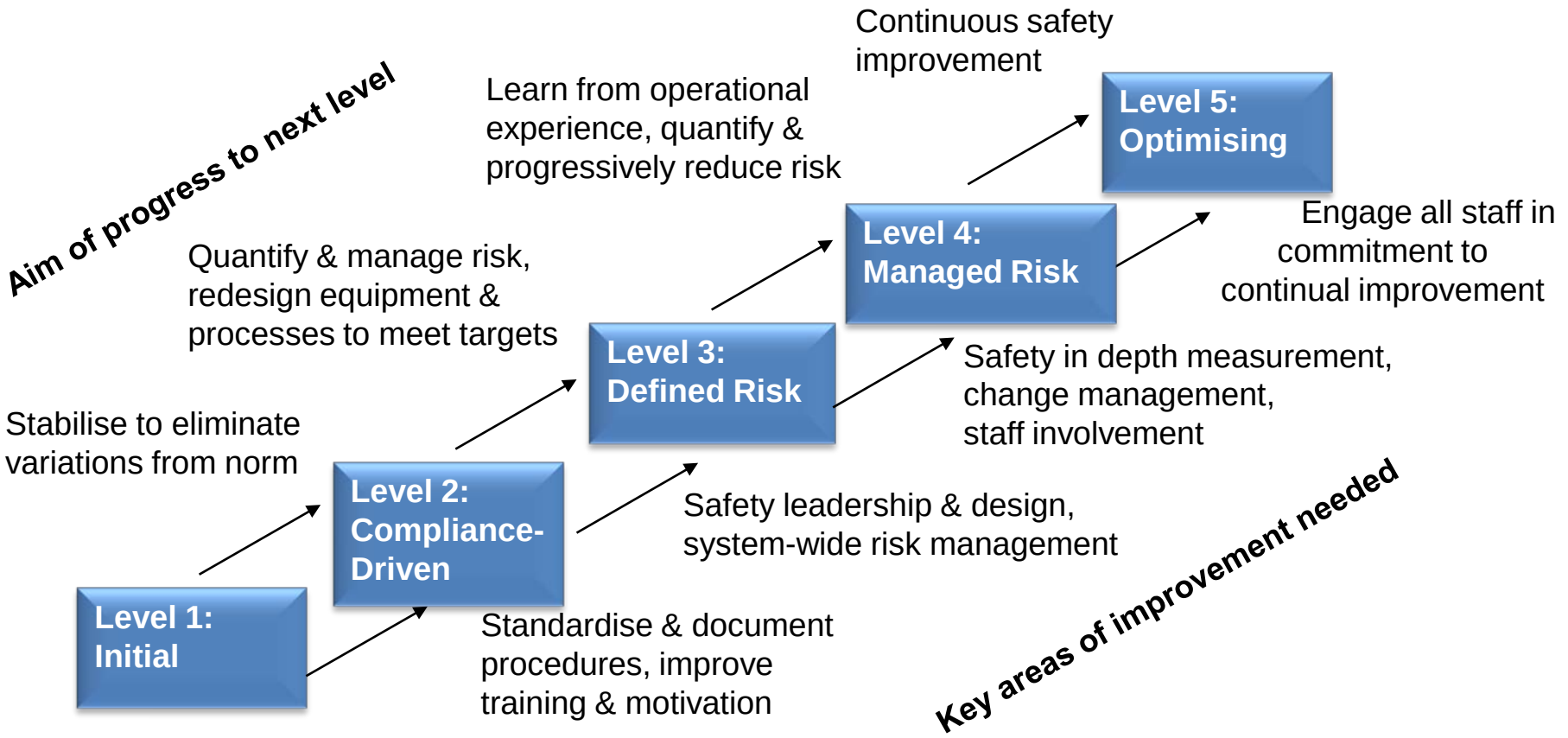
Safety Maturity Model

Aims to address not only human resource culture but also **technical, operational and methodological elements and actual achievements in terms of safety outcomes**



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Safety Maturity Model features

Initial	Compliance - Driven	Defined	Managed	Optimizing
Safety is defined in terms of technical and procedural solutions and compliance with regulations but is not seen as a key business risk	**Safety is defined not only in terms of technical and procedural solutions and compliance with regulations but also with safety training objectives**	Safety is seen as a key business risk covering the safety of customers staff, contractors and any other person on or adjoining organisation's property	All existing safety hazards are identified, registered and the risks evaluated and mitigated using structured, systematic assessment methods	Management is constantly searching for ways to continue reducing accidents frequency and the probability of any occurring with targets for year on year reductions in indicators of remaining risk
Safety department has the primary responsibility for safety	Operations & maintenance have the primary responsibility for safety	**Most frontline staff see themselves as responsible for mitigating safety risks within their own function**	As in defined risk but line managers are also responsible for identifying and mitigating risks within a defined time period. This is then cascaded down to frontline personnel	Management targets for year on year reductions in indicators of remaining risk but ensuring that those reporting such indicators are not deterred by these targets from reporting all such incidents
Most frontline staff are uninterested in safety	Frontline staff are aware of safety objectives but do not see themselves as responsible for mitigating safety risks outside their own responsibility	Most frontline staff notify management of any other hazards and risks that are not already on the hazard register	All employees are aware of the impact of their own function on safety and the quantified targets for that function and for the organization as a whole	**All employees are trained and motivated to look for ways of improving safety**
There is no systematic recognition, quantification or management of risk	Legacy systems and system-wide risks are not addressed, quantified or managed	All major safety hazards are identified, registered and the risk evaluated and mitigated	**Risks are aggregated and progress measured using a regularly updated model of quantified probabilistic risk analysis (QRA / PRA)**	Measurement of risk and progress is constantly updated to adopt new methods and changes in best practice

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Methodology

- A questionnaire consisting of 10 questions was distributed to assess a number of criteria for each metro on a numerical scale such as:

  1. Publication of safety reports
  2. Periodicity of safety monitoring
  3. Prioritisation of safety related incidents
  4. Efforts to mitigate risks and avoid incidents
  5. Description of safety procedures including the registration of hazards
  6. Monitoring of residual risks

- 11 participating metros in 2009

- A score of 0-4 was allocated for each question

- Each one of the questions has the same “weight” or importance

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Methodology

- Total Maturity Index is equal to sum of individual elements
- Maturity indexes were monitored against metro's levels of precursors, top events, injuries and fatalities per million passenger journeys
- Adjusted precursors (adj.) for metros that did not provide a full set of precursors used as previously

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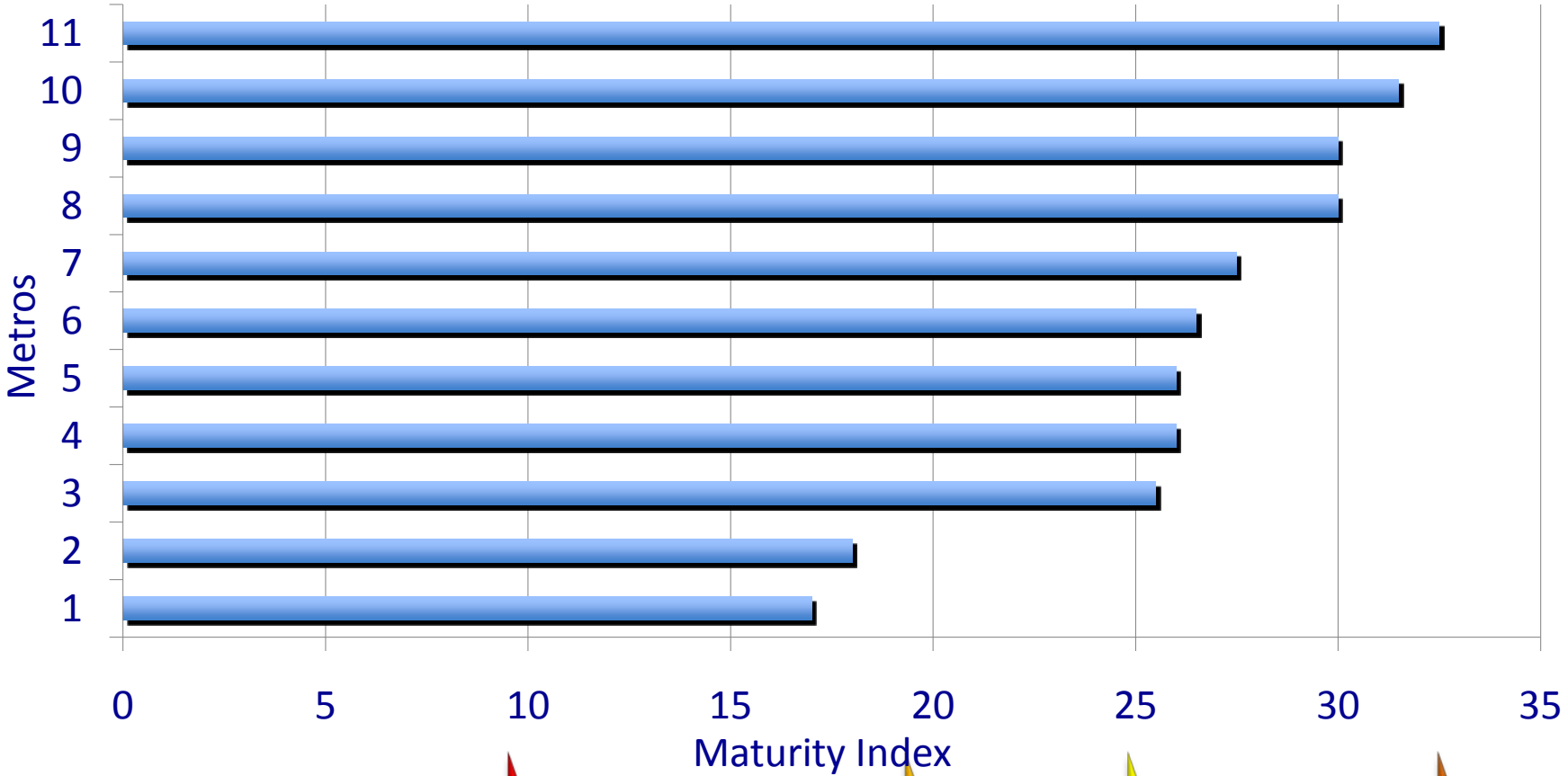
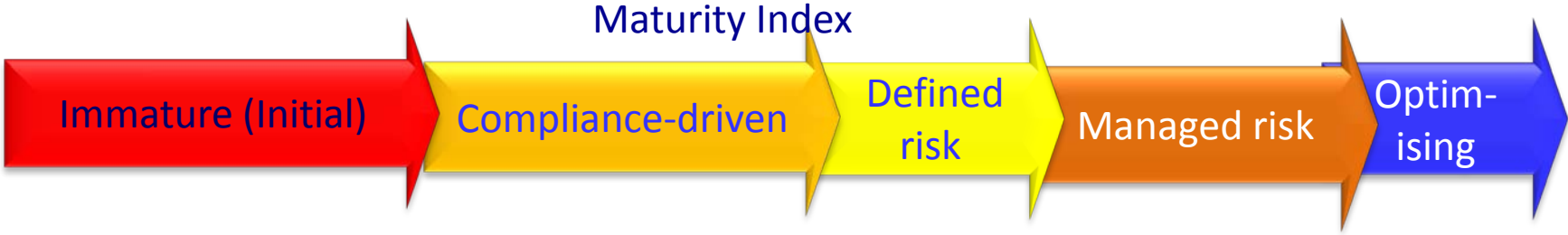
Maturity Index





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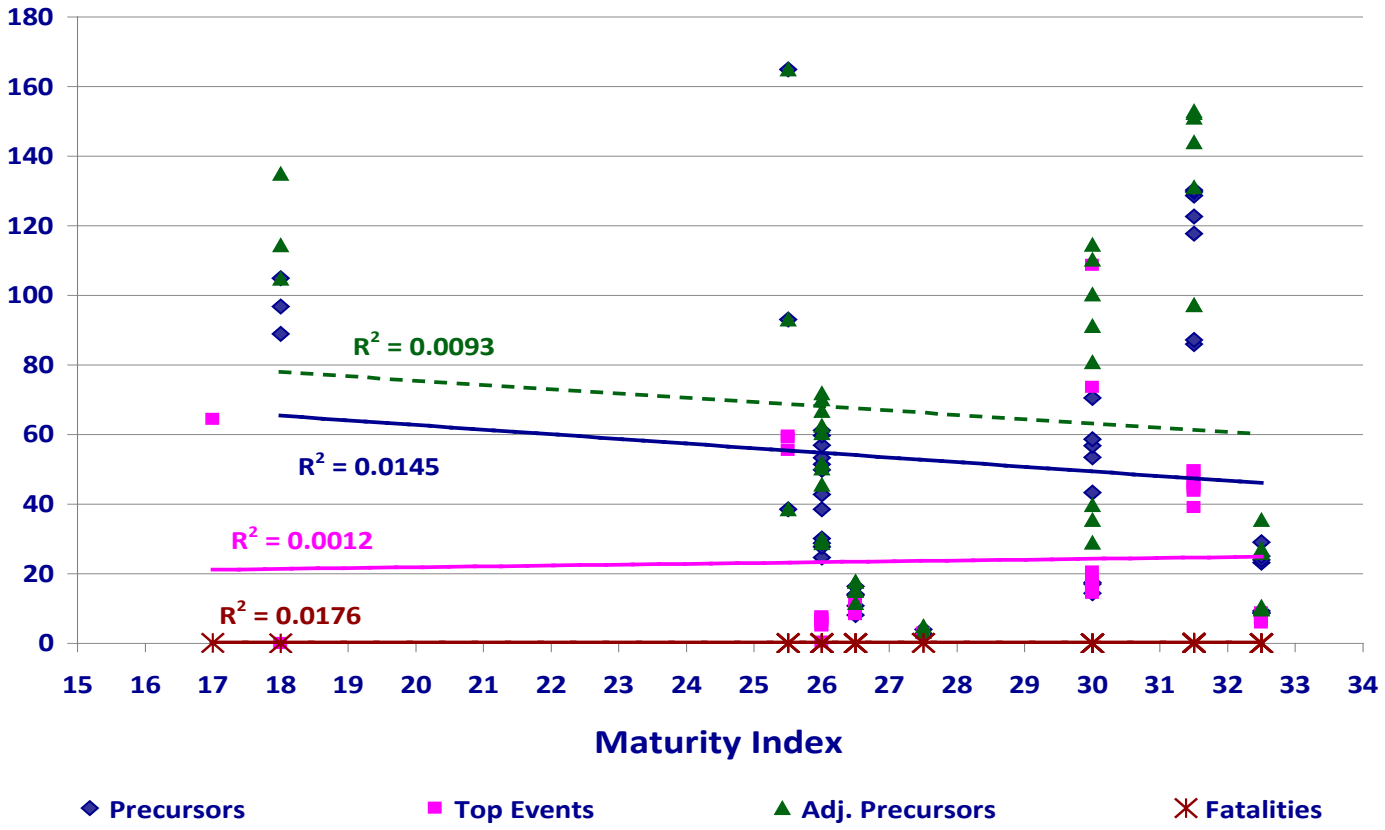
Results

Maturity Index correlated with passenger precursors - adj. precursors - top events and fatalities rate



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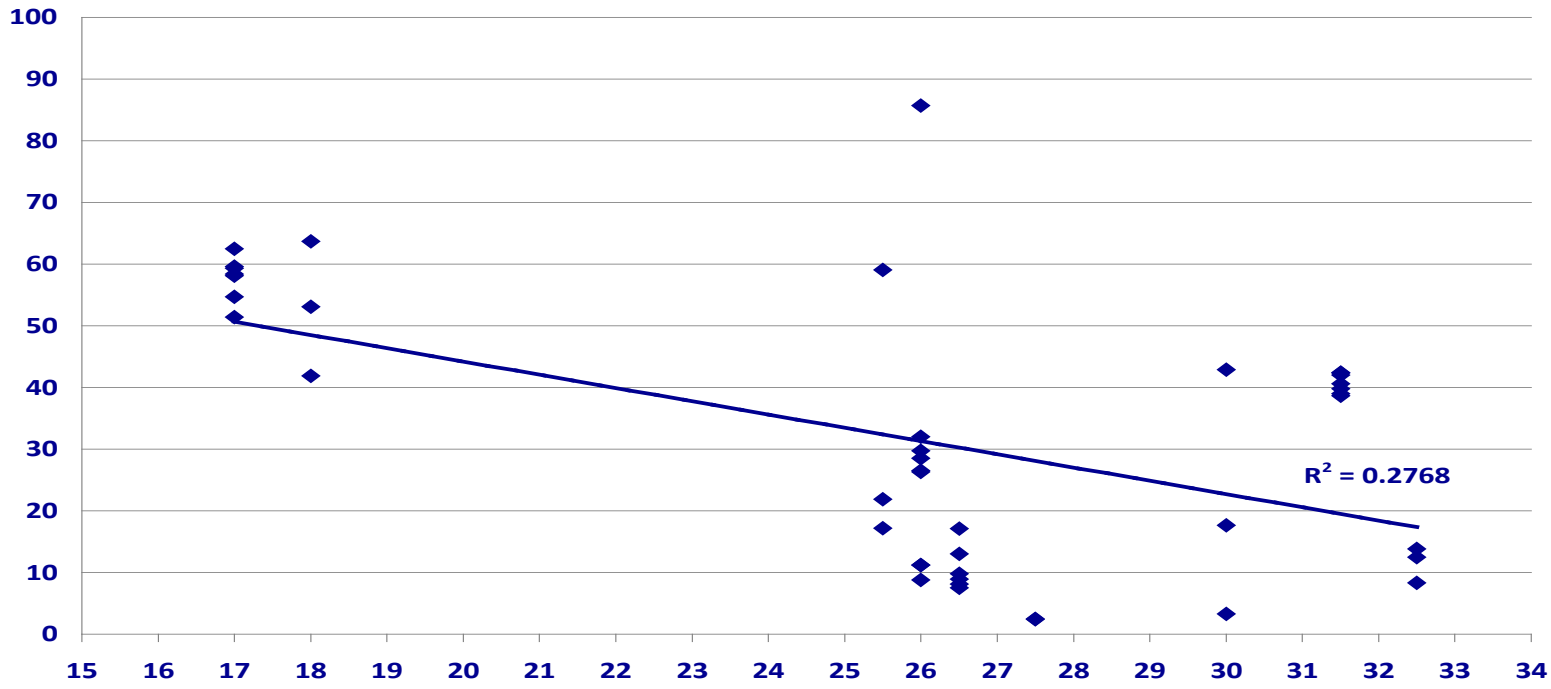
Results

Maturity Index correlated with passenger injuries rate

Higher Maturity Index leads to lower number of injuries



Sample: 43

Correlation coefficient: - 0.492

Significance: 0.001 (0.01 level)

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Conclusions for APM

- Through the accident precursor monitoring programme many improvements on metros safety have arisen
- Exchange of **best practices** between metros led to reductions in risk
- Risk reductions happen mainly due to improvements in technical design standards and equipment and to effective communication with passengers

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Best Practice

- Better operating procedures, training and controls improve **human performance**
- Consistent management attention reduces **technical failures**
- Better equipment and design standards reduces incidents caused by **passenger actions**
- Removing all flammable materials from trains and stations can reduce **fire** possibility
- More station security personnel or better ticketing system could reduce **malicious and illegal actions**

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Safety Maturity Conclusions

- The new safety maturity model proposes an index to assess metros safety performance
- First results showed that safety maturity criteria **do correlate** with the number of injuries
- First results showed that the safety maturity index **does reflect** metros' actual safety performance

However,

- The questionnaire is need to be reviewed
- Questions may need to be replaced or added
- Questions need to be "weighted"
- Additional criteria may emerge as significant: these should be incorporated

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Acknowledgments

- Participating metros
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- Lloyd’s Register Educational Trust

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