Risk based decision making for Russian Railways

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The problem of managerial decision-making

Knight at the crossroads: Where should I go to?
## Infrastructure and rolling stock facilities of JSC RZD

### Infrastructure:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Length/Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of operational tracks</td>
<td>85 200 km</td>
</tr>
<tr>
<td>Length of electrified lines</td>
<td>43 100 km</td>
</tr>
<tr>
<td>Lines equipped with signalling equipment</td>
<td>62 196 km</td>
</tr>
<tr>
<td>Railway stations</td>
<td>5 428</td>
</tr>
<tr>
<td>Traction substations</td>
<td>1 402</td>
</tr>
<tr>
<td>Service units (track divisions)</td>
<td>742</td>
</tr>
</tbody>
</table>

### Rolling stock fleet:

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight locomotives (electric and diesel)</td>
<td>11 191</td>
</tr>
<tr>
<td>Freight cars of all types and owners</td>
<td>1 600 000</td>
</tr>
<tr>
<td>Shunting engines (diesel)</td>
<td>6 016</td>
</tr>
<tr>
<td>Long-distance passenger cars</td>
<td>24 100</td>
</tr>
<tr>
<td>Commuter cars</td>
<td>15 600</td>
</tr>
<tr>
<td>Motive power and car depots</td>
<td>411</td>
</tr>
</tbody>
</table>
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."
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
Purpose of URRAN introduction: increase of the efficiency of railway transport operation based on adaptive management under the conditions of scarce resources
Risk definition and Regulatory support of risk management in railway transportation

According to GOST 33433 International standard. Functional safety. Risk management in railway transportation:

Risk is the combination of the probability and consequences of an event.

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.
JSC RZD risk types classification

**URRAN documents 2011-2016**

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSC RZD Regulations for risk management</td>
<td>1</td>
</tr>
<tr>
<td>International standard (GOST)</td>
<td>2</td>
</tr>
<tr>
<td>National standard (GOST R)</td>
<td>6</td>
</tr>
<tr>
<td>JSC RZD standard (STO RZD)</td>
<td>19</td>
</tr>
<tr>
<td>Concept</td>
<td>2</td>
</tr>
<tr>
<td>Regulatory and guidance documentation (methodologies, guidebooks, recommendations, classifications, norms, etc.)</td>
<td>121</td>
</tr>
</tbody>
</table>

**2017-2018**

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>International standard (GOST)</td>
<td>2</td>
</tr>
<tr>
<td>National standard (GOST R)</td>
<td>1</td>
</tr>
<tr>
<td>JSC RZD standard (STO RZD)</td>
<td>4</td>
</tr>
<tr>
<td>Regulatory and guidance documentation (methodologies, guidebooks, recommendations, classifications, norms, etc.)</td>
<td>29</td>
</tr>
</tbody>
</table>

**URRAN Single Corporate Platform (ÉKП URRAN)**

- **Federal law** On the protection of the environment dated 10.01.2002 No. 7-F3
- **Federal law** On industrial safety of hazardous industrial facilities dated 21.07.1997 No. 116-F3
- **TR CU 001/2011** On the safety of railway rolling stock
- **TR CU 002/2011** On the safety of high speed railway transportation
- **TR CU 003/2011** On the safety of railway infrastructure
- **Labor code of the Russian Federation**
- **Fl. No. 123-FZ Technical regulations on fire safety requirements**
Object and functional system hierarchy of Russian railways according to ISO 55001

**Railway Technical Systems**
- Railway track: rails, sleepers, fastenings, ballast, etc.
- Railway automation and remote control: relays, switches, cables, etc.
- Railway power supply: lights, relays, cables, etc.
- Railway telecommunications: supports, cables, switches, etc.
- Developing manufacturing, operation, personnel: KGO, ASP, OD CL, AFU, etc.
- Electric equipment: braking equipment, diesel equipment, electric traction machines, safety devices, etc.
- EMUs: electric locomotives, diesel locomotives, DMUs, etc.

**Services**
- Passenger traffic
- Freight traffic

**Processes**
- Traffic management
- Railway infrastructure and rolling stock maintenance, etc.

**Human Resources**
- Developers
- Manufacturers
- Suppliers
- Operational personnel
- Passengers, etc.

**Reliability**
- Reliability of service rendering
- Reliability of process
- Reliability of system
- Reliability of element

**Safety**
- Safety of service rendering
- Safety of process
- Safety of system
- Safety of element

**Risks related to violations of service rendering**
- Failure in infrastructure availability
- Failure of a rolling stock

**Risks related to process violations**
- Process violation

**Risks related to system failures**
- Complete failure
- Partial failure
- Dangerous failure

**Risks related to an element’s failure**
- Failure, damage, defect, error
Risk assessment principles

**MEM PRINCIPLE**
MEM - Minimum Endogenous Mortality: “Hazard related to a new system shall not increase the level of minimum endogenous mortality for a person”.

**GAMAB PRINCIPLE**
GAMAB (Globalement Au Moins Aussi Bon (France): “All new systems shall in total perform globally at least as good as any compared existing system”.

**ALARP PRINCIPLE**
ALARP (As Low As Reasonably Practicable): “Acceptable risk level is such a level of risk that cannot be reduced further and so, expenditures spent to reach it are economically beneficial”.
Typical levels of event rates

<table>
<thead>
<tr>
<th>Rate</th>
<th>Event frequency per year, $f$</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequent</strong></td>
<td>$f &gt; 10^{-3}$</td>
<td>Can occur frequently. Continuous hazard</td>
</tr>
<tr>
<td><strong>Probable</strong></td>
<td>$5 \times 10^{-4} \leq f &lt; 10^{-3}$</td>
<td>Repeated occurrence. Frequent occurrence of hazard is anticipated.</td>
</tr>
<tr>
<td><strong>Occasional</strong></td>
<td>$10^{-4} \leq f &lt; 5 \times 10^{-4}$</td>
<td>Probability of repeated occurrence. Repeated occurrence of hazard is anticipated.</td>
</tr>
<tr>
<td><strong>Remote</strong></td>
<td>$5 \times 10^{-5} \leq f &lt; 10^{-4}$</td>
<td>Probability of the event occurring sometimes during the life cycle of a facility. Grounded expectation of hazard occurrence.</td>
</tr>
<tr>
<td><strong>Improbable</strong></td>
<td>$10^{-5} \leq f &lt; 5 \times 10^{-5}$</td>
<td>Probability of occurrence is unlikely but possible. Hazard can presumably occur in extraordinary cases.</td>
</tr>
<tr>
<td><strong>Incredible</strong></td>
<td>$f \leq 10^{-6}$</td>
<td>Probability of occurrence is very unlikely. Hazard cannot presumably occur.</td>
</tr>
<tr>
<td>Typical levels of consequences severity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Catastrophic</strong></td>
<td>1 or more dead, or 5 or more railway employees critically injured or Train damaged to the point of being put out of the fleet park or Damage to infrastructure facility in the size of over 5000 MW</td>
<td>1 or more dead, or 5 or more railway employees critically injured or Threat to environment caused emergency of federal or interregional scale</td>
</tr>
<tr>
<td><strong>Critical</strong></td>
<td>Up to 5 railway employees critically injured or 1 dead, or 1 or more people critically injured as a result of deliberate or careless actions of the victim or other persons who are not railway employees or Damage to rolling stock requiring to do capital repair for its operation recovery or Damage to infrastructure facility in the size of 1500 to 5000 MW or Total loss of goods</td>
<td>Up to 5 railway employees critically injured. 1 dead, or 1 or more people critically injured as a result of deliberate or careless actions of the victim or other persons who are not railway employees. or Threat to environment caused emergency of regional or intermunicipal scale</td>
</tr>
<tr>
<td><strong>Marginal</strong></td>
<td>Mid-size damage to health or Damage to rolling stock requiring to do mid-size or depot repair for its operation recovery or Damage to infrastructure facility in the size of from 500 to 1500 MW or Partial loss of goods</td>
<td>Mid-size damage to health or Threat to environment caused emergency of local or municipal scale</td>
</tr>
<tr>
<td><strong>Insignificant</strong></td>
<td>Minor damage to health or Damage to rolling stock requiring to do running repair for its operation recovery or Damage to infrastructure facility in the size of less than 500 MW</td>
<td>Minor damage to health or Insignificant threat to environment</td>
</tr>
</tbody>
</table>
Guidelines for construction of corporate risk matrix were developed for the purpose of creating a single method for representation of risk evaluation results as regards railway infrastructure facilities and rolling stock operation.
**Risk evaluation**

<table>
<thead>
<tr>
<th>HAZARD RATE</th>
<th>ESTIMATION OF RISK DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENT</td>
<td>Undesirable</td>
</tr>
<tr>
<td>PROBABLE</td>
<td>Tolerable</td>
</tr>
<tr>
<td>OCCASIONAL</td>
<td>Tolerable</td>
</tr>
<tr>
<td>REMOTE</td>
<td>Negligible</td>
</tr>
<tr>
<td>IMPROBABLE</td>
<td>Negligible</td>
</tr>
<tr>
<td>INCREDIBLE</td>
<td>Negligible</td>
</tr>
<tr>
<td>INSEIGNIFICANT</td>
<td>MARGINAL</td>
</tr>
</tbody>
</table>

**SEVERITY LEVELS OF HAZARD CONSEQUENCES**

**Undesirable**
Risks are tolerated if the costs for their reduction are obviously disproportionate to the achievable profit.

**Tolerable**
Risk are tolerated if the costs for their reduction exceed the achievable improvements.

\[
K = \frac{R_{tol}}{R_{neg}} \quad K = k_f \cdot k_c
\]

\[
A = \frac{a_{max} \cdot a_{min} \cdot F_{max}}{F_{min}}
\]

- safety factors for the upper and the lower limits of a frequency range

\[
A_0 = \frac{a_{max} \cdot F_{max} \cdot F_{min}}{a_{min}}
\]

- frequency range center

\[
B = \frac{b_{max} \cdot b_{min} \cdot C_{max}}{C_{min}}
\]

- safety factors for the upper and the lower limits of a damage range

\[
B_0 = \frac{b_{max} \cdot C_{max} \cdot C_{min}}{b_{min}}
\]

- damage range center
## Decision criteria

<table>
<thead>
<tr>
<th>Risk level</th>
<th>Value range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerable</td>
<td>$R &gt; R_{tol}$</td>
</tr>
<tr>
<td>Undesirable</td>
<td>$0,1 \cdot R_{tol} \leq R &lt; R_{tol}$</td>
</tr>
<tr>
<td>Tolerable</td>
<td>$0,01 \cdot R_{tol} \leq R &lt; 0,1 \cdot R_{tol}$</td>
</tr>
<tr>
<td>Negligible</td>
<td>$R &lt; 0,01 \cdot R_{tol}$</td>
</tr>
</tbody>
</table>
Presentation of risk assessment results in the form of risk matrix

- m=6 is the number of frequency scale levels; n=4 is the number of consequence scale levels (if m and n are even numbers, the cell field is centrally symmetrical); $A_3$, $A_2$, ..., $A_1$ are the threshold levels of frequency scale; $B_2$, $B_1$, ..., $B_1$ are threshold levels of consequence scale; K is the relative spacing of risk scale; $R_{alw}$ is the allowable risk level.

- The purpose of the risk matrix is to identify the numeric values of the threshold levels of the frequency and consequence scales based on the specified $R_{alw}$ and available statistical data on the frequency and consequences of the considered undesirable (risk) event.
Algorithm of works on maintenance of railway track section according to principles of ISO 55001

Legend

- Process
- Criterion

M – maintenance
V – real speed
Vsp – specified speed
Th – handled tonnage
Tn – normative tonnage
Tn (concrete steel) = 700 mil. gross t.; Tn (wood) = 600 mil. gross t.

* Opposite system of logical inequations corresponding to “NO”

Forming of ranking list of sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Section 2</th>
<th>Section 3</th>
<th>Section 4</th>
<th>Section 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sect 1</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 2</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 3</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 4</td>
<td>0.13</td>
<td>0.27</td>
<td>0.27</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 5</td>
<td>0.27</td>
<td>0.27</td>
<td>0.27</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 6</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 7</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 8</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 9</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 10</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 11</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 12</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Sect 14</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.07</td>
</tr>
</tbody>
</table>

| Section priority | 2 | 1 | 2 | 2 |
Efficiency of URRAN in generation of track maintenance planning

This line was included into the maintenance plan based on URRAN methodology, which was executed in 2014.

Karymskaya — Tarskaya line

### Technical characteristics
- **Length**: 8,731 km
- **Freight traffic**: 129,9 mil gross t
- **Tonnage handled**: 991,22 mil gross t

### Before Repair
- **Failure rate, per year km**: $40.07 \cdot 10^{-2}$

### After Repair
- **Failure rate, per year km**: $5 \cdot 10^{-3}$

**EFFECTS**
- **Technical**: Reduction of failure rate by $4,02 \cdot 10^{-2}$ per year km
- **Economic**: Reduction of maintenance cost by 13,1 mil RUB
Efficiency of URRAN in generation of track maintenance planning

Zudyra — Ulyakan line

**BEFORE REPAIR**

<table>
<thead>
<tr>
<th>Failure rate, per year km</th>
<th>Track coordinate, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2\times10^{-2}</td>
<td></td>
</tr>
</tbody>
</table>

**AFTER REPAIR**

<table>
<thead>
<tr>
<th>Failure rate, per year km</th>
<th>Track coordinate, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>4\times10^{-3}</td>
<td></td>
</tr>
</tbody>
</table>

Scheduled for maintenance based on URRAN methodology in 2018. Overhaul performed in 2014.

**Technical characteristics**

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

**EFFECTS**

- **Technical**: Reduction of failure rate by 4.2\times10^{-2} per year km
- **Economic**: Contingent losses: maintenance cost 129.61 mil RUB

This line was not recommended by URRAN to be included into the rank, but repair was performed in 2014.
Efficiency of URRAN in generation of track maintenance planning

Technical characteristics
- Length: 13,114 km
- Freight traffic: 45 mil gross t
- Tonnage handled: 1,000,7 mil gross t

Before repair
- St. Punkt 151km — Tahtair line
- Failure rate, per year km: $5 \cdot 10^{-2}$
- Intolerable
- Undesirable
- Tolerable
- Negligible

After repair
- Failure rate, per year km: $1,3 \cdot 10^{-1}$
- Intolerable
- Undesirable
- Tolerable
- Negligible

Recommended for repair based on URRAN in 2014.
Residual operation — 241.8 mil gross t

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

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

Effectiveness of URRAN in generation of track maintenance planning
Fire-related risks at traction rolling stock

<table>
<thead>
<tr>
<th>Systems and components of a diesel locomotive</th>
<th>Fire frequency/ per section a year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel exhaust system</td>
<td>$5 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Diesel (other)</td>
<td>$3 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Diesel drainage system</td>
<td>$1 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Cooling system</td>
<td>$1 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Diesel lubricant system</td>
<td>$5 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Diesel fuel system</td>
<td>$5 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Turbo charger</td>
<td>$1 \cdot 10^{-3}$</td>
</tr>
<tr>
<td>Traction motor</td>
<td>$8 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Electrical system and equipment</td>
<td>$1 \cdot 10^{-3}$</td>
</tr>
</tbody>
</table>
Primary tasks of the situation center

- Safety monitoring of railway infrastructure and rolling stock in operation
- Forecasting the risk of traffic incidents and other events, development of preventive measures
- Quick response to traffic incidents and emergencies, recovery operations
- Reporting to JSC RZD top management of traffic, operations, transportation and fire safety at JSC RZD infrastructure facilities
- About 2 000 messages as regards traffic safety are processed daily by operational shift dispatchers
- About 1 000 000 messages as regards traffic safety are processed monthly by analysis unit specialists
Functions of the situation center

Traffic safety
Transportation Safety
Fire Safety
Monitoring of weather conditions
Dispatcher WS Functionality

- Automation of data search using key parameters: time, place, site
- Real-time automated access to industry-specific systems (over 20 ACSs and WSs)
- Custom interface with capability to interface with new resources
Shared panel of situation center duty shift
Single industrial platform
to support dependability and safety of business processes based on risk estimation results of Russian railways in compliance with ISO 55000:2014

| I. System for comprehensive management of operational assets at all lifecycle stages | Improvement of work productivity  
Intensification of company infrastructure utilization  
Reduction of industrial disaster risk  
Improvement of capital investment and operational costs efficiency  
Decision-making based on asset condition evaluation  
Improvement of condition and failure prediction accuracy  
Risk, income, costs management at all lifecycle stages of an asset |
|---|---|
| 1.1. Integrated automated system for recording, investigation and analysis of technical failures (KAS ANT) | Reduction of the number of technical failures  
Improvement of the quality of products acquired from suppliers  
Reduction of downtime at mass production enterprises |
| 1.2. Integrated automated system for recording, investigation and analysis of process violations (KASAT) | Improvement of the quality of business processes  
Reduction of non-production losses  
Improvement of work productivity and personnel motivation |
| 1.3. Corporate automated system for employee workplace and fire safety knowledge monitoring | Reduction of labor effort of organization, holding and documentation of training  
Elimination of the human factor in employee rating  
Improvement of technical training planning efficiency |
| 1.4. Integrated automated system for investment projects performance monitoring | Improvement of timeliness and efficiency of investment projects implementation  
Improvement of accuracy and efficiency of information exchange among project managers, customers, supervisors, asset holders and contractors |
### II. Innovative technologies of supervision and control of technical safety

Intended for condition monitoring of fire, industrial and environmental safety, analysis and planning of related activities.

- Improvement of fire, industrial and environmental safety
- Reduction of charged penalties
- Optimization of insurance expenditures
- Improvement of the efficiency of capital and operational expenditures related to the above safety activities

#### 2.1. Automated systems for industrial safety management of dangerous manufacturing facilities

- Reduction of charged penalties related to industrial safety violations
- Optimization of insurance of dangerous manufacturing facilities
- Electronic delivery of information on operational supervision of dangerous manufacturing facilities to the Federal Environmental, Industrial and Nuclear Supervision Service of Russia
- Ensuring accuracy and immediacy of information on dangerous manufacturing facilities
- Improvement of industrial safety

#### 2.2. Automated system for fire safety management of protected facilities

- Improvement of efficiency of fire safety supervision of protected facilities
- Improvement of efficiency of fire prevention activities
- Reduction of charged penalties related to fire safety violations
- Improvement of efficiency of fire safety activities implementation through objective evaluation of fire risks

#### 2.3. Automated system for environmental safety and nature protection activities management

- Improvement of efficiency of natural resources management supervision
- Improvement of the accuracy and immediacy of accountancy through automated document management
- Reduction of costs related to submission of reporting documentation to national executive authorities through electronic reporting
- Improvement of objectivity of natural resources management analysis
- Insurance of efficiency of environmental protection activities planning
- Insurance of efficiency of environmental protection activities
- Reduction of charged penalties related to environment protection legislation
- Reduction of natural resources management payments to the minimum possible level
Single industrial platform
to support dependability and safety of business processes based on risk estimation results of Russian railways in compliance with ISO 55000:2014

III. Situation Center

Intended for reduction of harm caused by incidents, accidents, emergencies, industrial disasters through monitoring of infrastructure facilities operation and support of recovery of reference operating modes.

The technology is designed for large factories, retail chains, industrial facilities for business process safety monitoring and immediate incident recovery.

- Reduction of harm caused by incidents, accidents, emergencies, industrial disasters.
- Improvement of manageability and interaction under emergency conditions through integration of major Russian enterprises into the national control system of Emergency and Defense Ministries situation centers.

Traffic safety
Transportation security
Fire safety
Monitoring of weather conditions
There is no limit for perfection, once started you should continue...