Welcome to the ‘HIGH SCHOOL’ for RAM / LCC experts

Crash Course RAM / LCC

Andreas Heinzmann

International Competence Centre Rail GmbH
Mitteldorfstrasse 17
CH – 6315 Oberaegeri
Switzerland

Mobil (D): +49 172 622 32 73
andreas.heinzmann@cc-rail.com
www.cc-rail.com
A brief overview ...

- Day 1 : Module 1 – Introduction to RAM
  - Requirements within standards and regulations
  - Normative requirements: IRIS, IEC 62278, EN 50126-1, TR 50126-3
  - RAM life cycle phases and RAM tasks at tender, design and demonstration phases

- Day 2 : Module 2 – Reliability, Availability, RAM Demonstration and FRACAS
  - Basic calculation methods, Reliability function, Availability up and down states
  - Failure Mode and Effects Analysis (FMEA)
  - Failure Reporting and Corrective Action System (FRACAS)

- Day 3 : Module 3 – Maintainability, Maintenance and Life Cycle Cost
  - Maintainability as a design objective
  - Preventive and Corrective Maintenance Analysis, LCC calculation

- Day 4 – Summary, tips and tricks, RAM and Integrated Logistic Support, final test
  - Tips and tricks for RAM analyses and quotations
  - Written examination and end of the training
A brief introduction to the topic ...

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Availability</th>
<th>Maintainability</th>
<th>Safety</th>
<th>LCC Life Cycle Cost</th>
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</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> Ability to perform as required for a given time interval under given conditions</td>
<td><strong>Definition:</strong> Ability to be in a state to perform as and when required, under given conditions, assuming that the necessary external resources are provided</td>
<td><strong>Definition:</strong> Ability to be retained in, or restored to a state in which it can perform as required, under given conditions of use and maintenance</td>
<td><strong>Definition:</strong> Safety is the state of being protected against failure, damage, error, accidents, which could be considered non-desirable</td>
<td><strong>Definition:</strong> Cost of ownership</td>
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<tr>
<td><strong>Measure:</strong> E.g. Mean Distance Between Failures (MDBF) according to a specified failure category (e.g. delay)</td>
<td><strong>Measure:</strong> E.g. number of up time hours compared to total hours or number of trains of a fleet available in the morning</td>
<td><strong>Measure:</strong> E.g. Mean Time To Repair (MTTR), man-hours, tools</td>
<td><strong>Measure:</strong> E.g. Safety Integrity Level (SIL), Tolerable Hazard Rate (THR)</td>
<td><strong>Measure:</strong> E.g. maintenance cost, energy consumption calculated and validated according to an agreed model</td>
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IRIS Requirements

Requirements with a view to RAM Management

- Maintainability of the product shall be an integrated part of the design and development Process
- Standardized routines for the Maintenance of software shall be established and recorded according to IEC 62278 (EN 50126), IEC 62279 (EN 50128), IEC 62425 (EN 50129) or other agreed equivalent models in accordance with the design and development Process
- The organization shall have a documented Procedure in place to cover all the aspects of RAMS activities, including:
  - Calculation and documentation
  - Data collection, analysis and improvement action plan set up
  - Implementation of defined tasks of the action plan
  - Implementation of defined tasks of the action plan
## RAM programme and life cycle phases

<table>
<thead>
<tr>
<th>Tender Phase</th>
<th>Design Phase</th>
<th>Operation Phase</th>
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<td>1</td>
<td>Concept</td>
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<tr>
<td>2</td>
<td>System definition and application conditions</td>
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<td>2</td>
<td>Risk analysis</td>
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<td>3</td>
<td>Risk analysis</td>
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<td>4</td>
<td>System requirements</td>
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<tr>
<td>5</td>
<td>Apportionment of system requirements</td>
<td></td>
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<tr>
<td>6</td>
<td>Design and implementation</td>
<td></td>
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<tr>
<td>7</td>
<td>Manufacture</td>
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<td>8</td>
<td>Installation</td>
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<tr>
<td>9</td>
<td>System validation</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>System acceptance</td>
<td></td>
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<td>Preliminary Analysis (1,2,4,5)</td>
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</table>
Survival function with the example of human beings

The probability of survival for a 60-years old man is 80%
80% of men will reach an age of 60 years or more, this is a probability of failure of 20%
Bathtub curve – schematic diagram

- **Early failures** (‘infant mortality’)
- **I. Decreasing failure rate**
- **II. Constant failure rate**
- **III. Increasing failure rate**
- **Random failures**
- **Wear out failures**
- **Observed failure rate**
Reliability Performance Indicators

Reliability parameters – examples for repairable items

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Dimension</th>
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</thead>
<tbody>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failure</td>
<td>Time</td>
</tr>
<tr>
<td>MDBF</td>
<td>Mean Distance Between Failure</td>
<td>Distance</td>
</tr>
<tr>
<td>MCBF</td>
<td>Mean Cycles Distance Between Failure</td>
<td>Cycle</td>
</tr>
<tr>
<td>MTBSF</td>
<td>Mean Time Between Service (Affecting) Failure</td>
<td>Time</td>
</tr>
<tr>
<td>MDBSF</td>
<td>Mean Distance Between Service (Affecting) Failure</td>
<td>Distance</td>
</tr>
</tbody>
</table>
Failure Modes and Effects Analysis

Versions of the FMEA

- **Functional FMEA (System FMEA)**
  - Identification of weak points in the system layout and configuration
  - Analysis of the effect of functional failures
  - Derivation of improvement measures within the system architecture
  - Aim: Improve reliability

- **Design FMEA**
  - Identification of weak points in the system (component) design
  - Analysis of the potential failure modes of system components
  - Strengthening of component design (e.g. environmental resistance)
  - Aim: Improve reliability (quality)

- **Process FMEA**
  - Identification of weak points in the manufacturing process (also operation and maintenance)
  - Process failures (human errors, machines, methods, etc.) are analysed with regard to their impact on the system and/or components

- **Component FMEA**
Availability

Availability calculation using up and down states of a system

- Ratio of (Up’s) the operational time of an item and the total (possible) time

Availability $A = \frac{\sum \text{Up’s}}{\sum \text{Up’s} + \sum \text{Down’s}} = \frac{26 \text{ h}}{30 \text{ h}} = 0.87 = 87\%$

- Availability $A \ [%] = \frac{\text{Total time} - \text{Down time}}{\text{Total time}} \times 100$

- Or: Availability $A = \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}} \times 100$ with MDT = Mean Down Time
FRACAS – Failure Reporting, Analysis and Corrective Action System

- Systematic approach to gather and analyse field data with the aim of identifying weak areas and introducing corrective measures for improvement
- Key features: FRACAS closed loop and Failure Review Board (FRB)
Weak Point Analysis

Identification of weaknesses and derivation of corrective actions

Failure mode 1
Corrective action 1

Failure mode 2
Corrective action 2

Failure mode 3
Corrective action 3
Catalogue of basic requirements see VDI 2246 Part 2

- Ability to identify
- Accessibility
- Interchangeability
- Serviceability
- Inspection
- Testing
- Transportation
- Storage
- Standardisation

http://www.pixabay.com
Maintenance types according to EN 13306
‘Maintenance – Maintenance terminology’

Maintenance

Preventive Maintenance
- Conditioned Based Maintenance
- Scheduled, on request, or continuous
- Predetermined Maintenance

Corrective Maintenance
- Deferred
- Immediate

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Potential-to-functional failure interval for Conditioned Based Maintenance

- **Worsening**: Point where the failure starts to occur
- **Potential failure symptom**: Point where it can find out that an item is failing
- **P-F interval**: Lead time between the ability to detect a failure process and the actual loss of function

**Prerequisite:**

- **P-F interval needs to be long enough!**
Aspects for determining the maintenance strategy

- Safety and Availability
- Operation
- Environment
- Design (difficulty, complexity)
- Resources
  - Maintenance staff
  - Qualification
  - Workshop facilities
  - equipment
- Economic criteria and costs
- Laws, regulations, ordinances
- ...

Module 3 – Maintenance / Maintenance strategy
LCC cost elements – example for railway applications (rolling stock)

*Life cycle cost*

**Acquisition cost**
- Vehicles
- Initial spare part stock
- Strategic (main) spare parts
- Workshop and equipment
- Special tools
- (Initial) Training
- ...

**Operation cost**
- Driver and/or train attended
- Warehousing
- Logistic, transport
- Periodic training
- Energy consumption
- Cleaning (external/internal)
- Management and administration
- ...

**Maintenance cost**
- Preventive maintenance
  - Inspection
  - Service
  - Overhaul
- Corrective maintenance
  - Failures
  - Vandalism
  - Accidents
- Maintenance of spares
- ...

**Disposal cost**
- Disposal
- Replaced spare parts
- Operating materials
- Recycling
- ...

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Summary – RAM activities along the V-cycle

- **Operation profile**
  - System / Subsystem description

- **FMEA**
  - LRU/LLRU_ID
  - Failure effect and maintenance task identification

- **FTA / RBD**
  - FAIL_ID
  - Maintenance task analysis (planning and support)
  - Overall System reliability analysis

- **PM/CM-Analysis**
  - LRU/LLRU_ID
  - FAIL_ID

- **RCM / Field Experience / subcontractor recommendations**
  - Standard and authorities regulations

- **Field data**
  - FRACAS

- **Module 4 – Wrap-up**
Your contact at CC-Rail

Andreas Heinzmann
International Competence Centre Rail GmbH
CH – 6315 Oberaegeri
Switzerland
www.cc-rail.com
andreas.heinzmann@cc-rail.com

Mobil (D): +49 172 622 32 73
Phone (D): +49 333 977 33 37

I would be very happy to hear from you again.
If you leave me a message, I will aim to return within 24 hours.