IOT ENABLED

PREDICTIVE MAINTENANCE

Kalman Tiboldi
Chief Business Innovation Officer

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TVH GROUP

2 business units

**TVH PARTS**
- Material handling parts (MPA)
- Industrial equipment parts (IPA)
- Agricultural equipment parts (APA)

**TVH EQUIPMENT**
- Sales (trade & domestic)
- Rental
- Service & repair

6 business lines

Facts & figures

- > 6000 colleagues worldwide
- Consolidated turnover € 1,34 billion

TVH Equipment around the world
SMART LOGISTICS – PART OF INDUSTRY 4.0

Smart Products
Smart Mobility
Smart Logistics
Smart Grids
Smart Buildings
LOGISTICS 4.0 FOR LIFT TRUCK INDUSTRY

Intelligent trucks
- Truck equipped with electronic control unit
- Increased efficiency also from driver assistance systems

Fleet data management
- Fleet data services connect trucks with management tool
- Optimise truck fleet usage
- Financial and safety benefits

Automated trucks
- Full range of automated series trucks
- Enable automation of the entire material flow

System solutions
- Customised integrated intralogistics solutions
- Automated trucks combined with further hard- and software

Growth drivers
- Wage inflation

Safety – fewer accidents
- Increasing precision and reliability
- Flexibility, esp. in handling complex material flows

No “Industry 4.0” without “Intralogistics 4.0”

Source: KION Group AG - 2015
TECHNOLOGY ENABLED FLEET MANAGEMENT

Operational Fleet Monitoring and Management
Real-time equipment tracking, KPI management per truck, fleet and location

Equipment dispatching
Assigning equipment to customers

Technician scheduling
Location, skill requirement, shift of work based crew scheduling

Asset tracking
Linked to overall fleet management, allows the tracking of all goods and physical items allocated to fleet operations

Condition based, predictive maintenance
Remotely view and manage equipment servicing

Security and safety
Equipment and driver security during operation or while stopped, recovery of stolen vehicles
TYPES OF MAINTENANCE

Corrective Maintenance
Performed to identify, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to an operational condition.

Preventive Maintenance
Schedule of planned maintenance actions aimed at the prevention of breakdowns and failures. Preserve and enhance equipment reliability.

Predictive Maintenance
Techniques that help determine the condition of in-service equipment in order to predict when maintenance should be performed. Minimize disruption of normal operations, while allowing right time repairs.
CONDITION MONITORING

- **Temperature**
  - Cracked Housing

- **Sight**
  - Loose Bearing Housing
  - Loose Bolts
  - Seal Problem
  - Leaking Lubrication

- **Vibration**
Your equipment tells you precisely what kind of service it needs, where, why, and what its estimated life time will be without that service.

**Sense**
Raw data is collected from hundred or thousands of sensors, locally processed or transmitted wireless to remote monitoring.

**Decide**
Analyze the data, take decisions locally or through remote analytical services. Private and public data are combined using cloud-based services.

**Act**
Adapt and optimize the performance of the process locally or take actions to replace the part causing problems.

Remote monitoring and self optimizing

Predictive, condition-based Maintenance
Allocate and plan maintenance tasks according to the anticipated, measured or calculated condition of a component, device or system.

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**BUSINESS OPPORTUNITY**

**IBM**
- Reduction in maintenance costs: 25-30%
- Elimination of breakdown: 70-35%
- Reduction of downtime: 35-45%
- Increase in production: 35-45%

**Gartner**
- Average cost reduction moving from preventive to predictive maintenance: 10-20%

**Volvo**
- Repair cost reduction vs. average 2011-2014: 49-51%

By 2022, IoT will save consumers and businesses $1 trillion a year in maintenance, services and consumables.

Source: IBM – Published on Oct 27, 2016
Source: Gartner – Published on Oct 17, 2016
Source: Volvo Construction Equipment 2016
TECHNOLOGIES DRIVING INDUSTRY 4.0

- Autonomous robots
- Mobile
- Cloud Computing
- Augmented reality
- Big Data
- 3D Printing
- Artificial intelligence
- IoT
- Analytics
- Internet Of Things

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SMART PRODUCTS

Physical Components
Mechanical and Electrical Parts

Smart Components
Sensors, chips, storage, software, embedded operating system…

Connectivity Components
Ports, antennae, protocols, wired or wireless connections

STILL CUBEXX
CYBER-PHYSICAL WORLD

MERGING THE REAL AND VIRTUAL WORLDS
DIGITAL TWINS

SENSORS

DATA

ANALYTICS

VIRTUAL MODEL FOR PHYSICAL PRODUCTS
Design – BUILD – OPERATE

Design
3D CAD twin

Simulate
First born digital twin

Monitor
Physical asset twin
GENERATING VALUE FROM DATA

Physical Asset

Real-time data

Digital Twin

Ecosystems
Collaborative product development

Asset performance
Analytics-based performance optimization

New digital business model
Based on the data produced by the Twin
IMMERSION INTO THE VIRTUAL WORLD
SERVITIZATION

CAT
Construction Equipment

Volvo

Rolls Royce

ThyssenKrupp

Atlas Copco

KAESER
Built for a lifetime.

Tennant

services

STILL

GE

MAN

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EQUIPMENT-AS-A-SERVICE

Lifting capacity as a service

Reducing downtime
Extending asset life

Measuring the residual value

Pay-per-usage

Detecting and avoiding overloading

MOVING FROM PRODUCT TO SERVICE

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CONNECTED EQUIPMENT ECOSYSTEM

ORIGINAL EQUIPMENT MANUFACTURER (OEM)
- Real-time alerts
- Consolidated view
- Improvement proposals
- Technical specifications
- Maintenance procedures
- Digital twin API

CUSTOMER
- Real-time alerts
- Maintenance and service issues
- Data produced by equipment
- Real-time alerts & updates
- Maintenance services
- Improved user experience

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SMART LIFT TRUCKS

- GPS
- Camera
- Speed & Accelerometer
- Heavy load position
- Mast & steering sensor
- Load presence
- Proximity sensor
- Mast Tilt Angle
- Engine data
- Fuel
- Temperature
- Tyre pressure
- Oil condition
- Battery

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More than 15000 connected machines
EDGE GATEWAYS FOR PdM

- Multi-Input/Output
  - Digital, Analog, CAN-Bus, HDMI
- Communication aggregation
  - RFID, Bluetooth, ZigBee, LpWan, USB, LTE, WiFi
- Data caching, buffering and streaming
- Data aggregation, transformation and filtering
- Edge Data Visualization
- Event processing
- Real-time data analytics
- Real-time decision making
- Command processing

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REAL-TIME ANALYTICS AT THE EDGE

The **Value** comes from the **Information** that’s hardest to manage

IoT *generates large quantities of data* that need to be processed and analyzed in real time

Most machine data is only valuable for a **short period of time**

Edge Analytics *limits the need for transporting and storing* the high volume of IoT data and allows real-time actions

Real-time analytics *at the Edge*. Just relevant data is forwarded to the cloud or central sites for additional processing

In *Maintenance Mode* a lift truck generates more than **3 MB / min** through CAN-bus

With Edge Computing we can do **analytics at the right place**
MOVING TOWARDS ADVANCED ANALYTICS

**BI & Reporting**
- Descriptive
  - What is happening?
    - Business Reporting
    - Dashboards
    - Metrics
    - Scorecards
    - Mobile BI

**Business Analytics**
- Diagnostic
  - Why did it happen?
    - Data discovery
    - OLAP
    - Ad-hoc query
    - Location analytics
    - Basic predicative modelling

**Advanced Analytics**
- Predictive
  - What will happen?
    - Predictive analytics
    - Support for BigData
    - Advanced data access
    - Experimentation

- Prescriptive
  - What should we do?
    - Decision modelling
    - Expert systems
    - Simulation
    - Optimization
    - Innovation

**Information Portal**
- BI Specialist

**Analytics Workbench**
- Information Analyst

**Data Science Laboratory**
- Data Scientist

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DISTRIBUTED ANALYTICS

EQUIPMENT

Data Sources → Data to Edge Node → Actions → Analytics → Data to Fog Node → Actions → Analytics → Data to Central Cloud Node → Analytics

LAN

Data Sources → Data to Edge Node → Actions → Analytics → Data to Fog Node → Actions → Analytics → Data to Central Cloud Node → Analytics

CLOUD

Data Sources → Data to Edge Node → Actions → Analytics → Data to Fog Node → Actions → Analytics → Data to Central Cloud Node → Analytics

Analyse the data in the RIGHT place
ML ENABLED PREDICTIVE ANALYTICS

- Signal Analysis
  - Root Cause Analysis
  - Sensor value distribution analysis
  - Linear regression ...
- Event Analysis
  - Event Tracking & Filtering
  - Event Correlation
  - Event Aggregations ...

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<table>
<thead>
<tr>
<th>MAJOR BENEFITS FOR TVH</th>
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<tbody>
<tr>
<td><strong>One-Step Maintenance</strong></td>
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<tr>
<td>Moving from Two-Step to One-Step maintenance</td>
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<tr>
<td><strong>Increase the availability of equipment</strong></td>
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<tr>
<td>optimize the usage and reduce the operational cost</td>
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<tr>
<td><strong>Improve driver safety</strong></td>
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<tr>
<td>promote responsible driving</td>
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<tr>
<td><strong>Empowering Equipment Maintenance</strong></td>
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<tr>
<td>combining Human Intelligence with Machine Learning</td>
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<tr>
<td><strong>New business model</strong></td>
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<tr>
<td>offering Lifting Capacity as a Service</td>
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The Internet of Things is about the transformation of physical objects into digital data products. It is radically changing the way businesses operate and people interact with the physical world.

The benefits of Predictive Maintenance are significant. Its implementation requires more than just technological choices. It has impact on the organizational structure and culture.

New digital business models require ecosystems of people, businesses and technologies that must scale beyond the enterprise.

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Thank You