Railway Maintenance
*Trends in Technology and management*

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LTU

Luleå University of Technology, Luleå
Our Strengths

- Leading-edge multidisciplinary applied research
- Our geographical location & climate
LTU is developing an attractive, sustainable society through:

- Research that brings changes through critical thinking
- Education that provides challenges
- Individuals who are trained to work together

Vision 2020
Key Figures - LTU

- Founded 1971
- Turnover SEK 1.6 billion (180 Million Euro)

- 17,000 students

- 1,600 Admin & Tech Staff
  - > 200 Professors
  - > 550 Teachers & Researchers
  - > 600 PhD students
- 82 Research Chair

- 60% External research funding
JVTC
RESEARCH PROFILE & PRIORITIES
STRATEGIC FOCUS OF JVTC IS ON MAINTENANCE OF RAILWAY ASSETS & SYSTEMS
TECHNOLOGY READINESS LEVEL-TRL

Overview

System Test, Launch & Mission Operations

Technology Demonstration

Technology Development

Research to Prove Feasibility

Basic/Applied Research

Contract research

Fundamental research

Technology Push

Market Pull

Technology to be explored, developed, assessed and used

2014 2025 2040

TRL 9
TRL 8
TRL 7
TRL 6
TRL 5
TRL 4
TRL 3
TRL 2
TRL 1
Core research areas

R&I = Research & Innovation

RAMS LCC Risk analysis

Condition Monitoring eMaintenance

Human Factors

Maintenance Optimization Methodologies & models
Design phase

- Function & Performance
- Application Environment
- RAMS, LCC & Risk analysis
- Maintenance program
- Safety, Environment, Sustainability, ROI

Research

Integrated Maintenance Solutions

Cost Effective Product Development & Life Cycle Management
Describing System state & behavior
Explaining
Predicting
Management and Control
Integrated Maintenance Solutions
Effective Asset & Production Management
Safety, Environment, Sustainability, ROI
Main Research Question

- Estimation of Remaining Useful Life
  - Component level
  - System level
  - System of system (SoS) level

Considering local & global risk scenario
Remaining useful Life (RUL) estimation

Expected Performance

Acceptable Limit

Time

Performance

Degradation starts

$x_1$

$x_2$

$x_3$

$P_1$

$P_2$

$P_3$

RUL loss rate
Data Segregation

- Components with no degradation
- Suspensions
- Maintenance limit
- Safety Limit
- ASME B31.3

Variables:
- Thickness (mm)
- MGT/Age (Years)

Data Segregation

- Segregation of data based on maintenance limits and safety limits.
Degradation Behaviour

- Wear depth (mm)
- MGT/Age (Years)
- Safety Limit
- Maintenance Threshold limit
- $T_{NOM}$
- ASME B31.3

The graph illustrates the degradation behaviour of a system over time, showing the relationship between wear depth and MGT/Age. The safety limit is indicated by the horizontal line at the bottom of the graph, and the maintenance threshold limit is shown by the dashed line. The graph also highlights the decision-making process through eMaintenance, which involves Facts (Data), Relationships (Information), and Patterns (Knowledge) leading to a Decision.
RAILWAY RESEARCH INFRASTRUCTURE

- CBM LAB
- RAILWAY RESEARCH CORRIDOR
- RAILWAY DATA CENTER
- eMaintenance LAB
Test facilities

Contact wire

Vision system

Track Logger

S&C Vision Logger

Track Stability

Machine Vision System Inspection

Wheel Profile

Truck Performance

Boden

Luleå
Wayside monitoring technologies

– Three wayside monitoring stations for forces.
– One station for wheel profile measurement.
– RFID-tagged vehicles for trending (~1400 vehicles).

Vehicle identification with RFID enable trending
CONDITION BASED MAINTENANCE

PREDICTIVE MAINTENANCE
PREDICTIVE MAINTENANCE

- Sensing
- Measurement
- Diagnostics of Faults-Failures
- Prognostics
- Context aware RUL
- PREDICTIVE ANALYTICS
- Decision Support Models
SENSEING

Science

Condition <-> Physical relationship <-> Measurable variable

Sensor technology <-> Engineering

Science, Engineering, Technology link
Science, Engineering, Technology link
Context-aware Decision Support Solutions for maintenance actions

Data Fusion & Integration

Information models

Knowledge models

Context models

Big Data Modelling & Analysis

Context sensing & adaptation

Link, Think & Reconfigure
Prescriptive Analytics delivers largest value
Understanding relations

Connectedness

Data

Information

Understanding patterns

Understanding knowledge

Understanding principles

Understanding wisdom
Information logistics and eMaintenance
THE NEW TECHNOLOGY FOR RAILWAY MAINTENANCE

• Industrial Internet (Industrial IoT)
• Digital Twin
Now's the time to switch on the internet of things...

Machines connected to the internet and "talking" to each other is a seismic development which promises to open up lucrative revenue streams, but adoption remains low.
THE FUTURE TECHNOLOGY RAILWAY MAINTENANCE

- Industrial Internet
- Digital Twin
Future Railway Maintenance Technology and Management solutions will greatly depend on development in IT capabilities and forces with respect to:

- **Mobility and Flexibility**
- **Robotics and Automation**
- **Big Data Analytics**
- **Cloud Computing & Storage**
- **Social Media (?)**
HOW DOES THE SWEDISH RAILWAY SECTOR LOOK TODAY?
Deregulated Swedish Railway Sector
What is e-maintenance?

e-Maintenance connects all the stake holders, integrates their requirements and facilitates optimal decision making in *real time* to deliver the planned and expected services from the assets and minimizes the total business risks.
Onboard monitoring. Impact from infra.

Wayside monitoring. Impact from traffic

Maintenance contractors Train operation

Trafikverket Infra. Managers

Maintenance contractors Infrastructure
Industrial data (O&M) is becoming the largest domain for big data analytics and target of data science.
Data analytics defines and decides business

It is not only labour-saving and cost efficient, the predictive power of data analytics can drive business forward.
Maintence Analytics

- Descriptive
  - What happened?
  - What is happening
- Predictive
  - What will happened?
  - Why will it happen?
- Prescriptive
  - What should I do?
  - Why should I do it?

- Enablers
  - Machine health reporting
  - Dashboards
  - Scorecards
  - Data warehousing
  - Data mining
  - Text mining
  - Web/media mining
  - Forecasting
  - Optimization
  - Simulation
  - Decision modeling
  - Expert systems

- Questions
  - Maintenance problems and opportunities
  - Accurate projections of the future states and conditions
  - Best possible Maintenance decisions and solutions
eMaintenance enabled bearings will open for new services connected to the bearing and its generated data.

- Remote diagnostics
- Planning of service
- Prognosis
- On line/ offline Statistics
- Safety and reliability
CONTEXT SENSING
AN EXAMPLE OF PREDICTIVE AND PRESCRIPTIVE ANALYTICS
E-Maintenance enabled bearing as a sensor for condition monitoring

- Error detection of bearing
- Error detection in boggie
- Detect rail damage
- Continuous scanning of rail
- Detect wheel damage
- Position of the car
- Load in the car
- Operation planning

Maintenance planning

- LKAB
- TRAFIKVERKET
Context aware eMaintenance decision support

Warning
CM indicates need for a system shutdown based on CI but....

RISK 1=0
RISK 2
RISK n

Risk for asset
Risk for business

SCENARIO 1
SCENARIO 2
RUL
Schematic of eMaintenance enabled bearing as sensor

Front end processes
- Customer Requirement

ERP

Back end processes
- Supply Chain

Sensor
- Embedded health card
- Variable Alarm System (Health & Performance)

Local Control- Room

Virtual Maintenance & Service Care Center

Product Support Center
Context driven decisions-
- To reduce total business risks

Three alternatives (CONTEXT DRIVEN)

❖ Reduce the speed and continue the journey if needed activate the actuators

❖ Reduce the speed and wait at the nearest Railway Station for support

❖ Stop the Train
Modern day integrated CBM systems are smart but they still lack the creative spark of humans.

Modern data fusion technologies and related instrumentation need to be further refined, developed and implemented for effective predictive and prescriptive solutions.”
Concluding remarks and Future directions

Technology of the type needed for the COMMERCIAL implementation of the CONTEXT DRIVEN CBM RAILWAY APPLICATIONS is still some way out but not far
THANK YOU

Please visit us

www.jvtc.ltu.se