ISO 55001 compliant risk management system for railways

Zamyshlyaev A.M.,
Deputy Director General JSC NIIAS
Head of R&D Complex for Traffic Safety and Station Automation Systems, Dr. Sci.
— Certainly, riding a motorcycle has its risks: in case of an accident the chance of grave injuries is higher than when driving a car. On the other hand, you constantly think of it and become more careful in all senses. People sometime fall asleep while driving, but never doze on a motorcycle.

— Malcolm Forbes, publisher of Forbes magazine
The role of the risk management system in the context of the ISO 55001 standard

«Understanding and managing risk is a universal requirement throughout ISO 55001. It is particularly prevalent in the definition and implementation of the overall Asset Management System, in planning what to do to the assets to manage risks, and in operations, i.e. doing things to the assets to manage risks».

(ISO 55001, item 1.5.3 The treatment of risk)
Main principles of risk management as part of deployment of asset management system as per ISO 55001

- Risk identification should be undertaken on each component of the Asset Management Framework from the setting of organizational objectives to the execution of work and operation of the network.
- A Corporate Risk Matrix describes the risk assessment criteria used to quantify and compare risks (usually probability and consequence).
- A risk register provides a structured format for recording risks. Each risk should be linked to one or more components of the Asset Management framework.
- The level of detail undertaken in the risk assessment should be commensurate to the severity and complexity of the risk. Formal approaches are required for safety risks, and most sophisticated risk tools have been developed in this area e.g. bow-tie, fault and event tree analyses.
- Risk actions should be prioritized to support achievement of the appropriate balance between costs, risks and performance.
Correlation of ISO standards for asset and risk management in JSC RZD
Infrastructure and rolling stock facilities of JSC RZD

Infrastructure:
- Length of operational tracks: 85,500 km
- Length of electrified lines: 43,700 km
- Lines equipped with signalling equipment: 62,196 km
- Railway stations: 5,428
- Traction substations: 1,402
- Service units (track divisions): 742

Rolling stock fleet:
- Freight locomotives (electric and diesel): 11,800
- Freight cars of all types and owners: 1,600,000
- Shunting engines (diesel): 5,900
- Long-distance passenger cars: 21,000
- Commuter cars: 14,300
- Motive power and car depots: 411
URRAN (asset management project) – set of standards, methods and guidelines used for management of life-cycle processes of the Russian railways according to ISO 55001.
# URRAN functions

<table>
<thead>
<tr>
<th>No.</th>
<th>Function Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Real-time assessment and prediction of dependability and safety indicators of infrastructure facilities and rolling stock</td>
</tr>
<tr>
<td>2</td>
<td>Risk management</td>
</tr>
<tr>
<td>3</td>
<td>Assessment of wear, residual operating life and limit state of infrastructure facilities and rolling stock</td>
</tr>
<tr>
<td>4</td>
<td>Prediction of infrastructure facilities condition, prediction of track prefailures</td>
</tr>
<tr>
<td>5</td>
<td>Assessment of life cycle cost of infrastructure facilities and rolling stock</td>
</tr>
<tr>
<td>6</td>
<td>Assessment of RZD units activities based on the actual dependability and safety indicators of operated infrastructure facilities and rolling stock</td>
</tr>
<tr>
<td>7</td>
<td>Management of resources directed towards the maintenance of infrastructure facilities and rolling stock</td>
</tr>
<tr>
<td>8</td>
<td>Managerial decision support using URRAN single corporate platform</td>
</tr>
</tbody>
</table>
Development of risk management system in JSC RZD

Development of company’s risk management system based on crossfunctional interaction of business units using SCP URRAN

Development and implementation of algorithms: aggregation of risks, estimation of integral risks, evaluation of the risks of processes, decision-making

Development and implementation of standards and guidelines, as well as tools to assets the item-related risk (standards, methods, recommendations for risk matrix construction)
Items and functions hierarchy of asset management in railway transportation

**TODAY**

- **Big Data Infrastructure**
  - Safety of process
  - Reliability of process
  - Safety of system
  - Reliability of system
  - Safety of element
  - Reliability of element

**RAILWAY TECHNICAL SYSTEMS**

- Catenary, power
- Supersstructure, viaducts, bridges
- RS fleet

**RAILWAY FACILITIES**

- Rails, sleepers, ballast
- Lights, relays, switches, cables
- Supports, cables, insulators, switches
- Other units

**STANDARDS AND REGULATIONS ON DEPENDABILITY AND SAFETY:** 85 DOCUMENTS

**FACTORIAL ANALYSIS**

- Online monitoring, simulation

**INTERACTION MODELS AND ASSESSMENT METHODS OF PROCESSES**

**TOMORROW**

- Integrated intelligent processes and services management system
- Process with inbuilt safety system
- Monitoring of unacceptable states and risks

**RISKS**

- Reliability of element
- Safety of element
- Reliability of process
- Safety of process
- Reliability of system
- Safety of system

**TODAY**

- Passenger traffic
- Freight traffic

**TOMORROW**

- Process with inbuilt safety system

**DYNAMIC MANAGEMENT MODEL**
General risk management algorithm (9 steps)

1. Statistical estimation of the risk associated with protection facilities based on the total data for previous periods
2. Development of audit criteria, including criteria of assessment of statistical data and actual state
3. Selection of network entities and risk assessment of network entity in general
4. Collection of data for each protection facility
5. Individual estimation of each protection facility
6. Risk assessment for a system entity based on individual estimates and its comparison with the estimate of Step 3.
7. Risk compensation measures
8. Repeated individual estimation of protection facilities and risk of system entity
9. Recalculation of risk of protection facilities at system (regional) level subject to individual estimation. Monitoring of undesirable events and state (tracking audit)

1.1 Risk matrix
1.2 List of types of entities with risk level above acceptable
3.1 List of network entities to be audited
3.2 Questionnaires for auditing in railway system regions
5.1 Probability of undesired event
5.2 List of identified irregularities
5.3 List of compensating measures
7.1 Scheduled M&R
7.2 Unscheduled M&R
7.3 Assessment of consequences
Standardization of risk management and risk matrix construction in URRAN

- This standard sets forth the approach and general rules of risk management in railway transportation in terms of functional safety of infrastructure facilities and rolling stock.

- The guidelines formalize the risk matrix construction procedure and improve the reliability of data through correct generation of risk matrix parameters that are associated with actual statistical data.
Risk-oriented model of occupational safety management. Algorithm of risk assessment and compensating measures

Risk assessment subject to adopted measures

- Increased duration of possession
- Training
- Provision of protective gear
- Provision of tools

COMPENSATING MEASURES TO BLOCK HAZARDOUS FACTORS

Risk matrix and base risk levels based on statistics (at central and regional levels)

List of hazardous factors that cause injuries (heights, electric current, etc.)

Risk assessment based on statistical criteria

Audit of processes, whose realization affects the probability of injury

Hazardous factor: fall from heights
Criterion: number of wooden poles decayed beyond the allowed level

Hazardous factor: electric current
Criterion: provision of means of communication with power dispatchers

Score cards and questionnaires for auditing of processes

Audit of processes, whose realization affects the probability of injury

Step 1. System-wide risk assessment based on event statistics. Generation of the list of hazardous occupations

Step 2. Selection of the directorate, in which state-based risk assessment will be performed

Step 3. Audit of the management system and processes implemented in a division

Step 4. Individual assessment of the hazard of identified states and risks by means of score cards

Step 5. Risk compensation measures

Step 6. Reconsideration of individual assessments of employees’ occupational risks. Safety reporting

Step 7. Recalculation of occupational risks at system (regional) level subject to individual assessments.
Rolling stock fire risks management system of JSC RZD

1. Identification of critical series (risk matrix)

Identification of critical series (risk matrix)

Declaration of compliance (with description of technical state and fire suppression systems)

2. Development of score card for individual risk calculation

<table>
<thead>
<tr>
<th>№</th>
<th>Часть узла</th>
<th>№</th>
<th>Пожароопасное состояние</th>
<th>Уровень риска</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Насосная</td>
<td>1</td>
<td>Присоединение и соединение трубопроводов</td>
<td>V</td>
</tr>
<tr>
<td>2</td>
<td>Насосная</td>
<td>2</td>
<td>Утечки</td>
<td>V</td>
</tr>
<tr>
<td>3</td>
<td>Насосная</td>
<td>3</td>
<td>Крышка люка</td>
<td>V</td>
</tr>
<tr>
<td>4</td>
<td>Насосная</td>
<td>4</td>
<td>Автоматика</td>
<td>V</td>
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<tr>
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<td>Насосная</td>
<td>5</td>
<td>Система охлаждения</td>
<td>V</td>
</tr>
<tr>
<td>6</td>
<td>Насосная</td>
<td>6</td>
<td>Система охлаждения</td>
<td>V</td>
</tr>
</tbody>
</table>

3. Individual fire safety auditing of critical locomotive series (spring commission inspection)

4. Assessment of the probability of fire in each locomotive

5. Planning of fire probability reduction measures

- Performed in depot
- Performed by central and regional directorates

6. Selection of most efficient fire prevention measures
Primary metal elements of a railway bridges, whose state defines the level of risk

1) Spans (with girders)
2) Truss (with ties)
3) Footpath/driveway
4) Strings, ramps
Estimates of the risk of corrosion of bridges and recommended year of corrosion protection activities

<table>
<thead>
<tr>
<th>№</th>
<th>Value name</th>
<th>Bridge no. 1 Gudermes - Samur line on the Azerbaijani border</th>
<th>Bridge no. 2 Krymskaya - RZD line</th>
<th>Bridge no. 3 Lozovaya - Rostov line</th>
<th>Bridge no. 4 ETC 9 km - Timashevskaya line</th>
<th>Bridge no. 5 Prokhladnaya - Gudermes line</th>
<th>Bridge no. 6 Armavir - Minvody line</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Risk of corrosion of metal bridge spans</td>
<td>Undesirable</td>
<td>Intolerable</td>
<td>Undesirable</td>
<td>Intolerable</td>
<td>Intolerable</td>
<td>Intolerable</td>
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<tr>
<td>2</td>
<td>Risk of corrosion of ties of main girders of metal spans</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Intolerable</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>3</td>
<td>Risk of corrosion of footpaths</td>
<td>Undesirable</td>
<td>Negligible</td>
<td>Undesirable</td>
<td>Negligible</td>
<td>Negligible</td>
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<tr>
<td>4</td>
<td>Risk of corrosion of strings/ramps</td>
<td>Negligible</td>
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<td>5</td>
<td>Overdue* corrosion protection</td>
<td>Tolerable</td>
<td>Tolerable</td>
<td>Tolerable</td>
<td>Tolerable</td>
<td>Tolerable</td>
<td>Tolerable</td>
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<tr>
<td>6</td>
<td>Level of priority based on line class</td>
<td>Tolerable</td>
<td>Undesirable</td>
<td>Tolerable</td>
<td>Intolerable</td>
<td>Tolerable</td>
<td>Undesirable</td>
</tr>
<tr>
<td>7</td>
<td>Level of priority based on proximity of population</td>
<td>Tolerable</td>
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<td></td>
<td>Integral risk figure</td>
<td>0.27</td>
<td>0.33</td>
<td>0.47</td>
<td>0.40</td>
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<td></td>
<td>Integral level of risk</td>
<td>Tolerable</td>
<td>Undesirable</td>
<td>Intolerable</td>
<td>Undesirable</td>
<td>Undesirable</td>
<td>Undesirable</td>
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<tr>
<td></td>
<td>Recommended year of activities</td>
<td>2021</td>
<td>2019</td>
<td>2018</td>
<td>2019</td>
<td>2019</td>
<td>2019</td>
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<tr>
<td></td>
<td>Declared cost of activities, rubles</td>
<td>2 554 275,20</td>
<td>3 302 159,20</td>
<td>8 097 384,20</td>
<td>2 137 145,20</td>
<td>22 241 761,00</td>
<td>5 160 234,40</td>
</tr>
</tbody>
</table>

* Past due date is defined based on the assumption that a delay of up to 5 years is acceptable due to mass failure to meet the deadlines for railway bridges painting
Algorithm of track maintenance according to URRAN risk-oriented criteria

Legend
- Process
- Criterion

M – maintenance
Vr – real speed
Vsp – specified speed
Th – handled tonnage
Cr – cropped rails
DR – defective rails

Th – normative tonnage
Th (concrete steel) = 700 mil. gross t.; Th (wood) = 600 mil. gross t.

* Opposite system of logical inequations corresponding to “NO”.

Vsp = Vr

Reconsideration of design speeds towards the decrease

Investment request

Yes

No

Analysis of causes

No

Yes

Restrictions by engineering

Structures, machined and other elements

Yes

No

Costs of M&R

Cm < Cr

Yes

No

(Th < Tn) * (Tres > Tad)

Yes

No

Maintenance

Forming of ranking list of sections

Sect 6

Sect 10

Sect 7

Sect 1

Sect 2

Sect 9

Sect 8

Sect 10

Sect 4

Sect 3

Sect 5

Sect 11

Sect 12

Sect 13

Sect 14

Legend

Roadbed deformation

Section 1

Section 2

Section 3

Section 4

TOTAL

<table>
<thead>
<tr>
<th>Section</th>
<th>Roadbed deformation</th>
<th>Single rail removal</th>
<th>Cropped rails</th>
<th>Number of defective clamps</th>
<th>Number of pumping sleepers</th>
<th>Perturbation of gauge geometry</th>
<th>Places of provisional restoration</th>
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</thead>
<tbody>
<tr>
<td>Sect 6</td>
<td>0.44</td>
<td>0.05</td>
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<tr>
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<td>0.02</td>
<td>0.02</td>
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<tr>
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<tr>
<td>Sect 5</td>
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<td>Sect 11</td>
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<td>Sect 14</td>
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<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Section priority

1
2
3
4

Object

section

Length of section, km

Handled tonnage, mil gross t.

Yes

No

Yes

No

Yes

No

Yes

No

Yes

No

Yes

No

Analysis of causes

Restrictions by engineering

Structures, machined and other elements

Vsp = Vr

No

Investment request

Th < Tn

(Tres > Tad)

M – maintenance

Vr – speed of freight train

Vsp – specified speed

Th – handled tonnage

Cr – cropped rails

DR – defective rails

Th (concrete steel) = 700 mil. gross t.; Th (wood) = 600 mil. gross t.

Vpas – speed of passenger train

Vfr – speed of freight train

CR – cropped rails

DR – defective rails

Legend
Efficiency of URRAN in generation of track maintenance planning

KARYMSKAYA — TARSKAYA LINE

BEFORE REPAIR

Failure rate per year km: $40,07 \times 10^{-2}$

AFTER REPAIR

Failure rate per year km: $5 \times 10^{-3}$

TECHNICAL CHARACTERISTICS

Length: 8,731 km
Freight traffic: 129.9 mil gross t
Tonnage handled: 991.22 mil gross t

TECHNICAL EFFECTS

- Technical: Reduction of failure rate by $4,02 \times 10^{-2}$ per year km
- Economic: Reduction of maintenance cost by 13.1 mil RUB

This line was included into the maintenance plan based on URRAN methodology, which was executed.
Efficiency of URRAN in generation of track maintenance planning

**ZUDYRA — ULYAKAN LINE**

**BEFORE REPAIR**

- **Failure rate**
  - Intolerable
  - Undesirable
  - Tolerable
  - Negligible

- **Track coordinate, km**
  - Failure rate, per year km: $8.2 \times 10^{-2}$

**AFTER REPAIR**

- **Failure rate**
  - Intolerable
  - Undesirable
  - Tolerable
  - Negligible

- **Track coordinate, km**
  - Failure rate, per year km: $4 \times 10^{-3}$

**EFFECTS**

- **Technical**
  - Reduction of failure rate by $4.2 \times 10^{-2}$ per year km

- **Economic**
  - Contingent losses: maintenance cost $29,61$ mil RUB

**TECHNICAL CHARACTERISTICS**

- **Length**: 9,974 km
- **Freight traffic**: 37.5 mil gross t
- **Tonnage handled**: 599.87 mil gross t

This line was not recommended by URRAN to be included into the rank, but repair was performed.

Scheduled for maintenance based on URRAN methodology in 2018. Overhaul performed in 2014.
Efficiency of URRAN in generation of track maintenance planning

**ST. PUNKT 151 KM — TAHTAIR LINE**

**BEFORE REPAIR**

- **Failure rate, per year km**
  - Intolerable
  - Undesirable
  - Tolerable
  - Negligible

- **Track coordinate, km**
  - Failure rate per year km: $5 \times 10^{-2}$

**AFTER REPAIR**

- **Failure rate, per year km**
  - Intolerable
  - Undesirable
  - Tolerable
  - Negligible

- **Track coordinate, km**
  - Failure rate per year km: $1.3 \times 10^{-1}$

**TECHNICAL CHARACTERISTICS**

- **Length**: 13,114 km
- **Freight traffic**: 45 mil gross t
- **Tonnage handled**: 1000.7 mil gross t

**EFFECTS**

- **Technical**
  - Increase of failure rate by $8 \times 10^{-2}$ per year km

- **Economic**
  - Increase of costs for running maintenance of the line by 5,86 mil RUB

Track line that should have been repaired based on URRAN methodology, but repair eventually was not performed.
Practical results of risk management (1)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of pedestrian injury at crossings</td>
<td>Improved pedestrian safety at crossings</td>
</tr>
<tr>
<td>Recommendations for pedestrian crossings renovation</td>
<td></td>
</tr>
<tr>
<td>Risk of rolling stock derailment due to broken bogie solebar</td>
<td>15 % reduction of the number of broken solebars</td>
</tr>
<tr>
<td>Recommendations for scheduled condition inspection of solebars to</td>
<td></td>
</tr>
<tr>
<td>identify cracks and prevention of destruction</td>
<td></td>
</tr>
<tr>
<td>Risk of corrosion of railway bridges</td>
<td>Yearly saving of 40 mln rub.</td>
</tr>
<tr>
<td>Recommendations for timing of painting</td>
<td></td>
</tr>
<tr>
<td>Risk of failure of railway track</td>
<td>Yearly reduction of maintenance costs by 8 mln rub. per 1000 km.</td>
</tr>
<tr>
<td>Recommendations for maintenance assignment based on risk level</td>
<td></td>
</tr>
</tbody>
</table>
### Practical results of risk management (2)

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Recommendations</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire risk</strong> of locomotives (traction substations, computer centers)</td>
<td>Recommendations for scheduled inspection of fire safety status of locomotives (traction substations, computer centers). Identification of fire hazard states</td>
<td>40-60 % reduction of the number of fires. Economic effect of about 10 mln rub. per year</td>
</tr>
<tr>
<td><strong>Professional risks</strong></td>
<td>Recommendations for improved occupational safety</td>
<td>10 % reduction of the number of incidents per year. Economic effect of 50 mln rub. per year</td>
</tr>
<tr>
<td><strong>Environmental risks</strong></td>
<td>Recommendations for measures to reduce environment pollution. Assessment of the economic efficiency of measures</td>
<td>25 % reduction of water and air pollution. Economic effect of 88 mln rub. per year</td>
</tr>
<tr>
<td><strong>Traffic safety risks</strong></td>
<td>Recommendations for identification of flawed technical systems and human errors. Development of measures for improved train traffic safety</td>
<td>Improved train traffic safety</td>
</tr>
</tbody>
</table>
Structure diagram of risk management in railway transportation

REGISTERS of risks of services (functional branches and subsidiaries)
- Track:
  - ...
  - ...
  - ...
- Signalling:
  - ...
  - ...
  - ...
- Motive Power:
  - ...
  - ...
  - ...

REGISTERS of factors that cause risks
- Track:
  - ...
  - ...
  - ...
- Signalling:
  - ...
  - ...
  - ...
- Motive Power:
  - ...
  - ...
  - ...

REGISTERS of sources of information on the status of factors
- ...
- ...
- ...

METHODS of factor analysis (mutual dependence between factors and risks)
- ...
- ...
- ...

METHODS of risk assessment (taking into account the development of measures for reduction of the effects of risk factors and preventive measures scenarios)
- ...
- ...
- ...

REGISTER of corporate risks JSC RZD and their classification features:
- ...
- ...
- ...

REGISTERS of risks of services (functional branches and subsidiaries)
REGISTERS of factors that cause risks
REGISTERS of sources of information on the status of factors
METHODS of factor analysis (mutual dependence between factors and risks)
METHODS of risk assessment (taking into account the development of measures for reduction of the effects of risk factors and preventive measures scenarios)
Intellectual statistics-based data analysis (with the example of the analysis of average daily performance of a locomotive)

1) Over 50 factors affecting the average daily performance of a locomotive

2) Statistics of each factor’s values

3) Unknown are the values of a complete set of factors that would allow using classic formulas

A MODEL IS REQUIRED THAT WOULD SIMULTANEOUSLY TAKE INTO ACCOUNT A NUMBER OF FACTORS
Successful asset management requires reliable information and knowledge of assets conditions, productivity, risks and costs, as well as their interrelation. (ISO 55000:2014)

Establishment of a single information environment for railway equipment developers, manufacturers and operators, as well as maintenance enterprises based on the Single Corporate Platform for Management of Resources, Risks and Dependability at Lifecycle Stages of Railway Facilities (EKP URRAN)

Provision of reliable, complete and timely information on company assets management
Integration of large amounts of raw data in SCP URRAN

Collection and processing of large amounts of heterogeneous information, including raw data, for fullest possible list of parameters of infrastructure facilities obtained by means of diagnostics.

Multidimensional non-linear statistical data analysis

Functions:
- real-time operation of infrastructure and rolling stock
- maintenance
- monitoring, prediction of further development
- condition-based planning of repairs

Access of executives, engineers and experts to information from any workstation connected to the JSC RZD Intranet

Analysis, monitoring, prediction of development, planning of repairs based on risk assessment

Provision of information to users

Acquisition, storage and processing of data from primary ACSs

CDI
DI
Line-level units
IMMC
IS ASUI
KSPD IZHT
...

Ranking matrix at the beginning of the observation period

Ranking matrix at the end of the observation period

Track condition map

www.railway-asset-management.org
Actions to address risks and opportunities for the asset management system (clause 6.1)

Recommended Evidence

✓ Risk management framework, processes and risk assessment criteria
✓ Risk management governance and escalation processes
✓ Corporate risk matrix (combines risk assessment criteria)
✓ Evidence of active use of risk management techniques and reliability engineering methods
✓ Risk registers at various levels of the organisation
  ▪ Alignment of risk assessments and risk registers
  ▪ Lifecycle cost models and outputs relating to costs, work volumes, performance and risk
  ▪ Process(es) for monitoring and assuring risk treatment actions and, where appropriate, closure of risks through appropriate planning and execution of work
  ▪ Traceability back to a common risk management approach and Asset Management decision making criteria (of which the risk assessment criteria are one example)
Thank you for your attention!