



Industry 4.0  
Smart Manufacturing  
Analytics Platform

# What you'll find inside:

- 01 Who we are
- 02 Strategic Point of View
- 03 Analytical Apps
- 04 Case Studies
- 05 Analytical project approach



# 01

## Who we are

We as PwC / Strategy& offer a unique combination of business expertise, engineering and Data & Analytics experts to our clients



# Our core team for Industry 4.0 Analytics & IoT

We've a highly motivated team with a strong background in state of the art analytics and IoT technologies.

**#AI, #MachineLearning, #R,  
#Python, #Csharp, #IoT, #Cloud,  
#Predix, #Azure, #MindSphere,  
#PowerBI, #CallUsForAnalytics**



AI & Machine  
Learning



Cloud &  
Internet of Things

Analytics Strategy



Reporting & Analytics

Application Programming



+150 in  
PwC Europe

# PwC's Data & Analytics capabilities include a global network of 2,000 data analytics experts and partnerships with tech firms, start-ups and institutes



## Expertise

2,000 data & analytics experts worldwide



## Data

1,000+ rich data sets



## Pilots

Innovation experiments with clients



## Insight

Transformation and industry expertise



## Apps

100+ analytic apps and app platforms



## Services

IaaS, PaaS, SaaS



## Relationships

100 + leading tech firms, start-ups, and 25+ universities

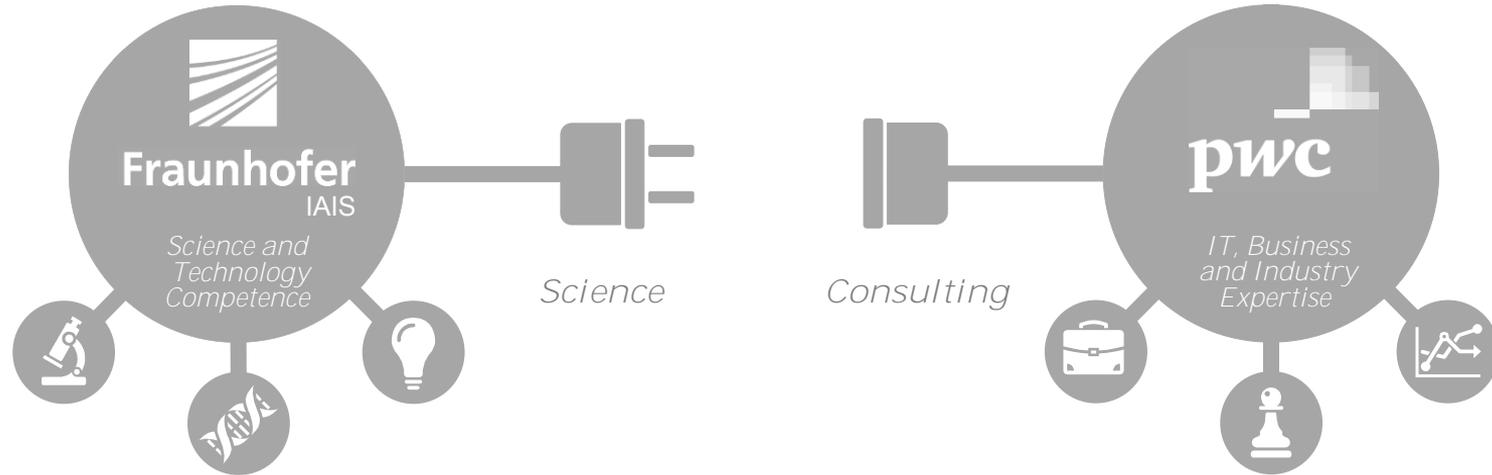


## Innovation

Experience and innovation centers in every major continent

# We cooperate with Fraunhofer IAIS and IOSB to leverage latest machine learning algorithms and leading scientific experts for our clients projects

Together we help our clients to achieve their goals and turn their data into real business value.

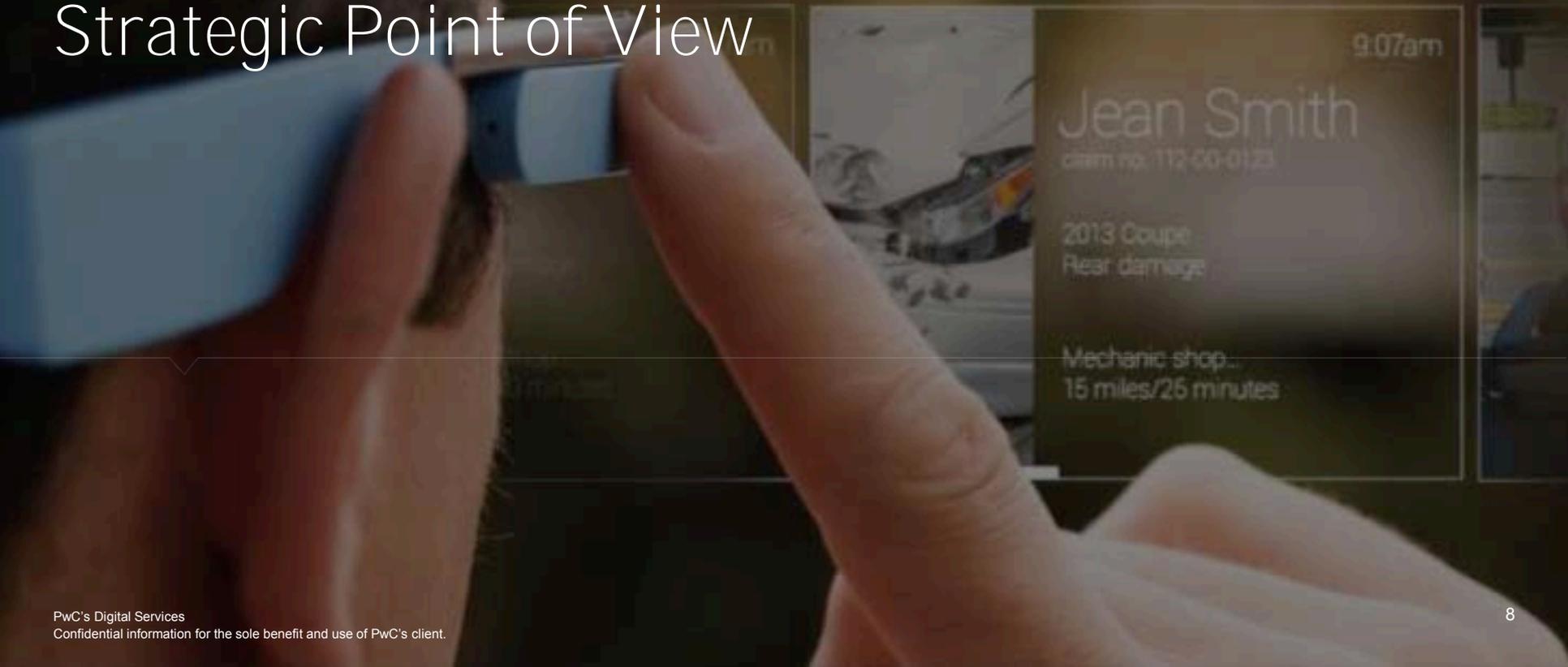


- Applied research in the field of Artificial Intelligence
- Leading Institute of the Fraunhofer Big Data Alliance

- Data & Analytics experience proven on many client projects
- Deep business and process understanding

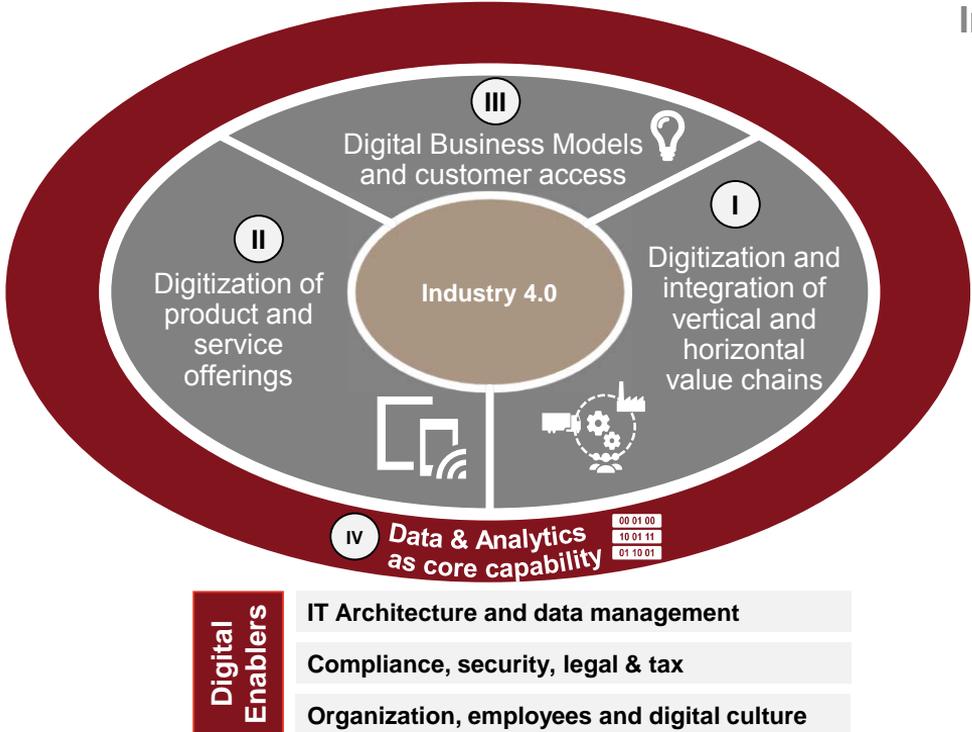
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## Strategic Point of View

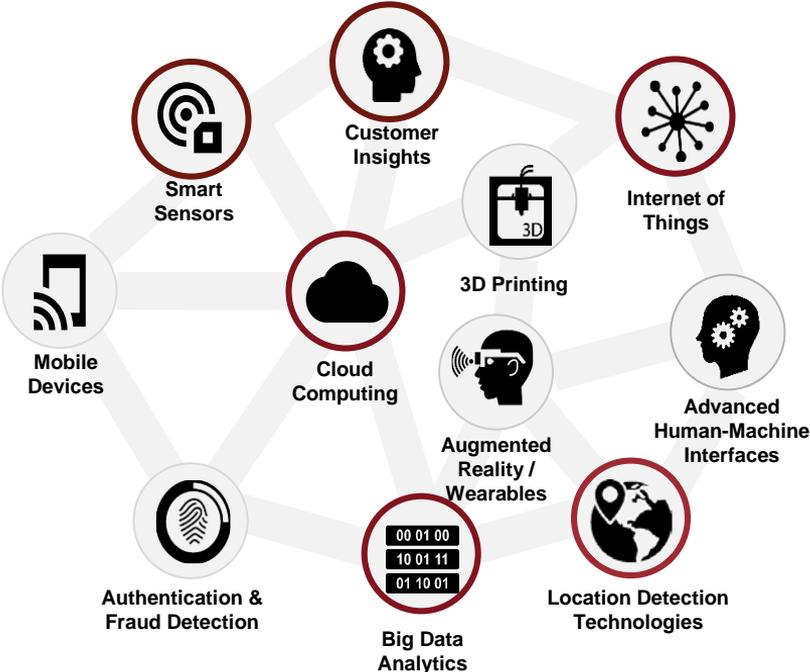


# The digital enterprise comprises of digitized and integrated processes, products & business models

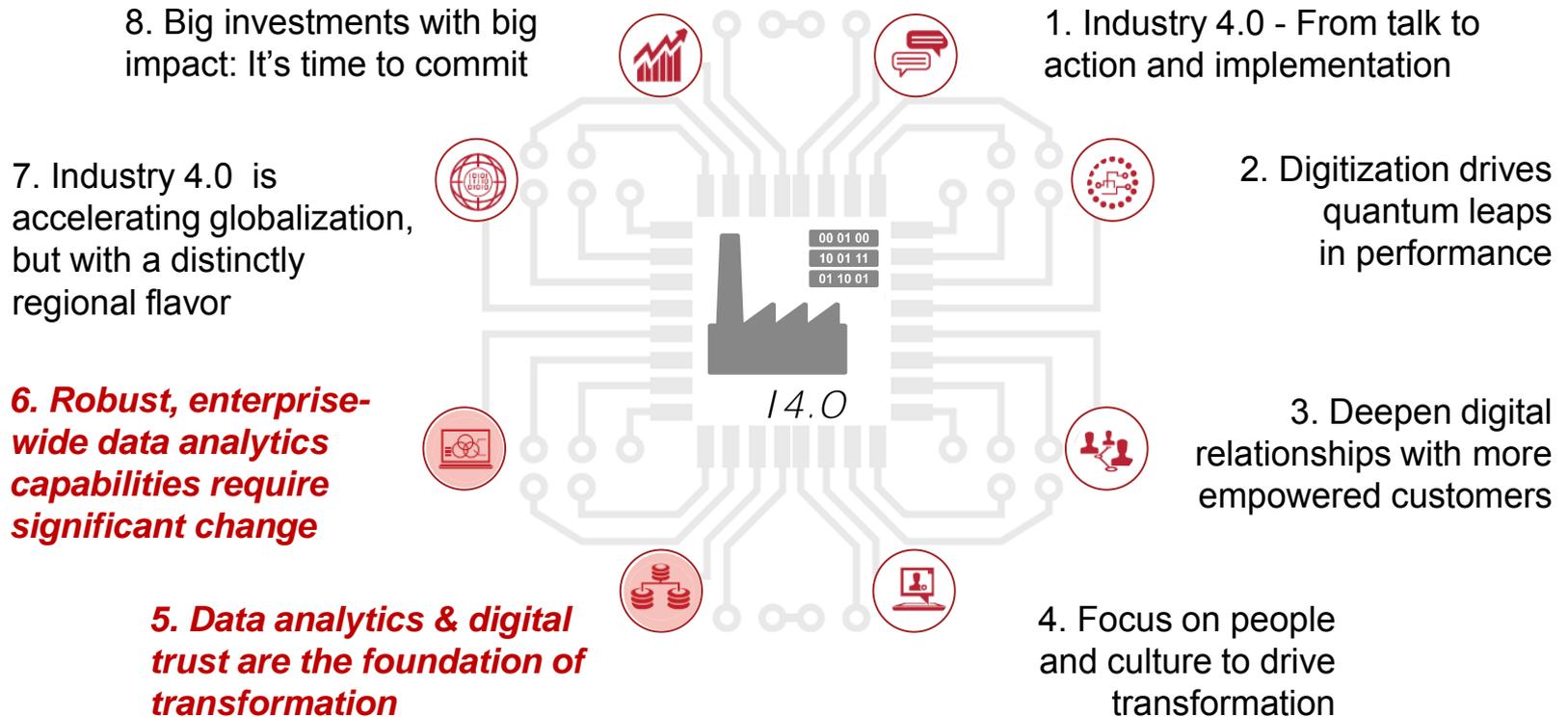
## Core Application Fields



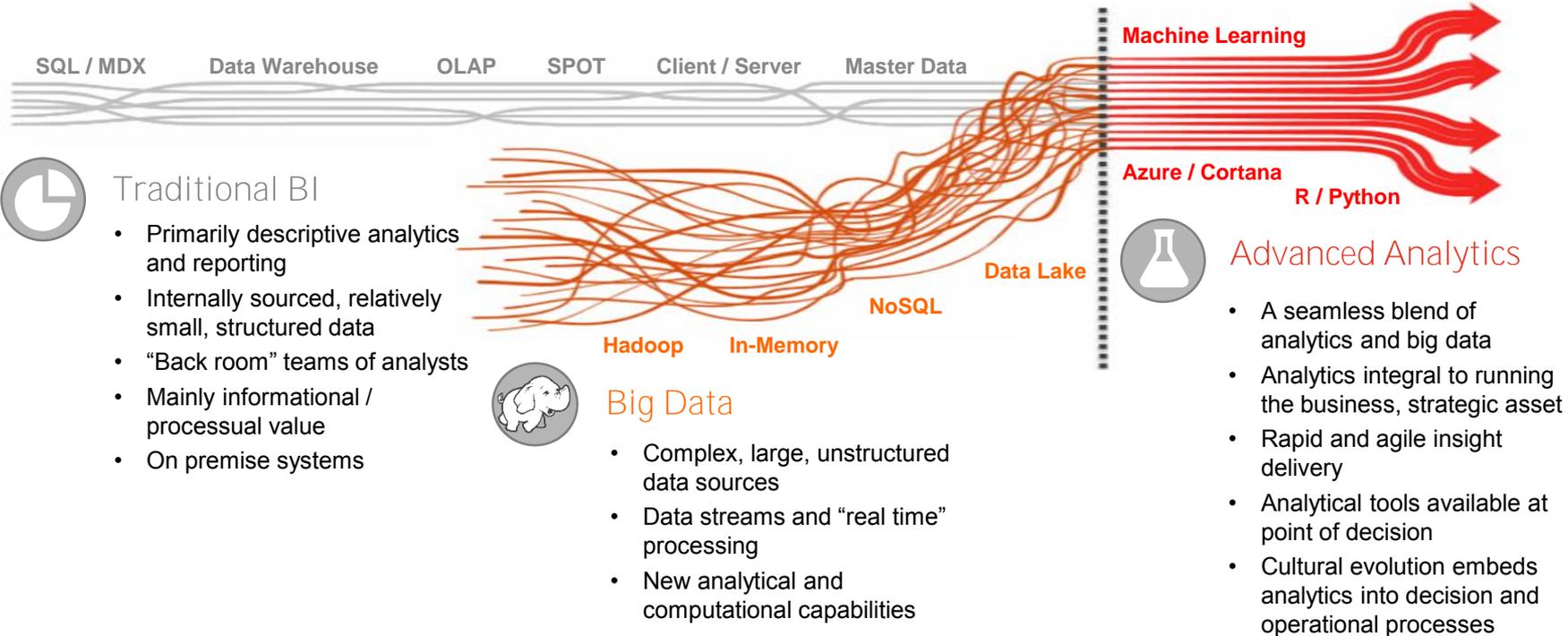
## Core technologies to provide innovative Industry 4.0 solutions



# The key findings of PwC's Industry 4.0 survey emphasize the critical role of Data & Analytics for successfully digitizing the manufacturing enterprise



# The field of Data & Analytics is evolving fast, driven by the large amount of data available as well as technological quantum leaps



## Traditional BI

- Primarily descriptive analytics and reporting
- Internally sourced, relatively small, structured data
- “Back room” teams of analysts
- Mainly informational / processual value
- On premise systems



## Big Data

- Complex, large, unstructured data sources
- Data streams and “real time” processing
- New analytical and computational capabilities



## Advanced Analytics

- A seamless blend of analytics and big data
- Analytics integral to running the business, strategic asset
- Rapid and agile insight delivery
- Analytical tools available at point of decision
- Cultural evolution embeds analytics into decision and operational processes

# To help manufacturers becoming data-driven, we provide a full set of analytical services, with the PwC Smart Manufacturing Apps at its core

## Data & Analytics Strategy



### Maturity Assessment

We assess the analytics maturity of your business and jointly select the right use cases for growing your analytics capabilities.



### Implementation Roadmap

We analyze the requirements of your stakeholders and jointly define concrete steps for implementing analytics in your organization.



### Business Intelligence

We define and implement production KPI systems, reports and dashboards to make production insights available across your enterprise.



### Smart Manufacturing Analytics

We provide you a suite of smart manufacturing **applications (“apps”)** based on Analytics, Internet of Things and Cloud technology.



### Customer & Supplier Insights

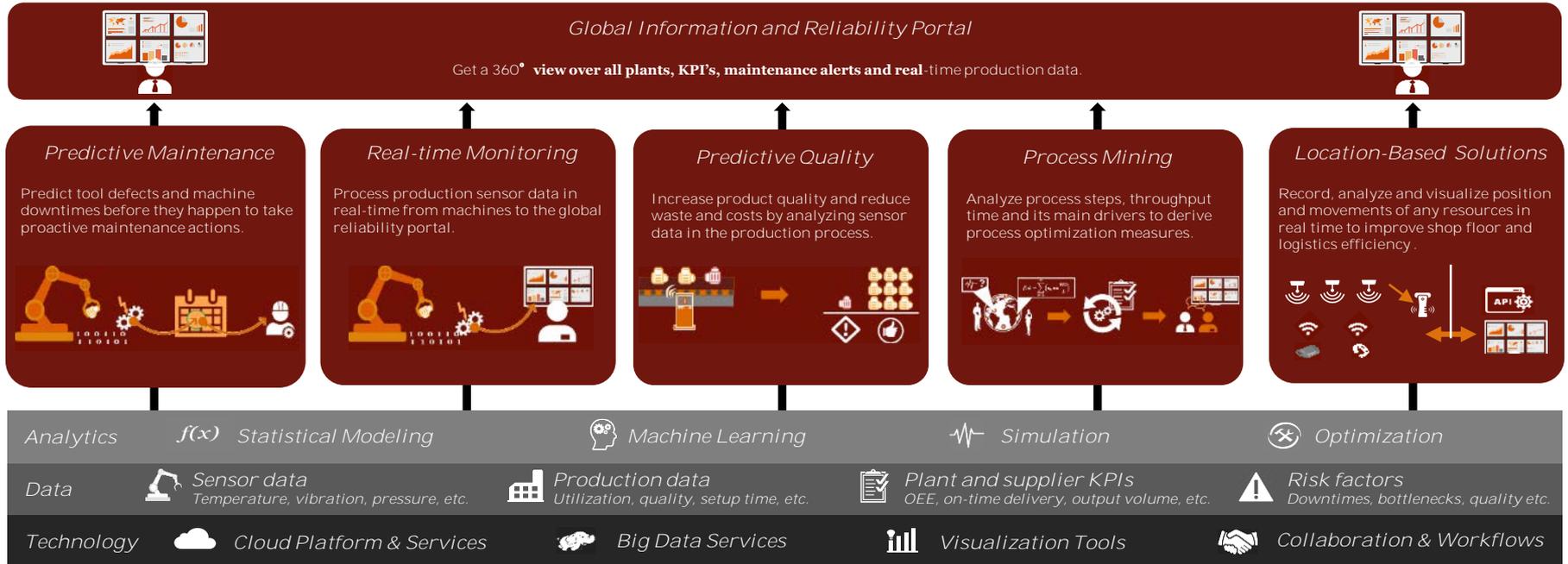
We leverage your sales & customer data as well as publicly available data to enrich manufacturing analytics with a customer perspective.

## Data & Analytics Services



# PwC Smart Manufacturing Analytics Platform

We have developed a set of analytic solutions to enhance the manufacturing process



# Plant Information and Reliability Portal

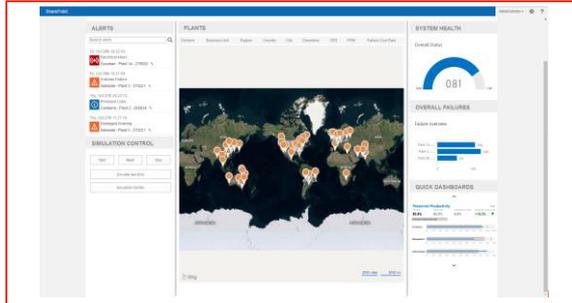
Get a 360° view over all plants, KPIs, maintenance alerts and real-time production data

## CHALLENGE

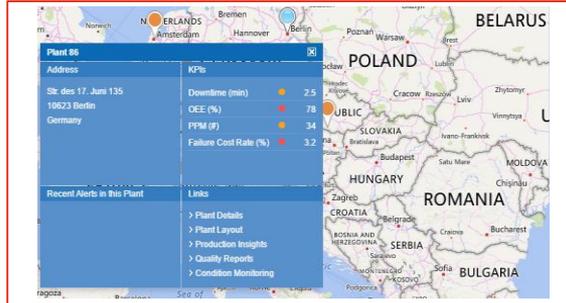
Production managers and stakeholders (e.g. quality, maintenance, supply chain) need to keep track of various production-related data, information and KPI's in order to effectively control costs, quality, employee skills and improvements in real time across all processes and manufacturing facilities.

## SOLUTION

Based on web and BI technology, we aim to establish a centralized and collaborative platform, which offers users a single-point-of-truth for plant data and top KPI's, as well as dashboards for maintenance alerts and real-time production data.



The portal provides an overview of all production plants on the world map, as well as a live feed of alerts and most important overall KPI's.



The world map interactively provides basic information and top KPI's for each plant. Furthermore, it is the entry point to more detailed information, reports and analytics on the plant-level.



For example, the user can drill down into a plant's layout plan to understand which production lines and processes are in place and which machines are deployed.

## BENEFIT

The Plant Information & Reliability Portal enables manufacturers to achieve a new, sustainable and significantly higher operational efficiency level based on a standardized, cost-effective solution architecture.

# Predictive Maintenance

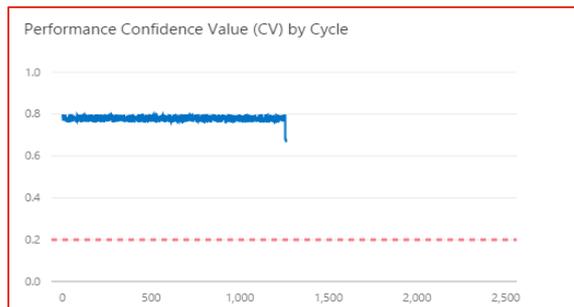
Predict tool defects and machine downtimes to take preventive maintenance actions

## CHALLENGE

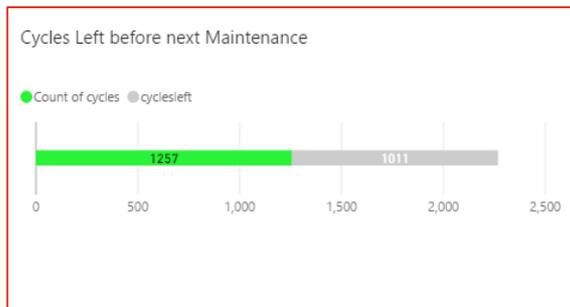
Production tool defects lead to unexpected machine downtimes, and thus critically impact production efficiency and effectiveness. Static maintenance intervals often don't fit to the maintenance needs of machines, resulting in wasted maintenance costs or not being able to avoid machine breakdowns.

## SOLUTION

Machine sensor data is often available, but not leveraged for maintenance planning. Predictive maintenance utilizes sensor data from production machines to assess current machine conditions and predict when the machine will most probably fail, as well as which maintenance is needed to avoid the failure.



Trained on historical machine condition sensor data, the predictive maintenance model predicts a confidence value for every production machine, based on its current condition.



Based on the predicted confidence value and machine type, the predictive maintenance app also provides a forecast on the number of production cycles left, before the machine is likely to break down.



The predictive maintenance app is fully integrated into the plant information & reliability portal as a dashboard, which helps production managers to proactively plan maintenance tasks based on current machine conditions.

## BENEFIT

Predictive maintenance enables manufacturers to establish condition-based preventive maintenance plans and achieve a higher production effectiveness, as well as more reliable product quality. Predictive maintenance is most powerful when combined with real-time condition monitoring of production machines.

# Real-time Condition Monitoring

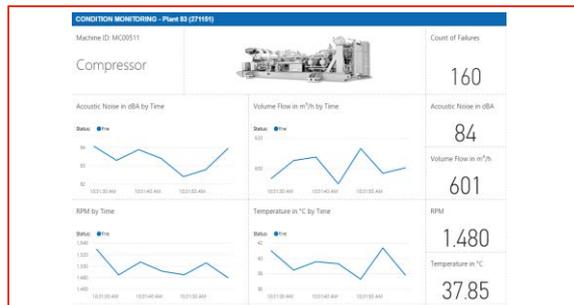
Measure, analyze and visualize sensor-data from production machines in real-time

## CHALLENGE

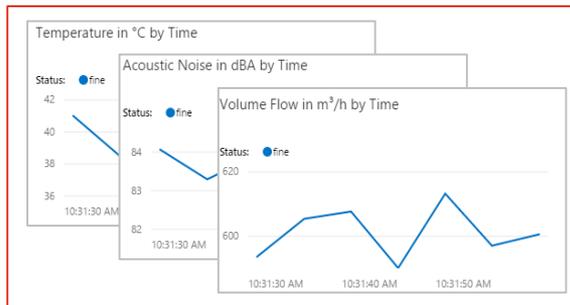
Claims to production efficiency and accuracy continuously increase. Therefore it is critical to detect anomalies such as machine failures or other risk indicators as early as possible, in order to quickly take counter-actions and assure production performance.

## SOLUTION

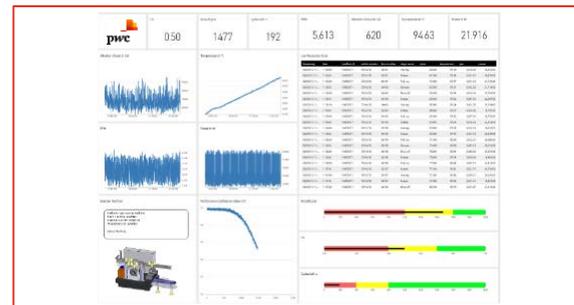
Real-time Condition Monitoring uses sensor data from production to provide a live view on production KPI's. Furthermore, real-time production data is measured against trends or thresholds and automatically triggers alerts for special events, e.g. for a machine breakdown.



Sensor data from production machines is transmitted in real-time into a monitoring dashboard, where time trends as well as latest KPI's are visualized.



E.g. for a compressor machine, such sensor data could be temperature, acoustic noise, volume flow, rotations per minute, vibration, energy consumption etc.



A detailed overview of monitored events allows further investigation. Significant anomalies trigger a warning and are displayed through the traffic lights system.

## BENEFIT

Real-time Condition Monitoring enables production managers to gain insights on the current state of production and get relevant alerts to quickly take counter-actions. It can be combined with Predictive Maintenance to preventively signal maintenance needs in real-time.

# Predictive Quality

Increase process quality while reducing production waste and costs through analytics

## CHALLENGE

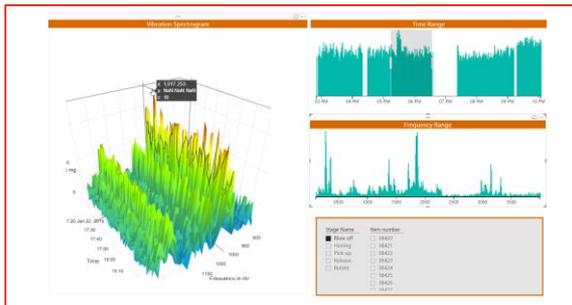
Process and product quality are often measured at single control points in the production process, but it is challenging to identify the exact root causes of quality issues in the complex, multi-staged production and assembly process.

## SOLUTION

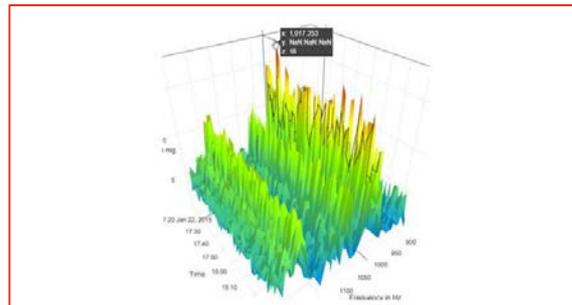
By relating sensor data from production to process and product quality data, Process Quality Analytics helps business users to detect relevant patterns and relations between production process parameters, machine settings and product/process quality.



A self-service analytics dashboard helps to identify patterns, relationships and anomalies in production and quality data.



Drilling down into specific events, attributes or time frames allows business users to get a deeper understanding of specific process situations.



Advanced data visualizations such as interactive 3D charts provide an interpretable view on complex data, which fuels discussions around production quality improvement.

## BENEFIT

Process Quality Analytics provides deep insights into process and product quality drivers in production, which help to identify improvement potential and to define actions for optimizing the production process and enhance product quality.

# Real-time location tracking with bluetrack

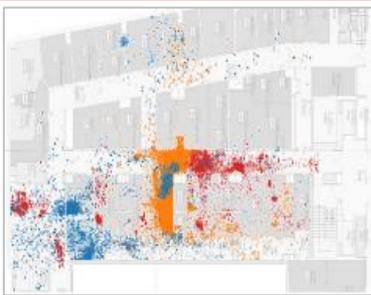
Record, analyze and visualize position and movements of any resources in real time

## CHALLENGE

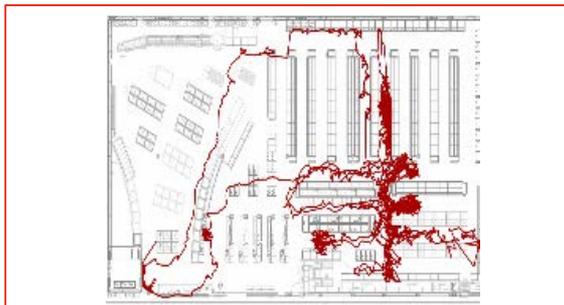
By now, resources are often not traceable since machine data is not available or positioning information is missing. To enable production managers or stakeholders to integrate those information in new routines or ad hoc changes, a reliable information about the location of assets or persons is needed.

## SOLUTION

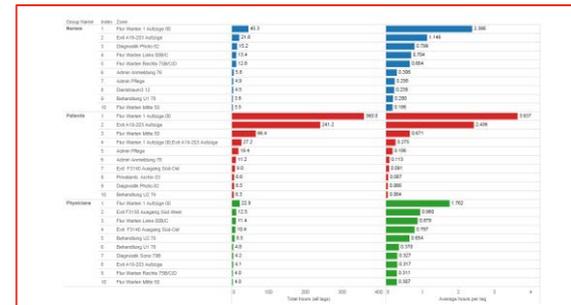
bluetrack is a high-precision indoor and outdoor real time tracking-system that records precise location information in 2D or 3D of any resources, like people, assets, or any work in progress, with accuracy down to a few centimeters. Movement patterns and workflows become visible at a glance and reveal enhancement potential. The bluetrack system is a reliable, versatile and scalable technology platform that can be easily integrated into other systems.



Positioning information from BLE smart tags or devices are transmitted to a network of corresponding antennas. The aggregated real-time data describes location and, if available, status information of resources with a frequency up to 50 Hz.



The positioning data allows advanced analytics to generate heat maps, pathway analysis, approximation analysis, utilization of space, real time value chain analysis and many further analyses.



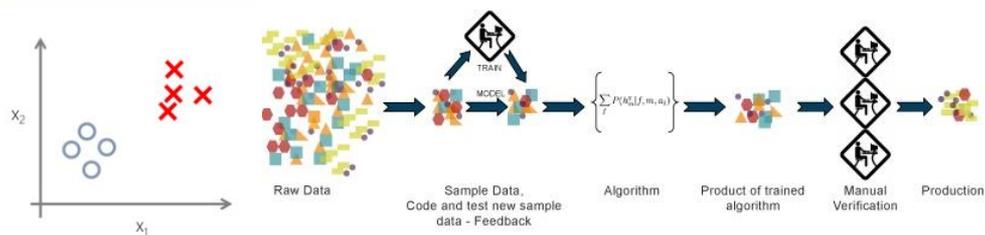
Customized management dashboards with detailed views on monitored data and defined KPIs facilitate decision-making or trigger actions to improve efficiency.

## BENEFIT

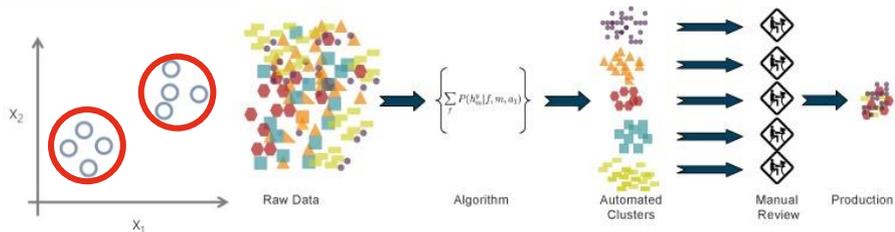
The precise location data correlated with other relevant production data enables advanced analytics on value chains to extract optimization measures within the shop floor and logistics areas.

At the core of each solution, we leverage a variety of ML algorithms to build accurate pattern recognition, anomaly detection and prediction models

### Supervised Learning



### Unsupervised Learning



ML

#### Regression

- Linear Regression
- GLM
- ARIMA
- Regression Trees
- Neural Networks

#### Classification

- Logistic Regression
- Decision Trees
- Random Forest
- Support Vector Machine
- Neural Networks
- Dimensionality Reduction (LDA, PCA)
- Ensembling (Boosting, Bagging, Stacking)

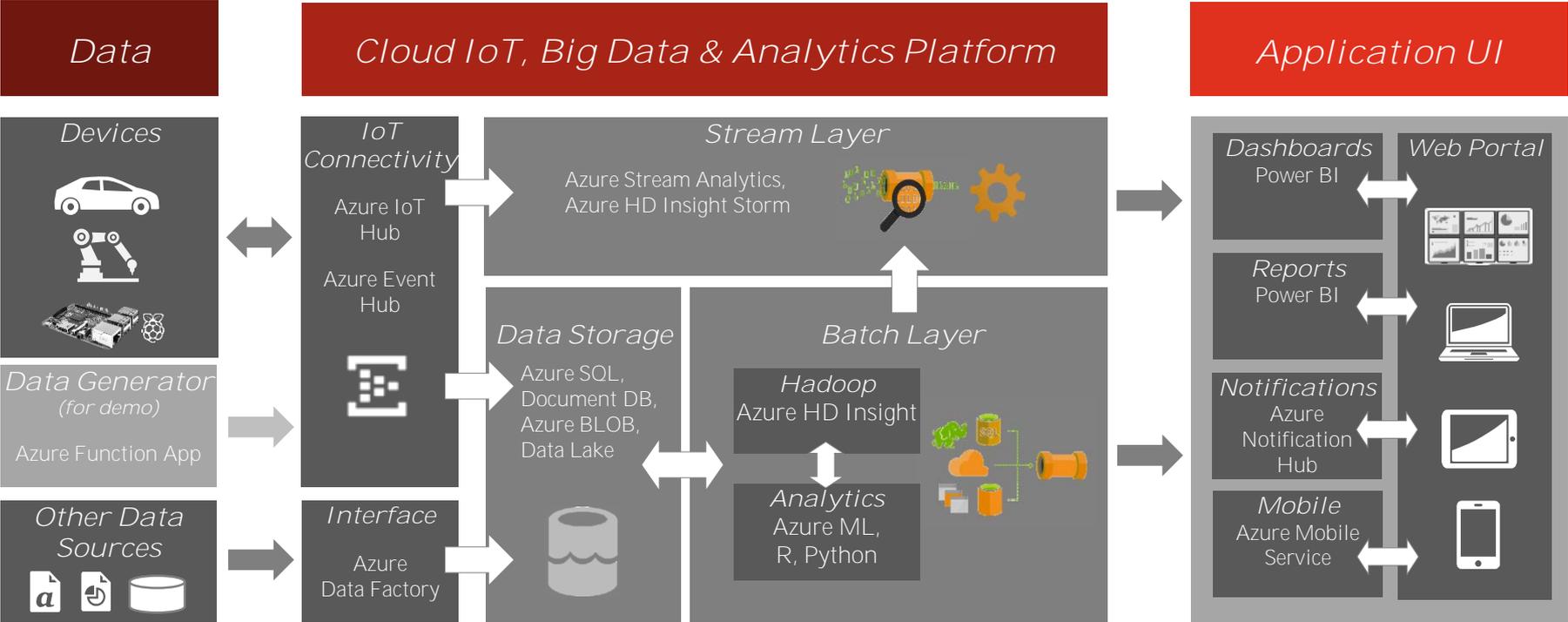
#### Clustering & Anomaly Detection

- K-means
- Hierarchical Clustering
- DBSCAN
- KNN
- One Class SVM
- Neural Networks

#### Association & Sequence

- Apriori
- Markov Chains

Our app platform is running on a scalable Microsoft Azure cloud architecture and leverages state of the art SaaS components.

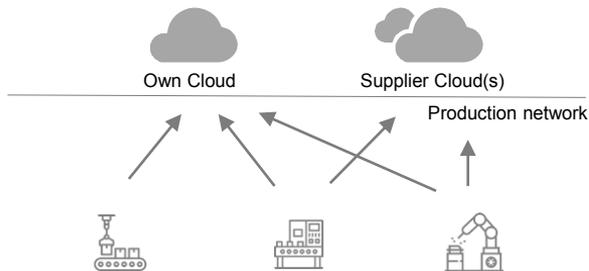


# We help our customers to select the right operationalization strategy to integrate our Data & Analytics solutions in a productive environment.



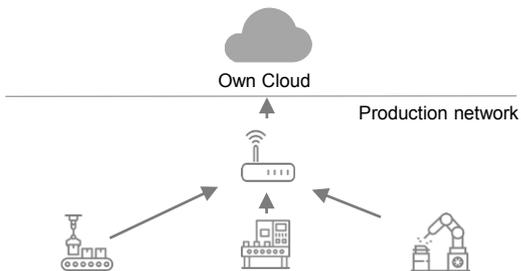
## Direct Connection

Direct connection of systems and machines to the selected cloud infrastructure.



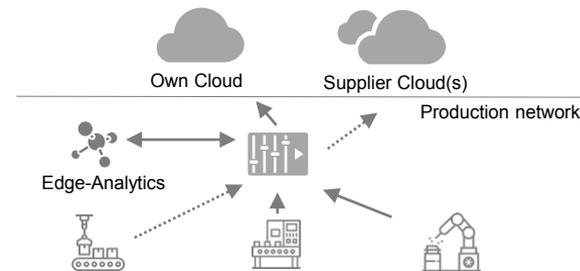
## Traditional Gateways

Connection with a central gateway as interface between production network and external network systems.



## Extended Middleware

Middleware layer which acts as a functional interface to enable multiple cloud delivery, extended security and edge analytics.



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## Customer References

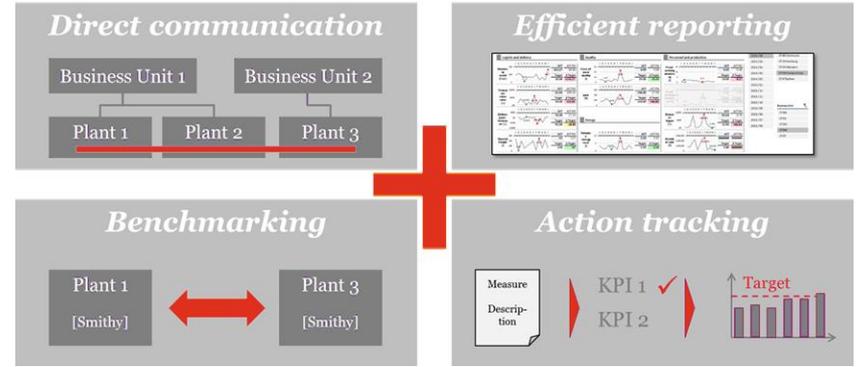


### Situation

- A successful Operational Excellence Initiative requires the possibility to visualize, comment and control costs, quality, employee skills and improvement across all processes and manufacturing facilities with measurable KPI.

### Solution

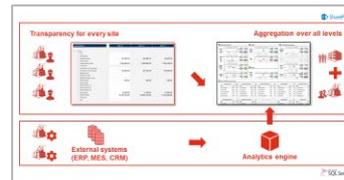
- The Plant Information Portal enables a centralized view on significant and uniform KPIs and allows cross-collaboration and networking between production experts and headquarters.
- Furthermore it allows self-service reporting capabilities for every business user on a uniformed set of master data.



Identify used KPIs by BU and underlying individual definitions.



Define a standardized set of KPIs based on customers global production system.



Design a flexible architecture based on familiar Microsoft technology.



One central point of entry for plant and production relevant information

## Automotive OEM – Analytics platform for automated guided vehicles

### Challenge

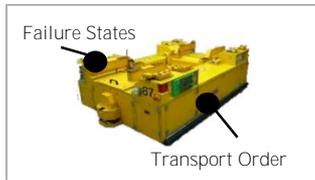
- AGV data is not collected and access is either not possible or highly complicated to realize. Therefore, AGV Data is not used for analysis and gaining insights.
- AGV data is important for a wide range of different departments – from operations to quality and maintenance as well as planning. This results in broad requirements for using AGV data in reports and analyses.

### Solution

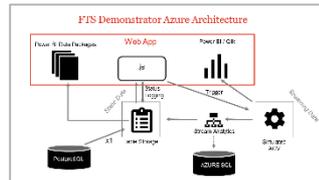
- Using Big Data Analysis for AGV data, a platform is implemented firstly to show how AGV data can be provided by vehicles, analyzed and how results can be visualized in the future.
- Design Thinking and creation of use cases for leveraging AGV data.
- Assembling a team of subject matter experts and specialists for web development, Data Science and databases.
- Short, iterative implementation cycles with frequent proofs of quality and confirmation with the customer.
- Leveraging cutting-edge cloud technology to ensure flexibility, scalability and fast reliable results.

### Project Result

- Better understanding of the benefit of AGV data in the future production.
- Analytics platform as web based portal for self service analysis of AGV data.
- Reference models for implementation of AGV Data analyses and applications.
- Recommendations for using the existing IoT and Analytics infrastructure and architecture,
- Embedding of Advanced Analytics visualizations with Microsoft Power BI.



AGV Data is collected and provided on a centralized platform.



Microsoft Azure Cloud Services accelerate prototyping and are used as scalable and pioneering Analytics platform.



Self-service analytics based on Microsoft Power BI enables highest possible flexibility concerning data analysis.



The Analytics platform allows self-service analysis and simulations based on the entire AGV Data and therefore improves efficiency in Production Processes and AGV assignment.



## Client Challenge

- Today, the client is a quality leader in the production of gearboxes and wants to maintain this position by exploring and implementing for promising machine learning approaches to increase production quality and efficiency.
- The production process includes complex tasks and different types of machines. Overall Equipment Effectiveness (OEE) is affected by unexpected tool fracture and undue maintenance tasks.
- Sensor data from the production process is available, but current analytic capabilities limit the usage of large datasets, resulting in less insights.

## PwC's Approach

- Deployment of a mixed team of domain experts and data science specialists.
- Steady implementation cycles with frequent quality gates as well as client consultations.
- Usage of cutting edge analytic tools and algorithms to ensure rapid results.

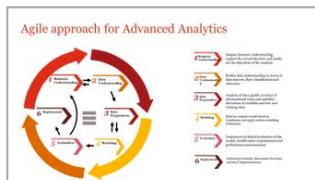
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Very good, valuable, and relevant insights have been gained using Machine Learning – many of the findings are new and unexpected and give concrete leads for further investigation.

Dr. Bernhard Rank  
Senior Manager Gear Quality  
ZF Friedrichshafen AG

## Project Outcome

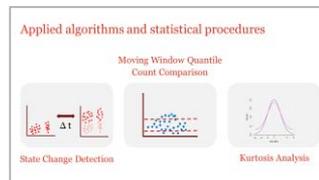
- Deep insights concerning machine failures and tool fracture have been gained and a detection and prediction model have been created.
- The detection algorithm is able to detect 99% of all tool fractures in real-time.
- Boundary values for sensors can be adjusted dynamically, making time consuming manual updates unnecessary.



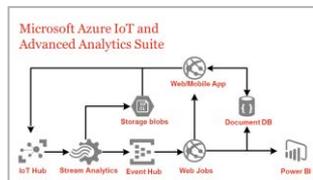
An agile process model was utilized to generate quick insights and cope with data uncertainties.

### PwC's Digital Services

Confidential information for the sole benefit and use of PwC's client.



Specific statistical methods and machine learning techniques made hidden data patterns visible and yielded meaningful models.



Microsoft Azure cloud services expedited model development and were used as scalable IoT and Advanced Analytics platform.



Insights gained in the project enable the client to improve production efficiency using Advanced Analytics and ML.



## Client Challenge

- The client is a world leading automotive supplier who is aiming for the highest quality in his products as well in his processes.
- The production of electronic systems for automotive applications is a very complex process including thousands of electronic parameters which requires very small tolerances. To ensure best possible uptimes in the field quality testing is driven to the edge in production processes.
- The functional tests at the end of line are so strict that a major part of scrap is caused by worn out or imprecise testing tools while the part itself is functional.

## PwC's Approach

- Analysis of the physical process in cooperation with the client's engineers.
- Usage of an agile project approach which was targeted for a feasible solution.
- Leveraging of cloud computing technology to ensure quick results and easy deployment.

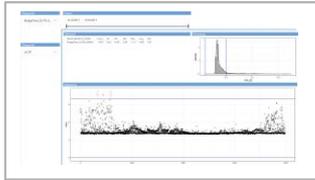
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The project showed us that identification of pseudo-scrap caused by worn out testing tools in test benches is possible and feasible in production. **We now can adjust our processes to prevent costly failures and increase quality.**

Senior Manager Electronic Systems Quality Assurance  
Automotive Supplier

## Project Outcome

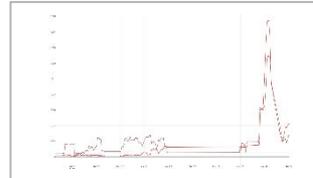
- Potential optimization of test bench maintenance and overall process performance.
- The identification of a pattern for testing tool wear using statistical measures.
- The creation of a clustering algorithm to separate potential scrap from the other parts along providing a measure for severity.



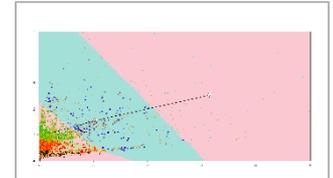
Based on process data factors with most impact on production could be identified.



The agile project approach made small iterations possible which was also powered by usage of cloud technology.



Based on advanced statistical methods a common behavior within the dataset could be extracted.



Clustering helped to separate scrap from other parts and now helps business users to evaluate potential faulty parts. 29

# Smart Manufacturing Analytics

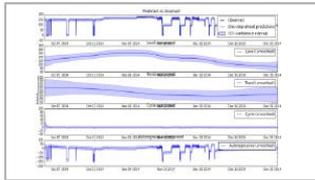
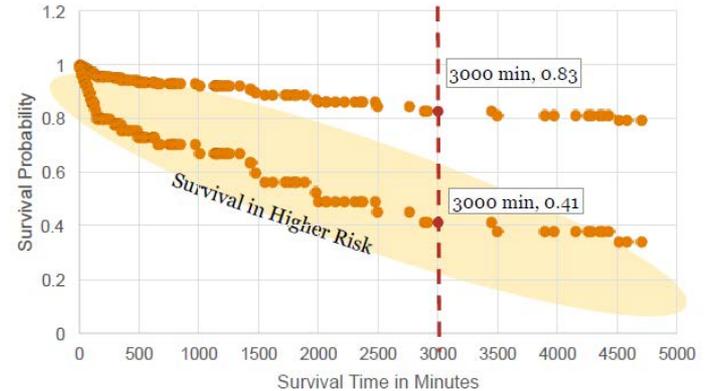
## Utilities Industry – Predictive Maintenance

### Situation

- Large machineries such as oil and gas pumps experience high failure costs and profit loss from downtimes.
- Technologies are there to send data from sensors to servers, but it often encounters data quality issues and only subtle indication of meaningful results, thus requiring sophisticated analytical techniques.

### Solution

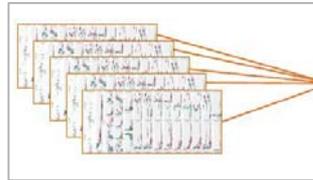
- We identified anomalies and patterns in the sensor data of pumps, which we used to create various risk profiles.
- We developed a time-series-based prediction model for pump risk profiles.
- We provided the customer with the capability to predict downtimes of pumps with enough lead time and sufficient maintenance information from incoming sensor data, which helps them to improve asset utilization.



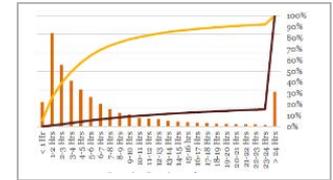
Prepare data by resampling, filling in missing values accordingly, and appending additional fields.



Explore patterns of normal operations vs abnormal operations by variables, and select variables to proceed with.



Develop a risk prediction model by engineering features, clustering on patterns, building ensemble models, and predicting risk probability based on the ensemble models.



Explore how to raise alerts based on the predicted risk probability.

# Injection Molding Industry – Machine Learning in Production

### Client Challenge

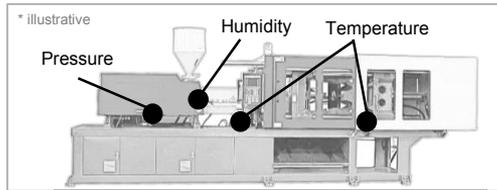
- The injection molding manufacturing client aimed to identify opportunities in Industry 4.0 and to leverage potentials in efficiency and quality improvement.
- Therefore, the client wanted to better understand how injection molding machine & process configuration can influence and improve product quality (e.g. short shots) using advanced analytics techniques.

### PwC's Approach

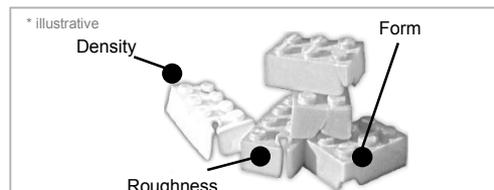
- Deployment of a mixed team of domain experts and data science specialists.
- Usage of cutting edge analytic tools and algorithms to ensure rapid results.
- Analysis of machine sensor data to detect patterns, anomalies and identify potentials for optimizing the production process and machine configuration.

### Project Outcome

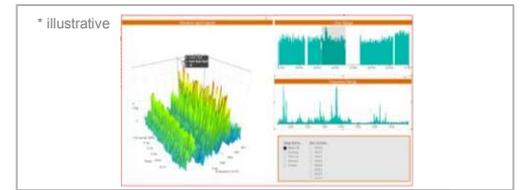
- We revealed hidden patterns and relationships between machine configuration, operation parameters and product quality issues.
- We identified and recommended improvement potentials in the production process in order to avoid product quality issues or monitor the influencing factors so to be able to identify and react to quality issues quickly.
- We established a roadmap with fields of actions to gain further insights and identify further improvement potential.
- The client gained new relevant insights into the production process as well as actionable recommendations, which help the client to increase production efficiency and effectiveness and improve product quality.



Molding machine configuration and operation parameters as well as sensors on the machine generate data which can be leveraged for analytics.



Quality control systems for molded parts produce data about production quality, which can also be leveraged for analytics.



Combining and analyzing this data produced useful information about cause/consequence patterns of machine configurations and revealed production improvement potentials.

## German Tier 1 Automotive Supplier – Production Process Quality Analytics

### Situation

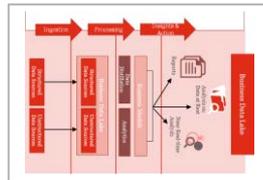
- With increasing cost pressure and quality requirements, claims to production accuracy continuously increased. To meet all these requirements it is necessary to have an complete inside view of quality and performance data across all systems.
- Business users needs an easy and comfortable way to discover existing data and define relationships between this data to identify existing quality or production problems.

### Solution

- Using Process Quality Analytics, production and quality data can be accessed seamlessly, easily combined and analyzed consistently by business users.
- Data latency is reduced and query performance is significantly improved leading to earlier detection of production and quality issues.



Identification of structured and unstructured data sources



Design a harmonized data access layer over different data sources



Train business users and design custom visualizations. Continuously pre-prepare data for easier consumption



Self-service analytics on massive production and quality datasets available for business users.

## Automotive OEM – Process Mining in Engineering

### Challenge

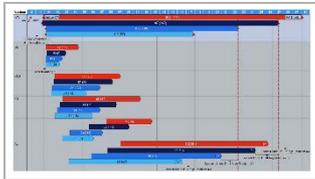
- In the Production Development Process (PDP) failures on developed vehicles need to be resolved as fast as possible to increase the product maturity level early.
- Fast run times of the Fault Elimination Process (FEP) are the key to a high early maturity level. In reality, there are long run times that strongly differ from the initial set points.
- In a process database faults and fault elimination processes are documented. Due to the large amount of data, simple analysis tools fail to create analyses.

### Solution

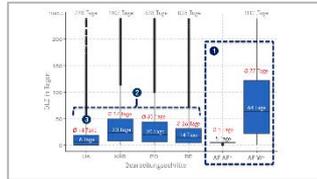
- Process Data is enriched with further data and consolidated in a central data model to create a consistent view on faults and FEP.
- Using statistical methods the FEP run time is quantified and presented in detail to enable a clear description of the initial situation.
- Process Mining methods help to analyze the process documentations to detect patterns and abnormalities, that point to bottlenecks and their root causes. They are discussed with the customer in frequent sprint reviews, hypothesis are formulated and recommendations are derived.

### Project Result

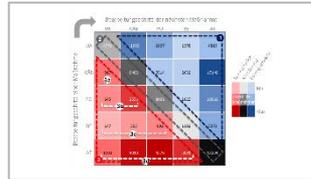
- The Analysis results allow the customer to identify and quantify Process Optimization Potentials faster and easier.
- Based on summary statistics and specified examples the conventional Process Optimization Process is complemented with data and facts from Big Data Analysis to enable a faster and more reliable decision making process concerning re-designing the process itself.



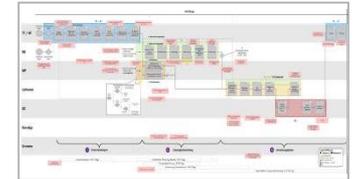
Detailed view on single process stages and priorities allows insights in the run time components.



Using statistical analyses the run times are communicated closer to the real state to the management level.



Process Mining Analyses reveal reasons for long run times like process loops.



Based on the Big Data Analysis Results the Fault Elimination Process was optimized and recreated.

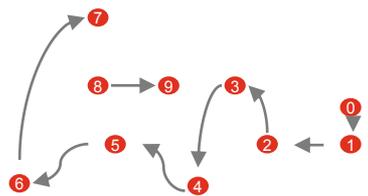
# International Chemical Producer – Workflow management and B2B & B2C relationship enhancement

## Situation

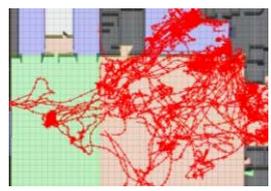
- The client is large scale international company supplying various products to customers worldwide. Beside sole product deliveries the client offers management support to their end-customers. To be able to offer a real-time-management solution the Bluetrack Real Time Locating Systems (RTLS) was used to provide tracking information and analysis from the customers production sites to the local management.

## Solution

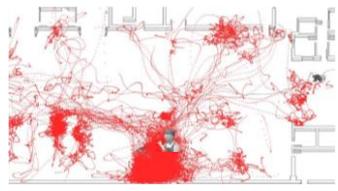
- Recording of individual journeys for assets and staff in an industrial environment.
- Analyzing and visualization of pathways, cycle time and other KPI's
- The study provided the basis for the development of a management dashboard that enables the client to develop new ways to improve their services



Identification of standard routines and workflows



Recording of individual journeys for assets and staff



Visualize movements to generate data for the establishment of customized dashboards



Build performance into daily shift routine, incentivize shop floor teams and highlight problems early.

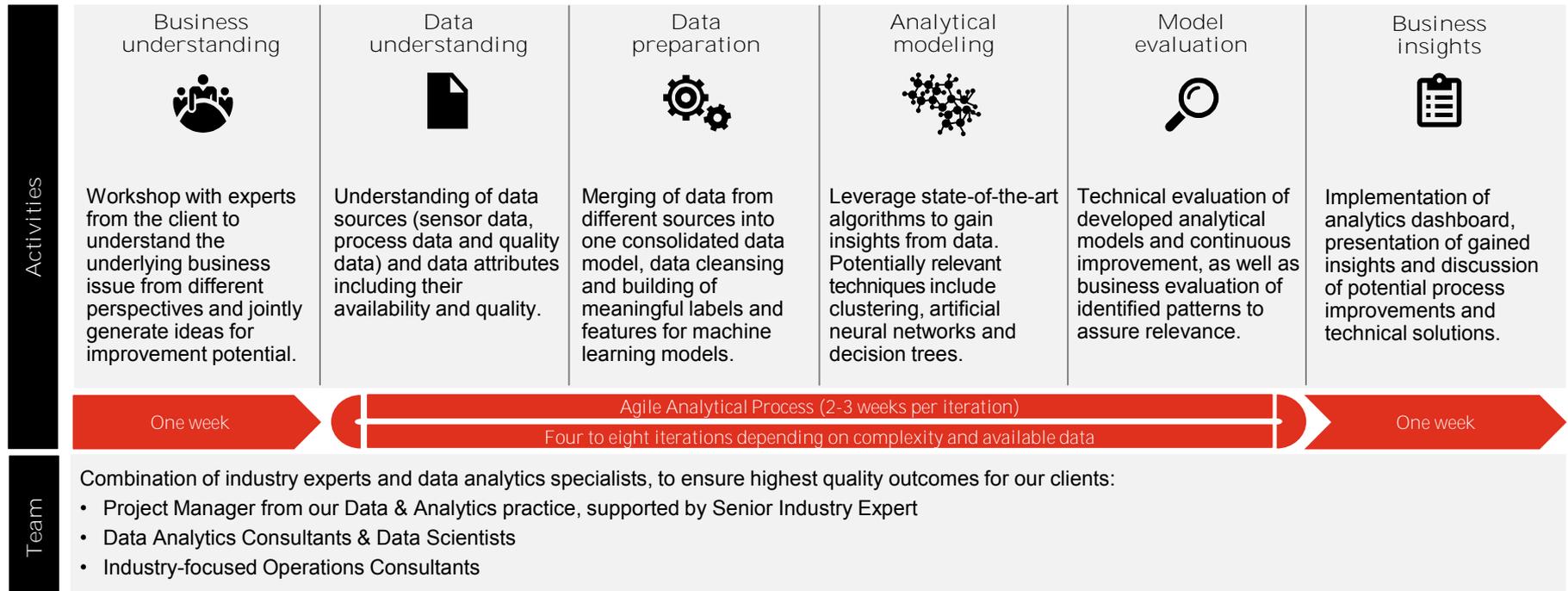
# 05

## Analytical project approach

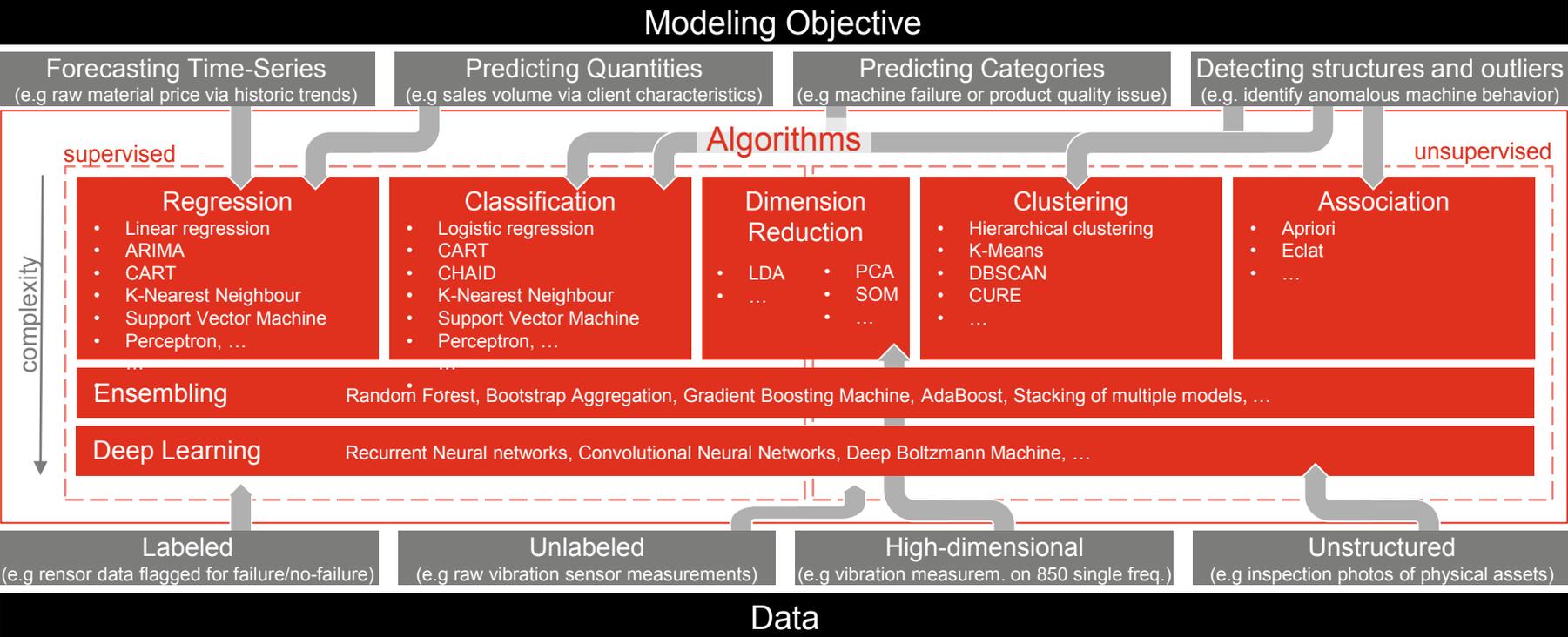


We recommend a proven agile approach, tailored to the specific needs of analytical projects, which ensures valuable outcomes for our client.

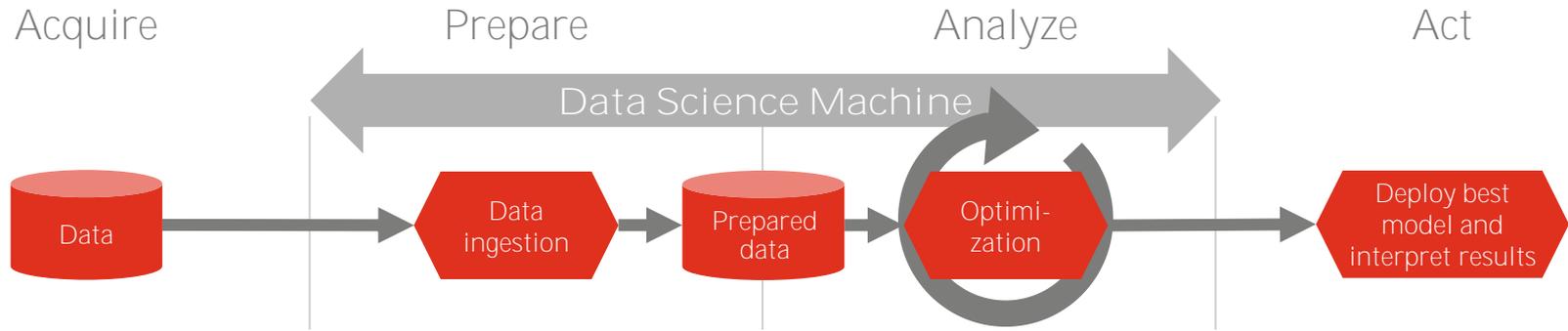
## Data & Analytics Pilot Project



There is a large variety of analytical techniques and algorithms, which are used by data scientists depending on the modeling objective and data



# With the PwC Data Science **Machine** we've developed to tool to relieve the Data Analyst from onerous and repetitive tasks with limited value-add



## Speed

Processing time reduction of up to 90% with out compromising quality

## Quality

Reliable, reproducible automated processing using standardized and validated algorithms

## Creativity

Fast feedback about key features allows rapid iteration of problem framing by the data analyst

## Scalability

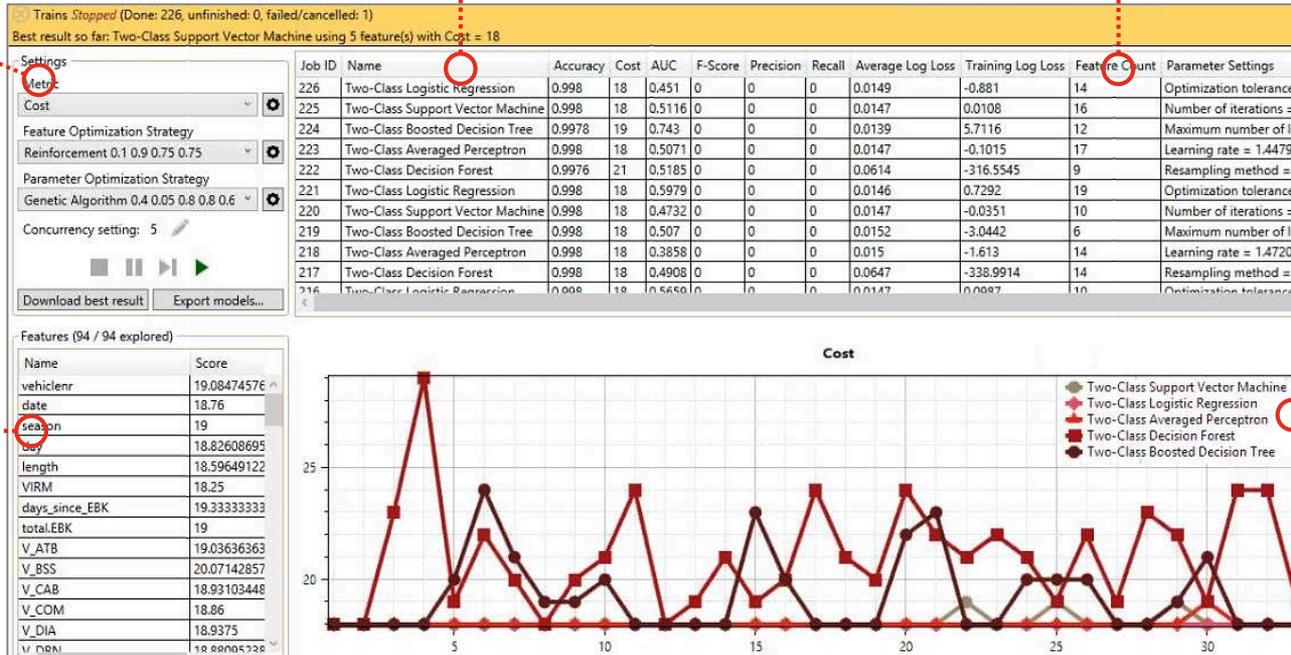
Deployment in cloud gives unprecedented computing power to the user

# The Data Science Machine identifies the most promising features and models in an automated way plus enables a clear focus

Comprehensive options for automated optimization of features and parameters

Automated execution of selected methods and visualization of pattern quality and parameter details

Overview of the identified features.

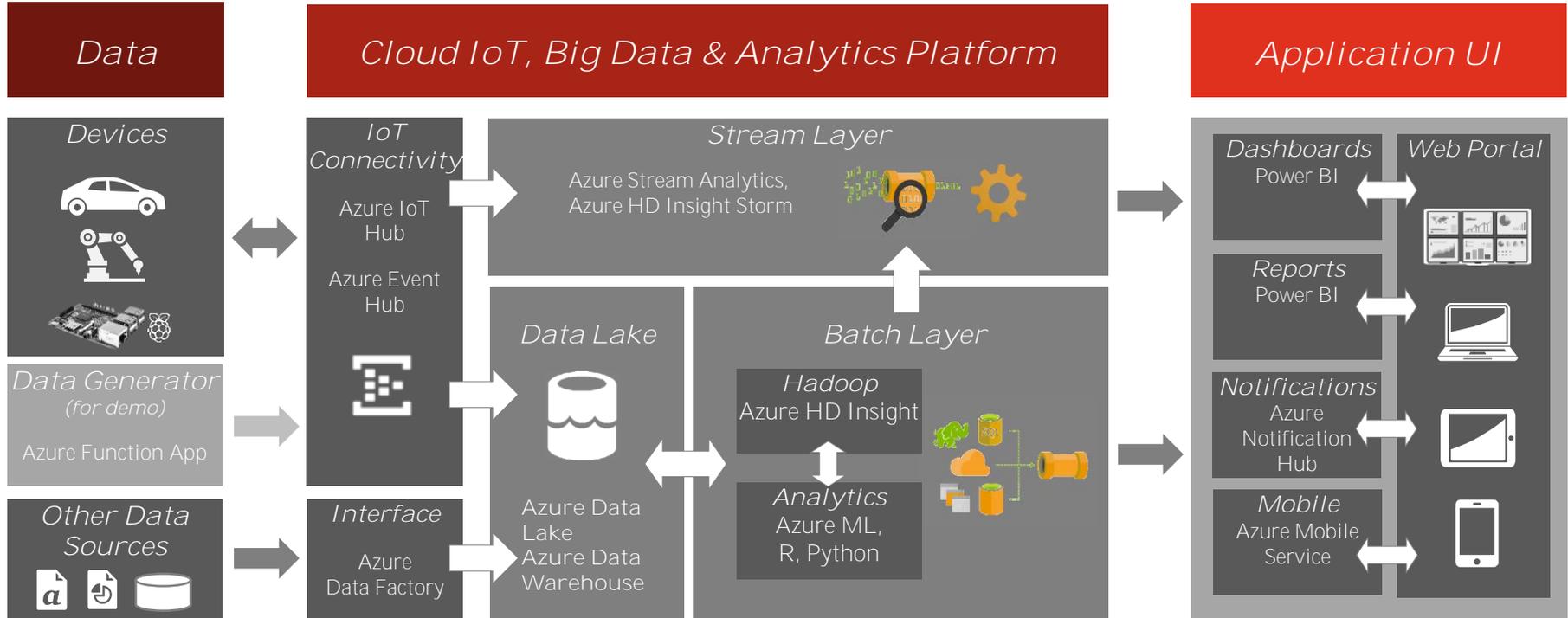


Detailed account of assessed features and identified scorings

Comparison of the selected approaches by means of the chosen optimization strategy

Furthermore, the analytical models need to be embedded into a robust (cloud) application architecture and connected to real-time production data

### Microsoft Azure Architecture





pwc

Experience the possibilities of IoT & Analytics

# IoT & Analytics Innovation Workshop



***Present  
Demos***



***Explore  
Technology***



***Generate  
Ideas***



***Identify  
use cases***

# Thank you!



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