24º Seminário Internacional de Alta Tecnologia

10 OUT 2019
Teatro Erotides de Campos
Engenho Central · Piracicaba · SP

Digitalização da Produção e Produção Digitalizada

ANAIS

Editado por Klaus Schützer

24° Seminário Internacional de Alta Tecnologia

Digitalização da Produção e Produção Digitalizada

Editor

Prof. Dr.-Ing. Klaus Schützer

Lab. de Sistemas Computacionais para Projeto e Manufatura

Faculdade de Engenharia, Arquitetura e Urbanismo

10 de Outubro de 2019

Teatro Erotides de Campos – Engenho Central, Piracicaba, SP

Lab. de Sistemas Computacionais
para Projeto e Manufatura
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Laboratório de Sistemas Computacionais para Projeto e Manufatura

O Laboratório de Sistemas Computacionais para Projeto e Manufatura (SCPM) da Universidade Metodista de Piracicaba (Unimep) está localizado no campus Santa Bárbara da Universidade Metodista de Piracicaba, tendo sido criado em 1995 com foco na pesquisa, residindo aí o seu diferencial, ou seja, sua finalidade primeira é possibilitar o desenvolvimento científico, através de projetos a serem desenvolvidos pelos estudantes sob supervisão dos professores deste laboratório. Esse é o papel que vem desempenhando ao longo dos seus mais de 20 anos de existência, sem descuidar da preservação da indissociabilidade das duas outras colunas de sustentação de uma universidade: o ensino e a extensão.

As primeiras atividades de pesquisa do SCPM foram apoiadas em dois projetos, o KIT #123 - FBaseDsgn, financiado pela Comissão Europeia, e o projeto para implantação de infraestrutura, financiado pelo Deutsche Ausgleichsbank. Em torno desse trabalho, aglutinou-se um grupo de alunos de graduação e pós-graduação que ajudou no planejamento e organização da primeira versão do que se tornou o Seminário Internacional de Alta Tecnologia. O primeiro evento, em 1996, introduziu no Brasil a temática da “Usinagem com Altíssima Velocidade”, que hoje é aplicada em diversas empresas.

Este grupo de pesquisa criou também o Núcleo para Projeto e Manufatura Integrados (NPMI), incluído no Cadastro Nacional de Grupos de Pesquisa do CNPq desde 1995, e que oferece a interface para integração de outros professores e pesquisadores aos trabalhos desenvolvidos no SCPM, além de participar ativamente de projetos de pesquisa em parceira com outras universidades brasileiras.

O SCPM conta hoje com uma equipe de pesquisadores em tempo integral composta de um professor titular, um professor colaborador, doutorandos, mestrandos, alunos de iniciação científica e pessoal técnico de apoio. As atividades científicas desenvolvidas são financiadas na sua maioria com recursos gerados através de projetos de pesquisa nacionais e internacionais, além da prestação de serviços e projetos em parceria com diversas empresas. A estratégia de desenvolver seus projetos de pesquisa o mais próximo possível das indústrias viabiliza uma rápida implementação dos resultados tecnológicos obtidos.

Reunir parceiros para desenvolver projetos mais arrojados tem sido a marca do trabalho do SCPM, o que resultou em parcerias estratégicas desde a sua criação, destacando o Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen (PTW) e o Fachgebiet Datenverarbeitung in der Konstruktion (DiK), ambos da Technische Universität Darmstadt na Alemanha. Essas parcerias já resultaram em inúmeros projetos de pesquisa em conjunto e

em um contínuo intercâmbio de alunos de graduação, mestrado e doutorado, além de professores de ambos os lados.

Desde 2005, o SCPM possui também uma parceria com o Institut für Werkzeugmaschinen und Fabrikbetrieb (IWF) da Technische Universität Berlin, Alemanha, e mais recentemente com a Hochschule RheinMain em Rüsselsheim, Alemanha.

O SCPM dispõe de modernos recursos de hardware e software para o desenvolvimento dos trabalhos de pesquisa, atuando em quatro linhas de pesquisa: Manufatura Inteligente e Fábrica Digital; Desenvolvimento Integrado do Produto; Usinagem com Altíssima Velocidade; e Monitoramento do Processo de Usinagem; além de oferecer suporte a pequenas e médias empresas para especificação, escolha e implementação de sistemas CAD/CAPP/CAM/PDM.

Adicionalmente, o SCPM possui uma Máquina de Medir por Coordenadas Tesa Micro-Hite DCC e um Sistema de Calibração Laser Renishaw, que possibilitam o desenvolvimento de projetos de pesquisa tanto com o foco na integração digital da cadeia CAD/CAM/CAQ, como também no desenvolvimento de métodos para comparação da representação de superfícies complexas nos sistemas CAD e do modelo real após a usinagem, permitindo a avaliação de estratégias de corte e métodos de interpolação da trajetória da ferramenta.

Neste ano o SCPM adquiriu três equipamentos de Manufatura Aditiva (FDM) dddrop Evo Twin pelo Projeto BRAGECRIM – SCoPE com a finalidade de intensificar os trabalhos desenvolvidos dentro da linha de pesquisa Manufatura Inteligente e Fábrica Digital, ampliando assim os recursos para os trabalhos desenvolvidos dentro da grande área Indústria 4.0.

Procurando atender às novas necessidades de empresas de pequeno e médio porte, o SCPM iniciou trabalhos de pesquisa voltados ao Gerenciamento do Ciclo de Vida do Produto (Product Data Management - PDM; Product Lifecycle Management - PLM). E hoje possui um ambiente de desenvolvimento do produto com as características de uma indústria, chamado de Fábrica para o Ensino do Processo de Desenvolvimento do Produto, atuando no projeto do produto e em simulações do processo de gerenciamento de dados do produto ao longo de todo o ciclo de desenvolvimento.

Ainda dentro de seu objetivo de trabalhar com sistemas computacionais que representem o estado da arte, o SCPM criou um grupo de trabalho para atuar no Planejamento Digital de Processos, tendo como foco o desenvolvimento de competências para atuar na temática Fábrica Digital, e hoje já realiza projetos de pesquisa nesta área em parceria com renomadas empresas.

O material didático desenvolvido pela equipe do SCPM nas áreas de projeto e manufatura auxiliados por computador, bem como em gestão do produto, tem sido utilizado não só nos cursos de engenharia da Unimep, mas também por muitas outras universidades de diferentes lugares do Brasil. Esta atuação pautada pelo trinômio pesquisa-ensino-extensão tem sido um importante processo realimentador de todo o trabalho.

Desta maneira, o SCPM, além de uma forte inserção na área de pesquisa, tem conseguido interagir de maneira positiva na definição das grades curriculares dos cursos de engenharia, trazendo o que existe de mais inovador em desenvolvimento integrado do produto, contemplando desde a concepção até a manufatura.

Atualmente, o SCPM desenvolve projetos financiados pela CAPES, CNPq e pelo DFG, além de projetos em parceria com a Volkswagen do Brasil Ltda., Robert Bosch Ltda. e Caterpillar.

Mesmo enfrentando as dificuldades e os desafios inerentes à conjuntura brasileira e à uma universidade particular, o projeto do SCPM visa uma formação ampla de seus pesquisadores e estudantes, enfatizando o aspecto da pesquisa e a inserção internacional de sua equipe através de intercâmbios, destacando-se assim dentro do projeto institucional como um moderno provedor de serviços, dedicado às necessidades dos alunos que atuam no laboratório, das indústrias com as quais tem desenvolvido projetos e da sociedade no seu todo.

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Parceiros SCPM

TECHNISCHE UNIVERSITÄT DARMSTADT

PTW

TU berlin

IWF

Fraunhofer IPK

Hochschule RheinMain

POLI USP

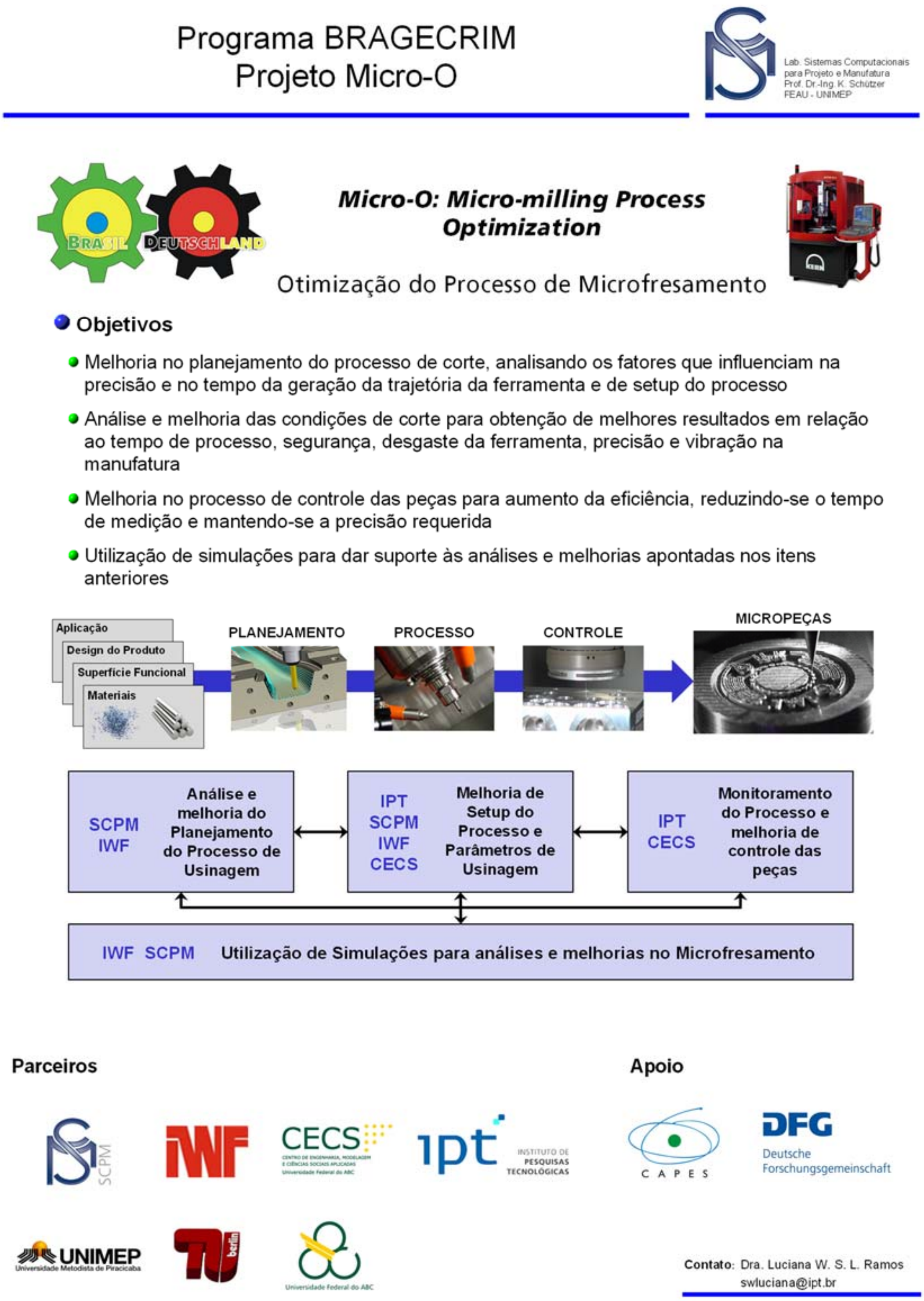
SIEMENS

Volkswagen

CATERPILLAR

BOSCH

Principais Projetos em desenvolvimento no SCPM



Manufatura Inteligente e Fábrica Digital

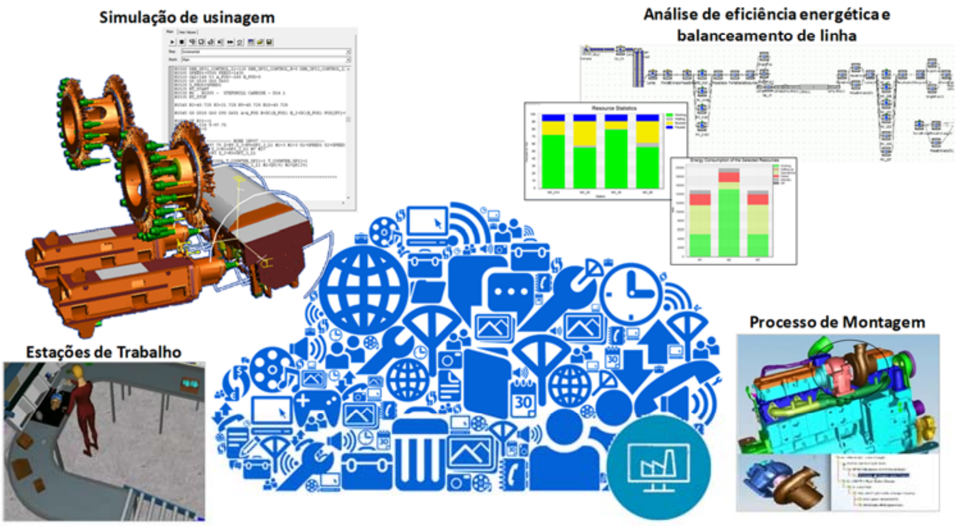
Lab. Sistemas Computacionais para Projeto e Manufatura
Prof. Dr.-Ing. K. Schützer
FEAU - UNIMEP

Temas da linha de pesquisa

- Produtos e manufatura inteligente
- Sistemas físico-cibernéticos de produção
- Comunicação componente-componente, componente-máquina e máquina-máquina (M2M)
- Critérios para seleção e implantação de sistemas para representação da Fábrica Digital
- Digitalização e simulação do processo produtivo

Projetos desenvolvidos

- Implementação de ferramentas de simulação no conceito de Fábrica Digital
- Construção de um modelo virtual para simulação e comparação com um processo de manufatura real da indústria
- Otimização da trajetória de ferramenta em processos de usinagem visando ganho de tempo no processo de produção
- Balanceamento de linha visando eliminação de gargalos
- Utilização da simulação visando a otimização de eficiência energética de uma linha de produção



Parceiros

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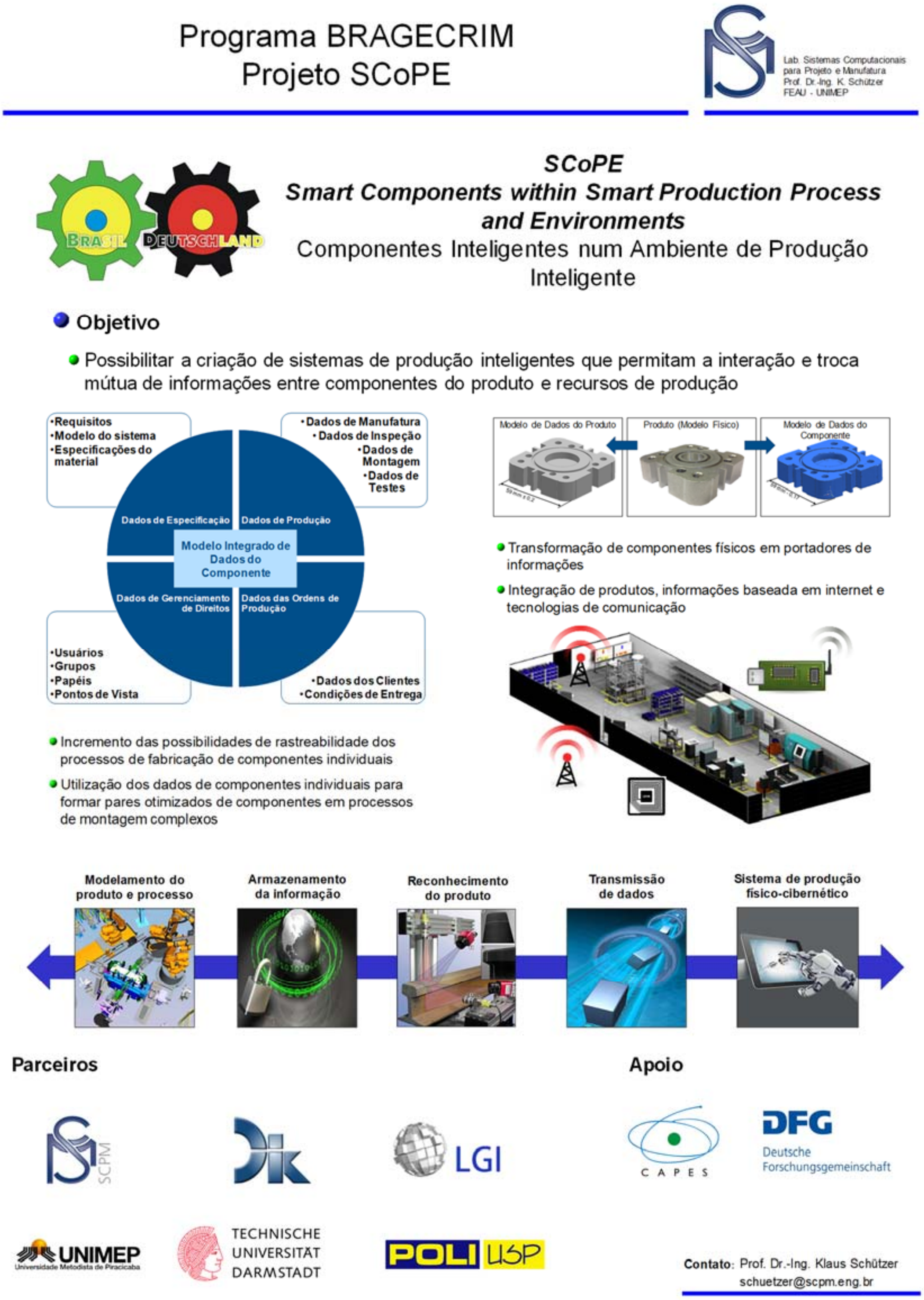

Programa BRAGECRIM
Projeto SCoPE
Lab. Sistemas Computacionais para Projeto e Manufatura
Prof. Dr.-Ing. K. Schützer
FEAU - UNIMEP
BRASIL
DEUTSCHLAND
SCoPE
Smart Components within Smart Production Process and Environments
Componentes Inteligentes num Ambiente de Produção Inteligente
Objetivo
Possibilitar a criação de sistemas de produção inteligentes que permitam a interação e troca mútua de informações entre componentes do produto e recursos de produção
•Requisitos
•Modelo do sistema
•Especificações do material
•Dados de Manufatura
•Dados de Inspeção
•Dados de Montagem
•Dados de Testes
Dados de Especificação
Dados de Produção
Modelo Integrado de Dados do Componente
Dados de Gerenciamento de Direitos
Dados das Ordens de Produção
•Usuários
•Grupos
•Papéis
•Pontos de Vista
•Dados dos Clientes
•Condições de Entrega
Modelo de Dados do Produto
Produto (Modelo Físico)
Modelo de Dados do Componente
Transformação de componentes físicos em portadores de informações
Integração de produtos, informações baseada em internet e tecnologias de comunicação
Incremento das possibilidades de rastreabilidade dos processos de fabricação de componentes individuais
Utilização dos dados de componentes individuais para formar pares otimizados de componentes em processos de montagem complexos
Modelamento do produto e processo
Armazenamento da informação
Reconhecimento do produto
Transmissão de dados
Sistema de produção físico-cibernético
Parceiros
Apoio
SCPM
LGI
CAPES
DFG
Deutsche Forschungsgemeinschaft
UNIMEP
Universidade Metodista de Piracicaba
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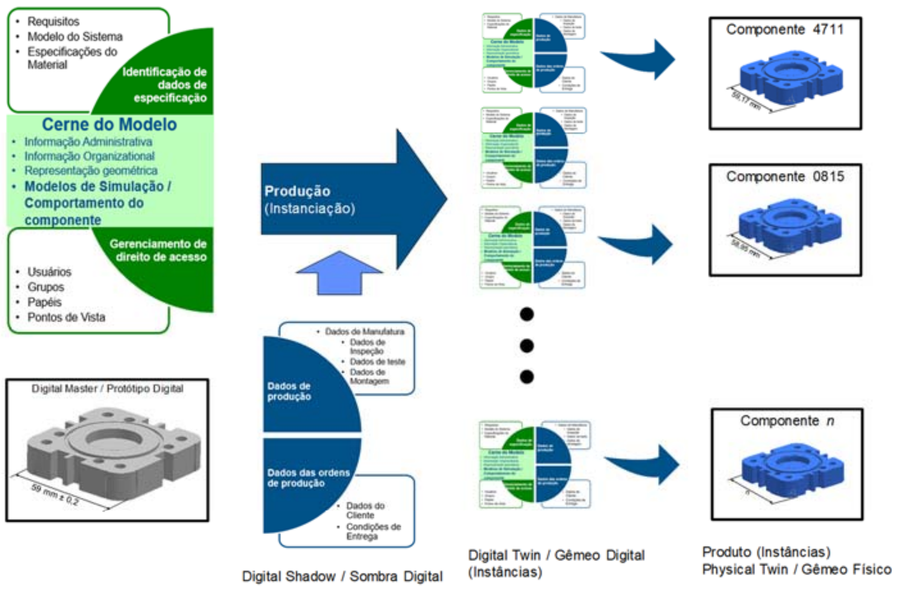
IndusTwin Gêmeo Digital (Digital Twin)

Lab. Sistemas Computacionais para Projeto e Manufatura
Prof. Dr.-Ing. K. Schützer
FEAU - UNIMEP

Desenvolvimento de um Gêmeo Digital baseado no ciclo de vida do produto para dar suporte ao processo de fabricação

Objetivos

- Desenvolvimento de um Gêmeo Digital do Processo de Manufatura baseado no ciclo de vida do produto e do processo de manufatura afim de fornecer diretrizes para a implementação do Gêmeo Digital do Processo de Fabricação
- Possibilitar a criação de sistemas de produção inteligentes que permitam a interação e troca mútua de informações entre componentes do produto e recursos de produção



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Demonstrador Indústria 4.0
Linha de montagem inteligente
Lab. Sistemas Computacionais para Projeto e Manufatura
Prof. Dr.-Ing. K. Schützer
FEAU - UNIMEP
Objetivo
Planejar e implementar um sistema de produção inteligente
Analisar e definir tecnologias habilitadoras da Indústria 4.0, incluindo Internet das Coisas, Sistemas Físico Cibernéticos e Big Data
Identificar dados para monitoramento
Monitoramento por câmera
Comunicação M-M
Retrofit
CNC
Previsão de falha
Consumo de energia "Estação 3"
Consumo de energia (kW)
Unidades produzidas
Motor 1
Motor 2
Motor 3
Visibilidade e Capacidade Preditiva
Adaptabilidade
Transparência
Auxílio sistema multimídia
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Ambiente de Aprendizagem
Processo de Desenvolvimento do Produto

Lab. Sistemas Computacionais para Projeto e Manufatura
Prof. Dr.-Ing. K. Schützer
FEAU - UNIMEP

Objetivos

- Desenvolver um ambiente de Desenvolvimento de Produto Integrado com suporte de PDM
- Criar estruturas do produto
- Criar *workflow* para o Desenvolvimento Integrado do Produto
- Implementar ferramentas de modificação do produto
- Avaliar os desafios e contribuições da Ferramenta PDM em um ambiente de Engenharia Simultânea
- Contribuir para o aperfeiçoamento técnico de alunos nas ferramentas PDM, CAD e CAM
- Capacitar pessoal técnico na área de Desenvolvimento de Produto para a Indústria 4.0
- Capacitar pessoal técnico na área de Manufatura Aditiva

CONCEPÇÃO

GESTÃO DE VERSÕES

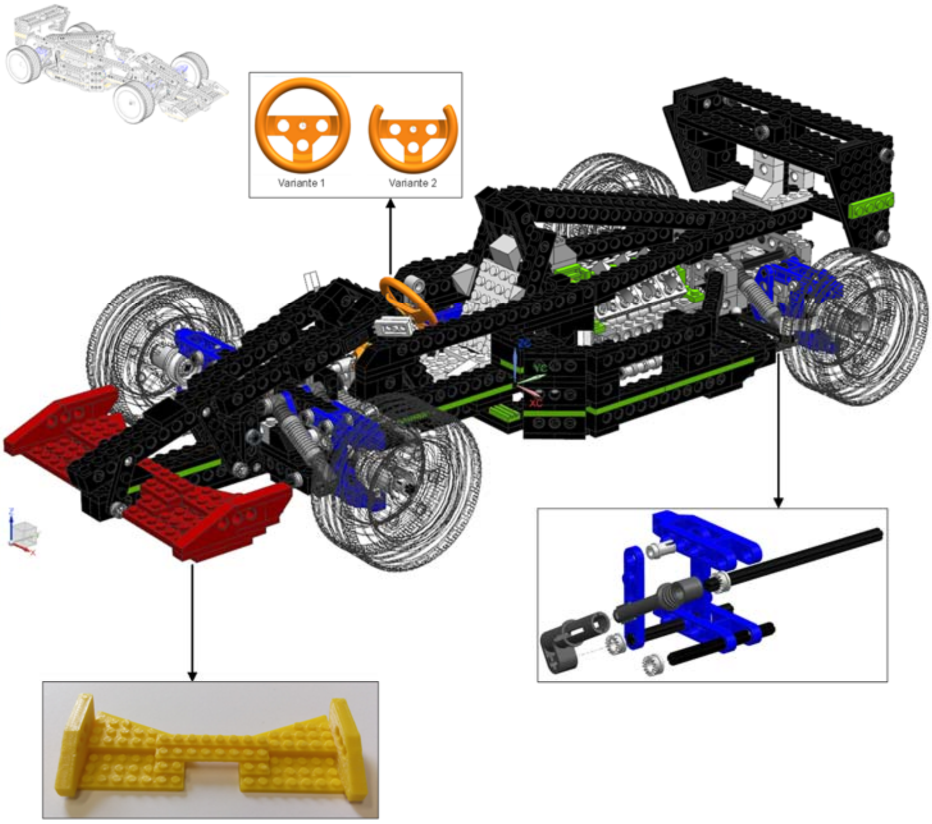
APROVAÇÃO DE PEÇAS

MONTAGEM

NOVAS VARIANTES

ECR

PROTÓTIPO



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Apresentação

Os períodos de instabilidade trazem em si dois elementos que impactam diretamente as empresas. Por um lado, há redução da demanda impactando em redução da produção e investimentos. Por outro lado, a pressão competitiva de um mercado globalizado impõe grandes desafios para as empresas, cobradas a investir para reduzir custos e aumentar a competitividade de seus produtos para se manterem à frente de seus concorrentes, exigindo para isso inclusive inovação em produtos e processos produtivos.

Dentro deste cenário, temos os desafios globais que direcionam as fábricas a serem mais inteligentes, mais enxutas, mais ágeis e muito mais produtivas se apoiando nos avanços da tecnologia de manufatura, na automação e na conectividade digital. A tomada de decisão rápida e confiável e a gestão inteligente do fluxo de informações são pré-requisitos, uma vez que a produção passa a ser movida pela informação.

Tendo esses desafios como perspectiva de ação, o Comitê Científico do 24º Seminário Internacional de Alta Tecnologia definiu como tema para o evento deste ano a Digitalização da Produção e Produção Digitalizada. É nosso objetivo discutir com os palestrantes convidados o processo e os desafios para a Digitalização da Produção, ao mesmo tempo que trazemos também especialistas que já possuem casos de sucesso de uma Produção Digitalizada para apresentar e discutir com nosso público seus resultados.

A tecnologia de informação e comunicação, os modelos digitais do produto e da produção, em conjunto com a internet e algoritmos inteligentes para tratamento de dados, caracterizam a grande mudança de rumo que vem ocorrendo na manufatura e originam o processo de Digitalização da Produção com os chamados Gêmeos Digitais (Digital Twin). Os obstáculos a serem vencidos são muitos e exigem uma combinação das mais diversas soluções com destaque para tecnologias inovadoras que conduzem à transformação digital das empresas, um dos principais pilares da chamada 4ª Revolução Industrial, ou Industria 4.0.

O movimento Indústria 4.0 não é um fim em si. Está intimamente ligado a objetivos econômicos claros e oferece potencial para uma diferenciação mais clara na concorrência global.

A introdução da Indústria 4.0 impõe outros desafios e oportunidades também para os recursos humanos das empresas, pois um dos principais requisitos para sua introdução bem-sucedida são os profissionais bem qualificados. Deve também permear questões relacionadas à sustentabilidade e programas que consideram estratégias de eficiência energética que podem

ajudar a reduzir custos operacionais da empresa, permitindo que a economia resultante seja investida em outras áreas para promover o crescimento e a inovação.

Considerando esse contexto, buscamos identificar as inovações que vêm sendo desenvolvidas em projetos de pesquisa ou que já estão sendo implantadas com sucesso em empresas de referência com o objetivo de gerar novas ideias e soluções que serão determinantes para o sucesso das empresas. Desta forma o Seminário aborda os seguintes subtemas:

- Digitalização da Produção
- Eficiência Energética e Sustentabilidade
- Lean na Indústria 4.0
- Inspeção e Metrologia 4.0
- Fábrica Inteligente (Smart Factory)
- Inteligência Artificial aplicada à Produção
- Big Data X Predictive Intelligence

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Índice

Artigos Completos – Full Papers

Artigos Completos

Full Papers

Univ.-Prof. Dipl.-Wirtsch.-Ing. Wilfried Sihn

In September 2004 Univ. Prof. Dr. Ing. DI Prof eh. Dr. h.c. Wilfried Sihn joined the TU Wien as a professor for industrial and system engineering at the Institute of Management Sciences and has since been head of this Institute twice, according to rotation. In November 2008, he was appointed Managing Director of the newly founded Fraunhofer Austria Research GmbH and manages the Division Production and Logistics Management in Vienna. He has been active in the field of applied research for more than 30 years now, taking part in more than 300 industrial projects. His areas of expertise include production management, corporate organization, enterprise logistics, factory planning, order management, life-cycle management, maintenance, modelling and simulation, and business process reengineering. His current focus is on implementing Industry 4.0 concepts, such as Smart Maintenance.Besides being part of advisory and administrative boards, he also holds several positions in various organizations, e.g. board member of the International Federation of Production Research (IFPR) as well as the German Chamber of Commerce (DHK) in Vienna, member of the European Academy for Industrial Management (AIM) and Fellow Member of the International Academy for Production Engineering (CIRP).

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IMW, TU Wien

The Research area of Industrial, System Engineering and Facility Management is part of the Institute of Management Science (IMW) with a long-term experience providing innovative, in-house solutions for design and management of manufacturing enterprise, especially focusing on production and logistics management, operation and engineering management, digitalized workplace and digital transformation in manufacturing enterprises (aka Industry 4.0). Prof. Wilfried Sihn directs this research area.

TU WIEN TECHNISCHE UNIVERSITÄT WIEN — imw INSTITUTE OF MANAGEMENT SCIENCE

Fraunhofer Austria

Prof. Wilfried Sihn serves as the CEO of Fraunhofer Austria leading the division of Production and Logistics Management and Advanced Industrial Management, both are located in Vienna, as well as the Innovation Center for Digital Transformation of Industries in Tirol. The main areas of research, closely connected to teaching, are namely Industrial Engineering, Production and Quality Management, Logistics Management, Digital Transformation and Industry 4.0, Knowledge Management and Industrial Data Science encompassing Smart Data and Production Information Management, Machine Learning for Production and Logistics Management.

Fraunhofer AUSTRIA

Industrial Data Science – From Raw Data to Useful Applications

Abstract

In the light of rapid technological enhancements and digitalization, complex process-related, technical and organizational interdependencies and correlations in production and logistics can no longer be grasped and resolved by domain experts exclusively. Modern data science methods and technologies, e.g. advanced machine learning, are needed to overcome the increasing complexity, to identify new potentials and ultimately to drive business values. From theoretical perspective, huge amounts of data have to be transformed into concrete conclusions and recommendations for action and decisions. However, in contrast to other business sectors, such as financial services, production industries, especially SMEs, suffer the lack of data quality and availability, resources for extensive data mining processes as well as data science competencies. Therefore, industrial data science projects should necessarily focus on how to generate new data with the help of industrial IoT (IIoT) and how to build simple but usable and accurate data models in cooperation with domain experts e.g. for predictive maintenance, process time forecasting or real-time collision detection for human-robot-collaboration. Furthermore, SMEs gain benefits from new approaches such as text mining or reinforcement learning applied for prescriptive maintenance and advanced production planning and control. Finally, yet importantly, achieving intelligent functions in the industrial value chain is explored by identifying challenges and potential directions toward the integration of artificial intelligence (AI) and industrial processes.

Keywords

Data Science; Production and Logistics Management; Data Mining; Machine Learning; Artificial Intelligence.

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1 Introduction to Industrial Data Science (IDS)

The famous equation "Data is the new oil" is widely credited over the past decade. The google trends reveal its interest over time, where the peak popularity has been achieved in February 2018. The most popularity has been indicated in New Zealand, India, United Kingdom, Australia, Canada, Germany, and the United States. The UK Mathematician Clive Humby coined the phrase in 2006 as "Data is the new oil. It is valuable, but if unrefined it cannot really be used. It has to be changed into gas, plastic, chemicals, etc. to create a valuable entity that drives profitable activity; so must data be broken down, analyzed for it to have value". Data is the new commodity and in fact, a resource, which potentially enables individual and enterprises to achieve the highest level of perception and performance. The key question is, "How the enterprise's potentials can be transformed into reality?"

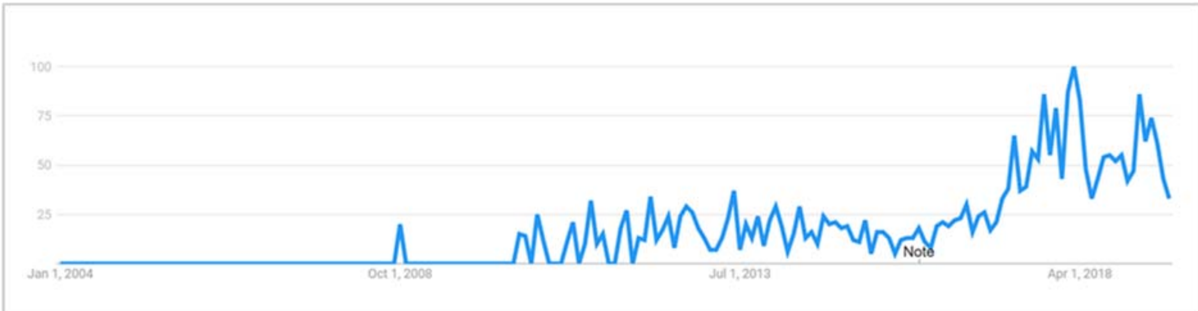

Figure 1: Google Trends for "Data is the new oil" – Accessed on July 14, 2019

The increasing availability and variation of product, process, (physical, intellectual and relational) asset and business data in current industries has led to the need for generating actionable information and reliable knowledge towards innovative business models, connected products and disruptive process optimizations enhanced by data mining and machine learning (aka automated data mining).

Many procedure models and attempts to standardize the data mining process have been under-taken during recent years. One especially widespread and widely credited approach is the cross-industry standard process for data mining (CRISP-DM) [1]. CRISP-DM describes several phases applied in parallel or sequentially to extract meaningful information (i.e., patterns, correlations, etc.) from data. Although some phases are defined and published in a standardized way [2], [3] and [4], the following detailed phases have been reasonably established in our Industrial Data Science (IDS) projects as exemplified by the use-cases (cf. Section 2). Figure 2 depicts the adopted version of CRISP-DM for IDS project, where ten phases are as follows:

1. **Potential analysis** covers the identification of challenges and problems that could be solved with the help of data as well as the definition of potential data-driven innovations.

2. **Business understanding** defines project objectives and requirements based on, business strategies and goals, and is to derive data mining tasks and milestones.
3. **Data acquisition** focuses on gathering data from various and heterogeneous data sources, such as sensors, intelligent connectivity based on Internet of Things (IoT), machines and robotic controls, from multidimensional organizational levels (strategic, tactical and operational levels) and related industrial information systems, e.g. enterprise resource planning (ERP), manufacturing execution system (MES), Supervisory Control and Data Acquisition (SCADA).
4. **Data understanding** deals with an initial data collection and proceeds with activities to explore first insights into the data (e.g., trends, correlations, anomalies, outliers), to establish the ground truth (e.g., target values), and to systematically evaluate data quality and availability.
5. **Data storage** is required to govern real-time data streams and historical raw data as well as pre-processed and processed data during all CRISP-DM phases. Scalable data warehouses and cloud-based IoT platforms represent one option for data storage with a high degree of collaboration capability.
6. **Data integration** stands for transforming heterogeneous data from different data sources into a clean and usable dataset.
7. **Data analysis and analytics** deploys mathematical, statistical and simulation-based modeling tools and algorithms to learn patterns and correlations in the given training data set collected from industrial use-case, and accordingly estimate similar patterns and correlations precisely and accurately once exposing to a new data set.
8. **Evaluation** is required to review and select an appropriate model according to specific quality parameters, such as prediction accuracy.
9. **Visualization** helps to gain information out of data, such as trends, correlations, or anomalies and interpret them by measures and indicators.
10. **Deployment** ensures that developed models are systematically transferred into sustainable solutions in practice.

The application of the CRISP-DM requires not only data mining expertise but also related domain knowledge (i.e., business and domain-specific understanding) in the industry context. In the use cases described in Section 2, the cross-disciplinary cooperation has been established among various domain experts, namely data scientists, production management experts as well as process and control engineers.

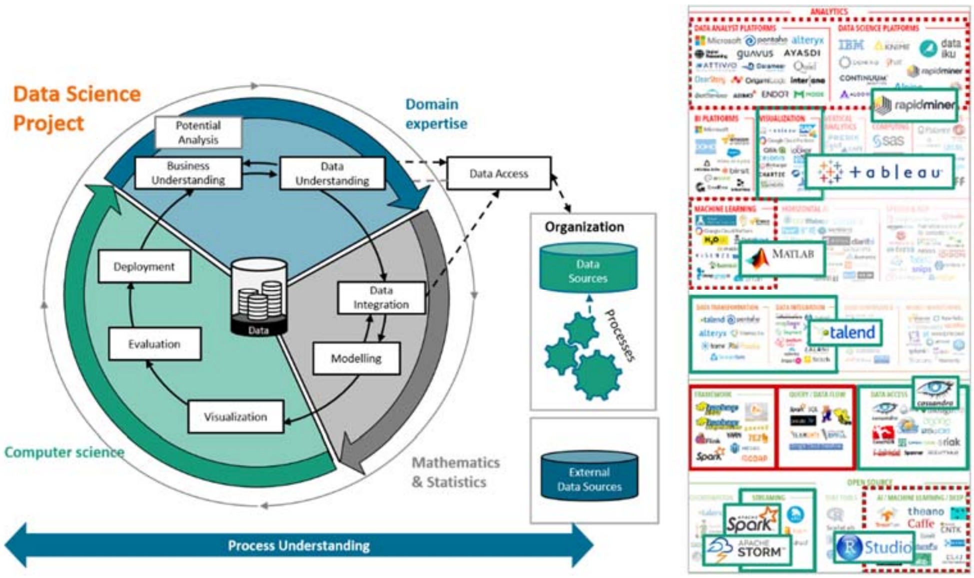

Figure 2: Adopted CRISP-DM for IDS Projects

The rest of the paper is structured as follows. Section 2 provides two applied IDS use-case in semi-conductor manufacturing industry, dealing with predictive maintenance and lead time forecasting. Section 3 elaborates on two specific IDS areas, as research in progress, namely automated simulation modeling and industrial IoT in (intra-)logistic Systems. Finally, Section 4 portrays the avenues for future research in IDS towards industrial artificial intelligence (AI), where challenges and directions for the integration of AI and industrial processes are discussed.

2 Applied IDS Use Cases: Success Stories in Semi-Conductor Manufacturing Industry

2.1 Predictive Maintenance by Focusing on OEE

In the use-case of predictive maintenance, the main has been set to combine expertise drawn from the fields of maintenance management and data science in order to monitor and predict maintenance relevant key performance indicators (KPIs) of a semi-automatic production line at an Austrian SME. The gained transparency of the KPIs facilitates the systematic and future-oriented improvement, optimization and control of production processes.

The key components within this use-case focus on i) the investigation on appropriate machine learning methods for efficient and effective prediction of maintenance relevant key performance indicators, in particular, overall equipment effectiveness (OEE), and ii) the development of a prototypical tool for the monitoring and visualization of results obtained by the established approach. The following hypotheses derived for the reference production line lay the ground for generating a machine learning model for predicting the OEE:

- The type of production order and its properties have a significant effect on the production time of the production order itself;
- The operator has a significant effect on the production time of a production order;
- The production time can be forecasted with a practically acceptable precision.

As a first step, a basis data set has been prepared, which was split into a training (containing 80 % of the records) and a validation data set (containing the other 20 % of the records). In order to compare different machine learning approaches and their precision, a variety of different models has been applied to the data set, namely: linear regression (LR), ridge regression (Ridge), lasso regression (Lasso) K-nearest neighbor regression (KNNR), decision tree regression (DER), random forest regression (RFR) and a boosted random forest (EXTR). The models have been trained and evaluated by using a cross-validation technique with ten splits and were compared by the metrics R^2, and the normalized root mean square error (nRMSE).

As shown in Figure 3, the best results could be reached with the RFR forecast model in the second parametrization (with 50 estimators), which has a precision of 82.40 % and is by 96.37 % better as a simple static mean (as the R^2 metric suggests) at forecasting the OEE. Based on these satisfying prediction results, a real-time capable data aggregation, streaming, and visualization IT-architecture was set up. Notably, the entire project and underlying methodology has been elaborated in [5] and [6].

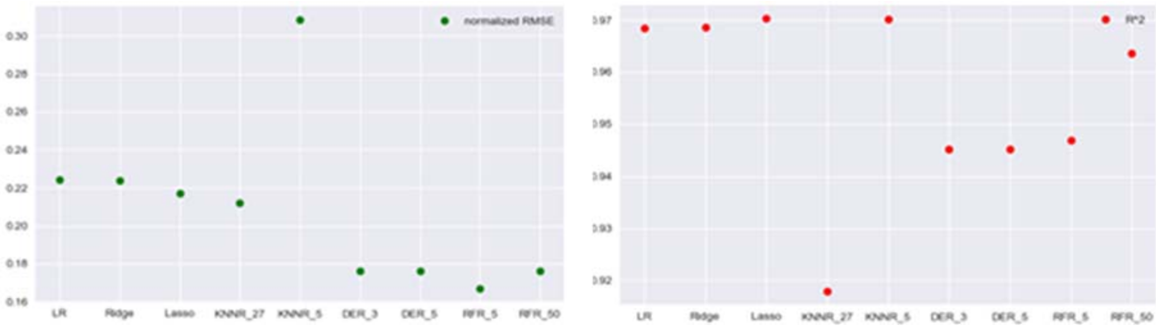

Figure 3: LEFT: NRMSE, RIGHT: R²

Predictive and prescriptive maintenance approaches (cf. [7]) mainly focus on the prediction of machine failures, wear conditions, or remaining useful lifetime and providing appropriate maintenance measures and strategies. The prediction of maintenance relevant KPIs is a relatively new research field, which can lead to multiple benefits in the area of maintenance and production:

- **Increased planning reliability and stability:** A production planner may react actively to future fluctuations in the OEE by dispatching of production orders and allocation of delivery dates.

- **Anticipation of the amount of impending machine failures:** In case a lower OEE is predicted, the maintenance sector is likely to experience a higher number of failures. Accordingly, personnel capacities can be made available in order to reduce the reaction time to disruptions. Similarly, it applies to the machine operator during minor interruptions to the system.
- **Indirect positive influence on strategically relevant key figures**: Key business indicators such as the delivery service level and total maintenance costs can be affected, especially by anticipating indirect and unplannable cost parameters.

2.2 Lead Time Forecasting for Improving Quality in Production Planning

Lead time is, on the one hand, an important performance indicator of a production system and a target figure of production planning. On the other hand, lead time is used for calculation of delivery dates, material requirements planning, and production control. Therefore the accuracy of the lead times used to calculate the production plan have a high impact on the quality of the production plan in the sense of actual and plan deviations. In this context, Schuh et al. (2015) [8] revealed that the planning quality drops by 75% after three days. One of the reasons is that currently used planning systems do not reflect stochastic effects within the production system.

One possibility to tackle this dilemma is to use machine learning algorithms to incorporate the individual stochastic effects on the lead time. The authors' conducted literature survey revealed that most research of time-related data mining analysis (e.g., flow time, (lot) cycle time, lead time): i) have focused on the whole process flow, ii) have used a dataset generated by simulation and iii) have applied and compared just a few machine learning algorithms (cf. [9], [10],[11], [12]). The authors determine several challenges in frequently used approach of training machine learning models on simulation-based data as follows:

1. A simulation model should be created, that depicts the underlying production system.
2. A machine learning model must be trained on the basis of the data generated by the simulation model.
3. Small deviations from the simulation model to the production system as well as the accuracy from the machine learning model to the simulation model can influence the overall accuracy of the prediction to the actual system.
4. The effort for all aforementioned steps can be considered as reasonably high especially considering the fact that modern cyber-physical production systems generate a huge amount of data nowadays.

Hence, the proposed approach does not need a simulation model to create a sufficient data source for training the models. The data comes directly from ERP and MES of a partner company. The methodological approach orientates on the CRISP-DM (cf. Section 1) and is depicted in Figure 4.

Furthermore, the proposed approach provides a set of standardized features that come from extensive literature research to support the practical user. As the system behavior may change over time, on the one hand, it is assumed that i) the train-test split must not be done randomly and ii) the model should be retrained from time to time on the other hand. This means that the training is done from a definable number of lots whereas these lots are selected from chronological order. The trained model can then be applied to the next defined number of lots, e.g., learn from 2000 lots and predict next 200 lots.

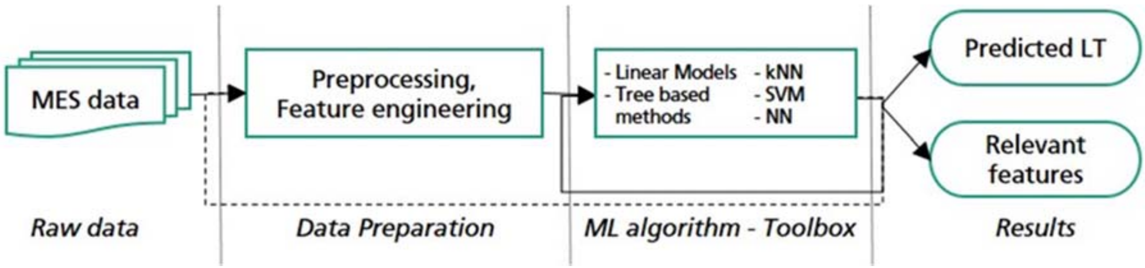

Figure 4: CIRSP-DM inspired Methodology for Lead Time Forecasting – Reprinted from [11]

The outcome of the approach will be demonstrated based on a project from the semiconductor industry. The product consists of several layers and is produced in cycles, running over the same machines for every layer. The prediction is done per layer and product, and the result is compared to the average value. Table 1 illustrates the normalized root mean squared error, the KPI that was chosen to evaluate the accuracy of the models for different product groups and the total number of lots. In most cases, machine learning algorithm gives a more accurate prediction for the lead time. Products with a low number of samples have a lower accuracy or in two cases time prediction with ML could be done at all. The more data is available; the accuracy of the prediction could be increased.

Notably, that the presented data is an example taken from the 10 various layers of the 14 different products. ML gives a far better cycle time prediction than the currently used static planned cycle times calculated with the average cycle times. This result shows the importance of ML-based methods and techniques in the production as well.

As the accuracy of the ML algorithm is highly depended on the amount of data, this approach has some disadvantage for products with new releases (new products or prototypes) or too few samples. This can be compensated to some extent when the model is generated by certain features that group parts to part families, whereas by part number.

Table 1: nRMSE values for the different Lead Time Calculations

Product	Average	ML	Number of lots
1	17.9	11.7	2228
2	12.5	12.7	1103
3	15.9	13.7	964
4	11.8	18	237
5	23.1	18.4	289
6	20.6	18.8	345
7	23.7	20.4	142
8	27.4	25.1	118
9	25.9	29	32
10	56	41	11
11	37.4	43.4	32
12	19.4	66.3	145
13	18.3	-	7
14	117.8	-	9

Figure 5 visualizes the overall result of the presented approach on lead time forecasting. The orange line shows the static average lead time used currently by the company for production planning. Dots displayed in black are the real times and in green are the predicted values. It can be seen that the difference between the real and predicted values are statistically smaller than between the average and real values for 85% of the products.

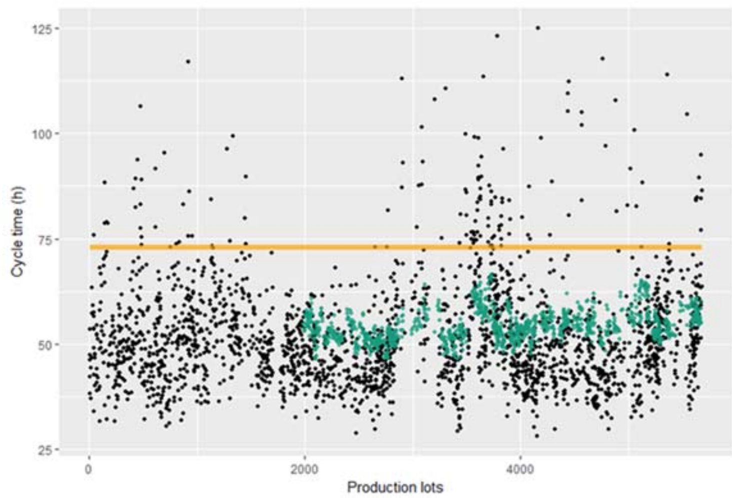

Figure 5: Example of Comparing Real and Predicted Cycle Times within the Current Planned Times

3 IDS Research in Progress and Future-oriented Approaches

3.1 Automated Simulation Modelling

An ideal, future-oriented and in fact challenging research area of IDS is to establish a realistic simulation model of a production system, with little effort, for every company, independent of technology, data quality, and employee qualifications, based on sensor data collections.

There are different approaches for an automatic simulation model generation (ASMG) as discussed and compared by Reinhardt et al. (2019) in [13]. The following approaches could be noticed:

- High-level modeling automation automated XML model building,
- ERP-driven automated modeling;
- Standards-based virtual factory modeling, and a digital twin for small and medium-sized enterprises,
- Approaches that rely on an intermediary database, derive data from PLC code, develop applications for data conversion, utilize data interfaces and standards or were directly integrated in existing data infrastructure.

Another more detailed classification scheme is based on case of application, type of production, unit of production, user group, degree of automation, approach to model generation, supported phase in simulation studies, required technical interfaces and model reusability (cf. [13] and [14]).

From a different point of view, simulation models can be generated by parametrization and combination of simulation model building blocks, by interpreting structural data of manufacturing systems, such as layout data from CAD software or by a combination of methods of artificial intelligence (cf. [13]and [14]). The common way seems to be that input data is manually entered by the model-building user, manually collected and intermediately stored, automatically collected and intermediately stored or directly retrieved from corporate business systems (cf. [13] and [14]).

The authors figured out that a considerable amount of reviewed approaches relies on an intermediate database or data exchange format, which is beneficial for separating data acquisition and transformation from model generation routines. These approaches often benefit from standardization efforts (cf. [13] and [14]).

There are still challenges for ASMG in incomplete data and modelling dynamics. The approach of "discrete event simulation" and ASMG should be defined as an essential feature for creating the digital twin of an entire factory while also encouraging the utilization methods for processing big data (cf. [14] and [15]). Information for ASMG may be provided explicitly or implicitly and, thus, has to be retrieved by more complex data processing (cf. [14] and [15]). In fact, most of the studied approaches rely on explicit input. However, in recent research, the usage of (automated) data mining (aka machine learning) techniques for additional knowledge extraction from data sources is brought up (cf. [14] and [15]).

Our ongoing research in the area of IDS focuses on providing an ASMG with the use of sensors technologies. In the first step, the goal is to develop a process model as a basis for the simulation model. To reduce the interfaces and the complexity the positional sensors are used, which provides coordinates (x, y, z) and time stamps. The derivation of the model is generated by a heat map with focal points and the processing stations are defined by various rules. These rules are adaptive for diverse use-cases with the integration of a parametric function. The possibility of model parameterization is considered in order to adapt the model so that it can be applied to various use cases.

Besides, an exact process model description should be provided in universal language of the production process with sensor technology; however, without the need of human analysis in the factory. Data for brown and green field (i.e., Reality vs. Ideal state) planning of factories is generated, which can be very useful in case of brownfield (Real state), to change and optimize a running factory system, or for greenfield (Idea) planning to build up a new optimized factory system based on historical data. The sensory systems also provide real-time data of the production, which can be used to build up a digital shadow for information control and production management.

A great benefit of this approach is to speed up the realization of projects on the production process, is no need for onsite optimizer in the factory (be physically in the factory) during the data col-lection phase.

The innovative character is related to transfer and consolidation of information collected from real-time production process data to a process model. The envisaged model is created by incorporating real-time data of the production process in the factory lays the ground for the automatically generated simulation model. Thus, the connection of the static process model with the dynamic simulation model is necessary to achieve the goal. Last but not least, provision of an agile solution independent of any in-house simulation know-how in partner companies, to get an overview of a production process is a great benefit and a step ahead towards the automation process of building a simulation model.

3.2 Industrial IoT in (Intra-) Logistic Systems: Duck Box, Drone and Digital Warehouse Management

Intralogistics comprises all internal material storage and handling and transport costs as well as approximately 25% of the total personnel input, 55% of the space required and 87% of the actual throughput time (cf. [16], [17], [18] ,[19]). These percentages reveal the great potential of an efficient implementation. An essential component of intralogistics is the material flow relationships that are required in the context of value creation. Despite increasing automation, these are usually carried out manually and are associated with high personnel and cost input. The distances covered by industrial trucks or forklift trucks vary, among other things, in terms of their distance, intensity, and relevance for the actual value-added process. These and other properties are investigated within the framework of a material flow analysis (cf. [16], [17], [18], [19]).

The current basis for the analysis of intralogistics material and goods flows is a large number of visualization and modeling tools. For the underlying database, so-called Indoor Positioning Systems

(IPS) or Real-Time Location Systems (RTLS) are used to locate transport vehicles and to draw conclusions about the existing traffic volume based on the positioning data (cf. [19], [20], [21], [22], [23]). By using such systems for further optimization, an efficiency increase of 15-20% can be achieved in the picking area of a warehouse (cf. [19], [20], [21], [22], [23]).

The advancing digitalization with the seemingly infinite number of different computational technologies and sensors is currently used by companies inadequately or not at all. A lack of standardization, poor user-friendliness and a myriad of influencing factors do not permit a specific application for location-based material flow analyses in an industrial environment (cf. [24],[25],[26]).

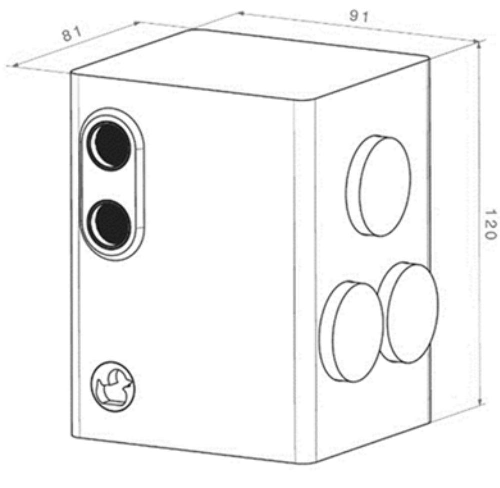

Figure 6: Isometric view of the Duck Box

The research in progress in IDS is aimed at developing a measuring unit entitled “Duck Box” (cf. Figure 6). It essentially has a processor which is powered by a mobile battery and which connects and controls various modules and sensors. All components have been selected for the highest possible economic efficiency and can be obtained easily and inexpensively from independent retailers. An ultrasonic sensor is used to record the loading condition.

Depending on company requirements, the position data, the distance traveled and the associated dwell times are to be recorded alternately using an active RFID (Radio Frequency Identification) tag, UWB (Ultra-wideband), WLAN or Blue-tooth. Depending on the selected IPS and sensor technology, the generated data is recorded locally on a storage medium or alternatively transmitted via a wireless connection to a database positioned in the analysis area. All components are accommodated in a compact and at the same time robust housing suitable for industrial use. The housing is manufactured using the 3D printing process and has various mounting options for industrial forklifts. Figure 7 illustrates the corresponding circuit diagram.

From IDS perspective, the innovative target is to link company-specific requirements and technological framework conditions, in order to make the use of modular, hybrid sensor technology possible and to create the basis for the analysis of material flows. Due to the different requirements resulting from the respective company conditions and processes, individualization is usually necessary. Different technologies and sensors have to be combined into a hybrid overall concept. The use of a modular, hybrid sensor technology enables the company to carry out a complete material flow analysis.

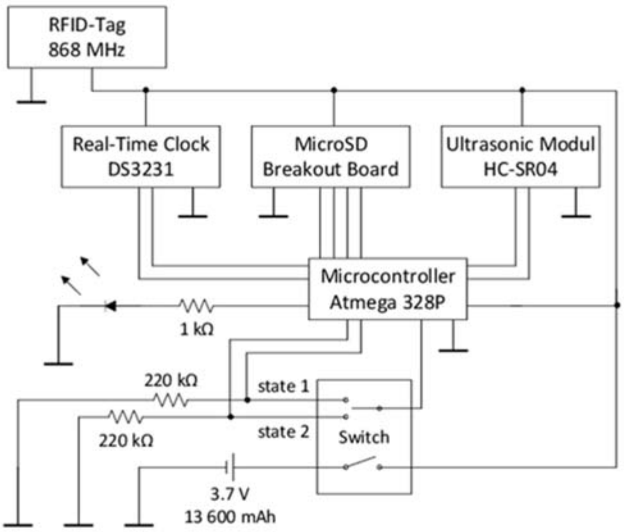

Figure 7: Duck Box's Circuit diagram of the components used

4 Outlook: Towards Industrial Artificial Intelligence

Taking the above-discussion on IDS and related use-cases as well as industrialization artificial intelligence (AI) [27], an undeniable question raise with respect to AI technologies (cf. Figure 8) as "How to go beyond IDS by the integration of AI technologies into industrial processes and ultimately by intelligentization industrial value chain?"

Figure 8: AI Technologies for Intelligentization of Industrial Value Chain

With no doubts, nowadays, AI enables a new generation of manufacturing machines, collaborative robots, transport systems, and vehicles to ideally "Think" and "Act" humanly. This has been relatively well accomplished in experimental lab settings and partially transferred into industrial systems. In real-world manufacturing and logistics systems, AI still has to deal with three major issues:

1. **AI contributions into value-oriented KPIs is still not justifiable,** especially in every section of lead industries, SMEs, and innovation-oriented enterprises. Key questions to be answered are:
   - Does deploying AI systems and technologies necessarily increase productivity?
   - Is the required technological and non-technological investments for AI systems affordable with regard to increasing of productivity?
2. **AI is not a stand-alone enabling technology,** i.e., applicability and affordability of AI should be assessed with regard to its interoperation and integration with state-of-the-art technologies and above that with respect to societal and ethical aspects, especially when AI interacts with human workforce or is supposed to substitute human resources. Key questions to be considered are:
   - What are the change management and leadership strategies with regard to AI implementations in lead industries and SMEs?
   - What is the "AI culture" (in terms of collaboration of the human workforce and AI agents)?
   - Does the ironies of AI neglect the value of human's creativity and innovation (i.e., substitutability of the human workforce by AI agents)?

3. **AI success, especially on AI-supported decision-making approaches, depends on not only availability but also quality, consistency, validity, completeness, and comprehensiveness of data** (cf. Figure 9). Key questions to be addressed are:

    - Do lead industries and SMEs achieve certain maturity and readiness level to overcome data quality management issues, especially with regard to sensor calibrations and processing unstructured data?

    - Do they establish in-house AI competences, implementation strategies, and roadmaps?

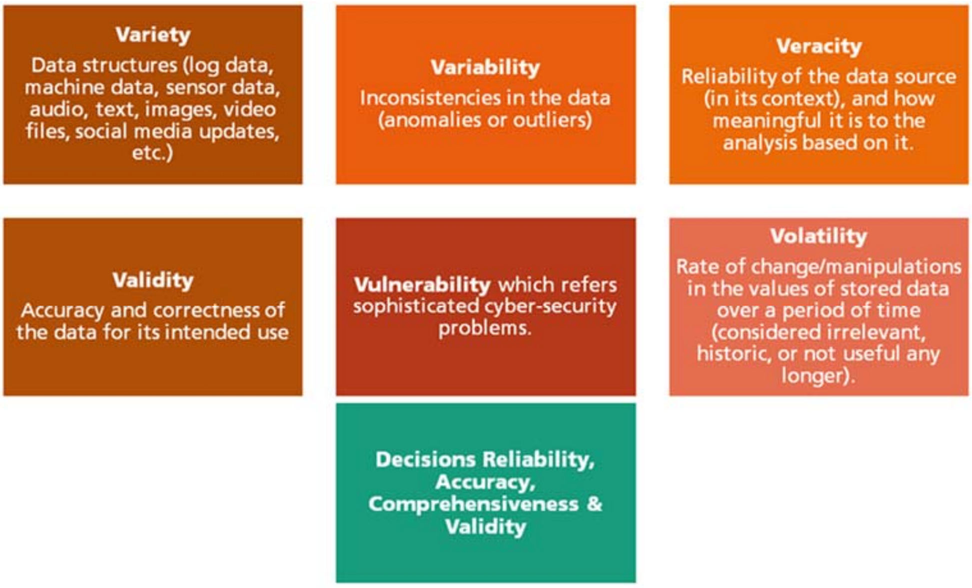

Figure 9: AI-based Decision-Making and Data Quality Challenges

Considering the challenges mentioned above, to the authors' point of view, AI is an enabling technology for the manufacturing and logistics industry, when:

- … its implementation contributes to productivity and is justifiable with respect to "economic factors". For instance, do we need to robotize the entire assembly lines in the automotive industry alike body shops? In reality, the human workforce could provide required flexibility in mass product assembly, and convince quality, time, and cost criteria, when assisted by digital technologies. To tackle this challenge, economically justifiable application areas, in which AI generates extra values, should be still explored. Systematic approaches and instruments are required to deepen the insights into operational and strategic KPIs, so that one may identify the potentials and establish roadmaps for implementing AI. Hence, **AI-based Productivity Index** should be defined. This will be a tangible index for justifying AI applicability and value generation potentials.

- … its potentials and applicability are further justified with regard to change management and leadership strategies required for creating effective implementation master plans.

The human workforce should not only be trained how to interact, e.g. with collaborative robots under safety conditions, but also the awareness about robotization and implementation of AI systems and technologies should be raised among personnel, including administrative, operators, engineers, and managers. It becomes more and more imperative that major part of "Today's Tasks" will be automatized in the next 5-8 years, where the division of labor will be changed from human to the machine workforce. However, "New Tasks" for "Human Workforce" (besides "Robot Tasks for Robots") will be emerged. Therefore, more "Industrial Data Scientifics" and "Industrial AI experts" will be demanded. Not forgetting that, still human workforce is super-ordinated in "Creativity" and "Innovative Thinking" comparing to AI for industrial problem-solving. Hence, lead industries and SMEs should put efforts not only on defining their positions with regard to AI, but also should establish **AI Culture**, where productivity and economic factors meet human-specific value creation factors, especially out-of-the-box and critical thinking, innovating and acting.

- … its computational and reasoning capabilities, especially in accomplishing complex physical and cognitive tasks and problems in industrial systems, are reinforced and sustained by providing quality data. Otherwise, AI integration in industrial processes, especially in decision-making is challenged by "misleadingness", "validity" and "correctness" of causalities, decisions, and pertained actions. As mentioned earlier, data is the oil of the future. However, in real-world industrial projects, the undeniable obstacle is data quality. Data quality will remain as the main hurdle to the success of AI. Therefore, lead industries and SMEs should invest more on **"Data Quality Management"**, especially with regard to **"Sensor Calibrations"** and **"Processing Unstructured Data"**. The former helps to filter noises and errors, and the latter avoids the dilemma of "Storing and Forgetting", where reports are written and stored in an archive forever and most probably will be forgotten after a while. AI itself may support increasing data quality by implementing **"Intelligent Filters"** and **"Anomaly Detectors"** on data streams and also to discover and visualize knowledge extracted from unstructured data, e.g., by means of **"Automated Text-Mining", "Text Summarization", "Word Association Mapping"** and **"Sentiment Analysis".**

To sum up, as the next step in IDS, Industrial AI should be considered as i) an enabling technology for manufacturing and logistics supply chain systems, and also as ii) a catalysis when it is combined with several other enabling technologies such as additive manufacturing, agile- and bio-based manufacturing, collaborative robotics, smart mobility and blockchain. In both cases, AI as an enabler or catalyst, production, and engineering management community should consider three aspects of "economically affordable value creation", "cultural and change management" and "improving data quality".

The above listed directions define the pathways for further investigations on IDS and Industrial AI.

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FRAUNHOFER AUSTRIA RESEARCH
From Raw Data to Knowledge Intelligence
Industrial Data Science
Brazil – 9th of October 2019
24º Seminário Internacional de Alta Tecnologia
Prof. Dr. Wilfried Sihn
Fraunhofer Austria Research GmbH
Division Production and Logistics Management
Vienna University of Technology
Institute for Management Science
Department Industrial and Systems Engineering
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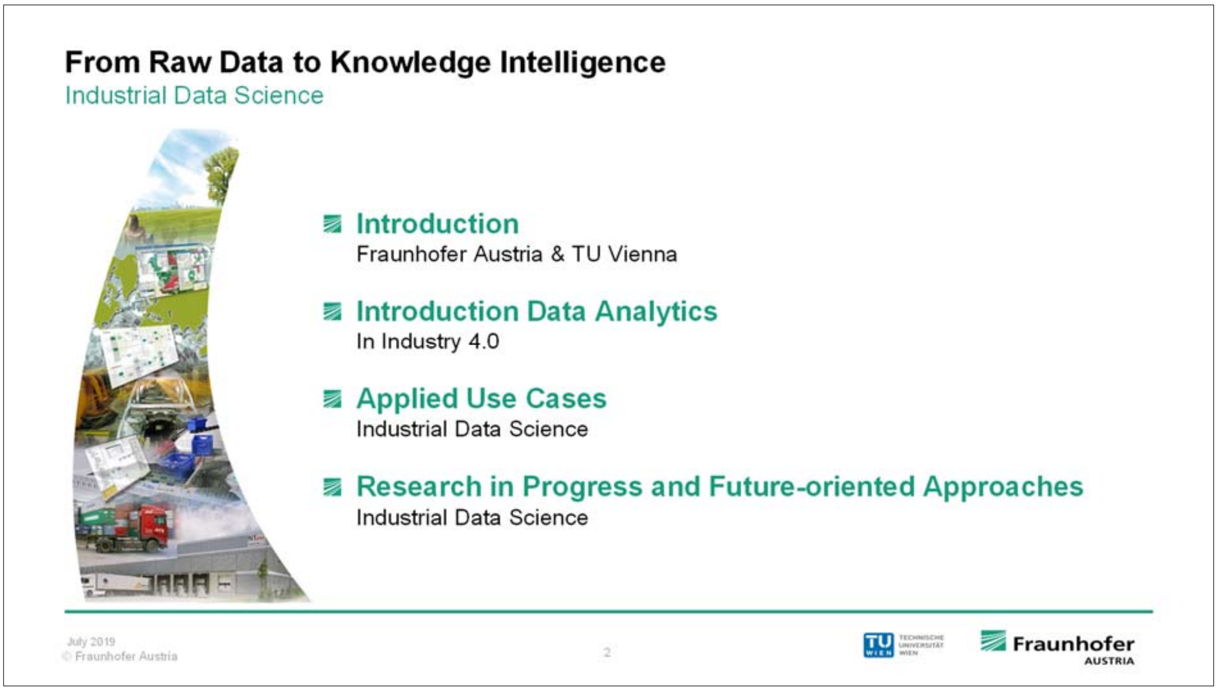
From Raw Data to Knowledge Intelligence
Industrial Data Science
Introduction
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Introduction Data Analytics
In Industry 4.0
Applied Use Cases
Industrial Data Science
Research in Progress and Future-oriented Approaches
Industrial Data Science
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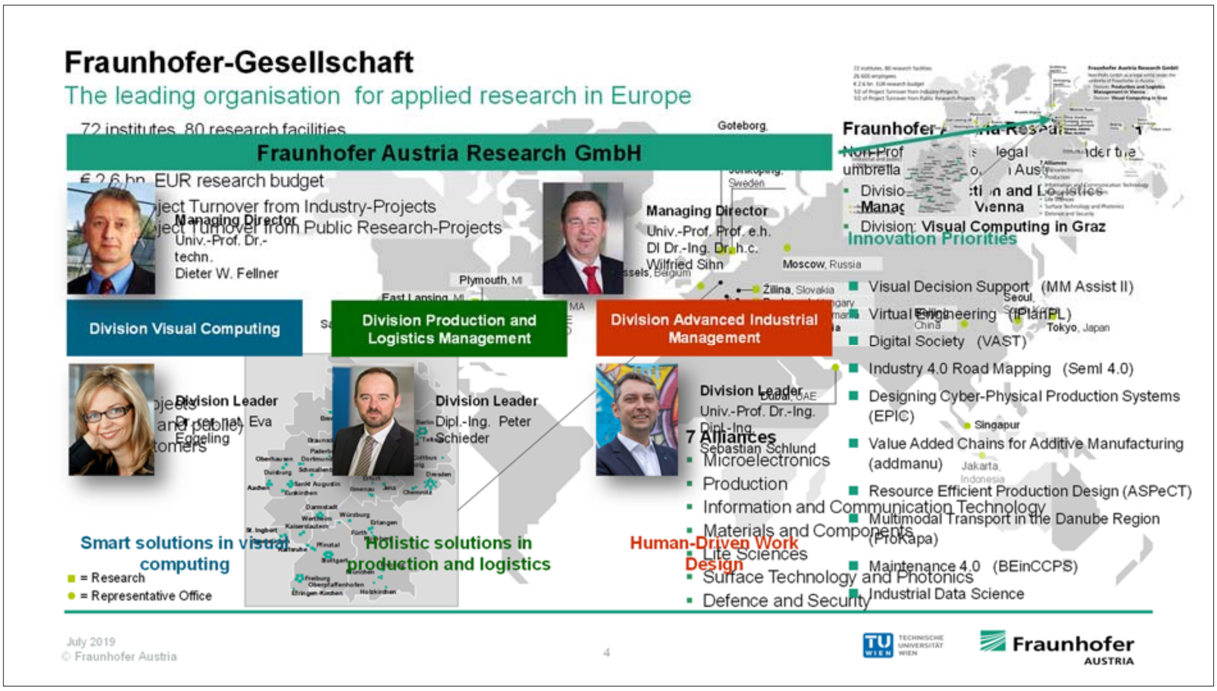
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Smart solutions in visual computing
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Digital Society (VAST)
Industry 4.0 Road Mapping (Seml 4.0)
Designing Cyber-Physical Production Systems (EPIC)
Value Added Chains for Additive Manufacturing (addmanu)
Resource Efficient Production Design (ASPeCT)
Multimodal Transport in the Danube Region
Maintenance 4.0 (BEinCCPS)
Industrial Data Science
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Microelectronics
Production
Information and Communication Technology
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Surface Technology and Photonics
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= Research
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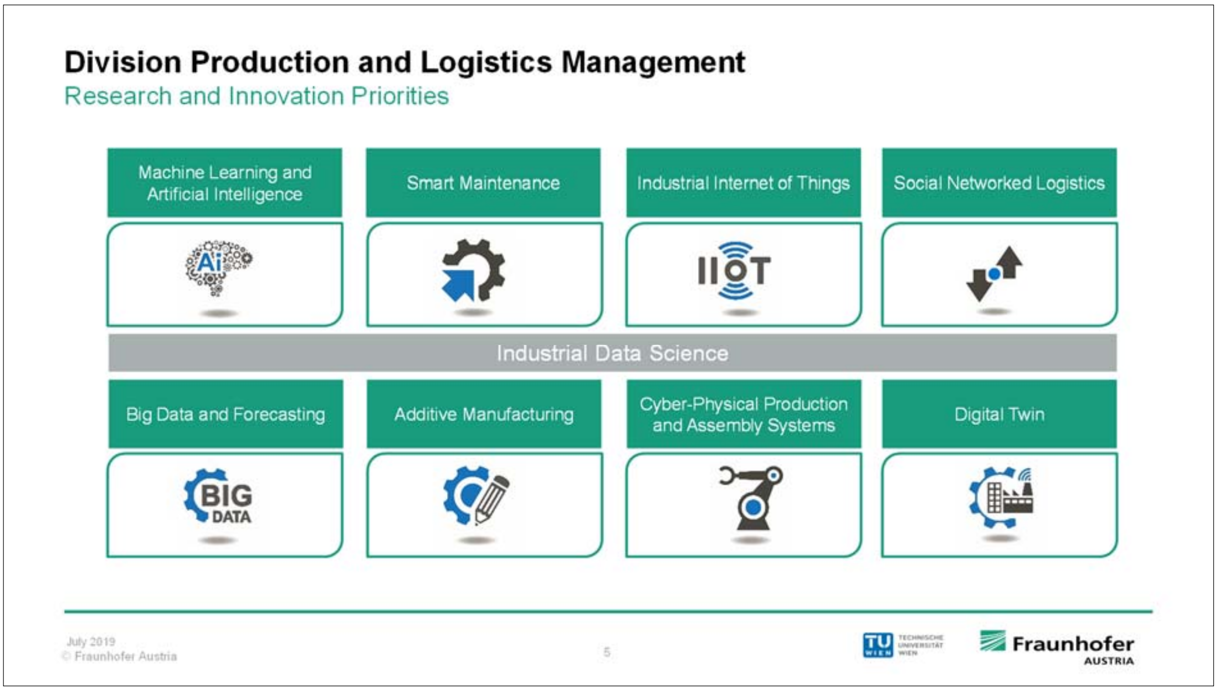
Division Production and Logistics Management
Research and Innovation Priorities
Machine Learning and Artificial Intelligence
Smart Maintenance
Industrial Internet of Things
Social Networked Logistics
Industrial Data Science
Big Data and Forecasting
Additive Manufacturing
Cyber-Physical Production and Assembly Systems
Digital Twin
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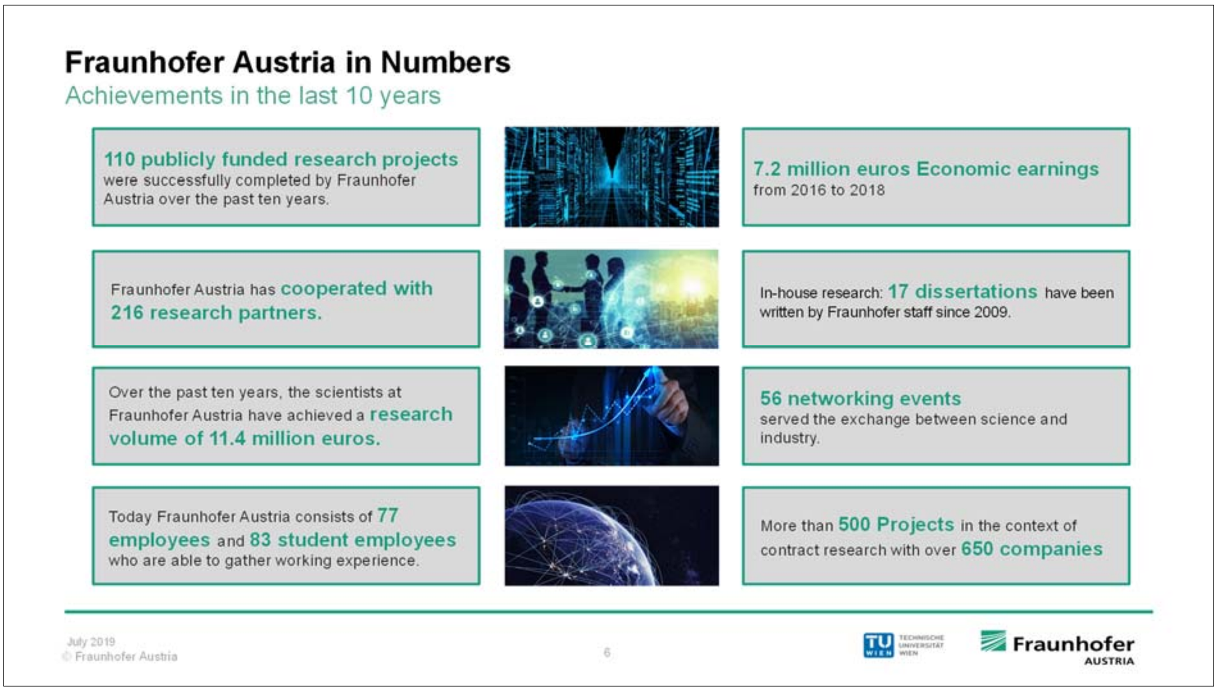
Fraunhofer Austria in Numbers
Achievements in the last 10 years
110 publicly funded research projects were successfully completed by Fraunhofer Austria over the past ten years.
7.2 million euros Economic earnings from 2016 to 2018
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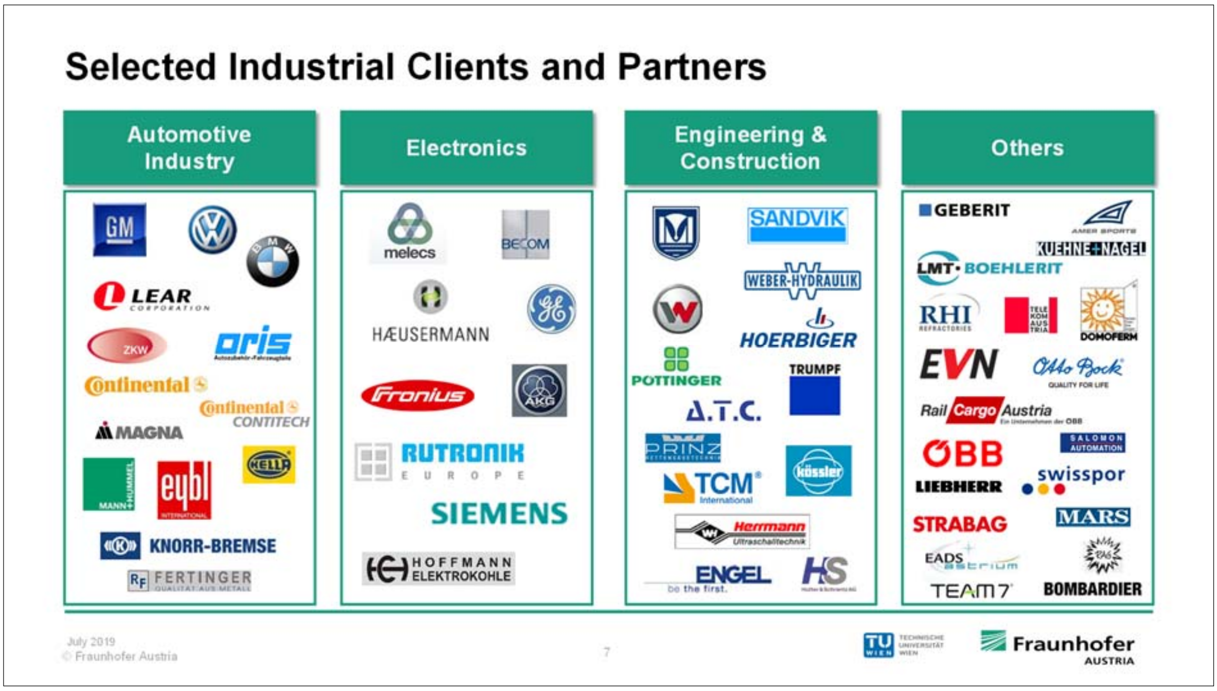
Selected Industrial Clients and Partners
Automotive Industry
Electronics
Engineering & Construction
Others
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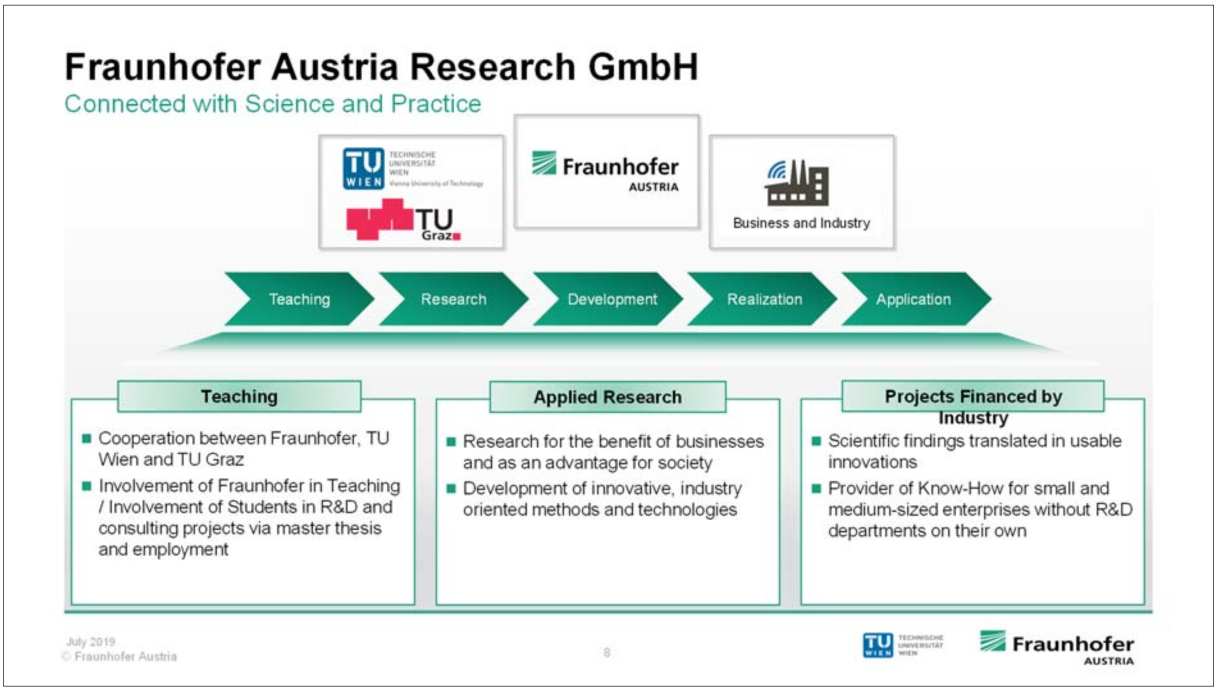
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Involvement of Fraunhofer in Teaching / Involvement of Students in R&D and consulting projects via master thesis and employment
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Projects Financed by Industry
Scientific findings translated in usable innovations
Provider of Know-How for small and medium-sized enterprises without R&D departments on their own
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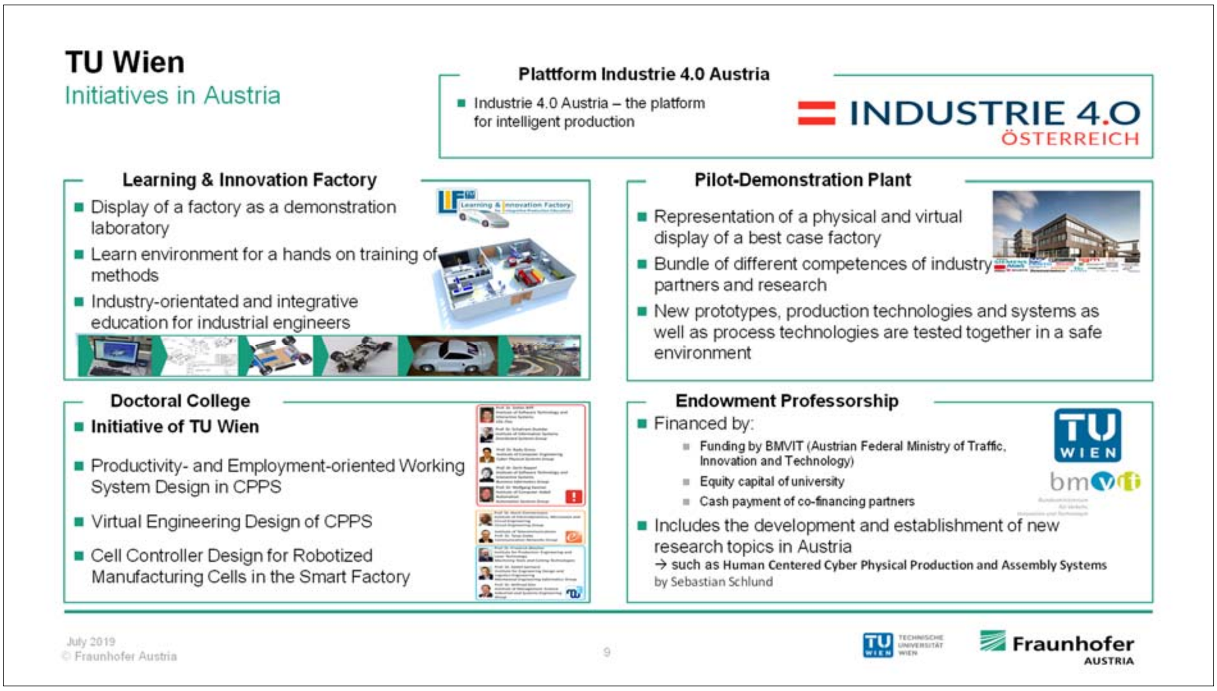
TU Wien
Initiatives in Austria
Plattform Industrie 4.0 Austria
Industrie 4.0 Austria – the platform for intelligent production
INDUSTRIE 4.0 ÖSTERREICH
Learning & Innovation Factory
Display of a factory as a demonstration laboratory
Learn environment for a hands on training of methods
Industry-orientated and integrative education for industrial engineers
Pilot-Demonstration Plant
Representation of a physical and virtual display of a best case factory
Bundle of different competences of industry partners and research
New prototypes, production technologies and systems as well as process technologies are tested together in a safe environment
Doctoral College
Initiative of TU Wien
Productivity- and Employment-oriented Working System Design in CPPS
Virtual Engineering Design of CPPS
Cell Controller Design for Robotized Manufacturing Cells in the Smart Factory
Endowment Professorship
Financed by:
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Includes the development and establishment of new research topics in Austria
→ such as Human Centered Cyber Physical Production and Assembly Systems
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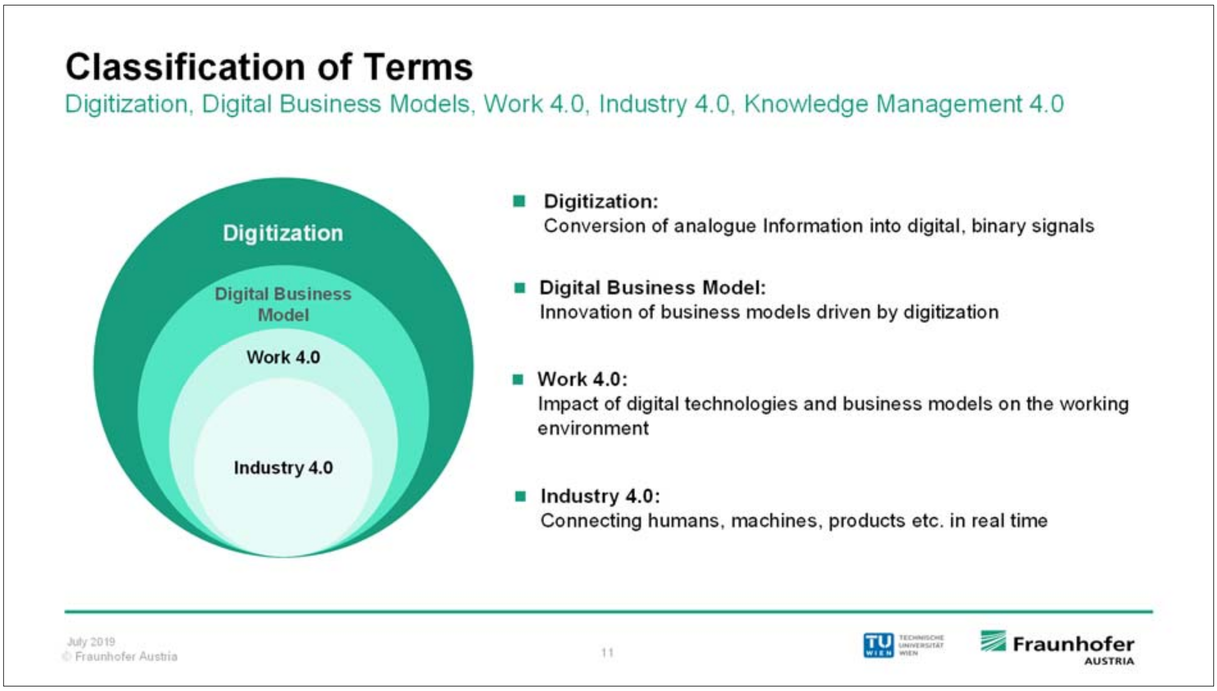
Classification of Terms
Digitization, Digital Business Models, Work 4.0, Industry 4.0, Knowledge Management 4.0
Digitization
Digital Business Model
Work 4.0
Industry 4.0
Digitization:
Conversion of analogue Information into digital, binary signals
Digital Business Model:
Innovation of business models driven by digitization
Work 4.0:
Impact of digital technologies and business models on the working environment
Industry 4.0:
Connecting humans, machines, products etc. in real time
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Industry 4.0
The Importance of Data
„Data is the Oil of the Future“
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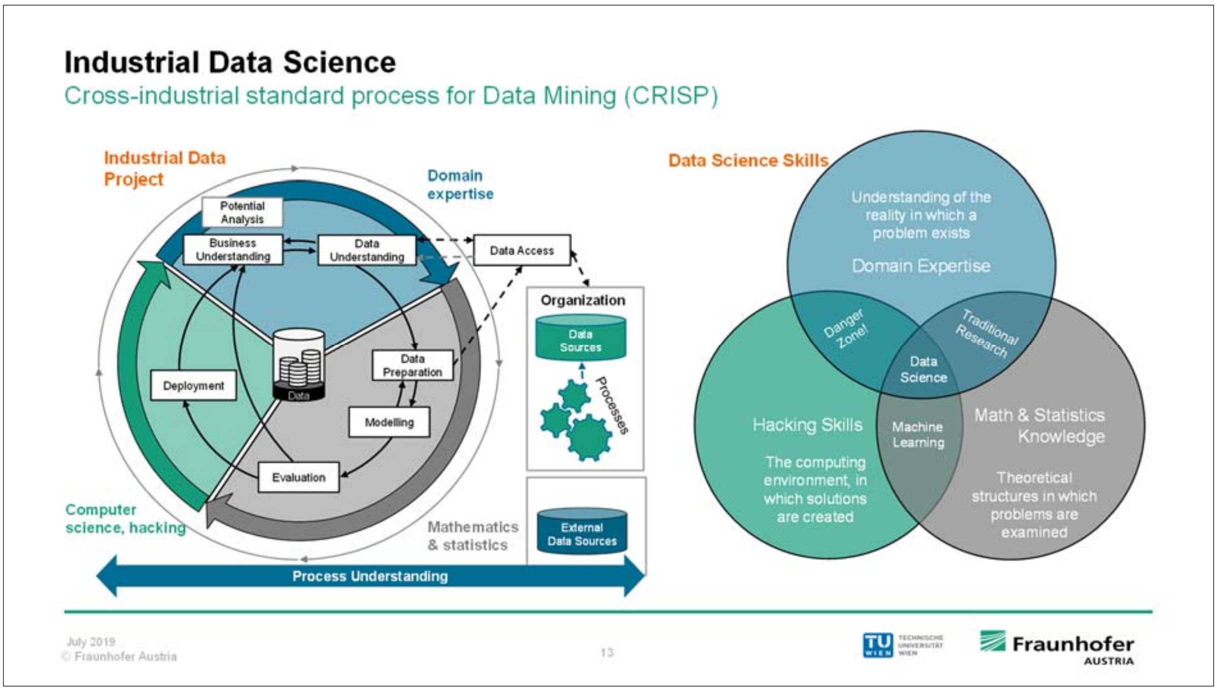
Industrial Data Science
Cross-industrial standard process for Data Mining (CRISP)
Industrial Data Project
Domain expertise
Potential Analysis
Business Understanding
Data Understanding
Data Access
Organization
Data Sources
Processes
Data Preparation
Deployment
Data
Modelling
Evaluation
Computer science, hacking
Mathematics & statistics
External Data Sources
Process Understanding
Data Science Skills
Understanding of the reality in which a problem exists
Domain Expertise
Danger Zone!
Traditional Research
Data Science
Hacking Skills
Machine Learning
Math & Statistics Knowledge
The computing environment, in which solutions are created
Theoretical structures in which problems are examined
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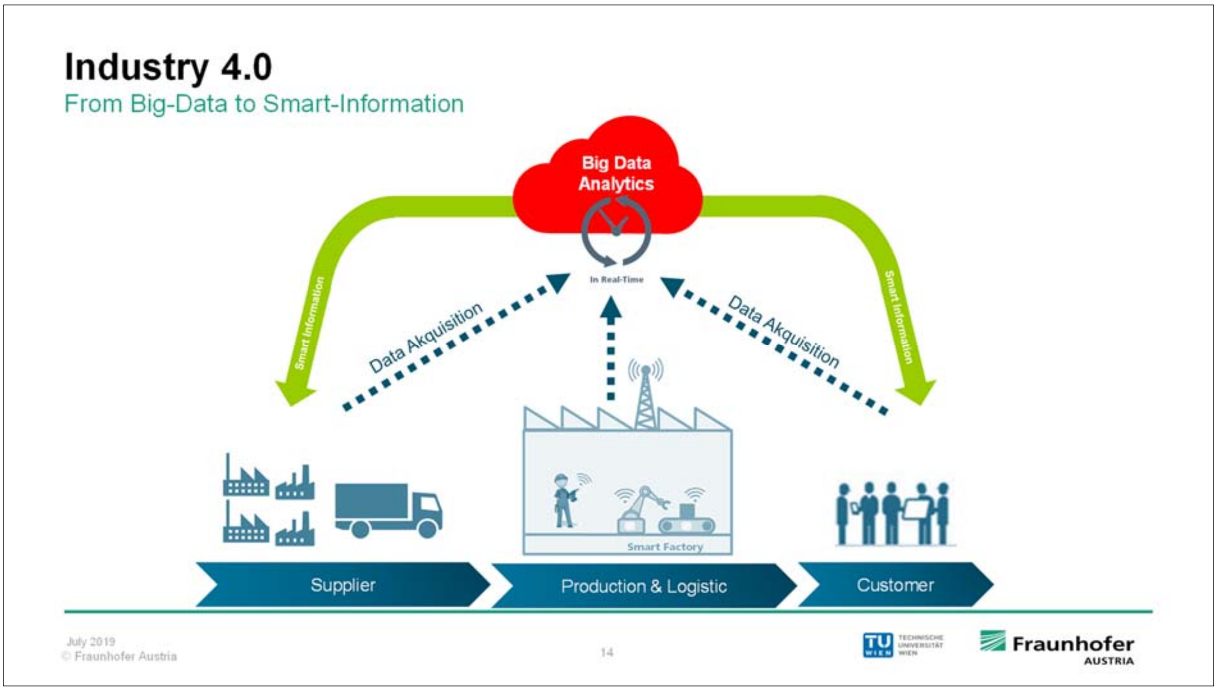
Industry 4.0
From Big-Data to Smart-Information
Big Data Analytics
In Real-Time
Smart Information
Data Akquisition
Data Akquisition
Smart Information
Smart Factory
Supplier
Production & Logistic
Customer
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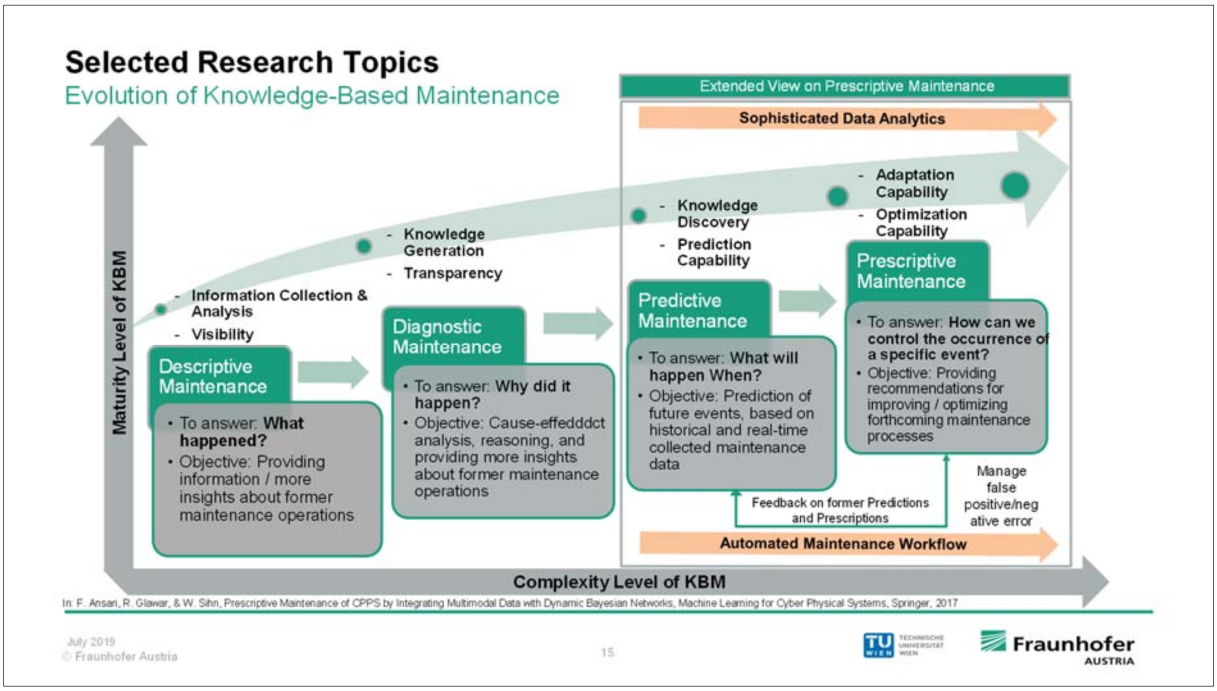
Selected Research Topics
Evolution of Knowledge-Based Maintenance
Extended View on Prescriptive Maintenance
Sophisticated Data Analytics
Maturity Level of KBM
- Information Collection & Analysis
- Visibility
- Knowledge Generation
- Transparency
- Knowledge Discovery
- Prediction Capability
- Adaptation Capability
- Optimization Capability
Descriptive Maintenance
• To answer: What happened?
• Objective: Providing information / more insights about former maintenance operations
Diagnostic Maintenance
• To answer: Why did it happen?
• Objective: Cause-effedddct analysis, reasoning, and providing more insights about former maintenance operations
Predictive Maintenance
• To answer: What will happen When?
• Objective: Prediction of future events, based on historical and real-time collected maintenance data
Prescriptive Maintenance
• To answer: How can we control the occurrence of a specific event?
• Objective: Providing recommendations for improving / optimizing forthcoming maintenance processes
Feedback on former Predictions and Prescriptions
Manage false positive/negative error
Automated Maintenance Workflow
Complexity Level of KBM
In: F. Ansari, R. Glawar, & W. Sihn, Prescriptive Maintenance of CPPS by Integrating Multimodal Data with Dynamic Bayesian Networks, Machine Learning for Cyber Physical Systems, Springer, 2017
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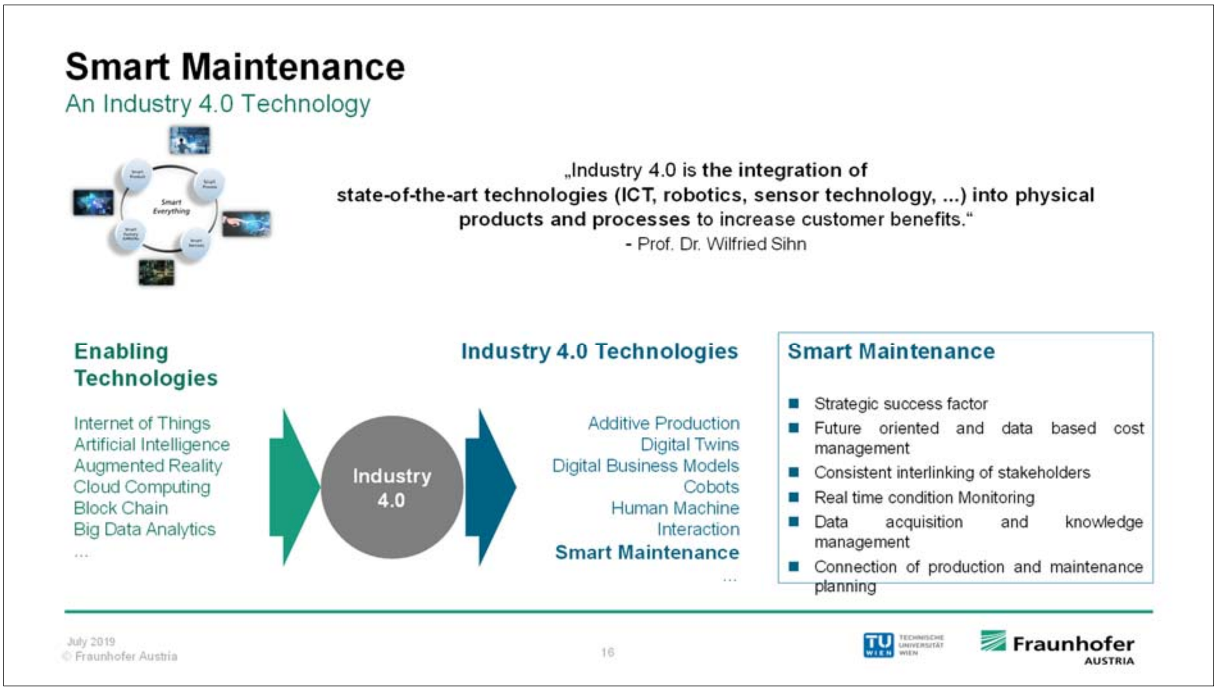
Smart Maintenance
An Industry 4.0 Technology
„Industry 4.0 is the integration of state-of-the-art technologies (ICT, robotics, sensor technology, ...) into physical products and processes to increase customer benefits."
- Prof. Dr. Wilfried Sihn
Enabling Technologies
Internet of Things
Artificial Intelligence
Augmented Reality
Cloud Computing
Block Chain
Big Data Analytics
...
Industry 4.0
Industry 4.0 Technologies
Additive Production
Digital Twins
Digital Business Models
Cobots
Human Machine Interaction
Smart Maintenance
...
Smart Maintenance
Strategic success factor
Future oriented and data based cost management
Consistent interlinking of stakeholders
Real time condition Monitoring
Data acquisition and knowledge management
Connection of production and maintenance planning
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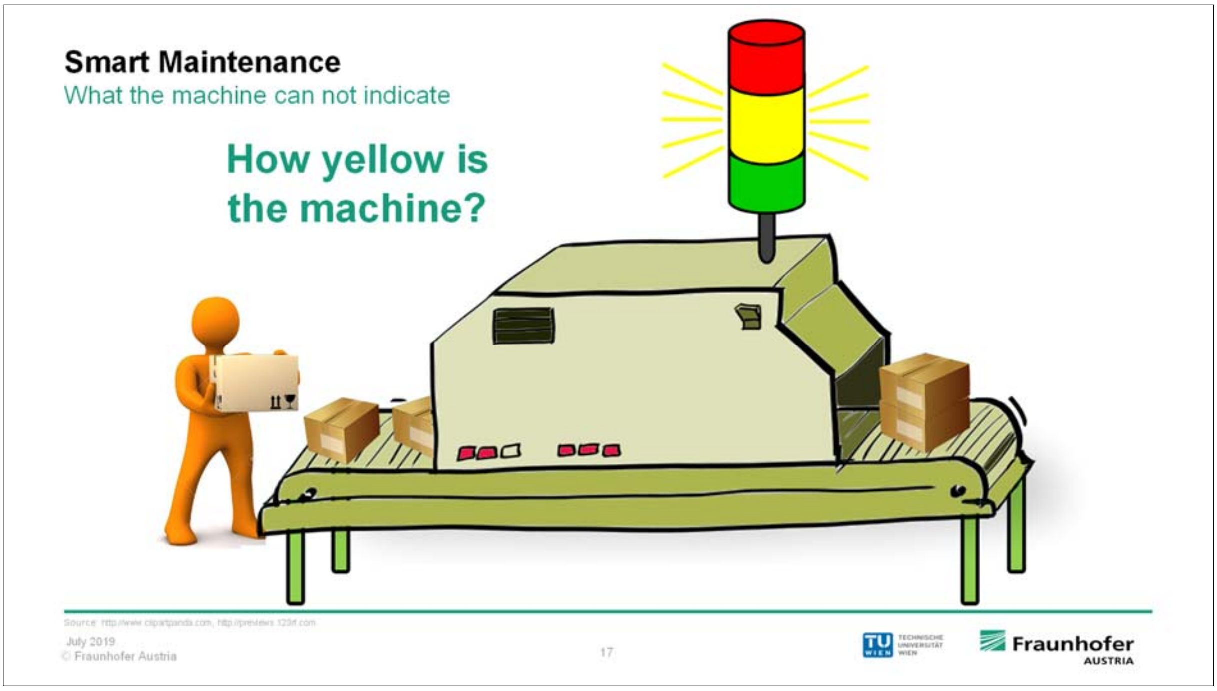
Smart Maintenance
What the machine can not indicate
How yellow is the machine?
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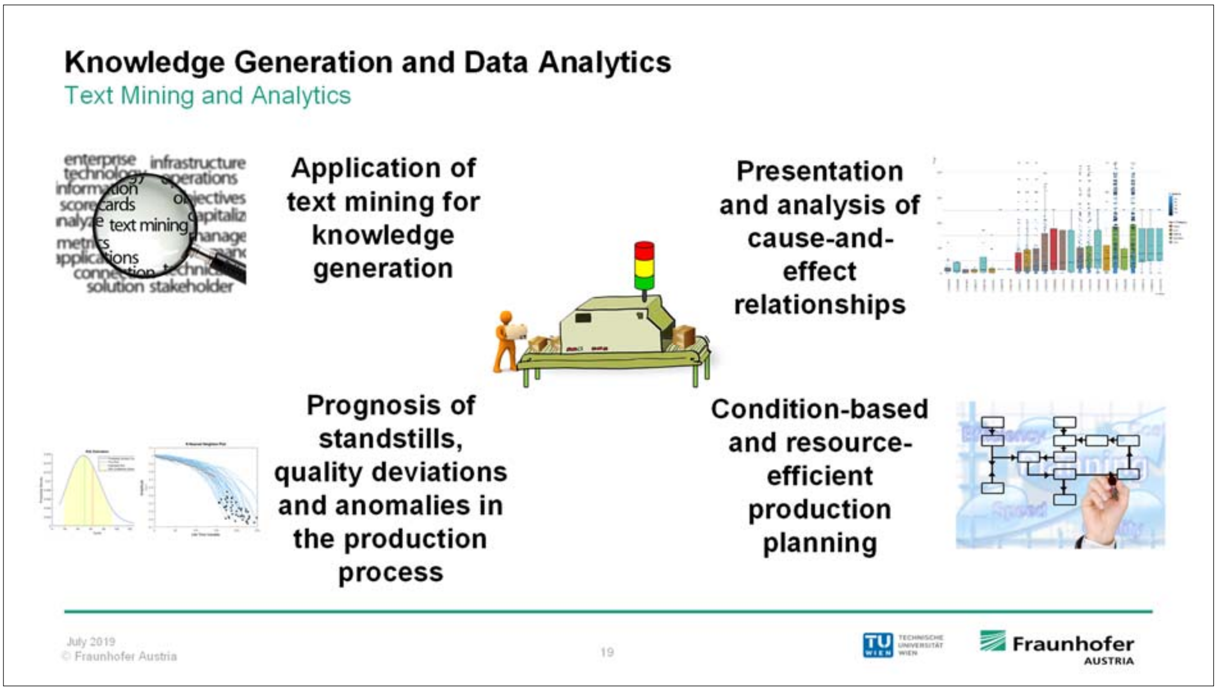
Knowledge Generation and Data Analytics
Text Mining and Analytics
Application of text mining for knowledge generation
Presentation and analysis of cause-and-effect relationships
Prognosis of standstills, quality deviations and anomalies in the production process
Condition-based and resource-efficient production planning
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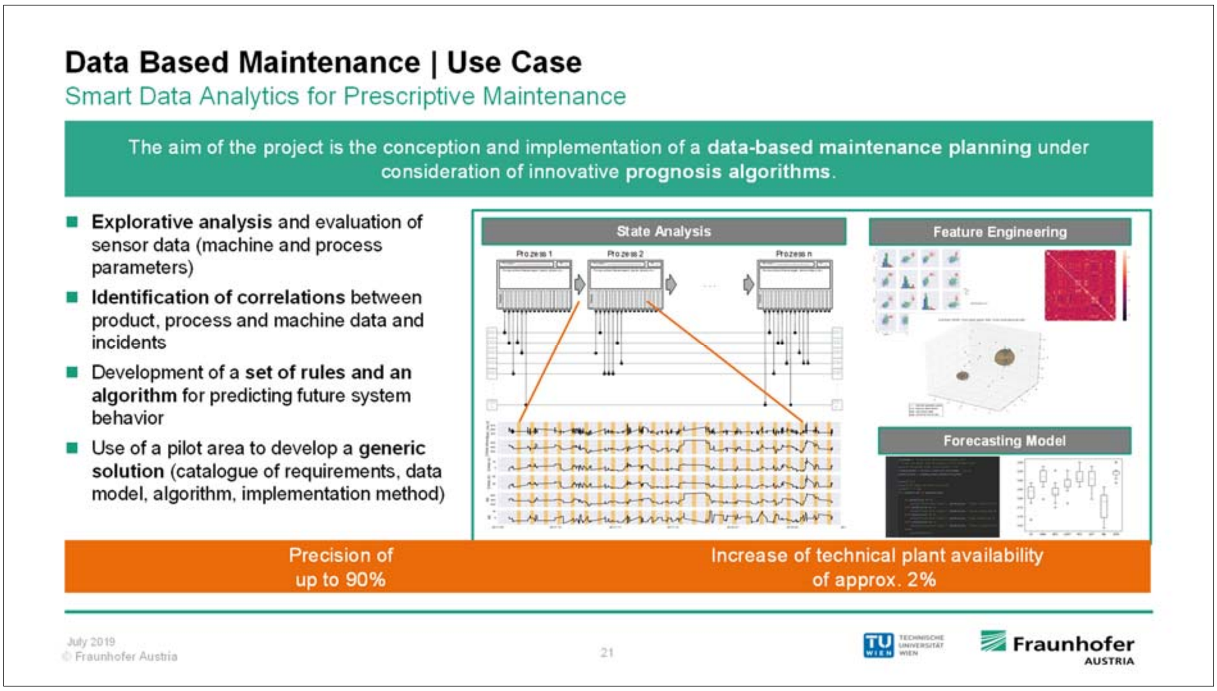
Data Based Maintenance | Use Case
Smart Data Analytics for Prescriptive Maintenance
The aim of the project is the conception and implementation of a data-based maintenance planning under consideration of innovative prognosis algorithms.
Explorative analysis and evaluation of sensor data (machine and process parameters)
Identification of correlations between product, process and machine data and incidents
Development of a set of rules and an algorithm for predicting future system behavior
Use of a pilot area to develop a generic solution (catalogue of requirements, data model, algorithm, implementation method)
State Analysis
Feature Engineering
Forecasting Model
Precision of up to 90%
Increase of technical plant availability of approx. 2%
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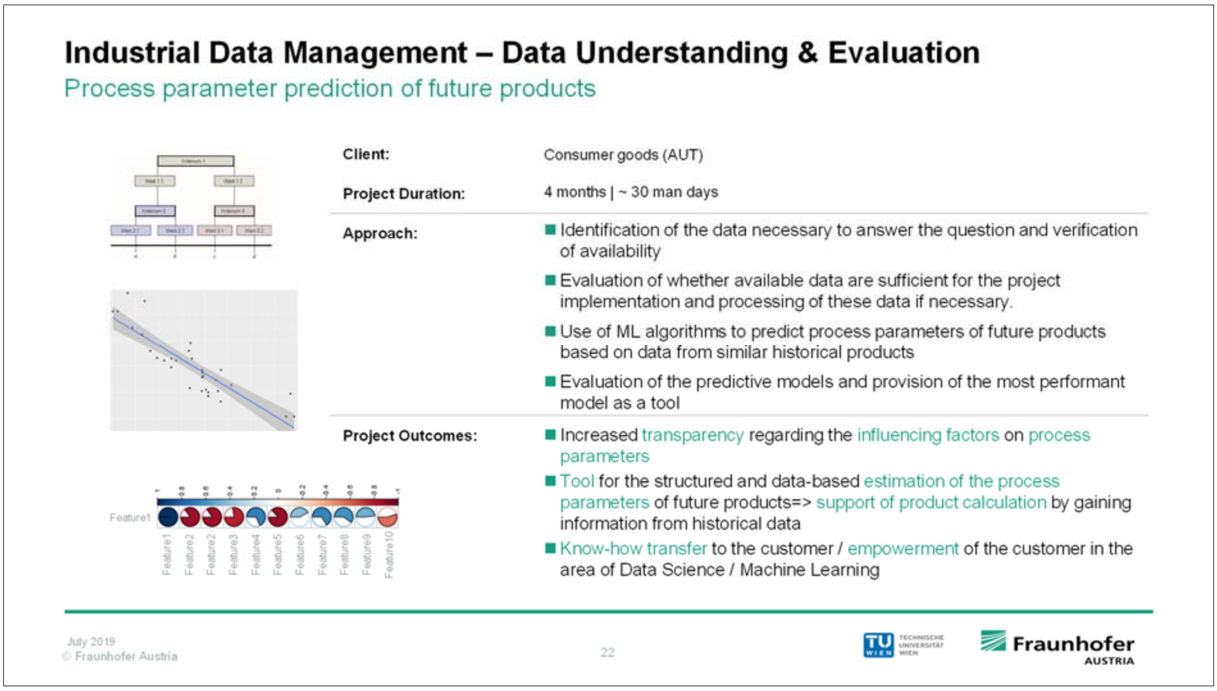
Industrial Data Management – Data Understanding & Evaluation
Process parameter prediction of future products
Client:
Consumer goods (AUT)
Project Duration:
4 months | ~ 30 man days
Approach:
Identification of the data necessary to answer the question and verification of availability
Evaluation of whether available data are sufficient for the project implementation and processing of these data if necessary.
Use of ML algorithms to predict process parameters of future products based on data from similar historical products
Evaluation of the predictive models and provision of the most performant model as a tool
Project Outcomes:
Increased transparency regarding the influencing factors on process parameters
Tool for the structured and data-based estimation of the process parameters of future products=> support of product calculation by gaining information from historical data
Know-how transfer to the customer / empowerment of the customer in the area of Data Science / Machine Learning
Feature1
Feature1
Feature2
Feature3
Feature4
Feature5
Feature6
Feature7
Feature8
Feature9
Feature10
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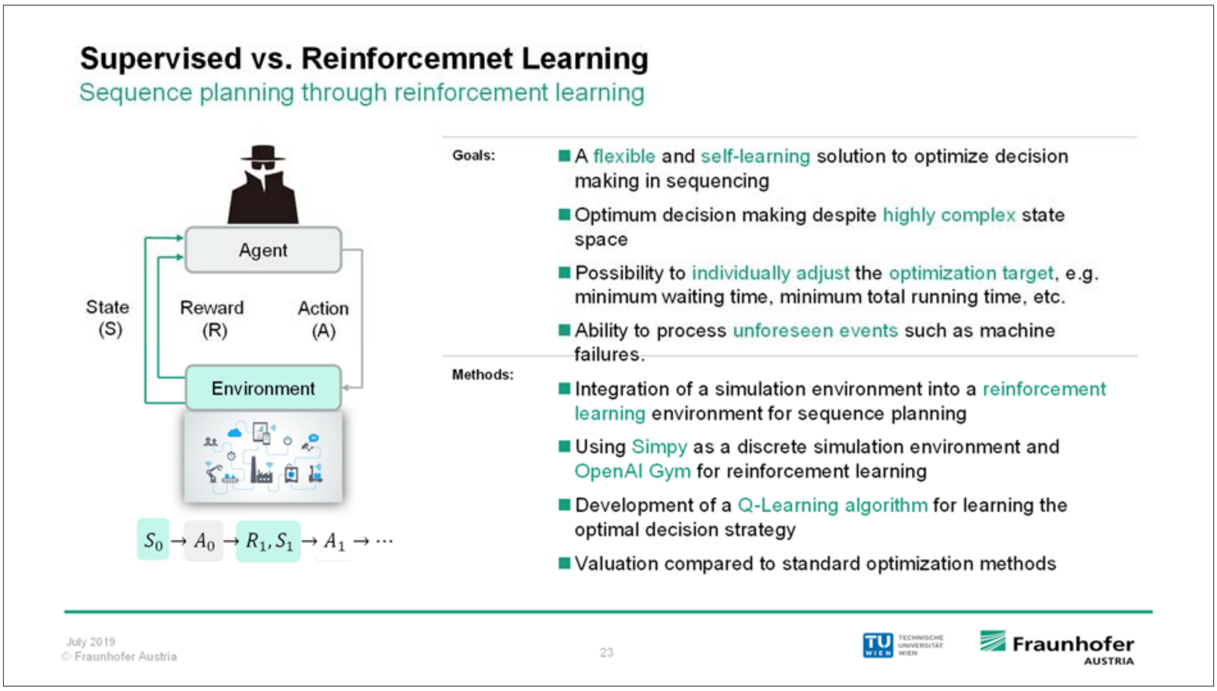
Supervised vs. Reinforcemnet Learning
Sequence planning through reinforcement learning
Agent
State (S)
Reward (R)
Action (A)
Environment
$S_0 \rightarrow A_0 \rightarrow R_1, S_1 \rightarrow A_1 \rightarrow \cdots$
Goals:
A flexible and self-learning solution to optimize decision making in sequencing
Optimum decision making despite highly complex state space
Possibility to individually adjust the optimization target, e.g. minimum waiting time, minimum total running time, etc.
Ability to process unforeseen events such as machine failures.
Methods:
Integration of a simulation environment into a reinforcement learning environment for sequence planning
Using Simpy as a discrete simulation environment and OpenAI Gym for reinforcement learning
Development of a Q-Learning algorithm for learning the optimal decision strategy
Valuation compared to standard optimization methods
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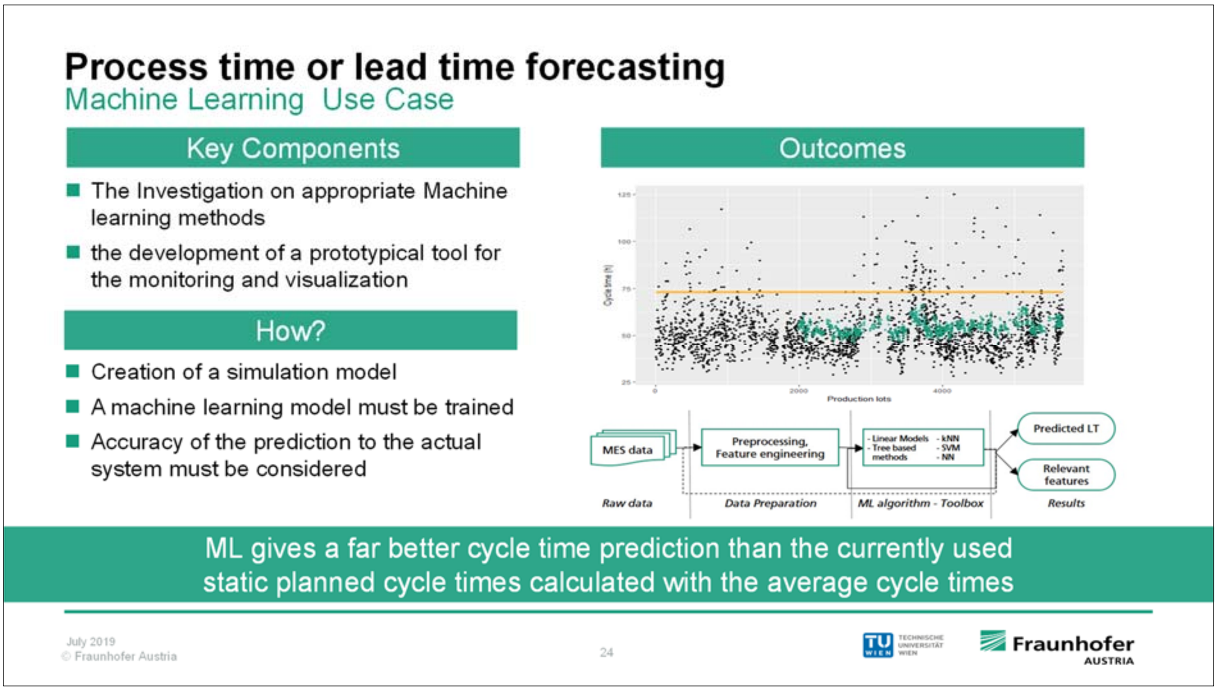
Process time or lead time forecasting
Machine Learning Use Case
Key Components
The Investigation on appropriate Machine learning methods
the development of a prototypical tool for the monitoring and visualization
How?
Creation of a simulation model
A machine learning model must be trained
Accuracy of the prediction to the actual system must be considered
Outcomes
Production lots
MES data
Preprocessing, Feature engineering
Predicted LT
Relevant features
Raw data
Data Preparation
ML algorithm - Toolbox
Results
ML gives a far better cycle time prediction than the currently used static planned cycle times calculated with the average cycle times
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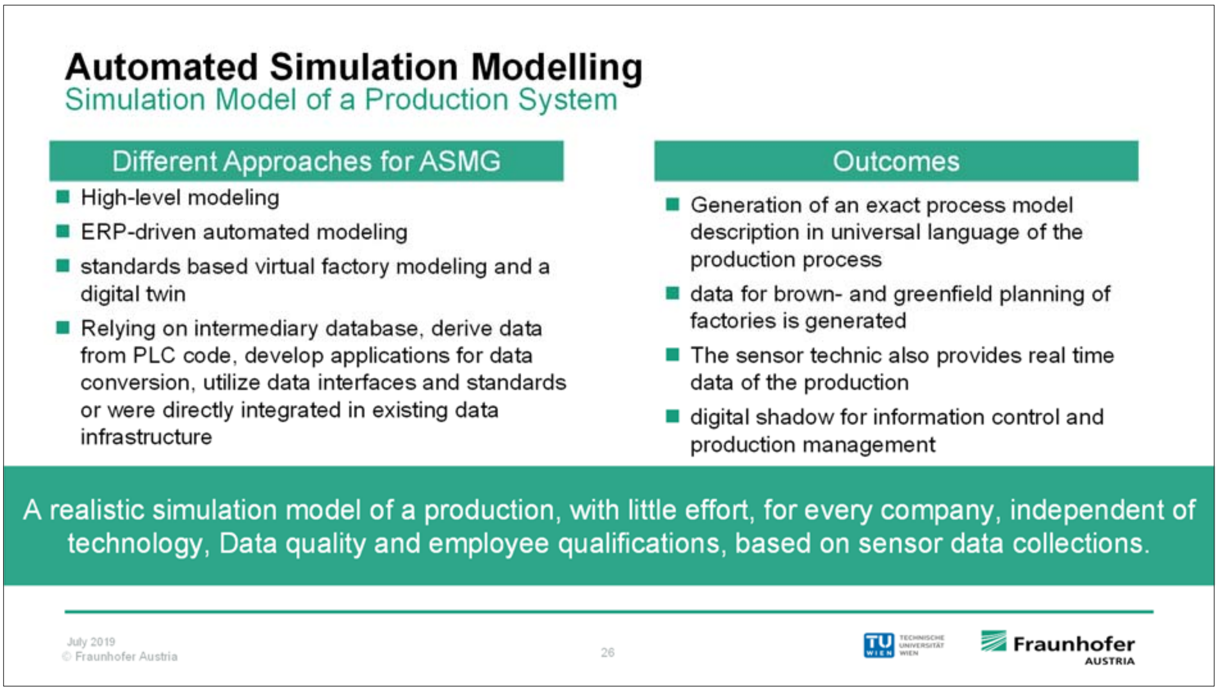
Automated Simulation Modelling
Simulation Model of a Production System
Different Approaches for ASMG
High-level modeling
ERP-driven automated modeling
standards based virtual factory modeling and a digital twin
Relying on intermediary database, derive data from PLC code, develop applications for data conversion, utilize data interfaces and standards or were directly integrated in existing data infrastructure
Outcomes
Generation of an exact process model description in universal language of the production process
data for brown- and greenfield planning of factories is generated
The sensor technic also provides real time data of the production
digital shadow for information control and production management
A realistic simulation model of a production, with little effort, for every company, independent of technology, Data quality and employee qualifications, based on sensor data collections.
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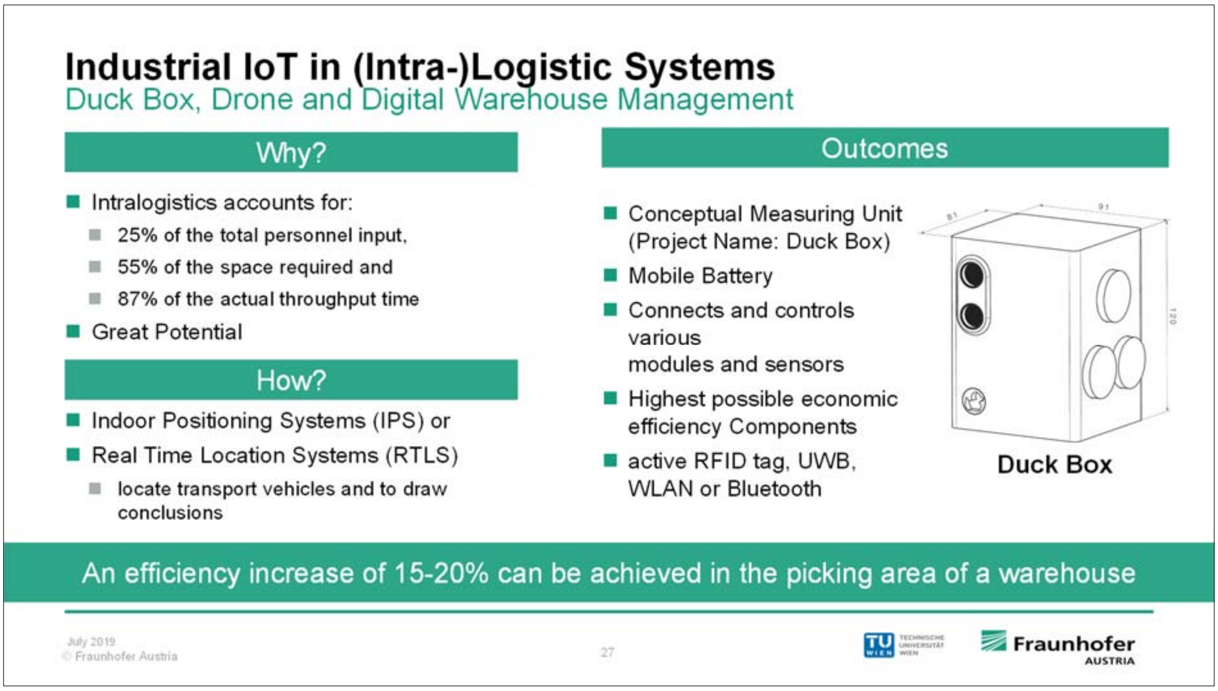
Industrial IoT in (Intra-)Logistic Systems
Duck Box, Drone and Digital Warehouse Management
Why?
Intralogistics accounts for:
25% of the total personnel input,
55% of the space required and
87% of the actual throughput time
Great Potential
How?
Indoor Positioning Systems (IPS) or
Real Time Location Systems (RTLS)
locate transport vehicles and to draw conclusions
Outcomes
Conceptual Measuring Unit (Project Name: Duck Box)
Mobile Battery
Connects and controls various modules and sensors
Highest possible economic efficiency Components
active RFID tag, UWB, WLAN or Bluetooth
Duck Box
An efficiency increase of 15-20% can be achieved in the picking area of a warehouse
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„When the winds of change blow, some people build walls and others build windmills.“

- Chinese Proverb

We are looking forward to accompanying you in innovative projects…

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„Fraunhofer Austria – on behalf of the future“

Prof. Dr. Wilfried Sihn
Fraunhofer Austria Research GmbH
Division Production and Logistics Management

Vienna University of Technology
Institute for Management Science
Department Industrial and Systems Engineering

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M.Sc. Maximilian Busch

Maximilian Busch finished his general university entrance qualification (Abitur) together with the International Baccalaureate Diploma (IB) in his hometown Bonn in 2011. He completed his Bachelor's degree at the Technical University of Munichin Mechanical Engineering and Management in 2015 with an internship at KUKA Systems GmbH. Maximilian continued his master studies with focus on control systems and robotics, finishing with the Master's degree in Mechatronics and In-formation Technologyin 2017. After working for half a year at a local research institute for software-intensive systems and services in the development of autonomous driving systems, he started his PhD. studies at the Institute for Machine Tools and Industrial Management (iwb) inAugust 2018. His main research focus is the application of machine learning techniques in order to improve the accuracy of robotic milling systems.

✉ maximilian.busch@iwb.mw.tum.de

IWB – TU München

Founded in 1875 the Institute for Machine Tools and Industrial Management (iwb) at the Technical University of Munich is one of the largest research institutions for production technology in Germany. It compasses two chairs at the Faculty of Mechanical Engineering in Garching near Munich. Both chairs, the Chair for Industrial Management and Assembly Technologies, as well as the Chair for Machine Tools and Manufacturing Technology, define the research content and the thematic focuses of the IWB. These lie in the areas of additive manufacturing, machine tools, battery production, assembly technologies and robotics, joining and separation technology, as well as in the field of production management and logistics. The staff at the iwb work in research, teaching, and industrial transfer in these fields. From the fields of engineering, electrical engineering, physics, IT and business administration, about 80 research associates are employed by the iwb. Around 25 employees active in the iwb's workshops, laboratories and administration ensure that the solutions are both implemented and long-term available. In addition, around 200 student assistants support the iwb.

iwb - Institute for Machine Tools and Industrial Management

Digital Twins of Machine Tools – How developers and users can profit from the virtual entity

Abstract

Industry 4.0, Big Data, the Digital Twin, Artificial Intelligence – Phrases like these are floating around when talking about trends in machine tool design and application. Recent research activities are exploring potentials of these fairly modern technologies in view of the targeted productivity increase and cost reduction in manufacturing. Data-driven approaches and computational intelligence algorithms offer very promising mechanisms for advanced system identification, process monitoring, and predictive maintenance systems. This talk will shed light on exemplary projects and point out potentials and limitations.

Keywords

Industry 4.0; Big Data; Digital Twin; Artificial Intelligence.

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1 Introduction

The desire to optimize production facilities and manufacturing processes by collecting and analyzing data is growing continuously. Key enabling technologies for efficient machine development, comprehensive process monitoring, robust control, and high system availability are accurate and precise models of a system's behavior. In case of production processes, the modeled systems can either be whole production systems, production shop floor systems, machine tool systems, or even process control systems themselves (see Figure 1). Additionally, in order to account for time-varying system behavior, those models need to be updated continuously during the runtime of the system.

In order to fulfill planning and control tasks for these systems, an adaptive virtual system emulation can support those tasks. These *Digital Twins*, as they are called, of real-world system entities close the gap between the physical and virtual world, forming virtual entities, which represent the physical behavior of plant network interactions, production scheduling scenarios as well as machine or process behavior. Additionally, concurrent adaptation and extension of these *Digital Twins* allow users as well as developers to rely on a precise, up-to-date model of their entity of the physical world; either to improve the efficiency of production processes or to use the model for the design and development of the considered systems.

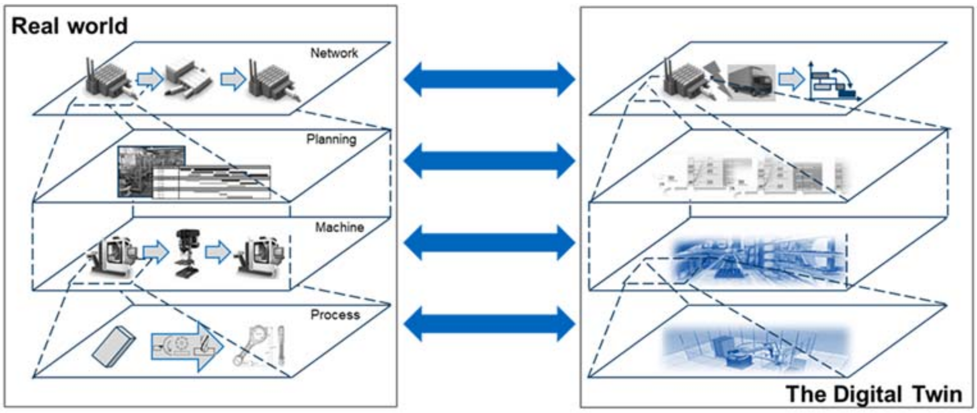

Figure 1: Concept of Digital Twins

In case of machining systems, e.g., considering milling machine tools or robot-based milling systems, the performance and operating accuracy of the milling system is mainly determined by the machine's dynamic behavior. Unbalanced dynamic properties of the systems in interaction with process forces can result in unwanted vibrations whose consequences can be insufficient surface qualities, increased component, and tool wear as well as damages to the mechanical setup. To avoid these effects while improving the performance of the machining system, a comprehensive virtual model of the physical system is the key element to increase the overall productivity. Thus, the *Digital Twin* of a machine tool or robot needs to model all relevant physical proper-ties of the real-world entity and adapt itself concurrently based on time-varying machine and process data. The necessity to provide the capabilities of a *Digital Twin* to the different stakeholders, such as users and developers, strongly encourages to implement the *Digital Twin* on a cloud platform.

Thus, three use cases of a *Digital Twin* are addressed in the following three chapters:

1. *Virtual Machining:* How can advanced modeling techniques, either physically motivated or data-driven, lower the implementation burden and modeling effort of *Digital Twins*?
2. *Model Adaptability:* How can algorithms from the field of computational intelligence support to concurrently update *Digital Twins*?
3. *Cloud-based Interoperability:* How can stakeholders profit from cloud-based *Digital Twins*, and how can the data security and safety be properly addressed?

2 Virtual Machining

Growing competition forces among machine tool manufacturers to reduce their development times and costs. A major key enabler to reduce development times are modern simulation tools, such as virtual images of a physical model or prototype, preferably during the iterative design phase (see Figure 2).

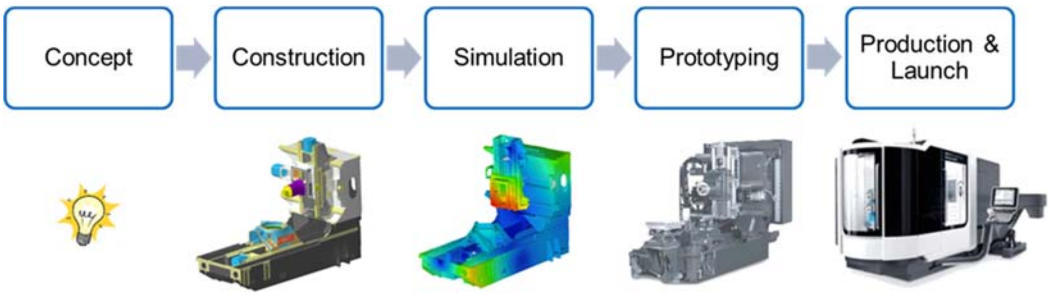

Figure 2: Iterative design process based on [1]

According to the current state of the art, this is usually done with explicit, physically motivated models, e.g. [2, 3, 4]. These types of models are based on explicit descriptions of the governing physical relationships, such as analytical equations regarding the laws of physics. Typical examples are FEM models, multi-body systems, or parametrized mechanistic models. Physically motivated *Digital Twins* provide flexibility, adaptability, and reusability since they can be interpreted and re-parameterized easily. Furthermore, since physical system knowledge is incorporated explicitly into the model, the results are robust and foreseeable, since they are humanly interpretable.

In the following, an advanced modeling approach to form a *Digital Twin* for machine tools is depicted. In particular, the presented, successive manner of building such a *Digital Twin* aims to reduce the modeling burden of complex, nonlinear damping effects between substructures of machine tool structures.

Following [1, 5], damping effects, in particular, have a significant influence on the dynamic behavior of machine tools. A correct and precise identification of the damping influences of the individual machine components is indispensable for a holistic digital image of machine structures.

In the mechatronic machine tool structure, the damping effects can be categorized into local dissipation sources of energy by the materials and contact points used and the influence of the feed drive components [1, 5]. However, the exact physical interactions are not yet sufficiently known to be able to transfer them to complex structures such as machine tools. Thus, the simulation of the damping behavior of a machine tool is only possible locally and not globally for the entire machine tool structure. Especially in continuously adapted virtual models during the development process, no reliable statements about the machine behavior can be expected. Consequently, when optimizing the dynamic receptance behavior of a machine, mainly changes in the stiffness and mass distribution are used.

In order to enable the continuous assembly of *Digital Twins*, accompanying the development process of their physical counterpart and in compliance with its precise dynamical properties such as damping, the dynamic properties can be calculated locally in each component and then coupled using modern dynamic sub structuring techniques [5]. Figure 3 illustrates such an approach.

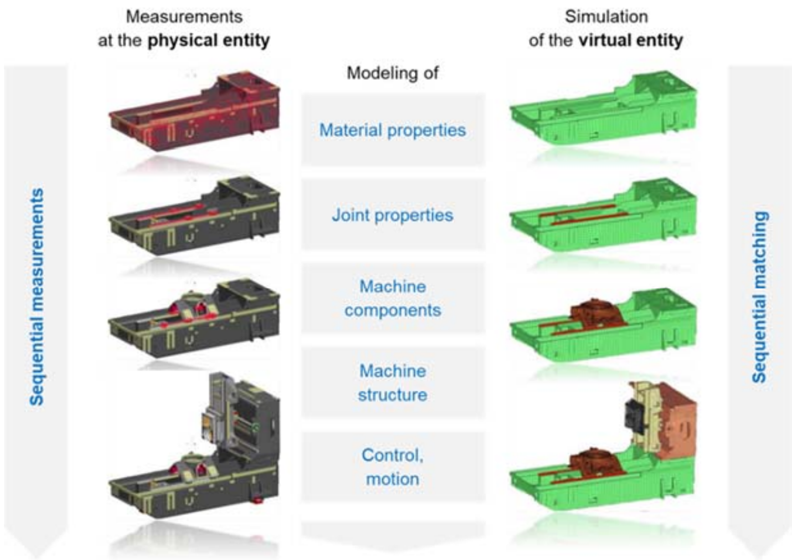

Figure 3: Sequential design of Digital Twins, based on [5]

Nonetheless, *Digital Twins* based on physical models often fail to model highly nonlinear dynamics and properties, e.g., nonlinear stiffness and damping effects for systems like milling robots [6, 7]. Due to increasing computational power and resources, data-driven approaches are gaining much popularity to identify and incorporate dynamical system properties solely based on data, e.g. [8, 9, 10]. Although data-driven approaches may handle highly nonlinear physical effects, two major disadvantages are the usually high amount of needed data and the non-interpretability of those “black-box”-models.

In order to circumvent such issues, it is an open research question on how information from physically motivated models and data-driven approaches from the field of computational intelligence can be fused to profit from both worlds.

3 Model Adaptability

Since *Digital Twins* aim to match the physical properties of their real counterpart, they form an ideal platform to monitor machine and tool conditions, predict machine and tool breakdown, and predict optimal maintenance intervals.

A critical issue in order to provide reliable models with those capabilities is the concurrent system identification of the physical model, together with the model adaption of the virtual entity. To provide an adaptive virtual condition model of machine tool components, meaningful indicators for machine and tool wear need to be identified and tracked during runtime of the system, either continuously or in previously defined time intervals.

In the following, an approach to identify and update the properties of a *Digital Twin* of a machine tool structure using defined test cycles is presented.

For machine tools, the wear of feed drive components, e.g., ball screws or linear guides, is the main contributor to time-varying machine tool dynamics [13]. To track this behavior concurrently and adapt the virtual machine tool model, the preload of these components can be the main indicator (*feature*) to infer wear in these components.

The preload condition decreases during runtime due to continuous abrasion, resulting in a time-varying receptance frequency response function (FRF) of the machine tool [11, 12]. Figure 4 shows such a shift in the dynamic response for time-varying preload conditions [13]. The simulation runs using a FEM based virtual image of the machine tool structure.

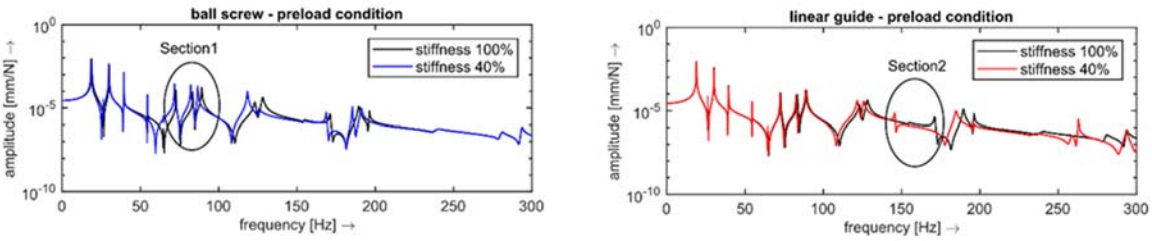

Figure 4: Receptance FRF showing the significance of a stiffness change, considering ball screw and linear guides [13]

To update the underlying model of the *Digital Twin*, a regular test cycle is necessary, during which the modal parameters of the feed drive system are extracted. A mechanism to enable regular test cycles to identify feed drive modal parameters is presented in [13].

Nonetheless, this classification in predefined and standardized preload classes does not yet allow a continuous forecast of the component's remaining service life. Therefore, the discrete classification problem of preload classes needs to be transformed into a continuous regression model of the feature. Such a transformation is presented in [14].

4 Cloud-based interoperability and data security

Current developments aim to increase data interoperability between production sites and processes, for example using data frameworks such as OPC-UA (TSN), MT-CONNECT or even standardized data models for machine tools such as *umati*[1] (which is still under development). Those data frameworks close the interoperability gap between the physical and the virtual world or even between different virtual entities.

Real-time process monitoring and control algorithms of machine tools, such as chatter avoidance and tool wear detection mechanisms, can be integrated into *Digital Twin* architectures using external computing capabilities, based on a cloud-based infrastructure. For example, such a cloud-based architecture was published recently in [15].

These cloud-based *Digital Twins* provide major benefits in contrast to local instances:

- The maintainer of the cloud platform can adapt and extend the existing code for a running *Digital Twin* and thus improve the current performance, ensuring data safety or initiate novel functionalities.
- The machine tool manufacturer gets valuable insight into his delivered machines in the field. This data feedback can significantly contribute to discovering an open room for improvement.

Exemplarily, the cloud-based *Digital Twin* is used to detect chatter. Such a scenario is depicted in Figure 5. The user profits directly from the novel and well-maintained algorithms for chatter detection, scalable computing power, and feedback for chatter avoidance strategies. Secondly, the user can also profit indirectly, since the machine manufacturer is able to identify critical process and system parameters, which can improve future machine developments.

Nonetheless, the willingness of machine users to share the valuable machining data is little, since machine and process data may contain highly confidential and critical information, e.g.,

[1] VDW Consortium created umati (universal machine tool interface). It enables machine tools and peripherals to connect to customer-specific IT ecosystems – easy, secure, and seamless. umati is an open standard for machine tool users throughout the world.

information on the company's production process know-how. Subsequently, new approaches to handle data integrity, data security, and data privacy are required.

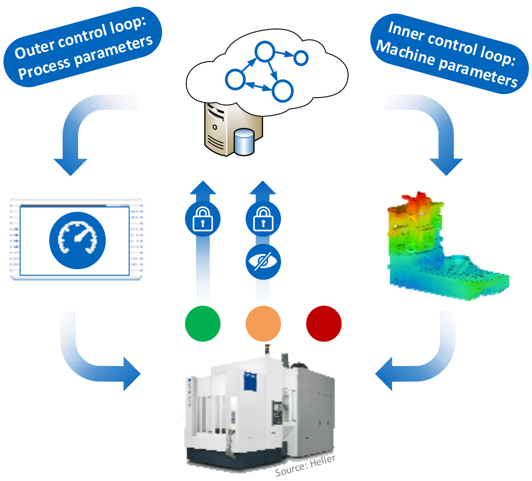

Figure 5: Cloud-based chatter detection approach

The explicitly or implicitly included information can be categorized into three major classes, forming an extended privacy classification scheme based on [16]:

- *Information on sensitive data*, incorporated in the data itself. Exemplarily, this is raw production data such as machining parameters, tool paths, or machine data such as motor currents. Indirectly, such data may also contain information, which is reconstructible from apparent noise and non-sensitive data, e.g., workpiece geometry by the integration of tool accelerations.
- *Personal user-related information*, such as usage times, usage durations and user identification. With regard to national data protection and privacy laws, this data may contain highly sensitive or critical information as well.
- *Location-dependent information,* which allows to identify or infer the location or even the identity of the client, based on tracking the data package routing.

To enable cloud-based applications for *Digital Twins* without transferring confidential or sensitive data to the cloud, the transferred data is anonymized before being transferred, forming an edge-computing architecture. The differences between cloud- and edge-computing are depicted in Figure 6. [17]

The concept of production data anonymization extends the usual data security interpretation that production data needs to be transferred in a secure and encrypted way within the network. By using those data anonymization techniques, data is modified using edge computing capabilities in such a way that other cloud users or the cloud operator do not receive any sensitive or critical information. Nonetheless, machine and process monitoring algorithms need to be enabled to handle anonymized data as well.

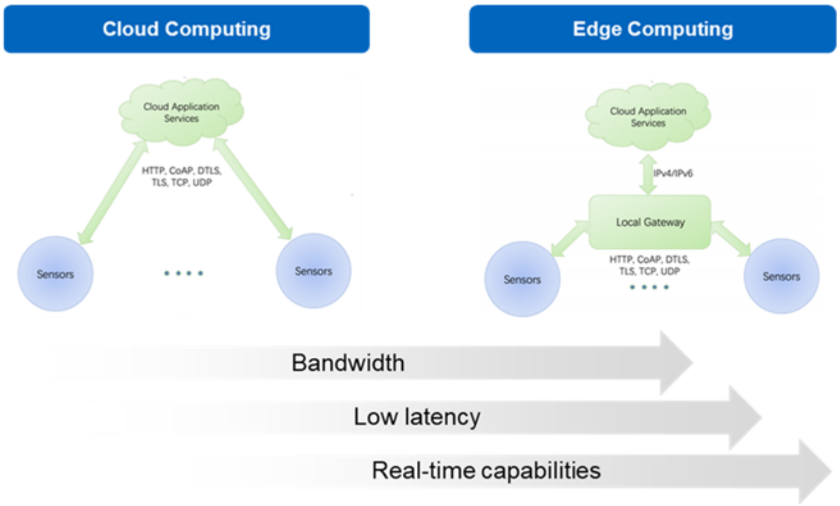

Figure 6: Differences between cloud- and edge-computing (based on [17])

Proper handling of anonymized data and the integrity of functions in the cloud and machine tools must be accompanied and certified by standard security techniques.

It is an open research question, how the privacy of production data can be *generally* defined and classified, how different levels of production data anonymization can be categorized and how cloud applications are able to compensate for possibly fuzzy or blurred data due to the anonymization.

5 Conclusion

Digital Twins of real-world systems, such as production networks, production shop floor systems, machine tools, and machining processes, offer a wide variety of promising applications. Since the virtual counterparts inherit the governing properties of the real-world entity, they can be used to monitor, plan, and control running production systems.

To design such powerful tools, special attention must be paid during the modeling process as well as during the continuous update process. The virtual counterpart must incorporate all relevant physical properties of the real-world system. Next, to state-of-the-art methods which are based on physically motivated models, advanced approaches from the field of computational intelligence can support this design and model update process.

Nonetheless, when integrated into an existing, cloud-based service structure, data security, data safety, and data privacy issues arise and require innovative approaches such as data encryption and especially data anonymization techniques.

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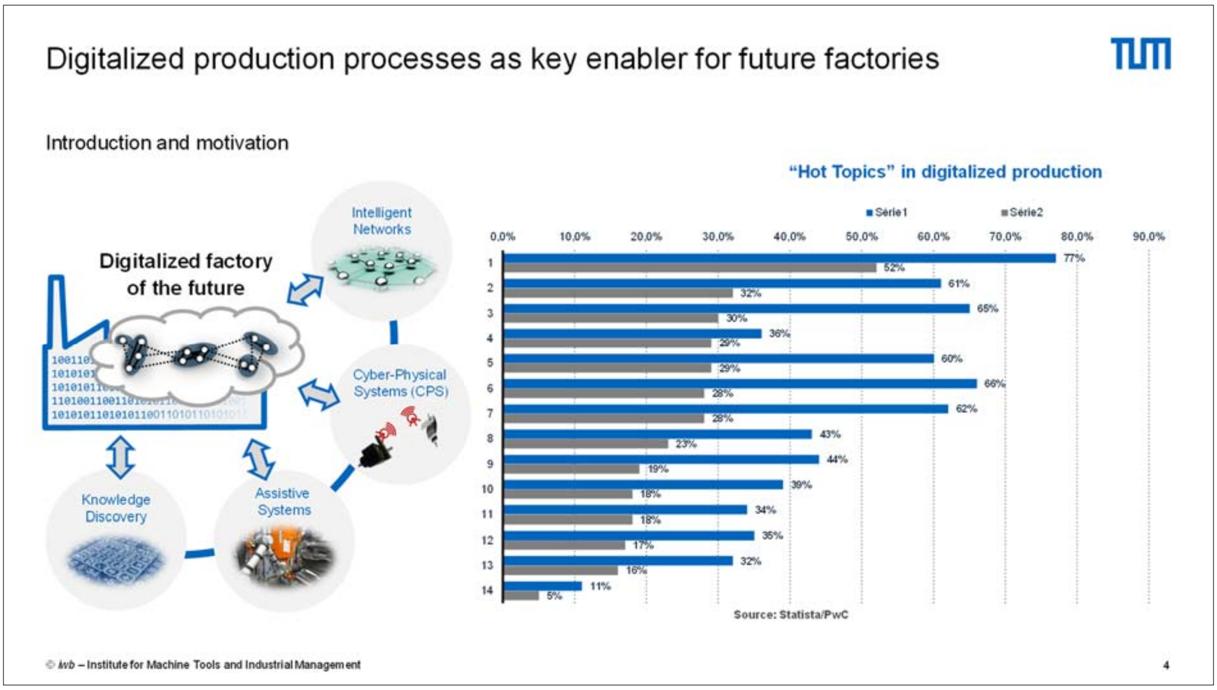
Agenda

1 Introduction and motivation
2 Implementation of virtual machines
3 Update mechanisms of digital models
4 Cloud-based approaches


Digitalized production processes as key enabler for future factories
Introduction and motivation
Digitalized factory of the future
Intelligent Networks
Cyber-Physical Systems (CPS)
Assistive Systems
Knowledge Discovery
"Hot Topics" in digitalized production
Série1
Série2
0,0% 10,0% 20,0% 30,0% 40,0% 50,0% 60,0% 70,0% 80,0% 90,0%
1 77% 52%
2 61% 32%
3 65% 30%
4 36% 29%
5 60% 29%
6 66% 28%
7 62% 28%
8 43% 23%
9 44% 19%
10 39% 18%
11 34% 18%
12 35% 17%
13 32% 16%
14 11% 5%
Source: Statista/PwC
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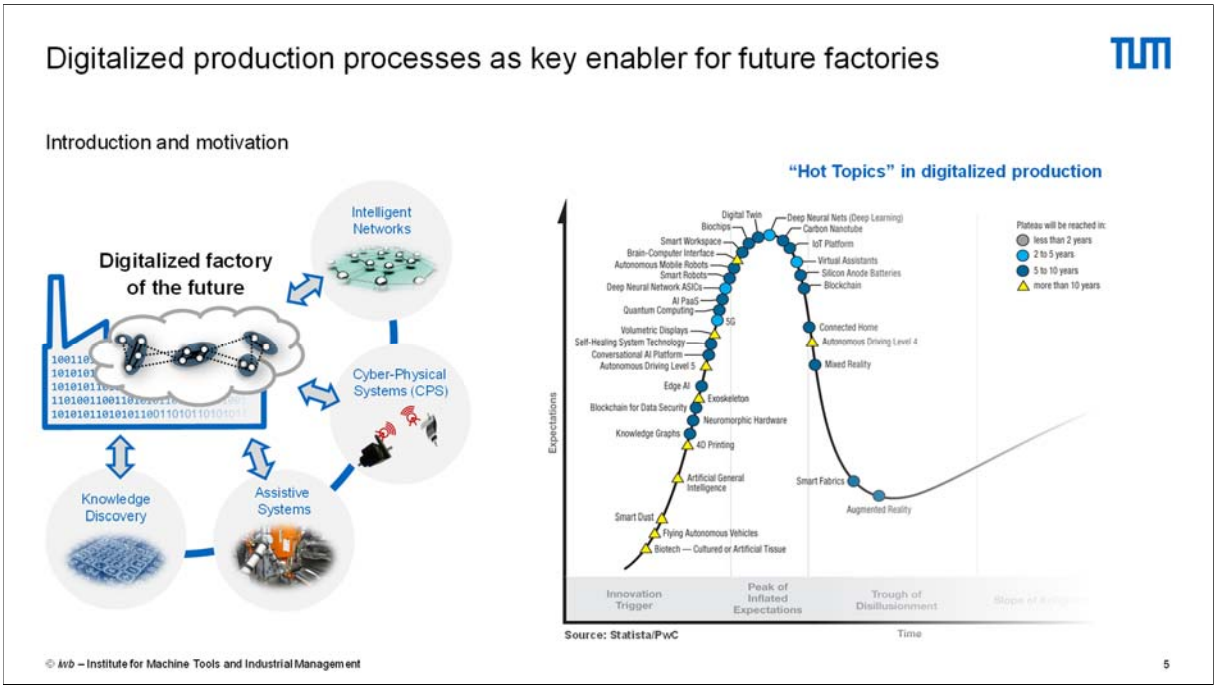
Digitalized production processes as key enabler for future factories
Introduction and motivation
Digitalized factory of the future
Intelligent Networks
Cyber-Physical Systems (CPS)
Assistive Systems
Knowledge Discovery
"Hot Topics" in digitalized production
Digital Twin
Biochips
Smart Workspace
Brain-Computer Interface
Autonomous Mobile Robots
Smart Robots
Deep Neural Network ASICs
AI PaaS
Quantum Computing
5G
Volumetric Displays
Self-Healing System Technology
Conversational AI Platform
Autonomous Driving Level 5
Edge AI
Exoskeleton
Blockchain for Data Security
Neuromorphic Hardware
Knowledge Graphs
4D Printing
Artificial General Intelligence
Smart Dust
Flying Autonomous Vehicles
Biotech — Cultured or Artificial Tissue
Deep Neural Nets (Deep Learning)
Carbon Nanotube
IoT Platform
Virtual Assistants
Silicon Anode Batteries
Blockchain
Connected Home
Autonomous Driving Level 4
Mixed Reality
Smart Fabrics
Augmented Reality
Plateau will be reached in:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
Expectations
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Time
Source: Statista/PwC
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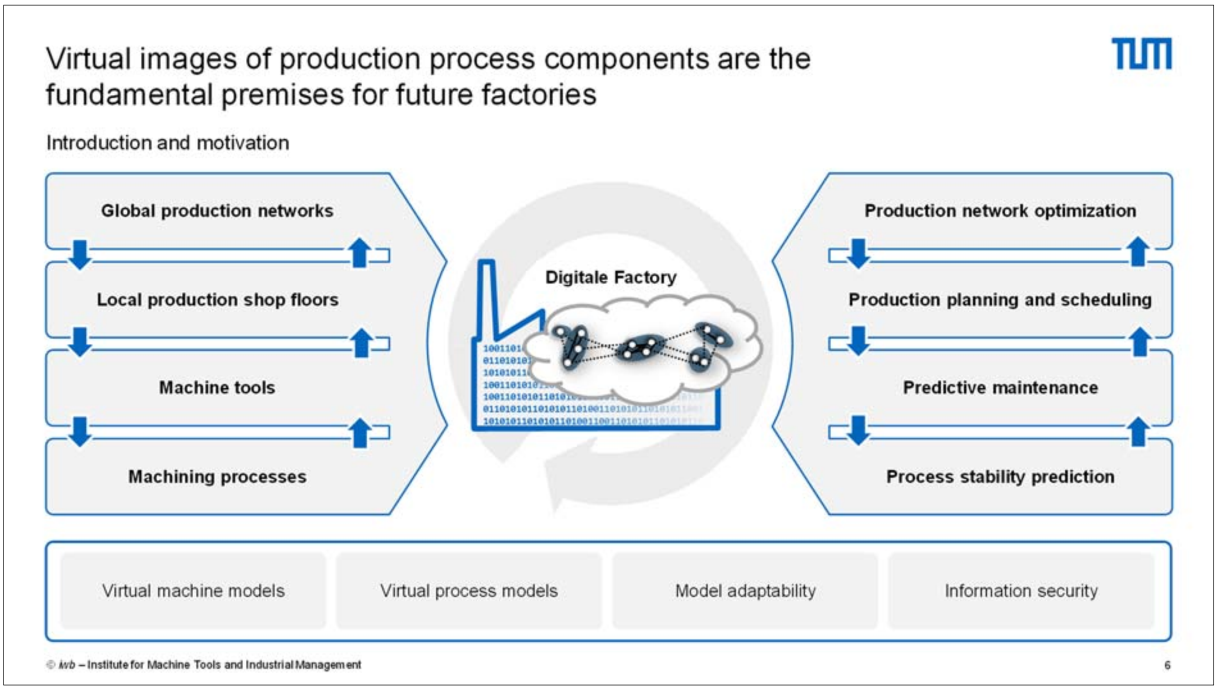
Virtual images of production process components are the fundamental premises for future factories
Introduction and motivation
Global production networks
Local production shop floors
Machine tools
Machining processes
Digitale Factory
Production network optimization
Production planning and scheduling
Predictive maintenance
Process stability prediction
Virtual machine models
Virtual process models
Model adaptability
Information security
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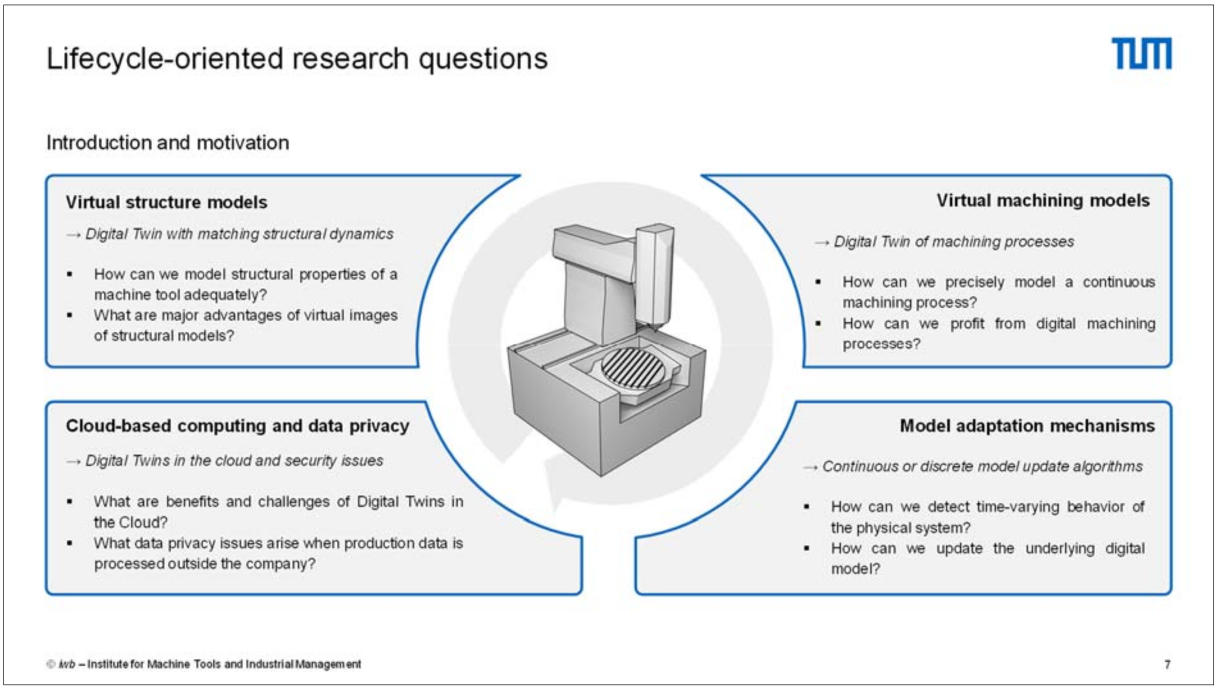
Lifecycle-oriented research questions
Introduction and motivation
Virtual structure models
→ Digital Twin with matching structural dynamics
▪ How can we model structural properties of a machine tool adequately?
▪ What are major advantages of virtual images of structural models?
Virtual machining models
→ Digital Twin of machining processes
▪ How can we precisely model a continuous machining process?
▪ How can we profit from digital machining processes?
Cloud-based computing and data privacy
→ Digital Twins in the cloud and security issues
▪ What are benefits and challenges of Digital Twins in the Cloud?
▪ What data privacy issues arise when production data is processed outside the company?
Model adaptation mechanisms
→ Continuous or discrete model update algorithms
▪ How can we detect time-varying behavior of the physical system?
▪ How can we update the underlying digital model?
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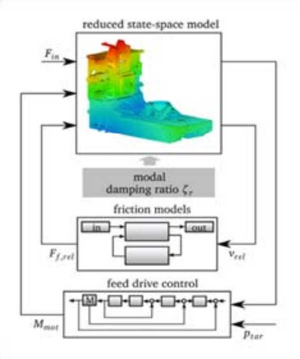
Insufficient simulation hinders reliable predictions

Implementation of virtual machines

Accuracy

- Unknown damping sources and effects
- Unknown nonlinear friction between each substructure and component
- Precise and accurate simulation and parameterization of the virtual controller



Digital Twin architecture of machine tool

Efficiency

- Low performance of flexible based multi-body simulation solely on FE
- Optimization of single components are computationally intractable

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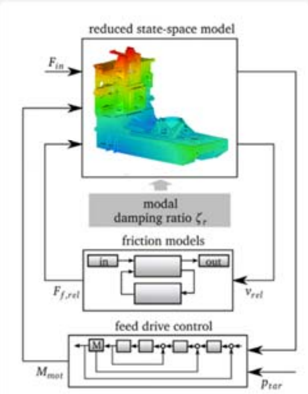
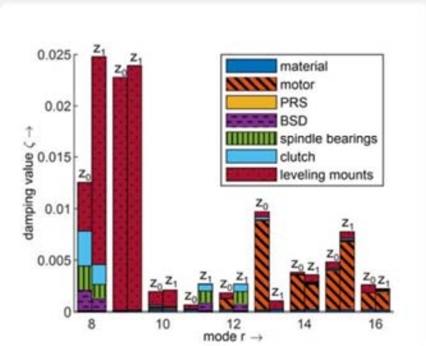
Accuracy increase with local linear damping models

Implementation of virtual machines



Digital Twin architecture of machine tool



Pose dependent linear damping sources

- Increase of accuracy due to local damping models
- Different energy dissipation sources need to be considered
- Linear damping effects are position dependent
- Global damping values based on hysteric or viscous spring-damper models

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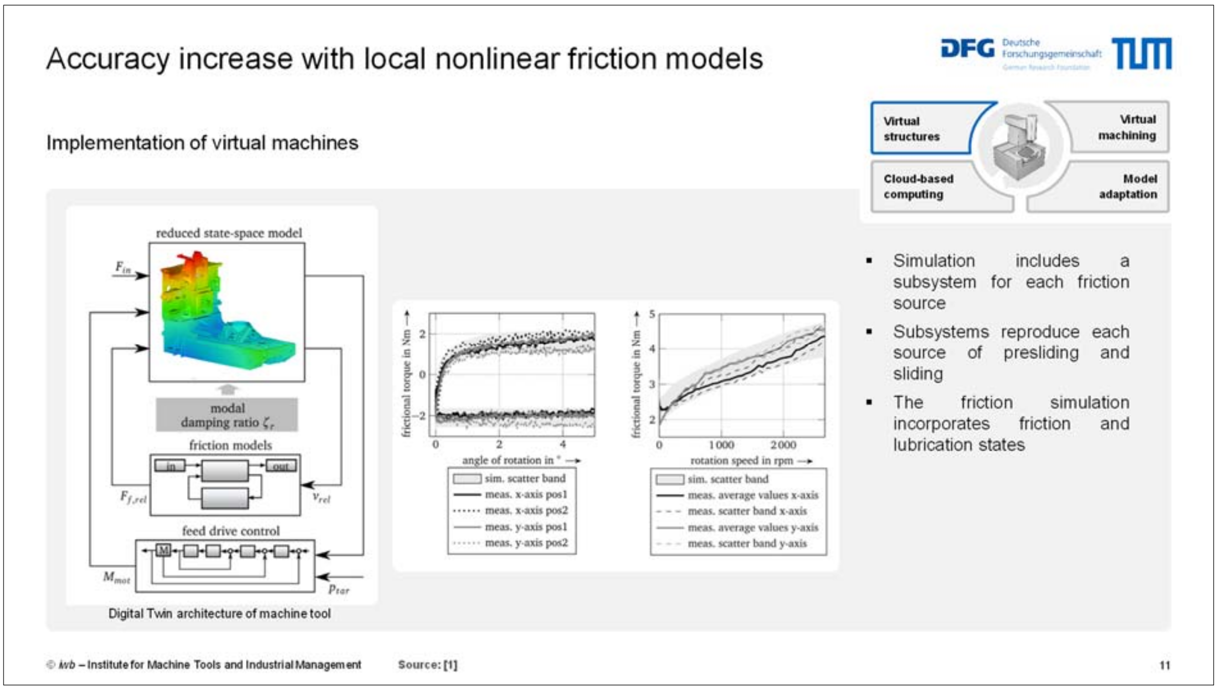
Accuracy increase with local nonlinear friction models
DFG Deutsche Forschungsgemeinschaft
TUM
Implementation of virtual machines
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
reduced state-space model
modal damping ratio
friction models
in
out
feed drive control
M
Digital Twin architecture of machine tool
frictional torque in Nm
angle of rotation in °
sim. scatter band
meas. x-axis pos1
meas. x-axis pos2
meas. y-axis pos1
meas. y-axis pos2
rotation speed in rpm
sim. scatter band
meas. average values x-axis
meas. scatter band x-axis
meas. average values y-axis
meas. scatter band y-axis
Simulation includes a subsystem for each friction source
Subsystems reproduce each source of presliding and sliding
The friction simulation incorporates friction and lubrication states
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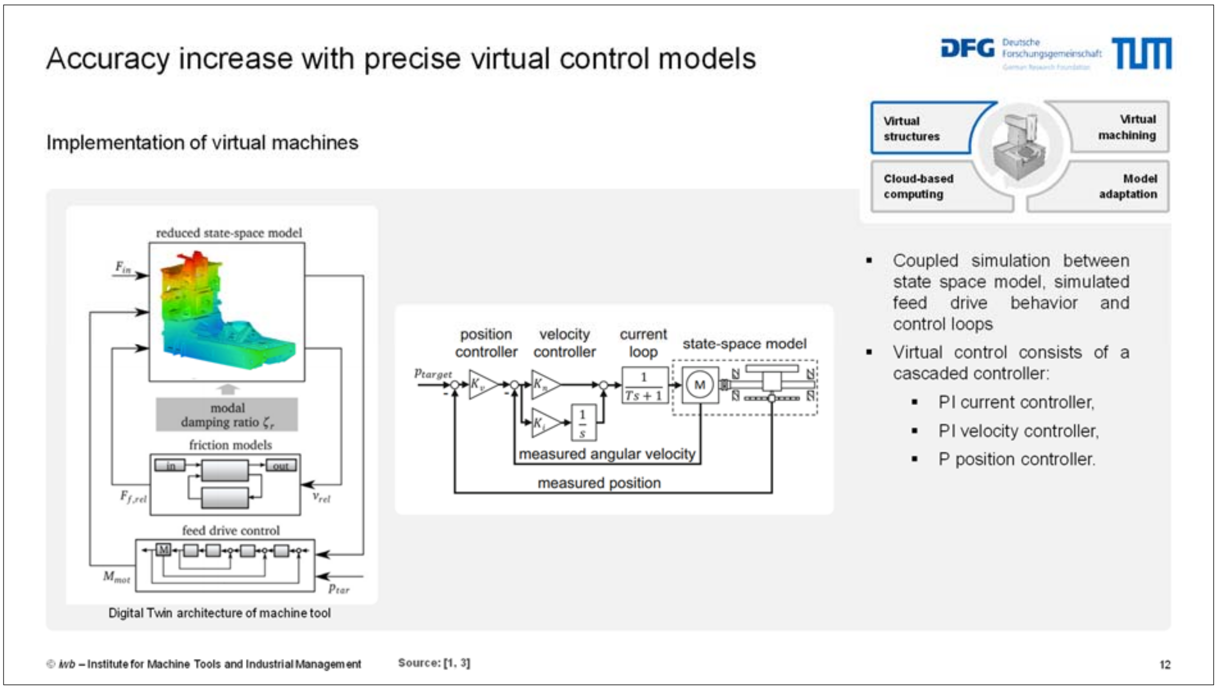
Source: [1]
11


Accuracy increase with precise virtual control models
DFG Deutsche Forschungsgemeinschaft
TUM
Implementation of virtual machines
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
reduced state-space model
modal damping ratio
friction models
in
out
feed drive control
M
Digital Twin architecture of machine tool
position controller
velocity controller
current loop
state-space model
measured angular velocity
measured position
Coupled simulation between state space model, simulated feed drive behavior and control loops
Virtual control consists of a cascaded controller:
PI current controller,
PI velocity controller,
P position controller.
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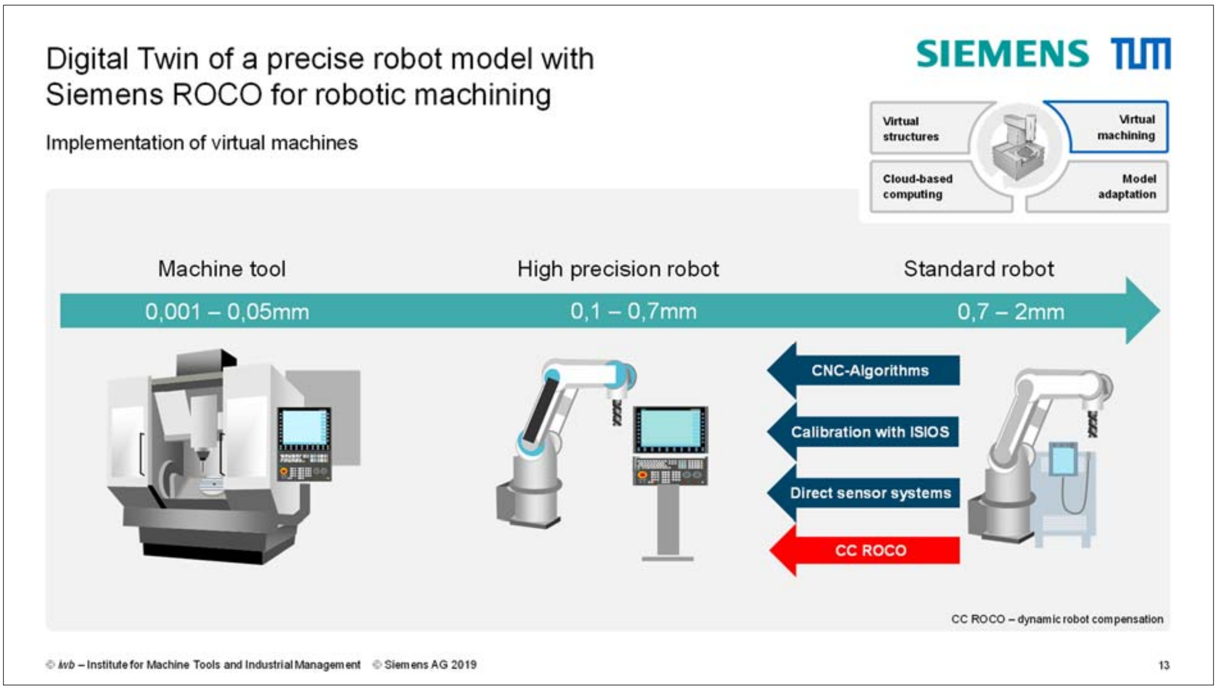
Source: [1, 3]
12


Digital Twin of a precise robot model with Siemens ROCO for robotic machining
Implementation of virtual machines
SIEMENS
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
Machine tool
High precision robot
Standard robot
0,001 – 0,05mm
0,1 – 0,7mm
0,7 – 2mm
CNC-Algorithms
Calibration with ISIOS
Direct sensor systems
CC ROCO
CC ROCO – dynamic robot compensation
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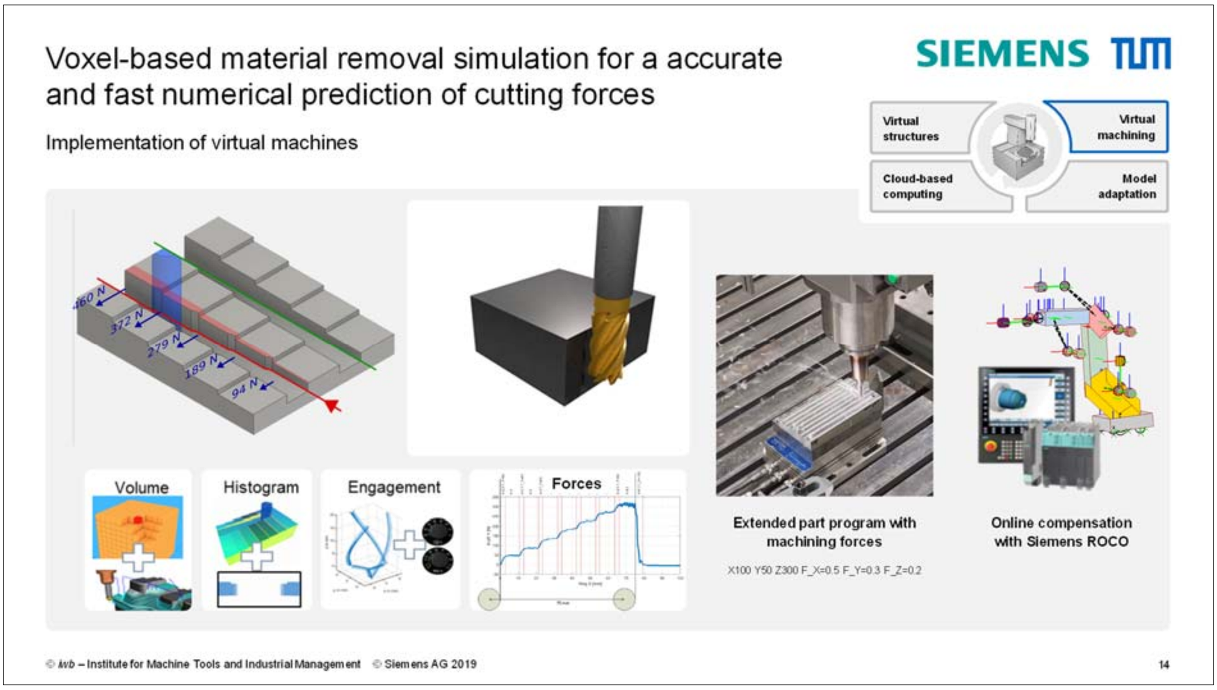
Voxel-based material removal simulation for a accurate and fast numerical prediction of cutting forces
Implementation of virtual machines
SIEMENS
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
460 N
372 N
279 N
189 N
94 N
Volume
Histogram
Engagement
Forces
Extended part program with machining forces
X100 Y50 Z300 F_X=0.5 F_Y=0.3 F_Z=0.2
Online compensation with Siemens ROCO
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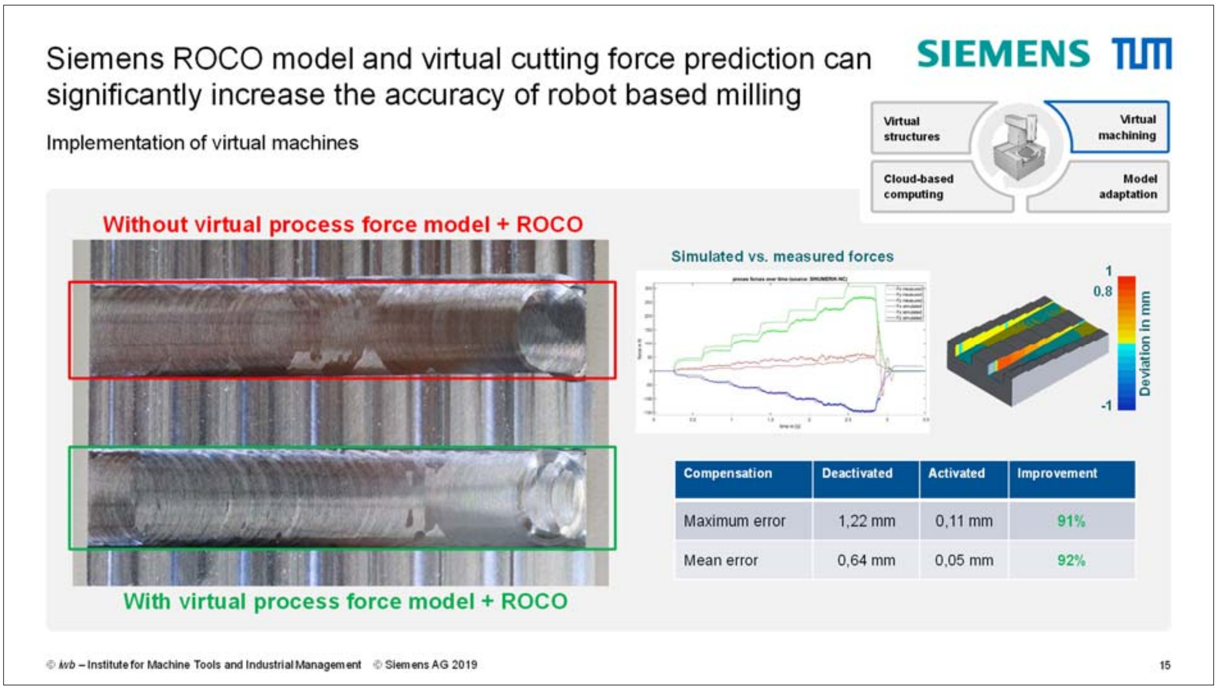
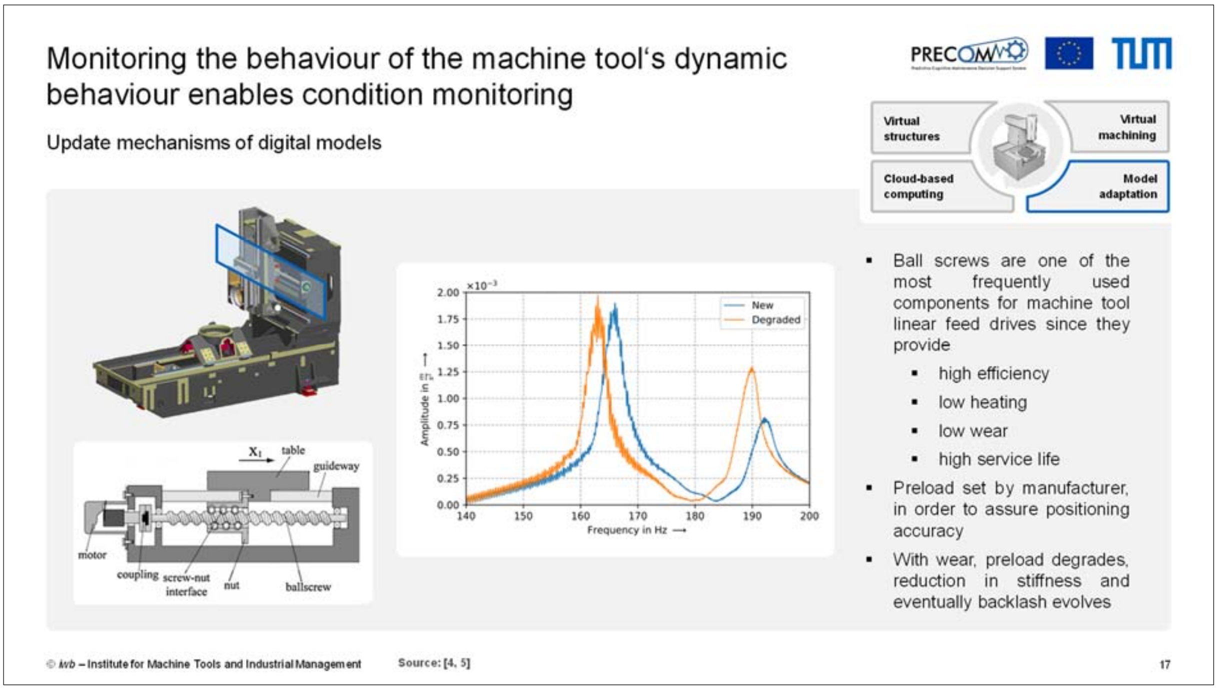
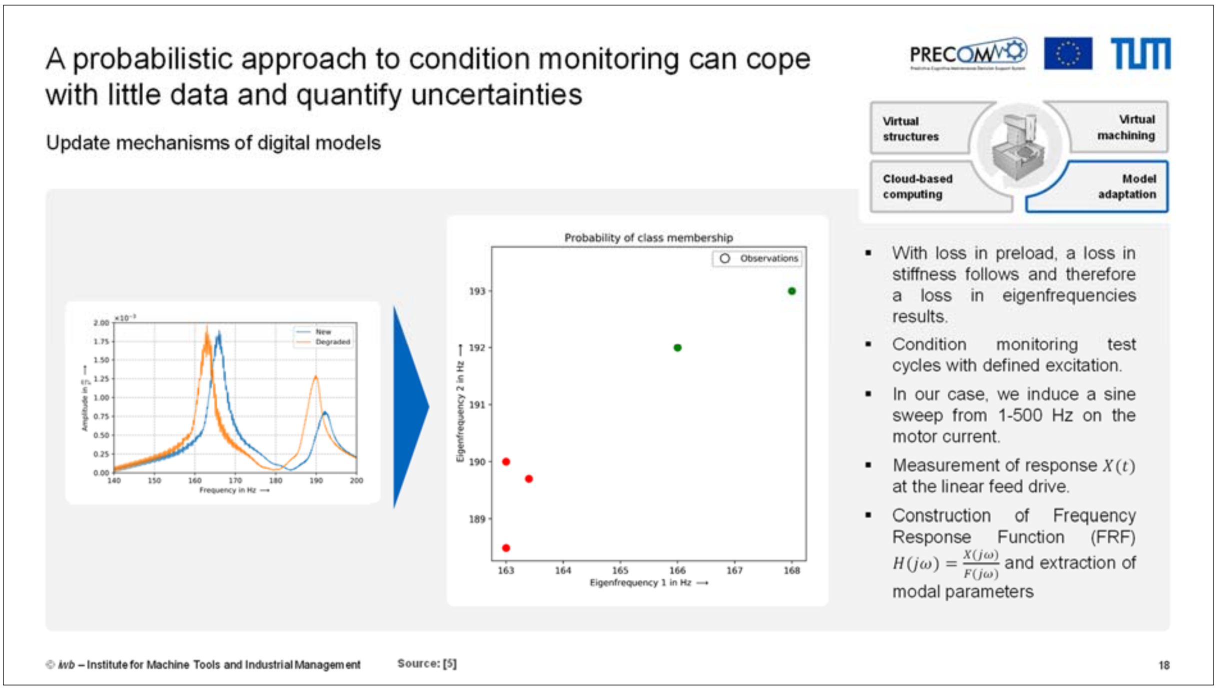
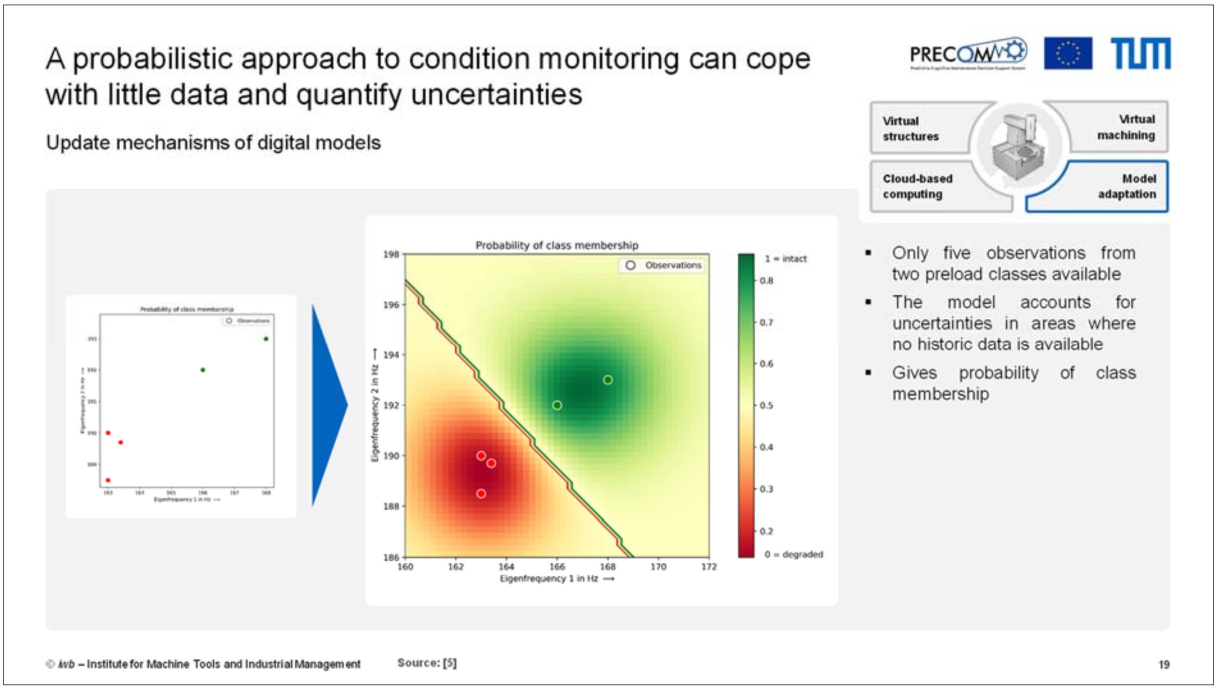


Compensation	Deactivated	Activated	Improvement
Maximum error	1,22 mm	0,11 mm	91%
Mean error	0,64 mm	0,05 mm	92%




A probabilistic approach to condition monitoring can cope with little data and quantify uncertainties
Update mechanisms of digital models
PRECOMM
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
New
Degraded
Frequency in Hz ⟶
Amplitude in
Probability of class membership
Observations
Eigenfrequency 2 in Hz ⟶
Eigenfrequency 1 in Hz ⟶
With loss in preload, a loss in stiffness follows and therefore a loss in eigenfrequencies results.
Condition monitoring test cycles with defined excitation.
In our case, we induce a sine sweep from 1-500 Hz on the motor current.
Measurement of response $X(t)$ at the linear feed drive.
Construction of Frequency Response Function (FRF) $H(j\omega) = \frac{X(j\omega)}{F(j\omega)}$ and extraction of modal parameters
© iwb – Institute for Machine Tools and Industrial Management
Source: [5]
18


A probabilistic approach to condition monitoring can cope with little data and quantify uncertainties
Update mechanisms of digital models
PRECOMM
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
Probability of class membership
Observations
Eigenfrequency 2 in Hz ⟶
Eigenfrequency 1 in Hz ⟶
1 = intact
0 = degraded
Only five observations from two preload classes available
The model accounts for uncertainties in areas where no historic data is available
Gives probability of class membership
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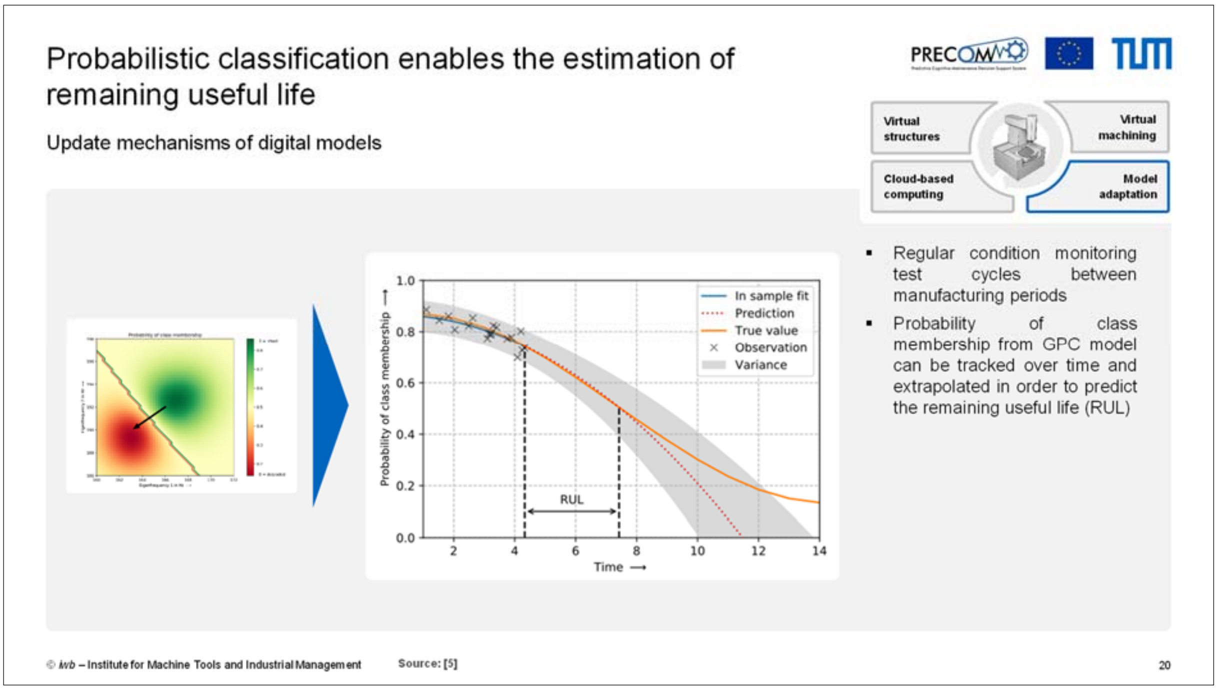
Source: [5]
19


Probabilistic classification enables the estimation of remaining useful life
Update mechanisms of digital models
PRECOM
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
1.0
0.8
0.6
0.4
0.2
0.0
Probability of class membership
2
4
6
8
10
12
14
Time
RUL
In sample fit
Prediction
True value
Observation
Variance
Regular condition monitoring test cycles between manufacturing periods
Probability of class membership from GPC model can be tracked over time and extrapolated in order to predict the remaining useful life (RUL)
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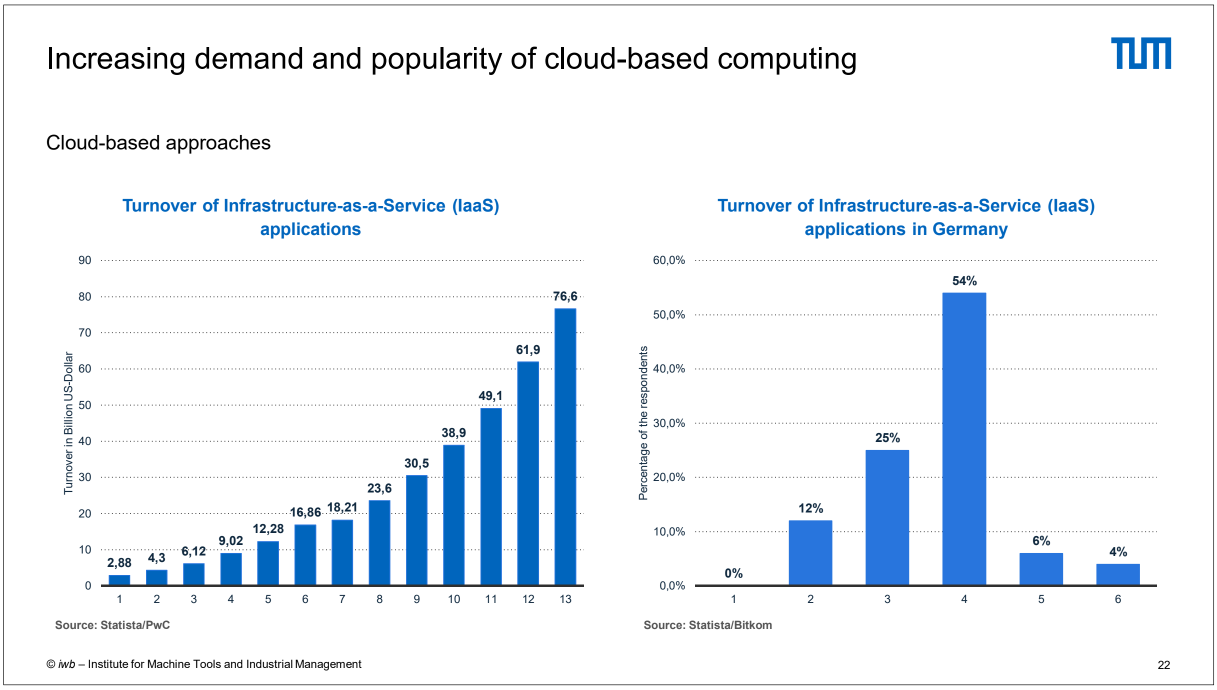
Source: [5]
20


Increasing demand and popularity of cloud-based computing
Cloud-based approaches
Turnover of Infrastructure-as-a-Service (IaaS) applications
Turnover in Billion US-Dollar
90
80
70
60
50
40
30
20
10
0
2,88
4,3
6,12
9,02
12,28
16,86
18,21
23,6
30,5
38,9
49,1
61,9
76,6
1 2 3 4 5 6 7 8 9 10 11 12 13
Source: Statista/PwC
Turnover of Infrastructure-as-a-Service (IaaS) applications in Germany
Percentage of the respondents
60,0%
50,0%
40,0%
30,0%
20,0%
10,0%
0,0%
0%
12%
25%
54%
6%
4%
1 2 3 4 5 6
Source: Statista/Bitkom
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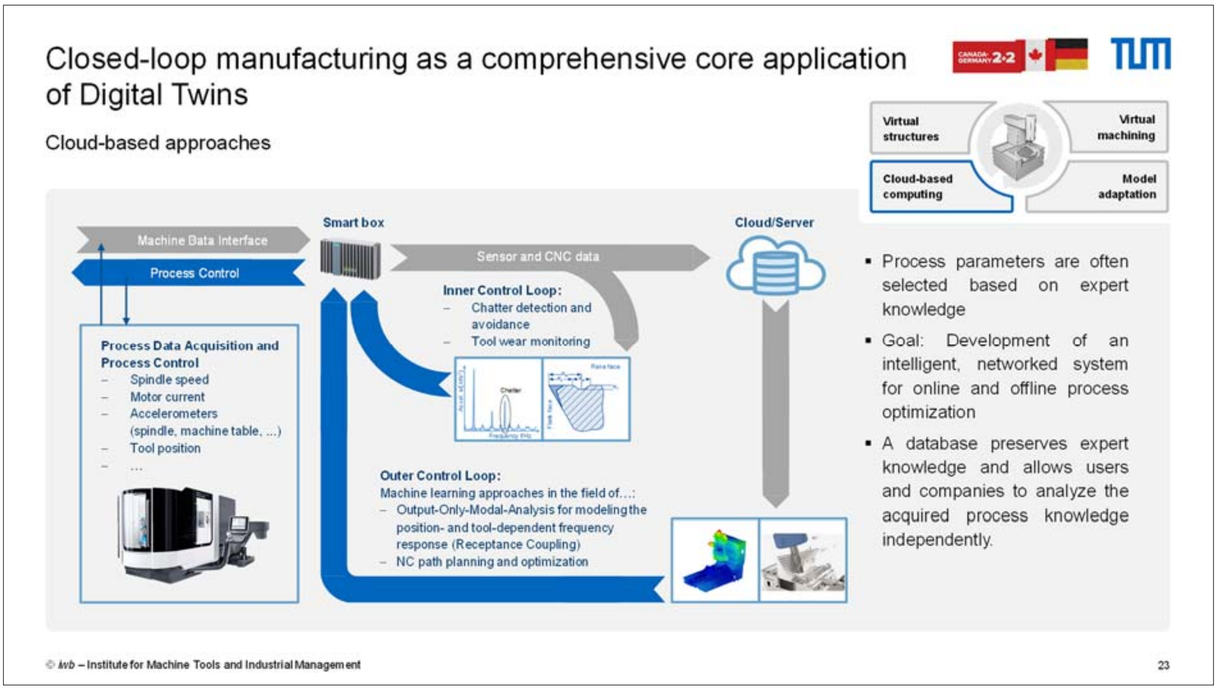
Closed-loop manufacturing as a comprehensive core application of Digital Twins
Cloud-based approaches
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
Machine Data Interface
Process Control
Smart box
Sensor and CNC data
Cloud/Server
Inner Control Loop:
– Chatter detection and avoidance
– Tool wear monitoring
Process Data Acquisition and Process Control
– Spindle speed
– Motor current
– Accelerometers (spindle, machine table, ...)
– Tool position
– ...
Outer Control Loop:
Machine learning approaches in the field of...:
– Output-Only-Modal-Analysis for modeling the position- and tool-dependent frequency response (Receptance Coupling)
– NC path planning and optimization
▪ Process parameters are often selected based on expert knowledge
▪ Goal: Development of an intelligent, networked system for online and offline process optimization
▪ A database preserves expert knowledge and allows users and companies to analyze the acquired process knowledge independently.
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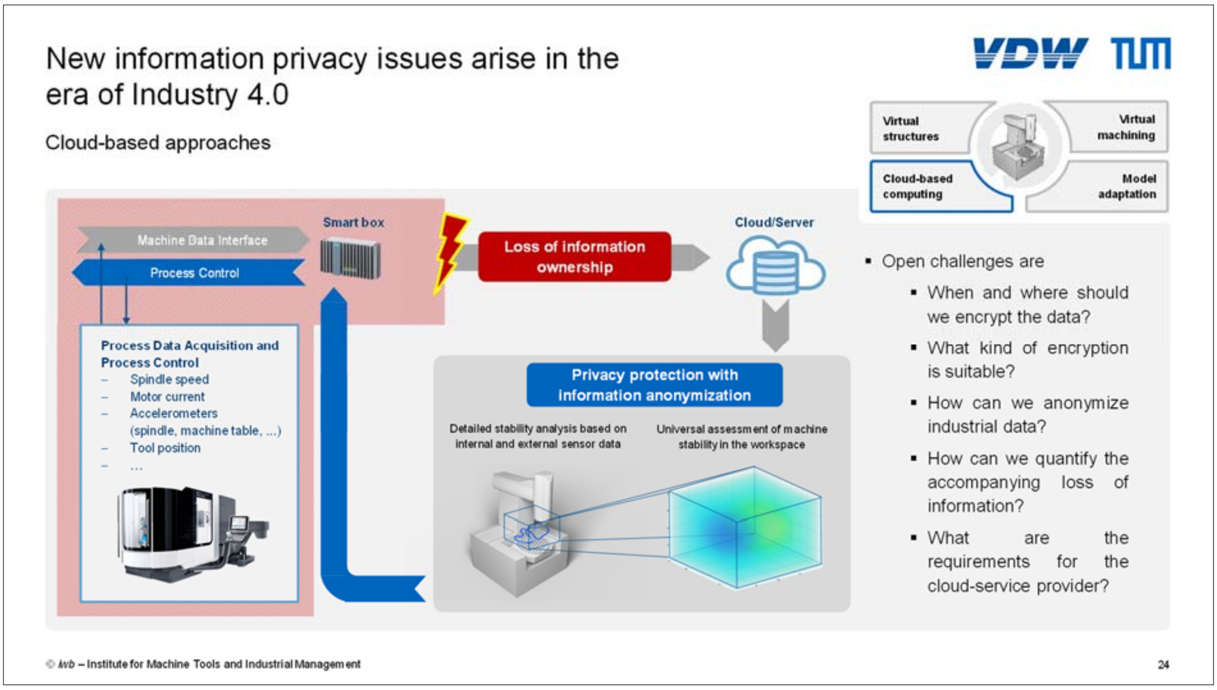
New information privacy issues arise in the era of Industry 4.0
Cloud-based approaches
Virtual structures
Virtual machining
Cloud-based computing
Model adaptation
Machine Data Interface
Process Control
Smart box
Loss of information ownership
Cloud/Server
Process Data Acquisition and Process Control
– Spindle speed
– Motor current
– Accelerometers (spindle, machine table, ...)
– Tool position
– ...
Privacy protection with information anonymization
Detailed stability analysis based on internal and external sensor data
Universal assessment of machine stability in the workspace
▪ Open challenges are
▪ When and where should we encrypt the data?
▪ What kind of encryption is suitable?
▪ How can we anonymize industrial data?
▪ How can we quantify the accompanying loss of information?
▪ What are the requirements for the cloud-service provider?
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PTW – TU Darmstadt

The Institute of Production Management, Technology and Machine Tools (PTW) is one of the leading German research institutes for production technology. It is directed by Prof. Dr.-Ing. Eberhard Abele and Prof. Dr.-Ing. Joachim Metternich. Currently about 65 associate researchers focus their work on innovations along the manufacturing value chain. This includes the development of machine components and cutting tools, technologies for high-speed machining, energy efficient machine tools, additive manufacturing processes and production management. As pioneer, the PTW opened in 2007 its own learning factory CiP on the campus of the Technische Universität Darmstadt. In 2016 another Factory ETA opened which addresses the energy efficiency of the machines as well as the storage of energy and the energetic linkage of the machines and the factory building.

Value Stream Method 4.0 – A holistic approach to analyze and design value streams from a lean perspective in the *Industrie 4.0*

Abstract

The value stream method is a common instrument for analysis and design of value streams. However, the classical value stream method is very strongly oriented towards the material flow and considers the information flow only from the point of view of production control. With the increasing digitalization of production, the information flows in the production context also increase. Therefore an extension of the classical value stream method to the value stream method (VSM) 4.0 is necessary. With its help, waste in information logistics can be analyzed and eliminated. This article focuses on the value stream design (VSD) 4.0 as part of the VSM 4.0 and shows its benefits on a practical example.

Keywords

Digitalization, Production Systems, Lean Production.

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1 Introduction

More than ever, digitalization is forcing companies to question their existing production systems and develop them further. Over the past three decades, many manufacturing companies have been inspired by TOYOTA and its principles of lean production. This production philosophy focuses on the principles of flow, takt time and pull, and its methods are strictly geared to achieving these goals. (Liker, 2004) A central method in this context is the VSM. In a first step, it can be used to analyze the current value stream, identify waste, and show potential for improvement. This is called Value Stream Analysis (VSA). In a second step, VSD is used to design a future target value stream. (Rother & Shook, 2009)

Digitalization and *Industrie 4.0* accentuate new target dimensions, some of which conflict with the principles of lean production. *Industrie 4.0*, for example, calls for the elimination of flow and takt, to make the production processes more flexible. The control of the product by the production is then carried out by intelligent algorithms, which are supposed to determine the most efficient way. Another difference is the improvement process in lean production, which is triggered by the deviation from defined standards and leads to further development of the existing production system through the implementation of an improved and more ambitious standard. In *Industrie 4.0*, fixed standards are abandoned in favor of self-optimizing systems and the prediction of future states. (Metternich, Müller, Meudt, & Schaede, 2017)

Companies must, therefore, be given methodical instructions on how they can use the potential of digitalization to further develop their production systems, taking into account the standards achieved through the consistent introduction of lean production in recent years. One possibility is the here presented VSD 4.0.

2 Literature Review

The value stream is understood as the totality of all material and information flows of a product family. This value stream should "flow" through the company as waste-free as possible in order to deliver the ordered product to the customer as quickly as possible, in the right quality and with low costs. (Rother & Shook, 2009) In order to achieve this, the value stream method of rother and shook has become very widespread in industry. According to a study by the Fraunhofer Institute for Industrial Engineering IOA, the VSM is used by 60% of manufacturing companies (Hämmerle & Rally, 2010). The advantages of this method for the production system have already been proven in several studies (Forno, Pereira, Forcellini, & Kipper, 2014; Serrano, Ochoa, & Castro, 2008).

However, the classic VSM reaches its limits when used in conjunction with *Industrie 4.0*. Information flows are only considered from the point of view of production control. The following example (Figure 1) shows the information flows in a classic value stream map.

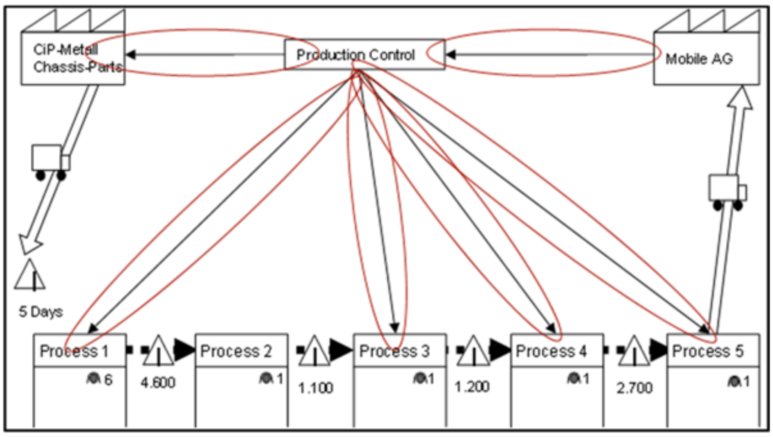

Figure 1: A classical value stream map

The digitalization of production leads to more and more complex information flows. Therefore their right design is of enormous importance to addition to the consideration of information flows, further aspects from the practical handling of VSM can be identified in connection with current challenges for companies, which should be taken into account when further developing the method:

- The business model of a company must be taken into account when digitizing and designing the value stream. This can be used to define WHAT generates value for the customer and HOW it should be generated.
- Information in the company and the processes should be used both to drive process improvements and to generate added value for the customer.
- VSM's focus should not be limited to the production phase, as it usually only accounts for a small part of the order throughput time. Rather, the complete order throughput should be taken into account.

set up efficient production processes. In The increasing complexity of value streams

As described above, digitalization and *Industrie 4.0* lead to an increasing importance of information flows. In order to realize the full potential for improving the scope of the value stream must be extended to the complete order throughput. These adaptions are shown in Figure 2. Here the value stream is not only divided into material and information flow, but a further differentiation takes place. The information flow is divided into a product information flow containing product-specific information and a process information flow containing product-independent information. The material flow can be divided into a product and a resource flow. The product flow includes all product-specific material flows, such as raw materials, semi-finished products, etc. The resource flow, on the other hand, comprises the material movements required by the processes to carry out their activities. This includes, for example, the transport of tools or the provision of fixtures. (Metternich, Meudt, & Hartmann, 2018)

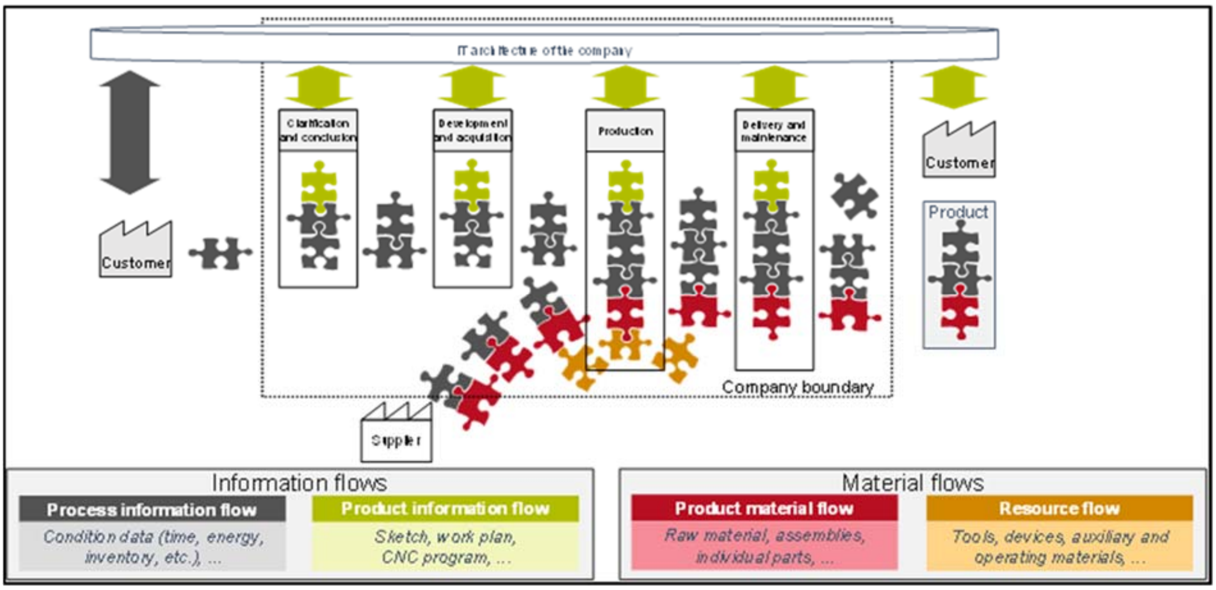

Figure 2: Value streams within an enterprise (Metternich et al., 2018)

In the indirect or administrative sections, the customer product is information. It starts at the customer and is further developed by the individual process steps. In the direct or production section, the product consists of the physical product and the product information. For an efficient and fast product flow, both parts of the value stream must, therefore, be designed synchronously and flow as waste-free as possible. (Metternich et al., 2018)

The customer takt is the basis for the analysis and design of value streams in classic VSM. A broader understanding of the business model is necessary in order to make optimum use of the possibilities offered by digitalization. This reflects the value proposition to the customer and thus makes it possible to define what is added or wasted and how the added value is to be generated. Digitalization enables simplified information processing and information generation. Thus, in addition to the physical product, added value advantages can be achieved for the customer, e.g. through the possibility to configure individual products or to provide him information about parameters as well as status data from production (Hartmann, Meudt, Seifermann, & Metternich, 2018a; Metternich et al., 2018). The data can be used in the product lifecycle in a way that enables companies to offer hybrid products such as a combination of the asset with maintenance.

In order to create efficient value streams with short processing times, only a lean material flow should be digitized; otherwise there is a risk that waste will be digitized and thus often standardized. Therefore, the classical methods for the analysis and design of value streams also form the basis for VSM 4.0. The approach is shown in Figure 3.

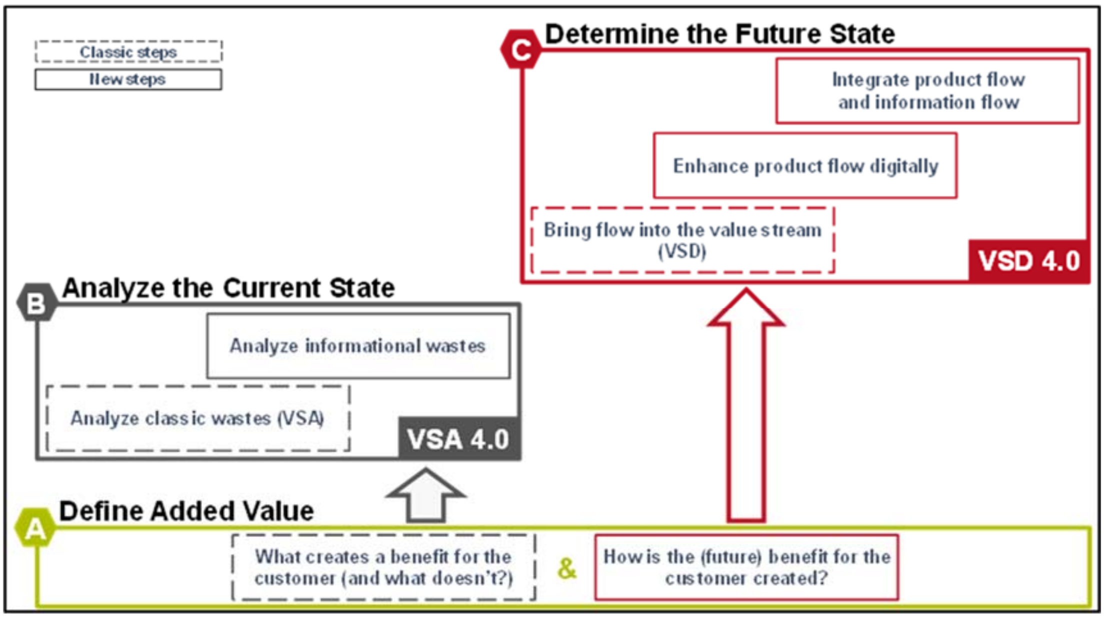

Figure 3: The Value Stream Method 4.0 (Metternich et al., 2018)

3 Value stream design 4.0

The analysis of classical wastes and such in information logistics within the VSA 4.0 forms the basis for the design of the target state. VSD 4.0 proceeds in three steps for this purpose:

First, classical VSD is carried out in order to create a waste-free material flow with short throughput times. Rother and Shook have defined questions for guidance (Rother & Shook, 2009):

1. What is the takt time?
2. Will you build to a finished goods supermarket, or directly to shipping?
3. Where can you use continuous flow processing?
4. Where will you need to use supermarket pull systems to control the production of upstream processes?
5. At what single point in the production chain (the “pacemaker process”) will you schedule production?
6. How will you level the production mix at the pacemaker process?
7. What increment of work will you consistently release and take at the pacemaker process?
8. What process improvements will be necessary for the value stream to flow as your future-state design specifies?

In the following step, obstacles and waste in the material and information flow, which could not be eliminated with the possibilities of the classic VSD, can be eliminated with digital solutions. Digitalization thus offers new possibilities for streamlining the value stream and shortening throughput times.

Once the digital methods have been selected, the last step is to synchronize and link the material and information flow. Both the information requirements of the individual process steps and those of the supporting functions, such as maintenance and quality management, must be taken into account. The individual steps are shown in the figure below.

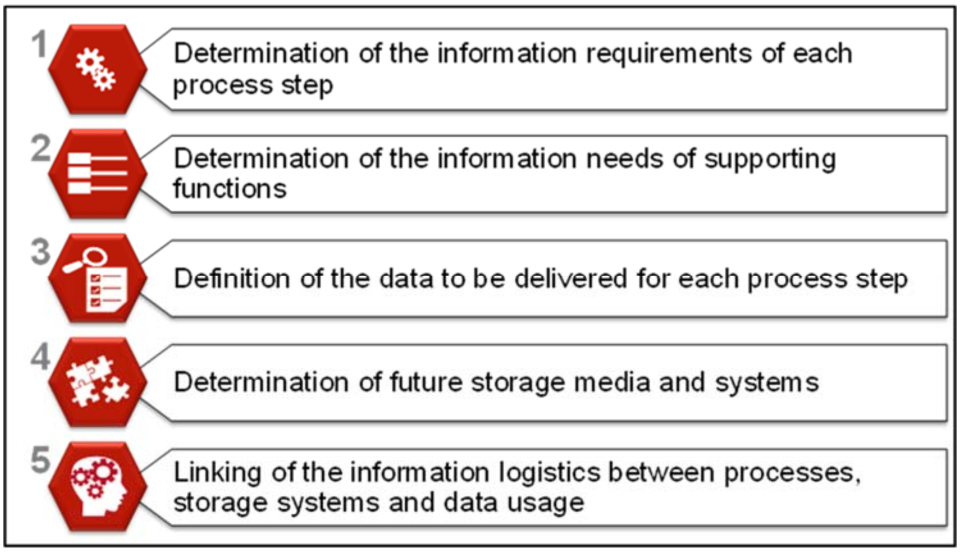

Figure 4: Steps to integrate and synchronize material and information flow

For a detailed description of the method, reference is made to (Hartmann et al., 2018a, 2018b; Metternich et al., 2018).

4 Application of the method at EventTender Solutions GmbH

The VSD 4.0 was used by EventTender Solutions GmbH to redesign a value stream. In this section, the results and advantages of the method, as well as its effectiveness, are shown.

EventTender Solutions GmbH is a start-up company that develops and manufactures mobile beverage solutions with autonomous power and water supply. The core element is the so-called SkyTender - a smart mobile, automatic device which is built into a trolley. The system is a sustainable solution that significantly reduces waste and over catering. The beverage offer ranges from Coffee Specialties (SkyBarista Line) to general hot, cold and carbonated beverages (SkyBar Splash Line) which can be dispensed from an elevated dispenser head through a touch screen operation. The water supply is provided by a specially developed water treatment system and guarantees constant water quality. In addition, the built-in RFID technology ensures transparency of consumption flows, provides a platform for data analysis and integrates ordering.

The company EventTender Solutions GmbH, founded in 2009, has its headquarter in Herborn, Germany. EventTender Solutions GmbH is part of SkyTender Holding, which is based in Schindellegi, Switzerland. The company EventTender Solutions GmbH has about 30 employees.

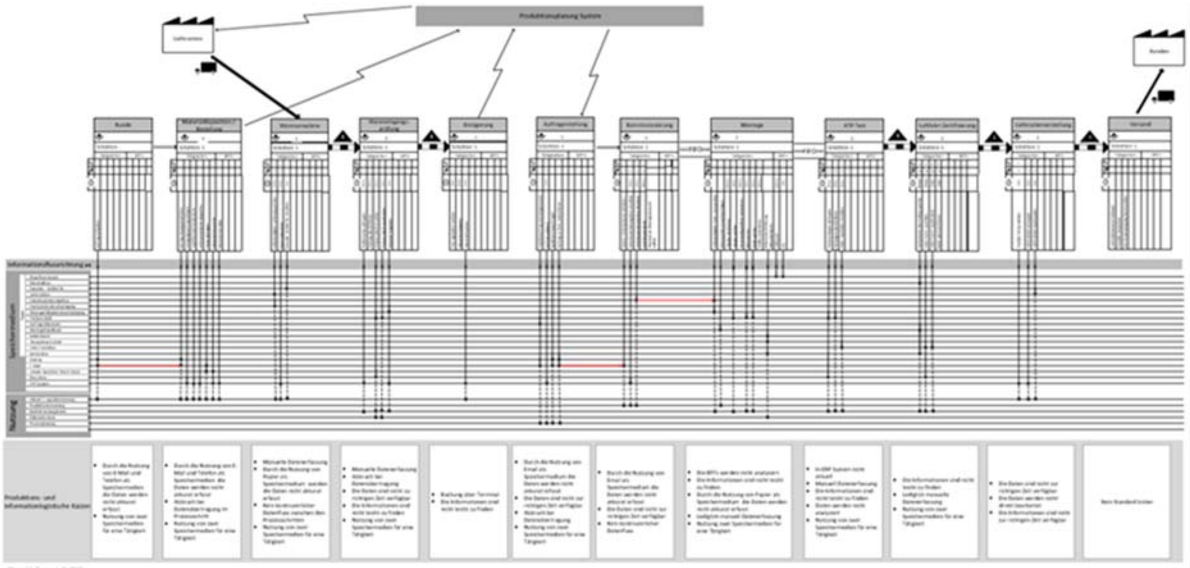

Figure 5: Depiction of the VSA 4.0 (Kaizen opportunities listed below the information flows)

The complete order processing process was analyzed. The result of the value stream analysis is shown in Figure 5, with the most important details discussed below. From the order by the customer over the completion in indirect areas with the order of purchased parts up to the assembly and the shipping of the trolley. Production orders are entered into logistics, the necessary components are picked, and then the order is pushed to the assembly. Production in the aviation industry is characterized by high quality and safety requirements. This is accompanied by a wide range of documentation obligations and standards. These, in turn, place special demands on the flow of information. It is noticeable that information is primarily stored on paper and is passed through the company. Due to a large number of documents and the time-consuming search for the required information, the processing of orders has a prolonged throughput time. In addition to waste through the handling of information, interfaces, and media breaks also lead to longer processing times. A total of 19 different storage media are in use in the value stream. There is no link between these media. Fourteen of the media are analog and five are digital.

For a better understanding of the method, one process step is depicted in detail in Figure 6. The figure shows the extension of the process box as well as the swimlanes for storage media and information usage. For each process step (in this case assembly) major activities and KPIs are noted in the vertical columns. For every activity or KPI, their frequency of acquisition or provision of information, type of the acquisition/provision and the actual value are given. Vertical lines connect the activity or KPI with the storage media and the usage swim lanes. The dot marks where the information is stored and for what purpose it is used. With this extension, the whole information flow of a value stream can be analyzed and designed.

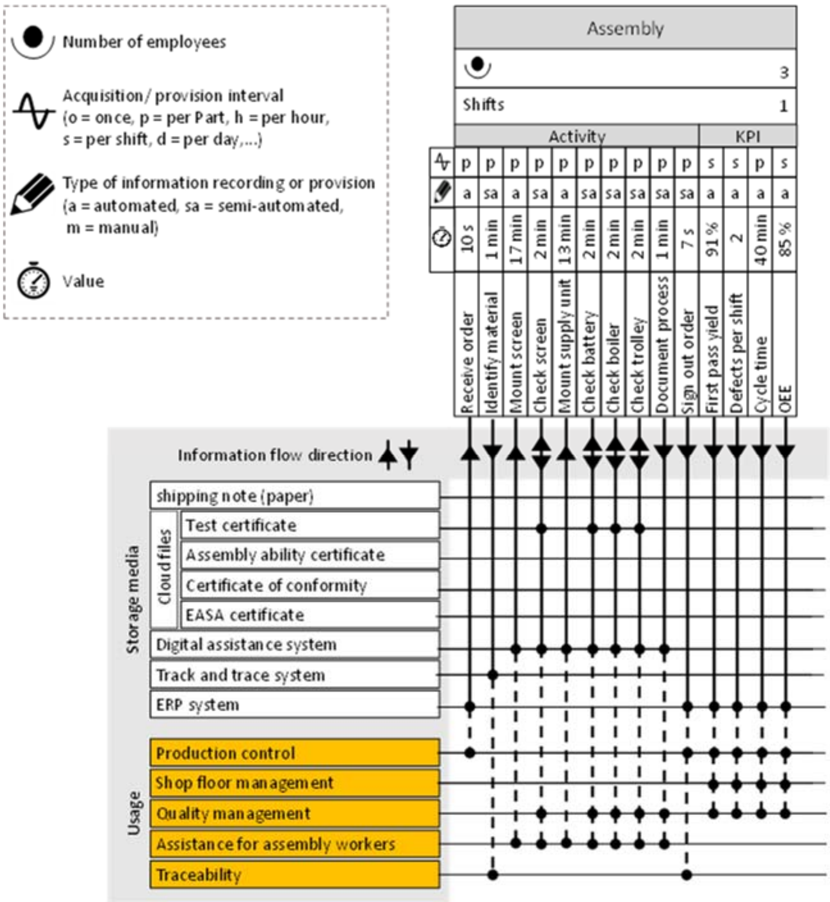

Figure 6: Exemplary depiction of a process step

In the first step of VSD 4.0 at EventTender, a lean material flow and the control of production orders were designed. As described in the previous chapter, the guidelines of rother and shook were followed. As far as possible, all processes are arranged in a flow or linked by FIFO lines or supermarkets. The supplier is also connected via a supplier Kanban. Production orders are only entered in the last production step, and the complete assembly is controlled via a pull system.

The next step of the VSD 4.0 is the selection of solutions for the digital improvement of the product flow. In this example, four solutions could be identified as being able to help eliminate waste in the information flow. An online platform is to be implemented for the connection and processing of customer orders. Previously defined product information can thus be queried, processed, and forwarded in a standardized way. Secondly, traceability was evaluated as a necessary solution for eliminating waste in the value stream. This enables products to be clearly identified and process information to be stored product-specifically. The integration of a worker assistance system (WAS) is intended to provide process- and order-specific information for employees. This eliminates the search and handling effort. In addition, the combination of WAS and traceability documentation obligations can be fulfilled more easily, since the relevant process parameters and quality criteria, as well as the performing employees, are recorded for each product.

A digital shop floor management system (dSFM) is to be introduced so that the process data can also be used purposefully for improvements and visualized to the employees.

The resulting target value stream with integrated material and information flow is shown in the following figure.

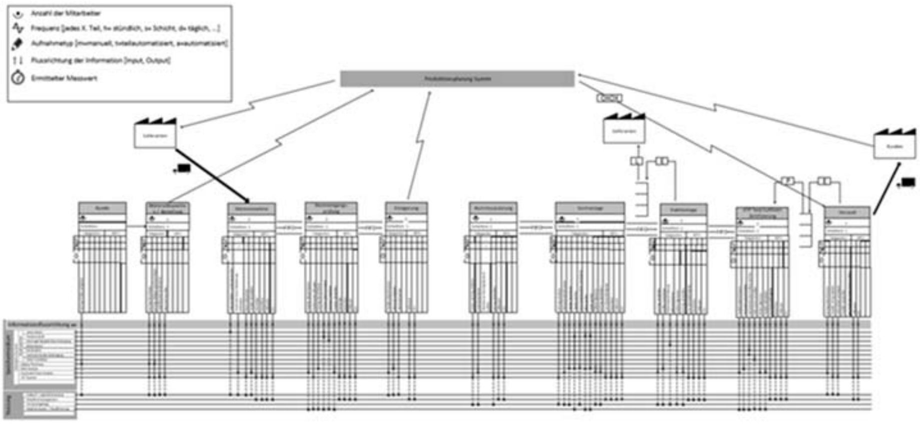

Figure 7: The Results of the VSD 4.0

After the execution of VSD 4.0 the following achievements have been obtained:

- A value stream for the complete order processing was designed with a continuous acquisition and provision of information.
- Wastes in information logistics were reduced, especially with regards to searching and processing of information.
- Reduction of storage media from 19 to 8.
- Reduction of analog and unlinked storage media from 17 to 0 (except the delivery note of the customer).
- All remaining storage media in the future state are linked to each other and exchange the relevant data.
- Paper is no longer used as a storage medium in the value stream.
- Information on the fulfillment of documentation obligations is stored product-specifically and can thus be easily further processed.

5 Conclusion

In this paper, the VSD 4.0 was presented, and a practical example was given. The method solves the shortcoming of the classical VSD that information flows are only considered from the point of production control and that information from the processes is not used to increase customer value or to improve processes. In addition, the case study shows that the method is applicable for a complete order completion process. That means for administrative processes as well as for production processes. By using the method, it was possible to improve the value stream in various objectives like used storage media, the number of analog data flows, and the use of paper in the production. Although some digital technologies have been integrated to reduce waste in information logistic and speed up the throughput time.

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Value Stream Method 4.0 – A holistic approach to analyze and design value streams from a lean perspective in the Industrie 4.0

24th International Seminar on High Technology
Piracicaba, Brasil | October, 10 2019

Lukas Hartmann, M.Sc. | Dr. Thomas Mützel-von Schwartz | Vasileios Tsianakas, M.Sc. | Prof. Dr.-Ing. Joachim Metternich

TECHNISCHE UNIVERSITÄT DARMSTADT

PTW TU DARMSTADT

Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold

Agenda

1. Introduction
2. The Value Stream Method 4.0
3. Examples from industry

Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 1

Lean vs. Industrie 4.0

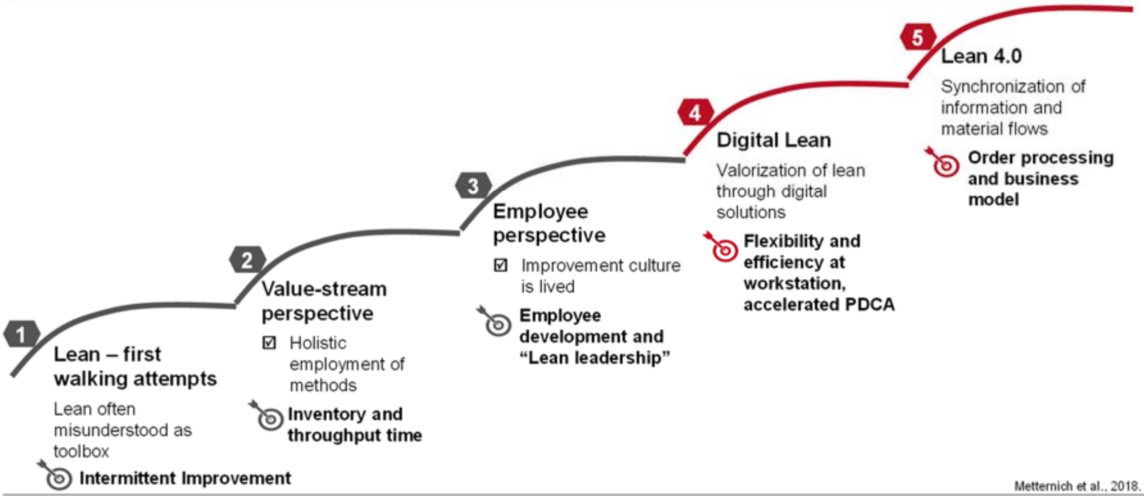
	Lean		Industry 4.0
Approach	Holistic (person + technology + organization)	⟷	Technology as driver
Philosophy	Respect, problem solving, employee development	⟷	Feasibility, (self-)optimization
Foundation	Stability and standardization	+	Networking, adaptive
Control principle	Flow, FiFo and Pull	+	Dynamic, situation-dependent
Information acquisition	Current location, current material ("Go and See")	+	Situation-dependent, data processing in real time
Improvement	Reactive in day-to-day business through employees	+	Self-optimization, prediction

⟷ contradiction + supplementation

Metternich et al., 2017.

Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 2

Maturity Levels of Lean



Metternich et al., 2018.

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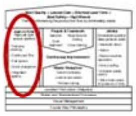
Value Stream Method: A core instrument in Lean Production

Basic and important method in Lean Production

- One of the elements in the Toyota Production System

Liker, 1992



Widely used in industry

- Fraunhofer IAO (*Hämmerle and Rally, 2010*): **60% of the companies use the VSM**, in manufacturing industry and automotive the percentage is even higher (N=301)
- *Winkler and Lugert, 2017*: **86% of the participants use the VSM** (N=170)

Appropriate tool for process improvement and redesign

- Waste identification
- Shows relationship between material and information flow
- Lead time reduction + variability reduction
- Area/workforce reduction
- Response time variability reduction

Rother and Shook, 1999; Serrano et al., 2008

Proven as a good tool to develop, discuss und communicate changes in the value stream

- Standardized symbols and method

Rother and Shook, 1999; Erlach, 2012.

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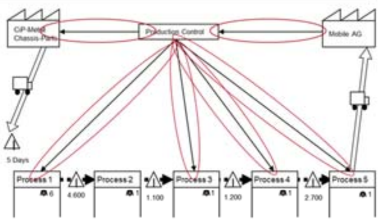
Information in the Context of the Value Stream Method

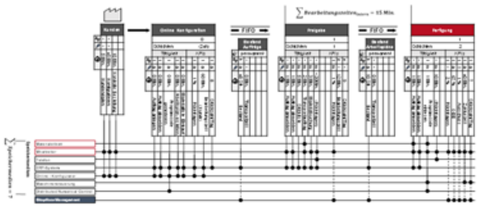
Today:

- Information flows are considered from the perspective of production control and its improvement
- Production is the focus of improvement work.



New:

- Waste in information logistics is avoided
- Information can be used for **process improvement**
- Information can be used to increase **customer benefit**
- Focus is expanded to the whole **order processing**



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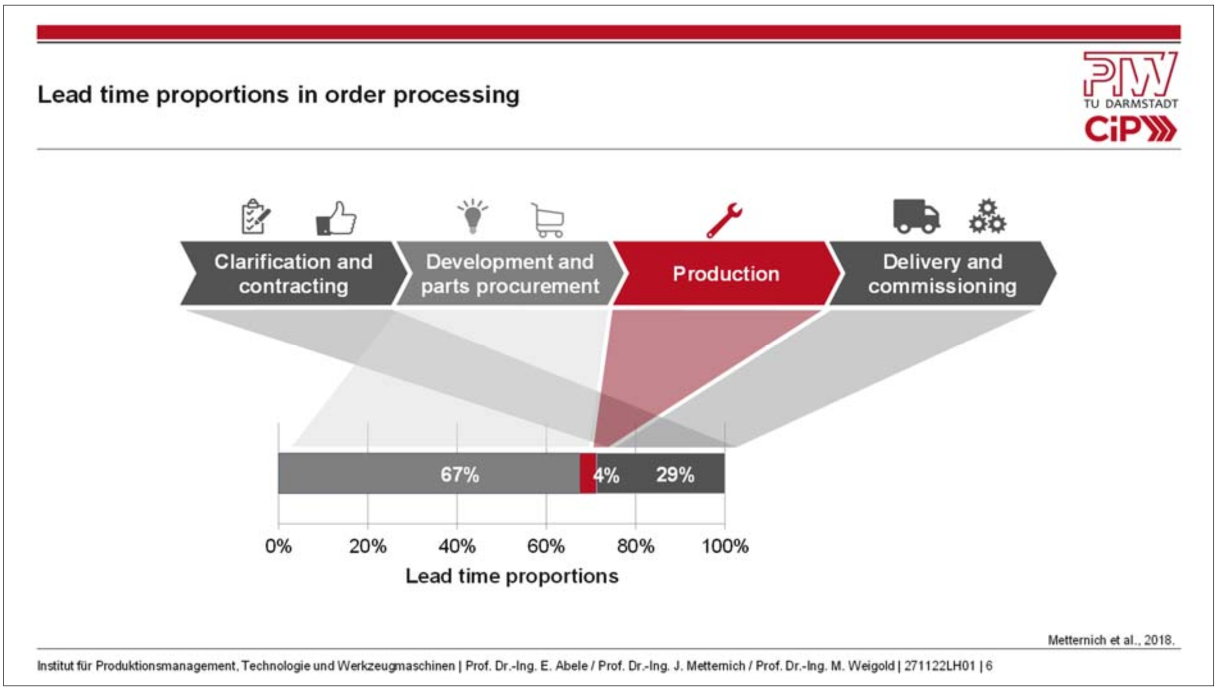
Lead time proportions in order processing
TU DARMSTADT
Clarification and contracting
Development and parts procurement
Production
Delivery and commissioning
67%
4%
29%
0%
20%
40%
60%
80%
100%
Lead time proportions
Metternich et al., 2018.
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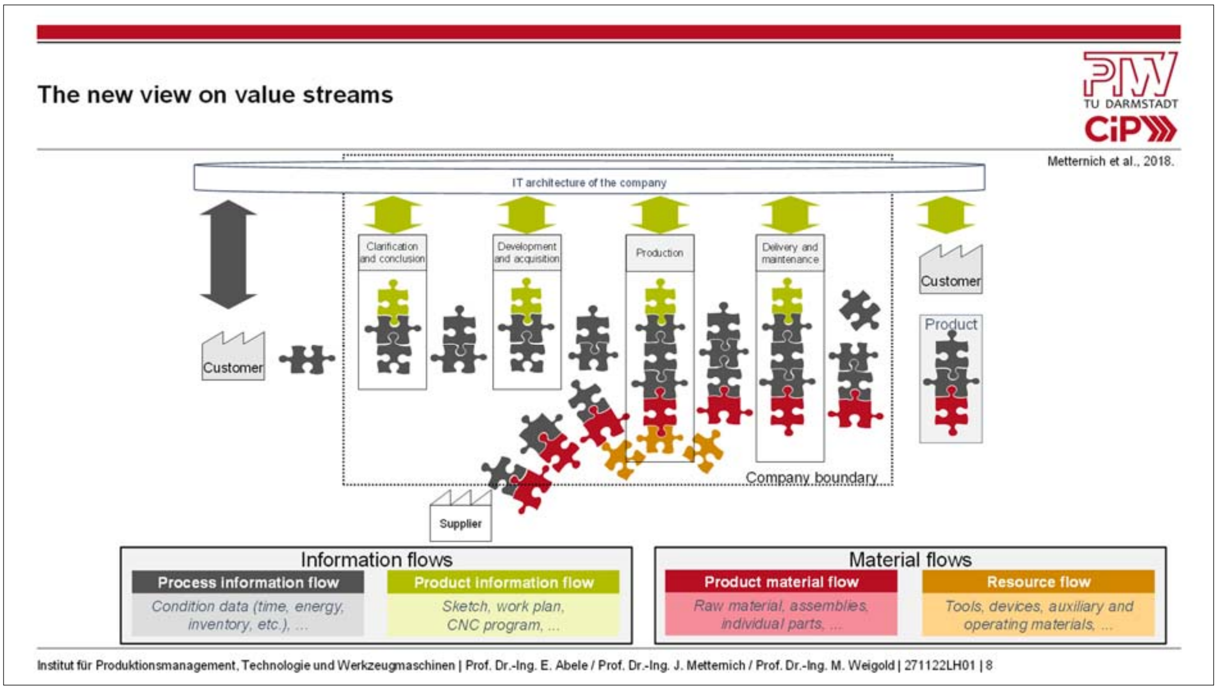
The new view on value streams
TU DARMSTADT
Metternich et al., 2018.
IT architecture of the company
Clarification and conclusion
Development and acquisition
Production
Delivery and maintenance
Customer
Customer
Product
Company boundary
Supplier
Information flows
Process information flow
Condition data (time, energy, inventory, etc.), ...
Product information flow
Sketch, work plan, CNC program, ...
Material flows
Product material flow
Raw material, assemblies, individual parts, ...
Resource flow
Tools, devices, auxiliary and operating materials, ...
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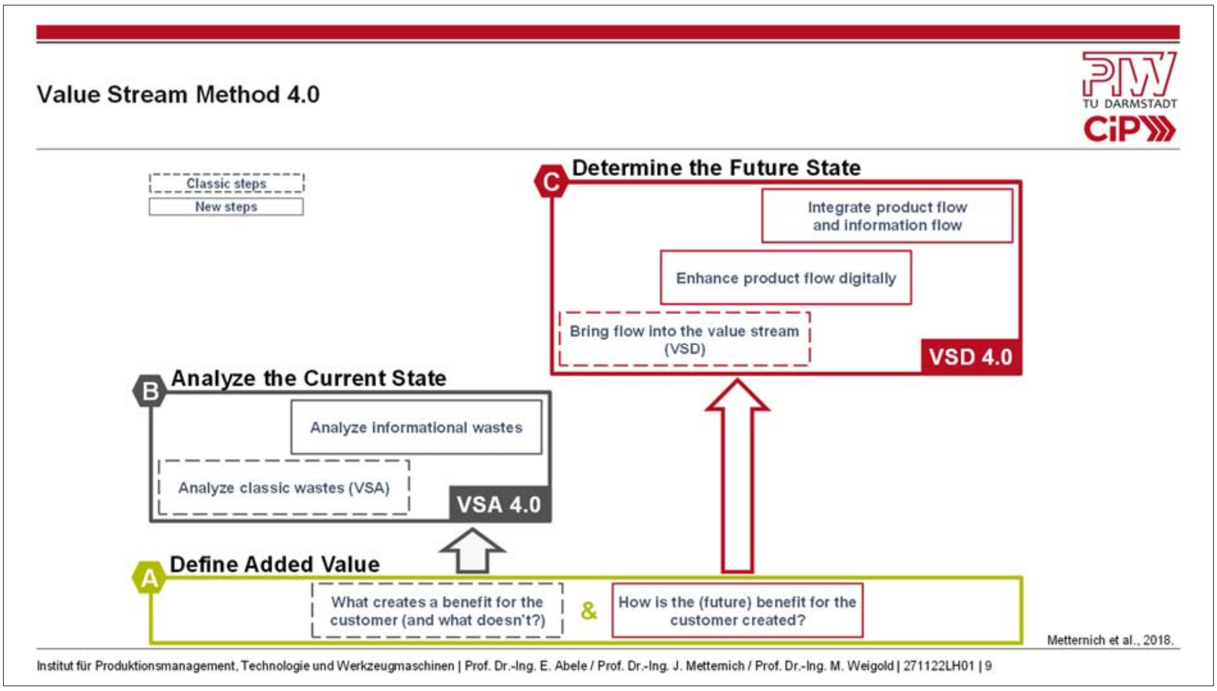
Value Stream Method 4.0
TU DARMSTADT
Classic steps
New steps
Determine the Future State
C
Integrate product flow and information flow
Enhance product flow digitally
Bring flow into the value stream (VSD)
VSD 4.0
B
Analyze the Current State
Analyze informational wastes
Analyze classic wastes (VSA)
VSA 4.0
A
Define Added Value
What creates a benefit for the customer (and what doesn't?)
&
How is the (future) benefit for the customer created?
Metternich et al., 2018.
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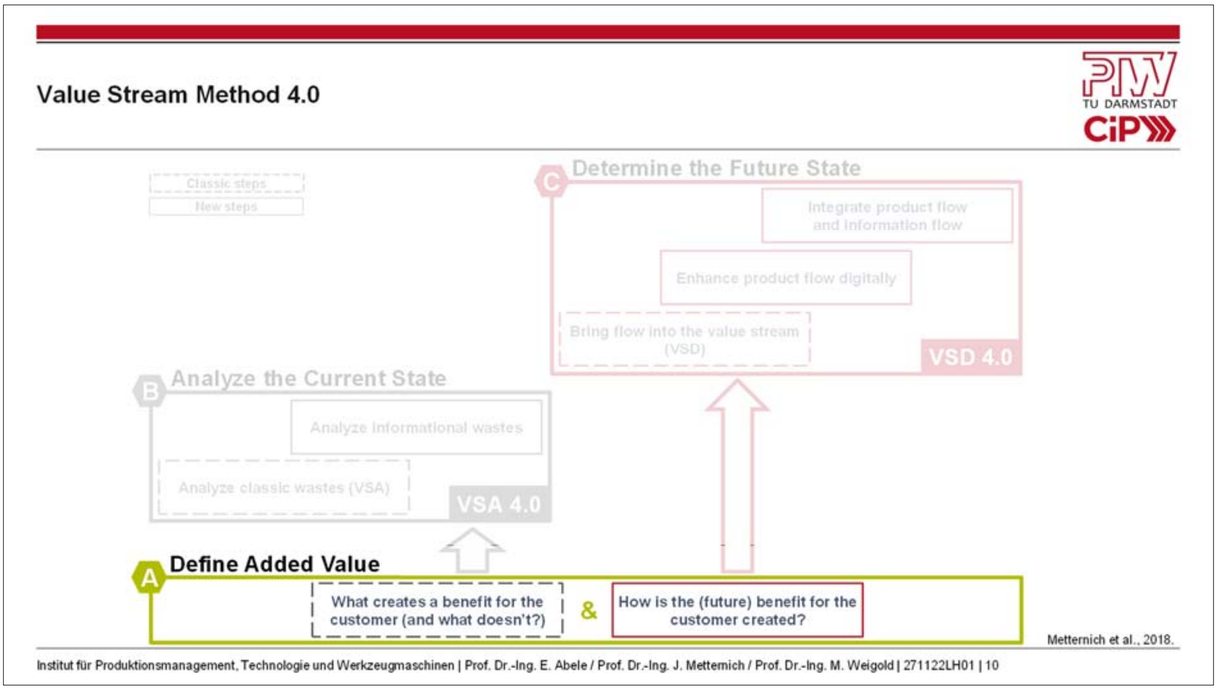
Value Stream Method 4.0
TU DARMSTADT
Classic steps
New steps
Determine the Future State
C
Integrate product flow and information flow
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Metternich et al., 2018.
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 10

Examples of new business models

Adidas' Speedfactory.
Source: Business Insider 26.04.2018

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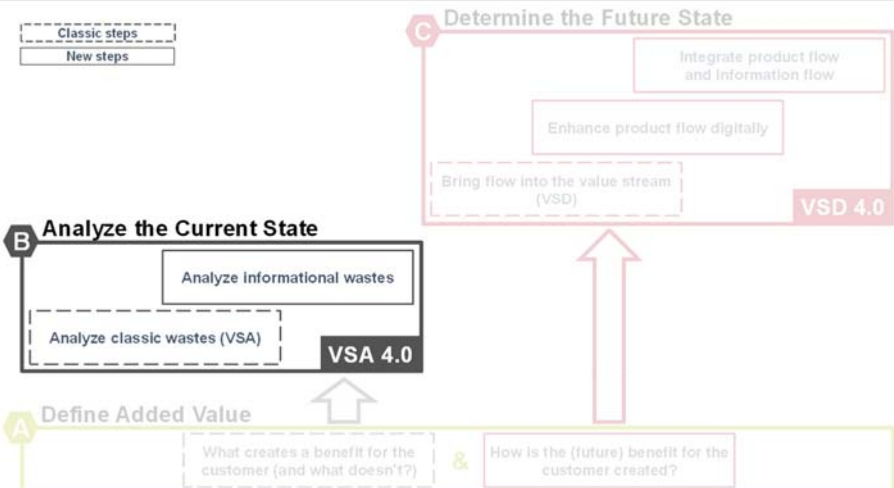
Value Stream Method 4.0



Metternich et al., 2018.

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8 areas of information-related logistical wastes
PTW TU DARMSTADT
CiP
data usage
data generation and data transfer
data processing and data storage
1 data selection
2 quality of data
3 data acquisition process
4 data transfer
5 inventory & waiting
6 transfer, movement & searching
7 data analysis
8 decision-taking support
1 Are the right data collected / used in the appropriate detail and stored for a reasonable length of time?
2 Is data collected accurately?
3 Is the (manual / automated) process of data collection appropriate?
4 Where and how are data transferred?
5 Are data processed directly? Is data available at the right time?
6 Are information adequately moved? Are information easy to find?
7 Are data analyzed? Are appropriate procedures implemented?
8 Are there any clear recommendations based on the analyzes?
Meudt et al., 2017
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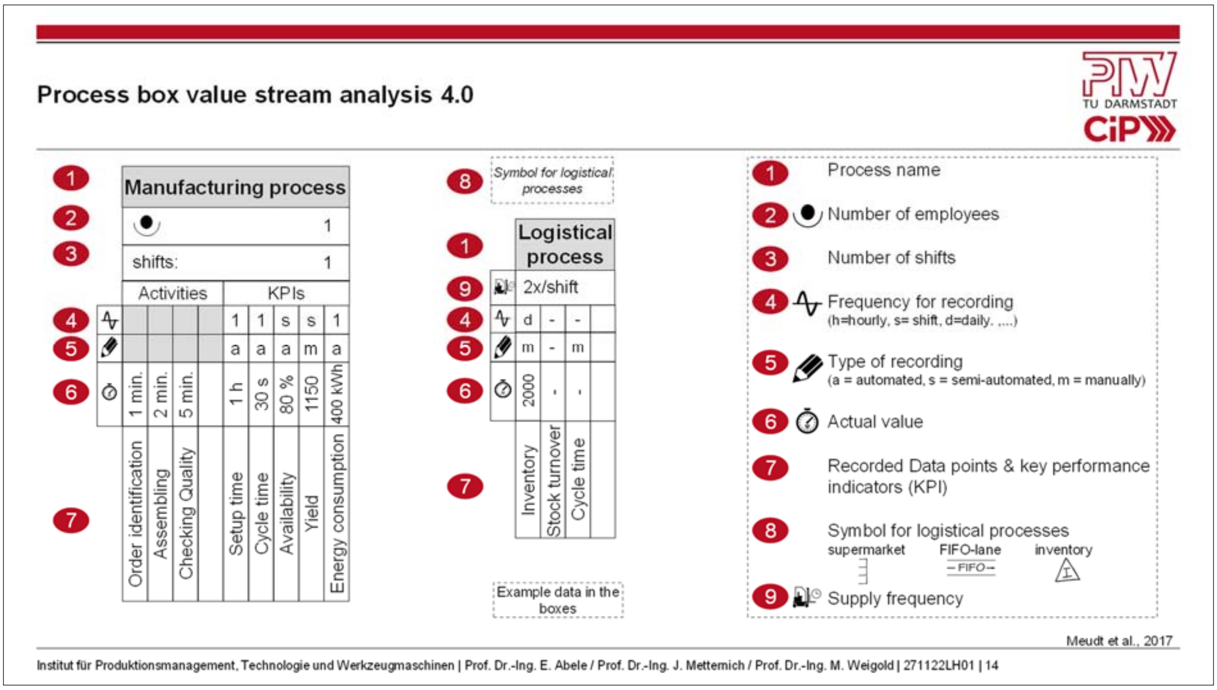
Process box value stream analysis 4.0
PTW TU DARMSTADT
CiP
Manufacturing process
shifts: 1
Activities
KPIs
Order identification
Assembling
Checking Quality
Setup time
Cycle time
Availability
Yield
Energy consumption
1 min.
2 min.
5 min.
1 h
30 s
80 %
1150
400 kWh
Symbol for logistical processes
Logistical process
2x/shift
Inventory
Stock turnover
Cycle time
2000
Example data in the boxes
1 Process name
2 Number of employees
3 Number of shifts
4 Frequency for recording (h=hourly, s= shift, d=daily, ,...)
5 Type of recording (a = automated, s = semi-automated, m = manually)
6 Actual value
7 Recorded Data points & key performance indicators (KPI)
8 Symbol for logistical processes
supermarket
FIFO-lane
inventory
9 Supply frequency
Meudt et al., 2017
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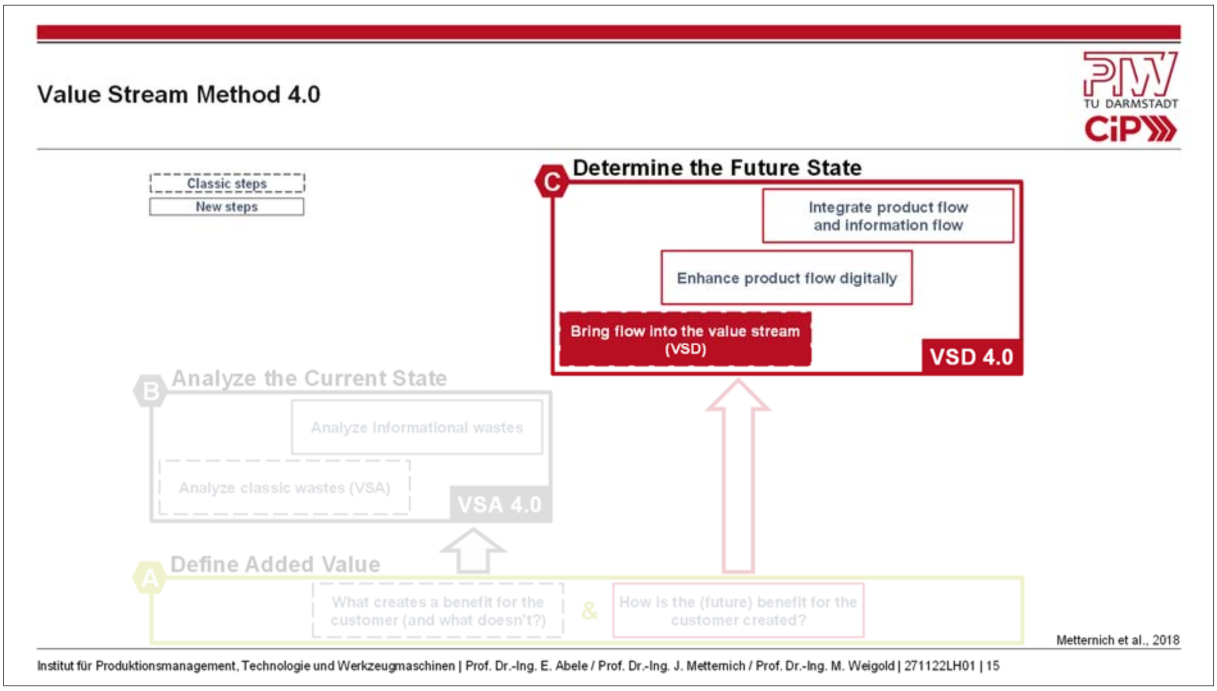
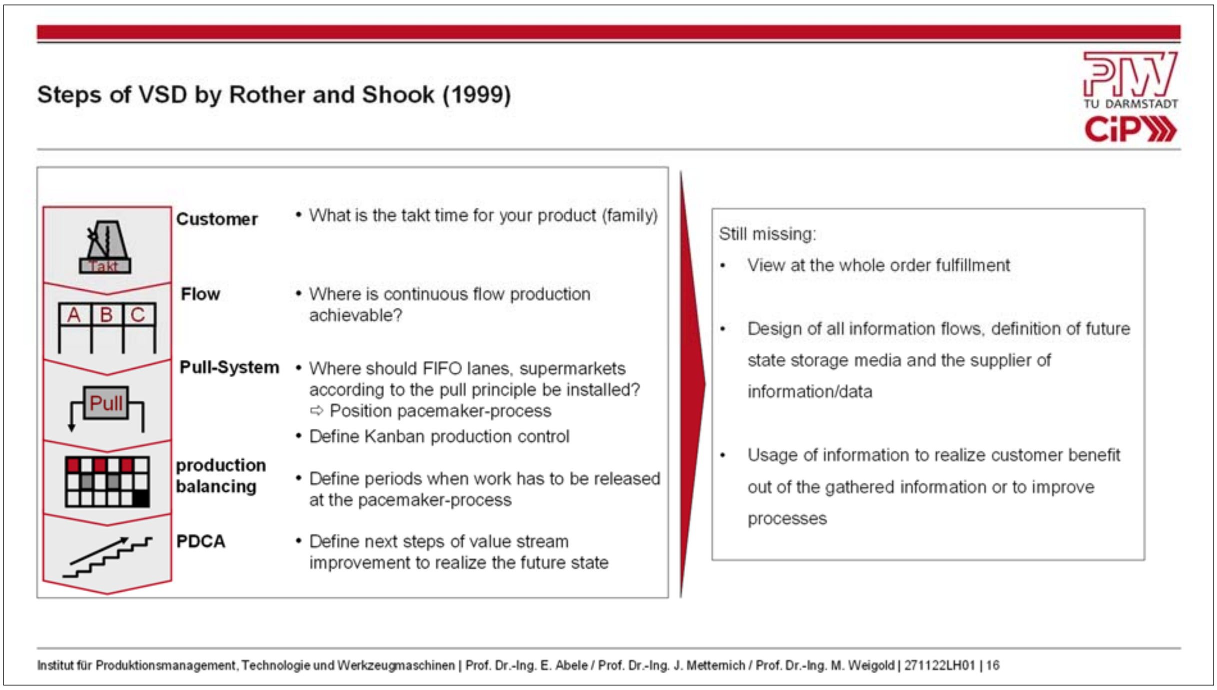

Value Stream Method 4.0
TU DARMSTADT
CiP
Classic steps
New steps
C
Determine the Future State
Integrate product flow and information flow
Enhance product flow digitally
Bring flow into the value stream (VSD)
VSD 4.0
B
Analyze the Current State
Analyze informational wastes
Analyze classic wastes (VSA)
VSA 4.0
A
Define Added Value
What creates a benefit for the customer (and what doesn't?)
&
How is the (future) benefit for the customer created?
Metternich et al., 2018
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 15


Steps of VSD by Rother and Shook (1999)
TU DARMSTADT
CiP
Takt
Customer
• What is the takt time for your product (family)
A B C
Flow
• Where is continuous flow production achievable?
Pull
Pull-System
• Where should FIFO lanes, supermarkets according to the pull principle be installed?
⇨ Position pacemaker-process
• Define Kanban production control
production balancing
• Define periods when work has to be released at the pacemaker-process
PDCA
• Define next steps of value stream improvement to realize the future state
Still missing:
• View at the whole order fulfillment
• Design of all information flows, definition of future state storage media and the supplier of information/data
• Usage of information to realize customer benefit out of the gathered information or to improve processes
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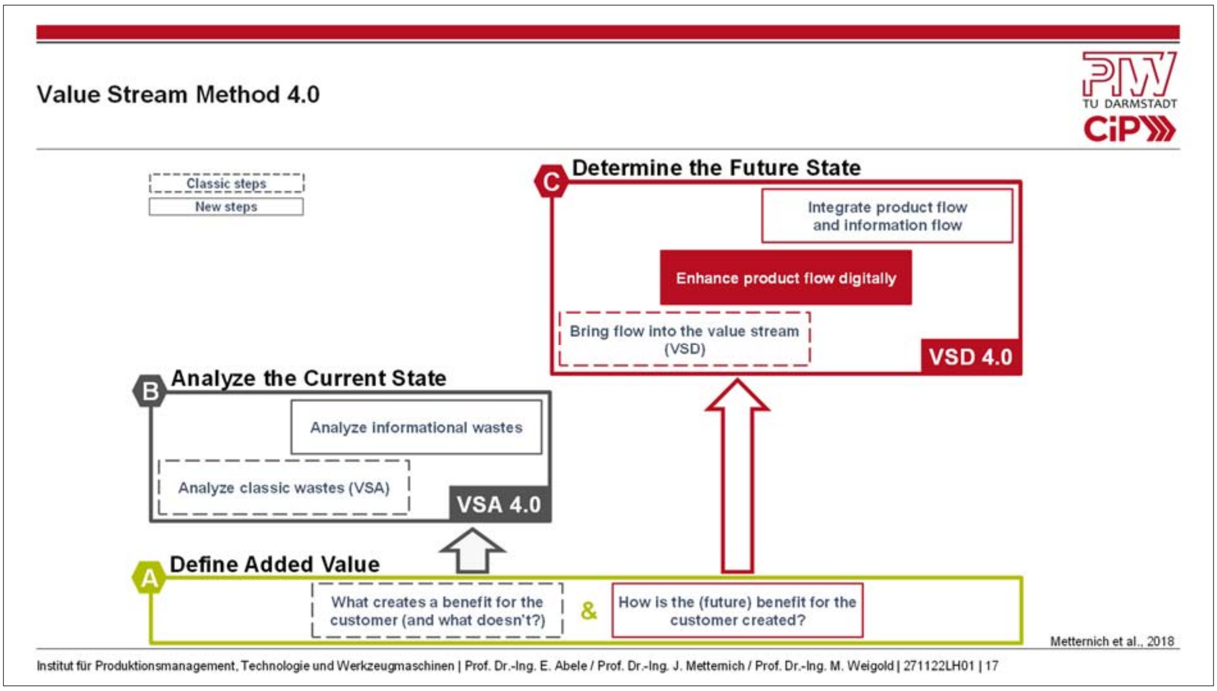
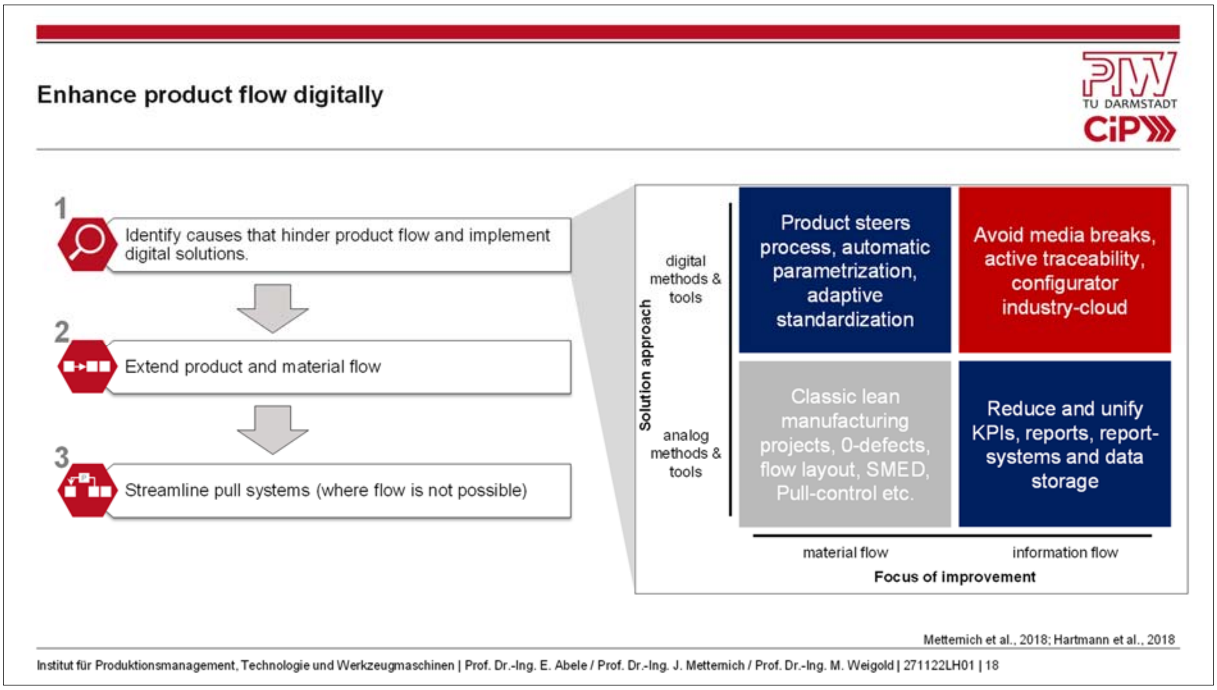

Value Stream Method 4.0
TU DARMSTADT
CiP
Classic steps
New steps
Determine the Future State
Integrate product flow and information flow
Enhance product flow digitally
Bring flow into the value stream (VSD)
VSD 4.0
Analyze the Current State
Analyze informational wastes
Analyze classic wastes (VSA)
VSA 4.0
Define Added Value
What creates a benefit for the customer (and what doesn't?)
&
How is the (future) benefit for the customer created?
Metternich et al., 2018
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 17


Enhance product flow digitally
TU DARMSTADT
CiP
1
Identify causes that hinder product flow and implement digital solutions.
2
Extend product and material flow
3
Streamline pull systems (where flow is not possible)
Solution approach
digital methods & tools
analog methods & tools
Product steers process, automatic parametrization, adaptive standardization
Avoid media breaks, active traceability, configurator industry-cloud
Classic lean manufacturing projects, 0-defects, flow layout, SMED, Pull-control etc.
Reduce and unify KPIs, reports, report-systems and data storage
material flow
information flow
Focus of improvement
Metternich et al., 2018; Hartmann et al., 2018
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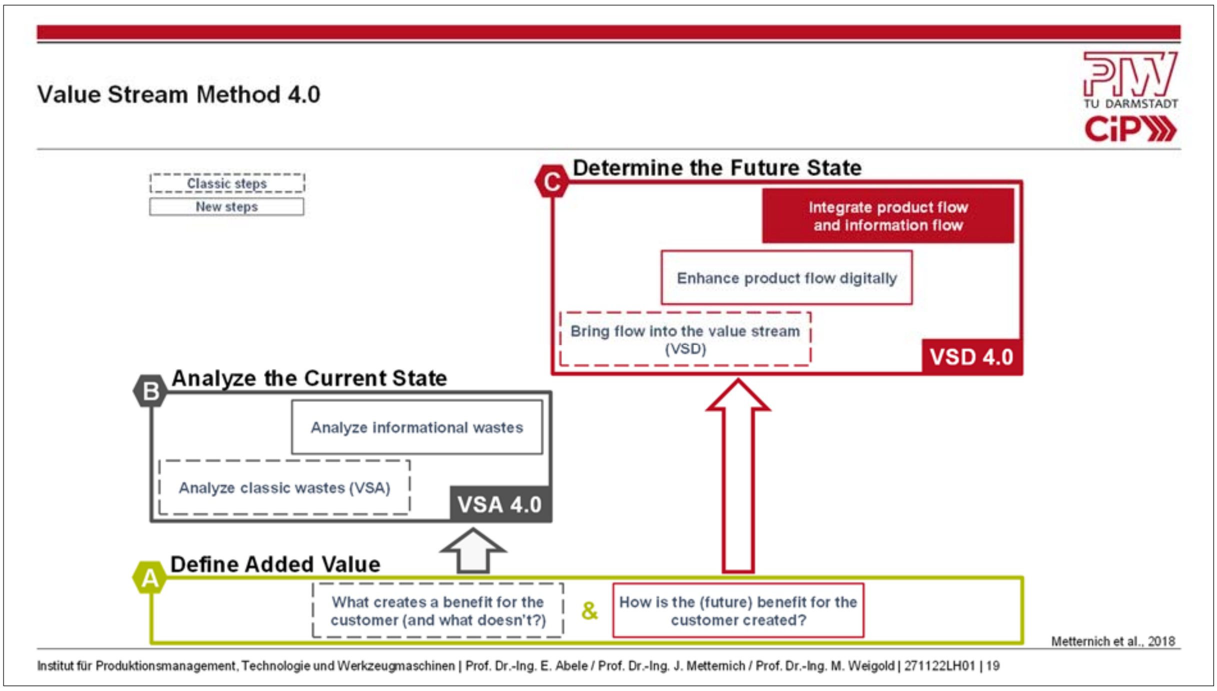
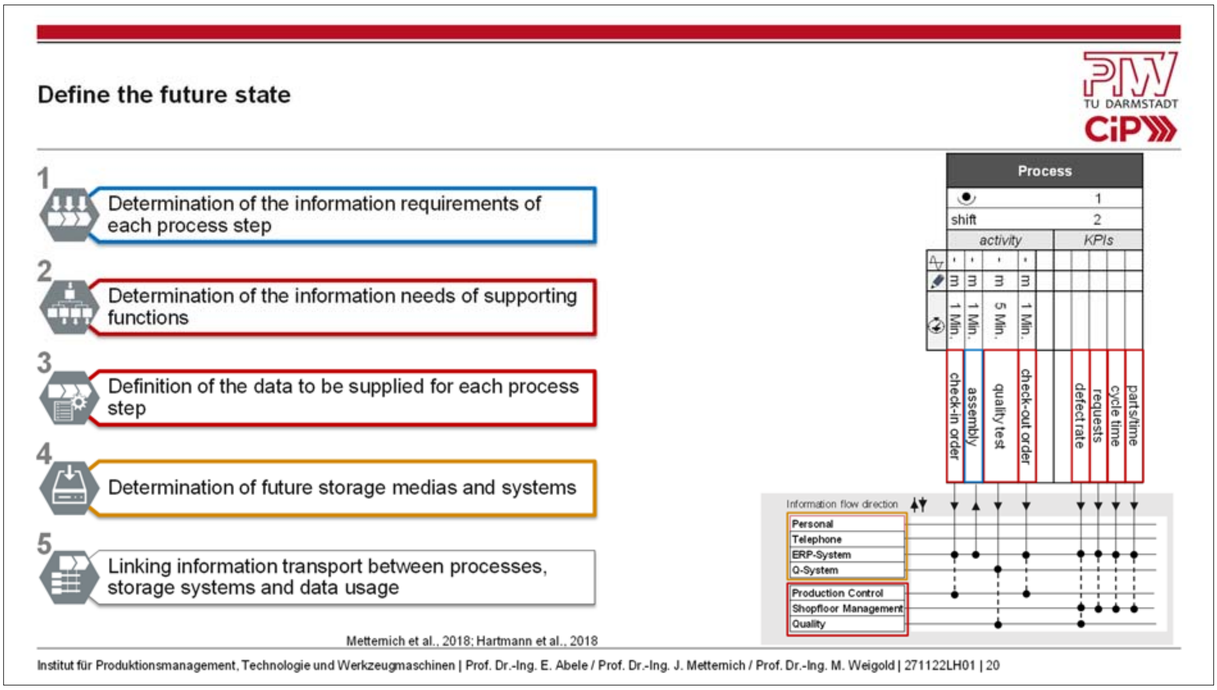
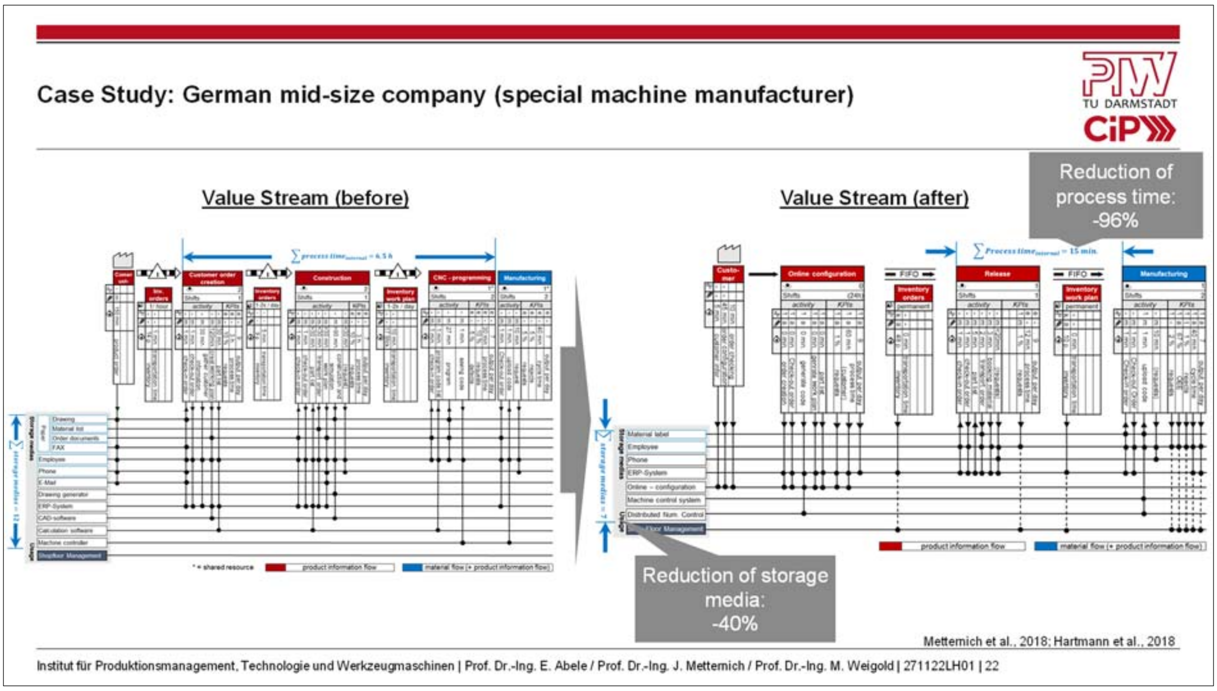
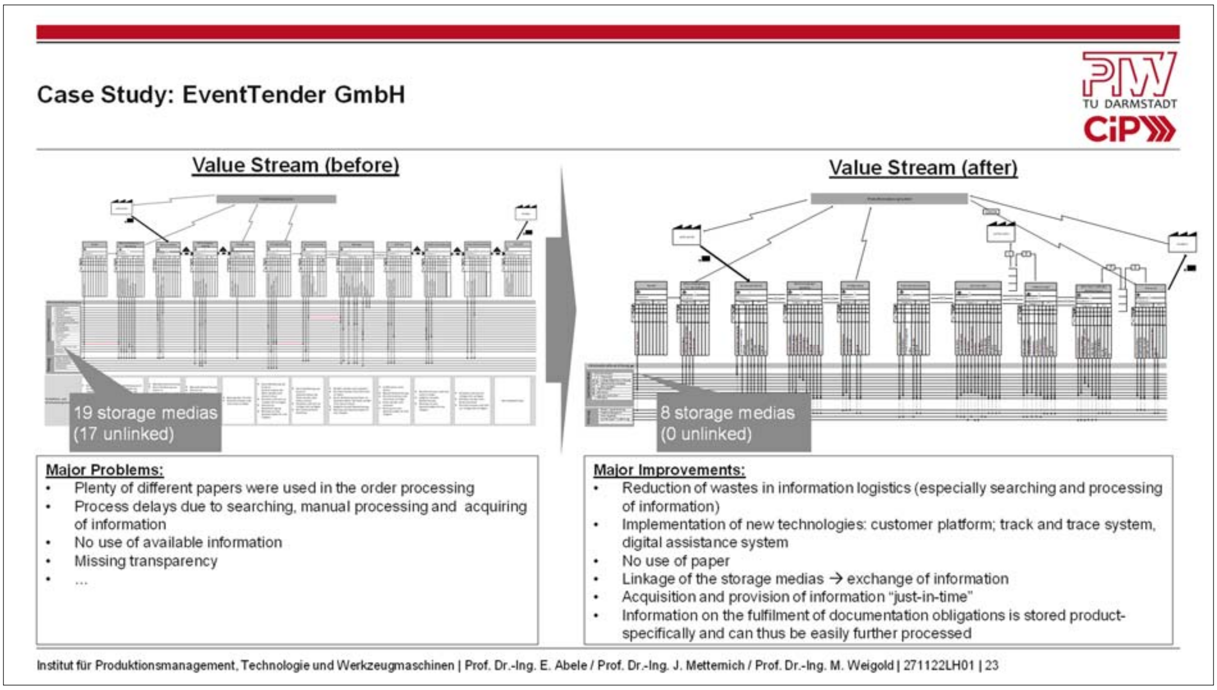

Value Stream Method 4.0
TU DARMSTADT
CiP
Classic steps
New steps
C Determine the Future State
Integrate product flow and information flow
Enhance product flow digitally
Bring flow into the value stream (VSD)
VSD 4.0
B Analyze the Current State
Analyze informational wastes
Analyze classic wastes (VSA)
VSA 4.0
A Define Added Value
What creates a benefit for the customer (and what doesn't?)
&
How is the (future) benefit for the customer created?
Metternich et al., 2018
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 19


Define the future state
TU DARMSTADT
CiP
1 Determination of the information requirements of each process step
2 Determination of the information needs of supporting functions
3 Definition of the data to be supplied for each process step
4 Determination of future storage medias and systems
5 Linking information transport between processes, storage systems and data usage
Process
shift
activity
KPIs
1 Min.
1 Min.
5 Min.
1 Min.
check-in order
assembly
quality test
check-out order
defect rate
requests
cycle time
parts/time
Information flow direction
Personal
Telephone
ERP-System
Q-System
Production Control
Shopfloor Management
Quality
Metternich et al., 2018; Hartmann et al., 2018
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 20


Case Study: German mid-size company (special machine manufacturer)
TU DARMSTADT
Value Stream (before)
Value Stream (after)
Reduction of process time: -96%
Reduction of storage media: -40%
Metternich et al., 2018; Hartmann et al., 2018
Institut für Produktionsmanagement, Technologie und Werkzeugmaschinen | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold | 271122LH01 | 22


Case Study: EventTender GmbH
TU DARMSTADT
Value Stream (before)
Value Stream (after)
19 storage medias (17 unlinked)
8 storage medias (0 unlinked)
Major Problems:
• Plenty of different papers were used in the order processing
• Process delays due to searching, manual processing and acquiring of information
• No use of available information
• Missing transparency
• …
Major Improvements:
• Reduction of wastes in information logistics (especially searching and processing of information)
• Implementation of new technologies: customer platform; track and trace system, digital assistance system
• No use of paper
• Linkage of the storage medias → exchange of information
• Acquisition and provision of information "just-in-time"
• Information on the fulfilment of documentation obligations is stored product-specifically and can thus be easily further processed
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Dipl.-Ing. Rainer Wittich

Rainer Wittich, started his career in 1992, when he was employed as a production equipment designer by the world's leading independent engineering partner, EDAG. Within the EDAG Group, which develops complete vehicles and production facilities mainly for the automotive industry, he was made Head of the Production Equipment Design Department in 1998, and later Head of the Design Profit Centre in the Production Development Division. In 2006, he took over the task of bundling and managing the integrated production development competencies in a newly founded profit center, "Production Solutions". In 2012, the profit centerbecame a separate company, and has since continued operations under the name of EDAG Production Solutions GmbH & Co. KG, a wholly owned subsidiary of what is today EDAG Engineering GmbH. Since then, Rainer Wittich has held the position as Chairman of the Board of Managementof the subsidiary, which currently employs a workforce of more than 1.580 at 30 locations in Germany and abroad.

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EDAG Production Solutions GmbH & Co. KG

EDAG Production Solutions is an all-round engineering partner which accepts responsibility for the development and implementation of production processes at 18 sites in Germany and at international sites in the United States of America, South Korea, India, the Czech Republic, Russia, Hungary, Brazil, Mexico and China. In addition to handling the individual stages in the product creation process and all factory and production systems-related services, Production Solutions are also able to optimally plan complete factories over all fields, including cross processes, and to provide the realization from a single source.

EDAG PRODUCTION SOLUTIONS

Continuously Connected Engineering in the Age of Digitalization

Abstract

In a global competitive environment where manufacturing companies strive for achieving maximum productivity, smart manufacturing has become a crucial concept for their long-term viability. Smart manufacturing uses interconnected equipment to monitor and control the production processes with the main goal of automating operations and boosting performance. To take full advantage of the smart manufacturing potentials, it is important to understand not only the key technological elements and features of a smart factory but also how they can be integrated into current and future industrial production environments, always having in mind that existing processes have to be analyzed and optimized before being digitalized. This paper tackles these issues based on EDAG Production Solutions (EDAG PS) long-standing holistic view of industrial production systems. More specifically, it explains how EDAG PS addresses the growing demand for digital, flexible, and agile solutions, offering an overview of our innovative multidisciplinary approach. Finally, the paper uses six use case applications to illustrate the successful integration of such solutions into an industrial manufacturing environment. Overall, this contribution aims at sharing EDAG PS insights and lessons learned while transitioning from a traditional engineering services company towards a digital production solutions provider.

Keywords

Industry 4.0; Smart Manufacturing; Intelligent Manufacturing; Digital Manufacturing; Smart Factory.

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Dr.-Ing. Anabela Reis
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Dr. Frank Breitenbach
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1 Introduction

Industrial production plays a key role in nations´ economic growth and competitive strength (Reis et al., 2016). In fact, research has shown that industrial production is directly linked to wealth and employment generation (Fingleton, 1999; Sirkin, 2011; Tolio et al., 2019). Consequently, several countries around the world (e.g., Germany, United States of America, South Korea) have established initiatives to support industrial competitiveness through the integration of cutting-edge technologies into their manufacturing industry (Kang et al., 2016). Despite the use of different catchwords to refer to this trend, namely Industry 4.0 (Kagermann et al., 2013), smart manufacturing (Kang et al., 2016), intelligent manufacturing (Zhong et al., 2017), and digital manufacturing (Behrendt et al., 2017), factories around the world are changing at an increasingly fast pace due to the introduction of novel technologies into their production processes. Innovative technologies, such as Internet of Things (IoT), wireless sensor networks, big data, artificial intelligence, cloud computing, embedded systems, digital twins, additive manufacturing, virtual reality and augmented reality are no longer a distant reality (Tolio et al., 2019; Wang et al., 2016). As manufacturers learn how to integrate different production processes, their factories become smarter. This means that manufacturers move away from a myopic process optimization view towards a holistic approach that considers the complete factory performance optimization.

It is well known that the advancement of scientific and technical knowledge in the fields of IoT, cloud computing, and artificial intelligence has been enabling the transformation of factories. In particular, the increased connection of manufacturing equipment to the cloud has led to the collection of new data and advance analytics analysis from the manufacturing processes. The insights resulting from these analyses are then being fed back into the production processes, creating a more predictive and agile environment and promoting a continuous improvement cycle. Given the rising complexity of smart factory technological developments, it is not surprising that the ability to integrate them into production remains the main challenge for many firms. Indeed, this transformation places additional competitive pressure on incumbents, while at the same time generates new opportunities for emerging companies.

Regardless of the sector in which companies operate, it is no longer appropriate to look into isolated business silos. A company only earns money if the system as a whole works efficiently. Optimizing subsystems (silos) is not effective. A full holistic approach is required to continue to morph and adapt to new game-changing events that define successful smart positioning. Understanding how companies can benefit from the integration of these technologies into their production environments implies assessing which conditions may accelerate their industrial transformation.

Therefore, in this paper, the main technologies that enable a smart production are examined in Section 2. Section 3 provides the innovative multidisciplinary approach put forward by EDAG

PS to address the increasing demand for digital, flexible, and agile solutions. Then, six use cases applications into an industrial production environment are presented in Section 4. Finally, Section 5, highlights the main conclusions and possible pathways for future research on smart production.

2 The Era of Digitalization

The German government coined the term “*Industrie 4.0*” back in 2011 to stimulate industry digitalization (Kagermann et al., 2013). Following the German lead, several other governments have launched digital initiatives with the ultimate aim of promoting economic growth and competitive strength. Some examples include the Foresight-project that describes the UK vision for the manufacturing future (Foresight, 2013), the Smart Manufacturing Operations Planning and Control Program established by the National Institute of Standards and Technology (NIST) in the US (Feeney and Weiss, 2014), “Made in China 2025” launched to enhance Chinese industrial capacity (Li, 2018), and the New Industrial French program designed to promote the movement of French companies towards high value-added activities (NFI, 2016). The worldwide interest in these topics is presented in Figure 1.

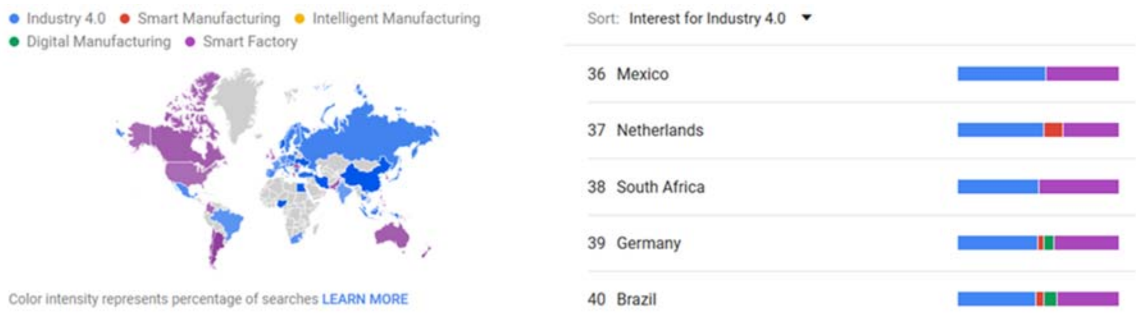

Figure 1: Regional breakdown of interest on digitalization topics: Industry 4.0, Smart Manufacturing, Intelligent Manufacturing, Digital Manufacturing, and Smart Factory. Source: Google Trends.

From the regional breakdown presented in Figure 1, it becomes apparent that “Industry 4.0” is more used in Europe and Asia, whereas “Smart Factory” is more used in North America. It is also interesting to notice that Germany and Brazil appear together, ranking 39th and 40th respectively, amongst the regions that show more interest in these topics.

Scientific research and technological innovation are of critical importance to the development of nations. In fact, research has shown that nations require an initial level of scientific and technological capabilities in order to take advantage of external knowledge, and technology developments (Cohen and Levinthal, 1990; Narula, 2004). Therefore, Figure 2 presents the evolution of published articles on the smart factory topic.

Figure 2 shows that the number of published articles on the smart factory and Industry 4.0 topics increased expressively since 2011, which is consistent with the general increased interest in these topics after the German government initiative in 2011. Once more, Industry 4.0 topics lead to more publications than the Smart Factory topic. One possible explanation is that Industry 4.0 can have a more generic focus. In fact, while most articles concerning Industry 4.0 focus on the factory environment, in others, the emphasis is no other application areas, such as smart products or smart cities (Lu, 2017).

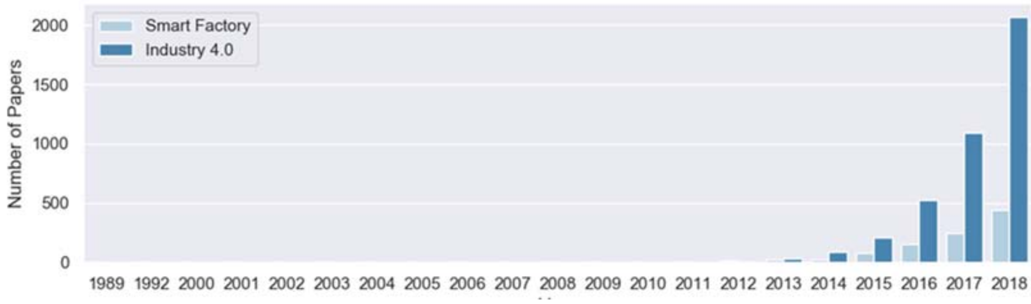

Figure 2: Evolution of published articles by topic. Data Source: Scopus.

Given the industrial production emphasis of this article, the paper focusses on the smart factory topic to analyze what are the most important concepts that appear in published articles. Therefore, Figure 10 presents the most common words in the articles´ keywords after removing contextual words (e.g., industry, smart, digital, transformation, and manufacturing, amongst others).

Figure 3: Top 15 words in articles' keywords after removing contextual words. Data Source: Scopus

3 EDAG-PS Conceptual Approach

Reviewing the smart factory underlying technologies has been a strategic focus of EDAG PS in recent years. More specifically, EDAG PS has focused its attention on understanding how a traditional engineering services company can transition towards a digital production solutions provider. Therefore, this section introduces EDAG PS and offers an overview of our innovative multidisciplinary approach towards the implementation of the smart factory concept.

3.1 Company Overview

The EDAG Group is one of the largest independent engineering partners to the global automotive industry and specializes in the development of vehicles, derivatives, modules, and production facilities. Founded in 1969, the company business is organized in the segments: Vehicle Engineering, Production Solutions, and Electrics/electronics. This extensive competence enables EDAG to provide its customers with all-round support, from the original idea for the design, through product development and prototype construction, to turn-key production systems. As an innovative technological leader, the company also has competence centers for ground-breaking future technologies for the automotive industry: lightweight design, eMobility, car IT, integral safety, and new production technologies. The Vehicle Engineering segment consists of services along the vehicle development process as well as responsibility for derivative and complete vehicles. The range of services offered by the Electrics/Electronics segment covers the development of electrical and electronic systems for the complete vehicle. This includes, in particular, the growth domains eMobility, autonomous driving, and digital networking both inside and outside of the car. Also included in the range of services are developments relating to comfort and safety systems.

The Production Solutions segment, operating through the independent company EDAG PS, is an all-round engineering partner, which accepts responsibility for the development and implementation of production processes at 30 sites around the world. In addition, EDAG PS relies on its 45 years of engineering experience and a workforce of 1582 employees to handle the individual stages in the product creation process and all factory and production systems-related services, EDAG PS is also able to optimally plan complete factories over all fields, including cross processes, and to provide realization support. The Industry 4.0 methods and tools serve as the basis for the networked engineering between the product development and plant construction processes. From an economic point of view, EDAG PS closed 2018 with a revenue of 159,2 million Euros (EDAG, 2019).

In the field of **concept engineering**, EDAG PS provides its customers with an integrated approach to process planning. This means that EDAG PS provides companies with factory and production planning support – with both the implementation of new plans and with the conversion, expansion or optimization of existing systems while the operation is in progress. By offering support from concept engineering to the preparation of detailed product specifications, it is possible to cover all the steps required for the production process and to design interfaces with other media, buildings, and logistics. In the context of simultaneous engineering, concept engineering favors an integrative approach, with the Product Development, Systems Planning and Production Simulation departments all working together to design project interfaces.

In the **implementation engineering** department, digital factory methods are used in all production lines (digital, virtual, and real-life) to guarantee that the functional requirements of body in white (BIW) facilities are met. To meet customers' requirements, the engineers develop realistic 3D simulation cells in which the planning, design, and technological concepts are implemented and validated in line with process requirements. Early involvement during the engineering process makes it possible to improve production processes systematically. This enables the department to develop ideal production concepts for customers.

Productions Solutions' portfolio is also complemented by **Feynsinn**, a process consulting and CAx development department. IT-supported sequences and methods are developed here, as is software for product design, development, production, and marketing. Feynsinn also offers consulting, conceptual, and realization services in the field of visualization technologies. Our range of training opportunities completes the portfolio.

3.2 Towards the Smart Factory Implementation

The digital transformation has been playing a prominent role in EDAG PS. Consequently, EDAG PS has been positioning itself as a key provider of the following competencies for the smart factory implementation (see Figure 4): intelligent and flexible logistics, smart maintenance, individualized automation, paperless factory, smart building, proactive production monitoring and control, big data analytics, flexible and modularized production, and digital order processes.

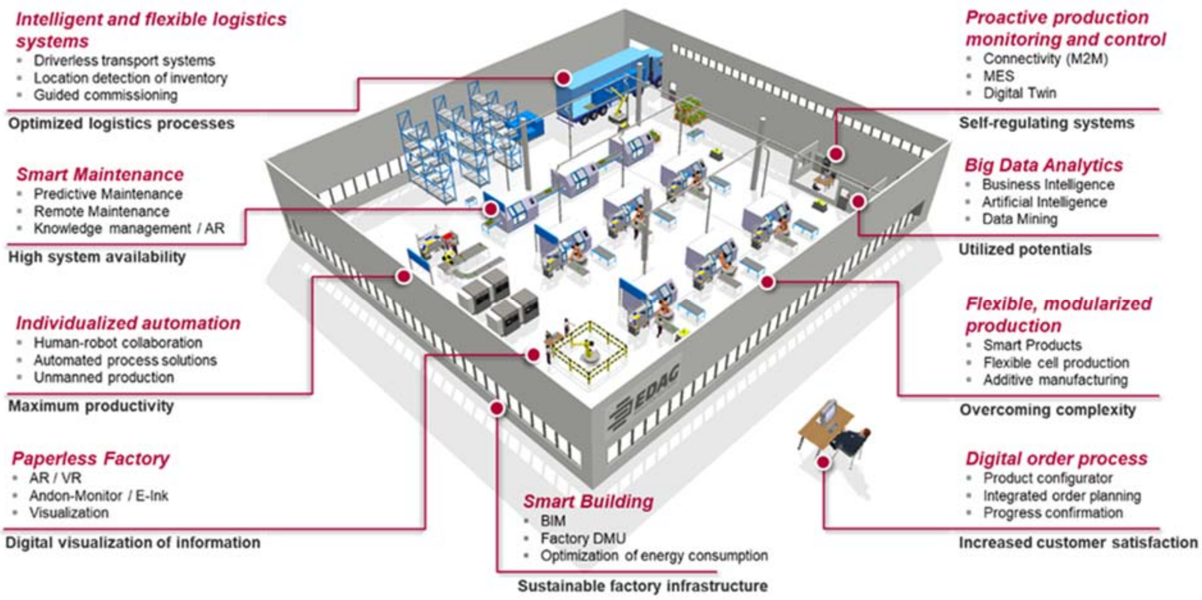

Figure 4: EDAG PS Key Competences for Enabling a Smart Factory Implementation.

Intelligent and Flexible Logistics Systems

Achieving an optimized logistic process constitutes a central aspect of smart manufacturing as material, components, and products handling as well as transportation can have significant impacts on production costs (Kusiak, 2018). As connectivity between systems improves, it becomes possible to introduce more and more reliable network-based structures that rely on real-time architectures. Real-time architectures are essential for the implementation of intelligent and flexible logistics systems, such as driverless transportation systems, location detection applications for inventory, as well as guided commissioning solutions. However, the optimal logistics solution is dependent on the individual smart factory's requirements.

Smart Maintenance

Succeeding at increasing systems´ availability is one of the main goals of manufacturing companies, given this yields major economic benefits (Lao et al., 2014). Smart maintenance approaches, such as predictive maintenance, remote maintenance, and knowledge management through augmented reality applications, can contribute to attaining this goal. These approaches entail detecting that there are anomalies in the behavior of the monitored systems, diagnose the type of problem occurring, identify the affected components, and predict the time frame or remaining useful life of the system through the probability of failure. To this end, advanced cognitive capabilities are used to analyze data collected from the sensors installed in the manufacturing equipment, which is in turn, used to provide customized maintenance solutions.

Individualized Automation

Boosting production productivity plays a critical role in every manufacturing facility (Thoben et al., 2017). In the automotive industry, for example, car bodies are produced almost without any human intervention. Nevertheless, a lot of manual work is still required to assemble a complete car. Applying automated process solutions that led to improved human-robot collaboration or even unmanned production creates new opportunities for running factories seamlessly and without interruptions. Robots endurance and ability to perform repetitive tasks complement the human´s rationality and experience. However, achieving successful human-machine cooperation, special safety requirements must be met and implemented.

Paperless Factory

Although digital technologies hold great promises to revolutionize the manufacturing shop floor, paper still prevails in many factories. Heinrich et al. (2018) advanced four reasons for this: paper´s flexible nature and robustness allow to create and adapt individual information into the manufacturing environment, reinterpreting information through annotations, combining information handover with social interaction, and leverage on visual cues. On the other hand, paper documentation is not only more prone to human errors but also wastes resources and reduces efficiency. Therefore, the challenge is to retain the benefits of paper while providing real-time support through digital technologies, such as augmented and virtual reality, Andon E-ink displays.

Smart Building

The green factory topic has attracted significant attention from both academia and industry in recent years (Herrmann et al., 2014; Kreitlein et al., 2015). One important reason for this trend has been the need to protect the environment while saving costs and resources. Thus, analyzing existing production procedures and standards, optimize factory and process planning for energy efficiency, simulate energy consumption and replace energy-intensive production machines (e.g., with compressed-air free production) have become increasingly more important. Building information modeling (BIM), factory digital mock-ups (DMUs), and energy consumption optimization techniques promote sustainable factory infrastructures. However, the implementation of such a green perspective and technologies is only possible through a holistic understanding of the manufacturing processes.

Proactive Production Monitoring and Control

The machines and tools used in the factories change-over time, which affects the quality of products and production. In order to improve quality control and performance, it is crucial to enable the connection of cyber-physical production systems in which the connected machines can, for example, make automatic small corrections between production steps within certain specified tolerance areas ("self-regulating systems") to compensate for quality fluctuations. This can only be achieved if one first simulates the process and its individual steps virtually during the planning phase, then check the drift of the measured values and run an analysis to establish which parameters can be changed and how this affects the quality of the product. Actions that only result in low "side effects" can, therefore, be specified for different scenarios. This horizontal networking in the planning phase provides improved quality in long production periods by means of automatic corrections.

Big Data Analytics

Despite the hype of big data analytics, only a small number of companies is able to benefit from its potentials and profit from their operationalization (Pearson et al., 2014). Companies understand that business intelligence, data mining, and artificial intelligence can play an important role in boosting the quality and efficiency of production. However, they want to be sure about the return on investment before they commit resources to it. This is especially true for small and medium-sized suppliers, which rely on limited resources and therefore have a reduced investment capacity. In order to efficiently use big data in production, it is important to understand not only how to set up the right infrastructure to collect the manufacturing data from the programmable logic controllers (PLCs) and embedded sensors, but also which data needs to be collected and processed to address the problem at hands.

Flexible and Modularized Production

Flexibility and modularization play an increasingly important role in the context of manufacturing as manufacturing systems transition from mass-produced products towards product customization, adapted to the customer requirements (Friedrich et al., 2015). Smart systems that are able to sense the changing operation conditions and take corrective actions are vital for implementing flexible cell production units in a manufacturing facility. Additive manufacturing (commonly known as 3D printing) is also a key enabler of customized production. However, to implement this approach into production, companies need to be able to overcome the complexity of combining different functions and modules.

Digital Order Process

As products become more complex and tailored made for customers´ specific needs and requests, it becomes increasingly more important to provide manufacturing customers with solutions that satisfy their individual requirements and expectations. Digital order processing tools, such as product configurators, integrated order planning, progress confirmation, allows customers to simply and quickly visualize their orders according to their individual requirements. Therefore, the challenge is to be able to capture the increasing number of interdependencies and regulations that must be considered through digital order processing tools.

Overall, to achieve a successful integration of such solutions into an industrial manufacturing environment, it is of special importance to implement an intelligent approach making use of best-practice processes, cutting-edge technologies and a full understanding of the overall factory. In the next section, six use cases that exemplify how EDAG PS has been able to pave the way forward as a digital production solutions provider are provided.

4 EDAG PS Continuously Connected Engineering

This section discusses six use case applications that illustrate EDAG PS experience in integrating connected engineering solutions into industrial manufacturing environments, namely: predictive maintenance in automotive production, production control systems, media free lightweight gripper, couch engineering, smart fleet analytics, and efficient intralogistics.

4.1 Predictive Maintenance in Automotive Production

Predicting operation breakdowns before they occur aids automotive manufacturers to save money by improving industrial equipment´s availability. To achieve this goal, our customer needed to be able to plan maintenance activities for BIW construction in advance. Therefore, collecting real-time raw performance data from sensors embedded in their industrial hardware equipment was a fundamental step to implement a predictive maintenance solution. New IoT concepts were needed to collect the raw data from the embedded sensors.

Our solution first pinpointed the production stoppages that grasped the best cost-benefit for our client based on the Pareto´s principle. According to this principle, roughly 80% of the breakdown effects come from 20% of the cases. Thus, to begin with, our team focused on this

20% to derive malfunction hypotheses based on its long-standing experience in developing solutions for the production environment.

Industrial robots comprise several servos that are used for positioning and speed control functions. Typically, these exhibit irregularities in their power consumption before a breakdown occurs. Therefore, a relevant hypothesis for our customer was whether a preventive action could be taken to prevent the occurrence of a breakdown by monitoring the power consumption of the servo under observation. To verify the proposed hypothesis, it was implemented a cloud computing solution that allowed us to store the data collected from the servos and other sensors. The collected information was analyzed through data mining techniques, real-time analytics, and machine learning algorithms that detect patterns in the behavior of the equipment. This process enabled us to build models that predict failures before they occur and roll them out into production. In this way, we helped our customer to increase the productivity and availability of its BIW construction.

4.2 Production control system

Manufacturing execution system (MES) has been the core platform of industrial manufacturing and is likely to remain so in the upcoming years. Implementing fully integrated MES solutions that meet the real-time changing demands and conditions of the factory, supply network, and customer needs are becoming increasingly more important. Achieving better operational performance continues to be a critical issue amongst our customers. In the automotive industry, modular MES solutions that rely heavily on real-time data are now the norm.

In this context, EDAG PS has been responsible for designing and developing modern MES solutions for shell, paint, assembly, logistics, and conveyor technology. These solutions entail the acquisition and reporting of large amounts of data that need to be processed for a regulated order management and control process. Using the orders data, EDAG PS MES ensures constant monitoring and control of production targets, the supply of material and operating resources to plants and machines, personnel management, which in turn, contributes to the control and optimization of manufacturing processes. In fact, based on an optimized production of the different vehicle alternatives, the developed MES guides production work procedures (e.g., Pick2Light, screwing data, test stands, filling stations, etc.).

Our modern and reactive MES also includes energy management, as well as storage and buffer control (“sequence healing”), which maximizes plant productivity and improves operation efficiency and flexibility. EDAG PS´ MES solutions leverage on the influx of data to deliver end-to-end, real-time process visibility and traceability, along with the seamless integration, management, and synchronization of all the systems involved in our clients´ production processes.

4.3 Media Free Lightweight Gripper

Additive manufacturing has several advantages over traditional manufacturing techniques, namely: faster development cycles, lightweight applications, part consolidation, and increased design freedom that allows to exploit the results of topology optimization algorithms. This is especially relevant in the context of smart manufacturing.

This is the reason why EDAG developed a revolutionary lightweight, modular gripping system for car body construction using additive manufacturing (3D printing). Our robot-assisted gripper concept can be integrated into the vehicle assembly process without its own actuators or pneumatics. In fact, by using the energy available from the robot movement and dispensing additional motors and sensors, weight savings of up to 75 percent are possible, compared to conventional systems. Another advantage is the high sustainability that this solution offers due to energy-free operation, other media, or their components like directional control valves, initiators, or cables are no longer necessary. Further advantages are simple assembly and easy-to-change components, should repairs be needed. Standardized assemblies mean that warehousing space can be significantly minimized. Moreover, all parts required as spares or for modifications can simply be re-printed using the additive manufacturing method.

The media free lightweight gripper concept constitutes a significant milestone on our Smart Factory vision and provides an impulse towards the development of complementary solutions that consistently save media (e.g., electricity, air) and reduce the space required in the production network. The potential value of this concept was also recognized at the Automotive Engineering Expo, where EDAG PS received the AEE Innovation Award 2017.

4.4 Couch Engineering

Virtual reality (VR) and augmented reality (AR) technologies are enabling companies to step forward into a new design era. While VR technologies immerse users in a digital environment, totally shutting them off from the rest of the world, AR technologies extend users reality by presenting digital images on top of their real-time view of objects, people, or spaces in the physical world. Companies are now leveraging on both these technologies to craft immersive experiences, which allow users to experience products and spaces in unique ways.

In the era of virtual realities and reproductions of entire factory landscapes, work has become independent of a fixed location and, at the same time, independent of fixed working hours and time zones. In this context, EDAG PS developed a pioneering concept for product engineering that combines VR and AR collaborations and can be implemented from the planning stage right up to maintenance operations. Using photorealistic 3D scans, the work environment is integrated into reality. The coupling of real control engineering with digital twinning with the cell can be carried out in real-time. By using this concept from collaborative engineering projects, on-site meetings can be minimized, saving time and resources.

Being able to carry out networked tasks in automotive engineering projects from the couch establishes the foundations for a better work-life balance with no loss of efficiency. EDAG PS' sustainable and efficient concept brings together particular staff or the whole team to work simultaneously or staggered as a community towards a new manufacturing world.

4.5 Smart Fleet Analytics

Smart fleet management contributes to achieve higher fleet efficiency. On-board sensors installed in forklifts and other vehicles used to transport goods in a manufacturing facility collect real-time data, which enable the production of detailed fleet analyses and reports. With these insights, our customers are able to examine operation trends, such as material delivery across equipment types, areas, and even facilities, which ultimately allow them to make informed decisions to maximize productivity, reduce inventory faults, and lower operation costs.

Even though onboard telematics has provided much transparency to the warehouse decision-making process, fleet operations in production facilities can still be taken one step further with the application of machine learning algorithms. As a result of machine learning developments, EDAG PS is now able to find relevant, statistically significant relations hidden in the captured data. Furthermore, EDAG PS has established a methodology for smart fleet analytics that increases the value of data by bringing different datasets together. In particular, fleet location combined with warehouse orders data is used to derive optimized fleet management and material delivery solutions tailored to the customer particular needs.

Our innovative data science approach allows to forecast the fastest delivery routes using machine learning algorithms, which provides our customers with vital information that they can use to optimize material delivery and vehicle usage. This, in turn, frees up resources (vehicles and operators) that can be used to transport additional orders. In addition, the use of fleet location-based data in combination with warehouse orders data contributes to uncover hidden patterns within the data and recognize the best demand patterns across groups of products and production areas.

4.6 Efficient Intralogistics

The design of an efficient logistic system is a key factor to improve productivity and reduce costs within a manufacturing site. The use of automated guided vehicles (AGVs) as a transport system has now reached a maturity level that enables their integration into existing manufacturing systems. Despite the high capital investment cost, AVGs provide significant economic benefits due to their lower maintenance requirements, ability to function on a 24/7 basis with minimum human intervention, and reduction of accidents resultant from improved safety.

As part of a greenfield site planning, EDAG PS was awarded a contract to develop a holistic, end-to-end optimized, and competitive intralogistics concept. The material and information flow scope included the supply of battery manufacturing lines and handling of finished products up to shipping. EDAG PS has investigated several logistic concepts and supported the automated logistics solution as the most competitive one. The use of AGVs as a transport system is an integral part of the solution for fully-automated intralogistics systems, and helps to achieve that purpose. The use of specifically synchronized and make-to-order AVGs have several benefits, namely higher productivity and flexibility, increased inventory efficiency and accuracy, less expensive than fixed automation systems, and increased safety.

With those advantages in mind, EDAG PS has developed an automated transport system to build up the operational excellence, and therefore ensure the implementation of a competitive and robust logistic system. With experience, methodical competence, and interdisciplinary expertise from many different fields (e.g., logistics, material flow simulation, production IT, and safety engineering), EDAG PS accompanied the customer on its way to achieve the overall optimum.

5 Conclusions

The digital transformation process in the automotive sector continues at an enormous rate. Automotive companies around the world are massively invested in the development and application of novel sophisticated technologies, such as IoT, artificial intelligence, and cloud computing. In this new digitalization age, where the information volume and complexity has tremendously grown, it is no longer possible to rely solely on the human ability to sporadically analyze that information. New digital business models, where the information is automatically analyzed, and actions are taken without human intervention, are needed to enhance the performance and competitiveness of complex industrial ecosystems.

EDAG has been no exception to this trend, and in the course of the last 50 years, the company has succeeded in reinventing itself again and again. From a small design office focused on vehicle bodies and production equipment to an engineering multinational responsible for the development of vehicles and production facilities around the world, the company has established its position as a proactive engineering services specialist.

To take full advantage of the smart factory potentials, manufacturing companies need to be able to bring all the different aspects of the business together. It is no longer adequate to strive to achieve the peak performance of an isolated unit (e.g., assembly, painting, logistics, etc.), but instead, the challenge is to bring all the business units together to achieve the peak performance of the overall factory. Therefore, the challenge going forward is to be able to grasp all the dependencies between the units of the factory in order to consider the complete system. In this case, the complete factory.

Grounded in its engineering experience, EDAG PS has been breaking business silos in the productive environment and paving the way for a fully holistic view of the smart factory. The six different use case applications presented in this paper are an example of that. They show that the interoperability and knowledge integration aspects of EDAG PS´ approach to digitalization. Industrial engineering experience is decisive for implementing successful digital transformations as it provides the contextual information required to understand what production firms should be considering, what information is appropriate, and what modifications in the operations, processes or analytics may be desirable. In this respect, EDAG PS will continue to expand its range of digitalization services towards a continuously connected engineering world.

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EDAG
PRODUCTION SOLUTIONS
EDAG PRODUCTION SOLUTIONS
CONTINUOUSLY CONNECTED ENGINEERING IN THE AGE OF DIGITALIZATION
RAINER WITTICH
MAKING IDEAS PERFORM
24th International Seminar on High Technology


// AGENDA
EDAG
PRODUCTION SOLUTIONS
1 Our Challenges
2 Our Company
3 Our Solutions
4 Conclusions
Digitalization
ctrl
alt
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July 29th, 2019

II OUR CHALLENGES

EDAG PRODUCTION SOLUTIONS

High cost pressure

- currently difficult situation on the automotive world market
- requires an effective use of best cost country resources
- high project management costs
- high training demand

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II OUR CHALLENGES

EDAG PRODUCTION SOLUTIONS

High time pressure

- high volatility in the projects
  (targets, variants, quantities)
- short model lifecycles imply decreasing engineering periods

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// OUR CHALLENGES

EDAG PRODUCTION SOLUTIONS

Global networks and worldwide distributed specialists

- ➡ expect rapid operational readiness and adequate expertise on site
- ➡ require an efficient recruiting
- ➡ demand knowledge transfer and dissemination

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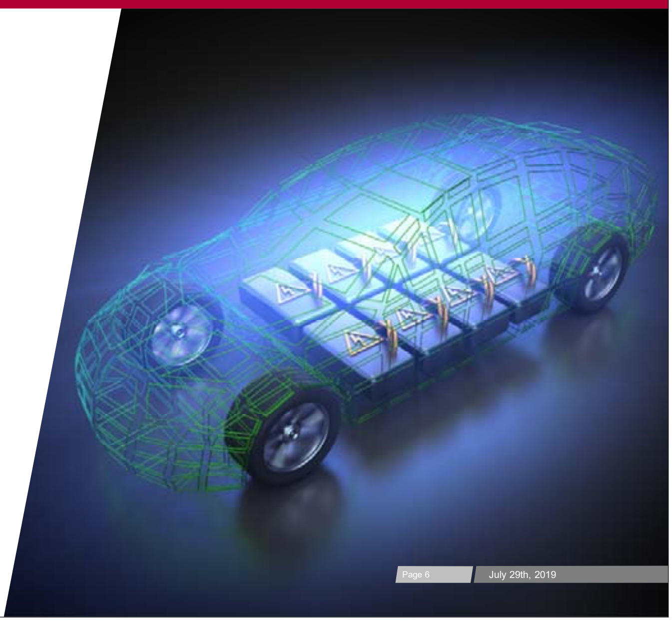
// OUR CHALLENGES

EDAG PRODUCTION SOLUTIONS

New OEMs

- ➡ enable the contribution of the complete EDAG/EDAG PS know-how (product and production)
- ⬅ often have incomplete process landscapes
- ⬅ often have demanding schedules



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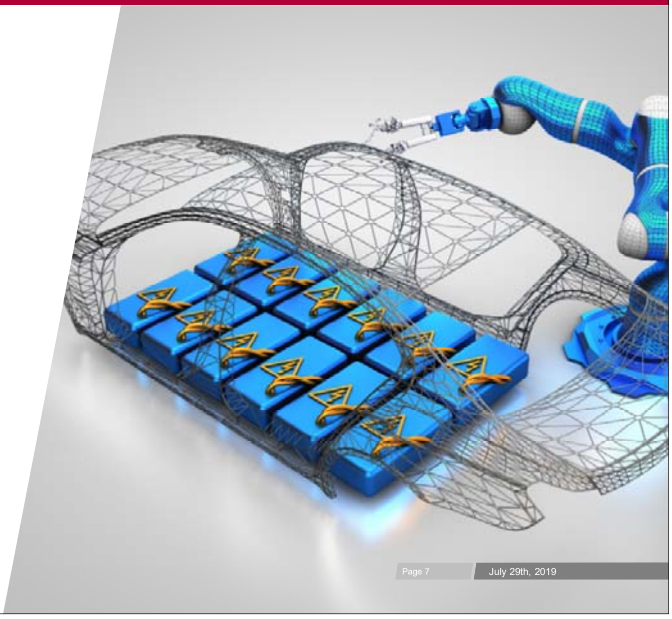
// OUR CHALLENGES

EDAG PRODUCTION SOLUTIONS

Innovative techniques

- electromobility, batteries, fuel cells
- Additive Manufacturing
- Human Robot Collaboration
- 5G
- Digital Transformation
  (Smart Factories, Industry 4.0)



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// EDAG GROUP – SEGMENTS

EDAG PRODUCTION SOLUTIONS

EDAG ENGINEERING GROUP, SWITZERLAND

EDAG ENGINEERING GMBH, GERMANY
Executive Board: Cosimo De Carlo – CEO, Harald Keller – COO und Holger Merz – CFO

PRODUCT DEVELOPMENT		PRODUCTION SOLUTIONS
EDAG Vehicle Engineering Vehicle development	**EDAG Electrics/Electronics** Electrical/electronic development, car IT	**EDAG Production Solutions** Development of production facilities
		
EDAG	EDAG BFFT ELECTRONICS	EDAG PRODUCTION SOLUTIONS

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// EDAG PRODUCTION SOLUTIONS – FACTS, FIGURES, DATA
EDAG
PRODUCTION SOLUTIONS
1,582
EMPLOYEES
YEARS OF ENGINEERING EXPERIENCE
50
30
LOCATIONS
REVENUE
€ 159,2 million
* Figures as per 31 Dec 2018
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July 29th, 2019


// EDAG PRODUCTION SOLUTIONS – LOCATIONS
EDAG
PRODUCTION SOLUTIONS
GLOBAL NETWORK EDAG GROUP
Belmont
Detroit
Spartanburg
Atlanta
Royal Leamington Spa
Helmond
Gothenborg
Prag
Mlada Boleslav
Györ
Warsaw
Kaluga
Germany
Changchun
Beijing
Seoul
Yokohama
Sant Agata B.
Arbon
Turin
Barcelona
Shanghai
Guangzhou
New Delhi
Pune
Kuala Lumpur
Puebla
Sao Paulo
SUBSIDIARIES EDAG PRODUCTION SOLUTIONS
GERMANY
Fulda (Head Office)
Bremen
Aachen
Eisenach
Friedrichshafen
Hamburg
Hannover
Heilbronn
Ingolstadt
Karlsruhe
Cologne
Munich(2)
Sindelfingen
Weingarten
Wiesbaden
Wolfsburg
EUROPE
Sweden, Gothenborg
Czech Republic, Mlada Boleslav
Hungary, Györ
WORLDWIDE
Brazil, Sao Paulo
China, Shanghai
India, New Delhi
India, Pune
Mexico, Aguascalientes, Ags.
Mexico, Puebla, Pue.
Russia, Kaluga
South Korea, Seoul
USA, Atlanta
USA, Detroit
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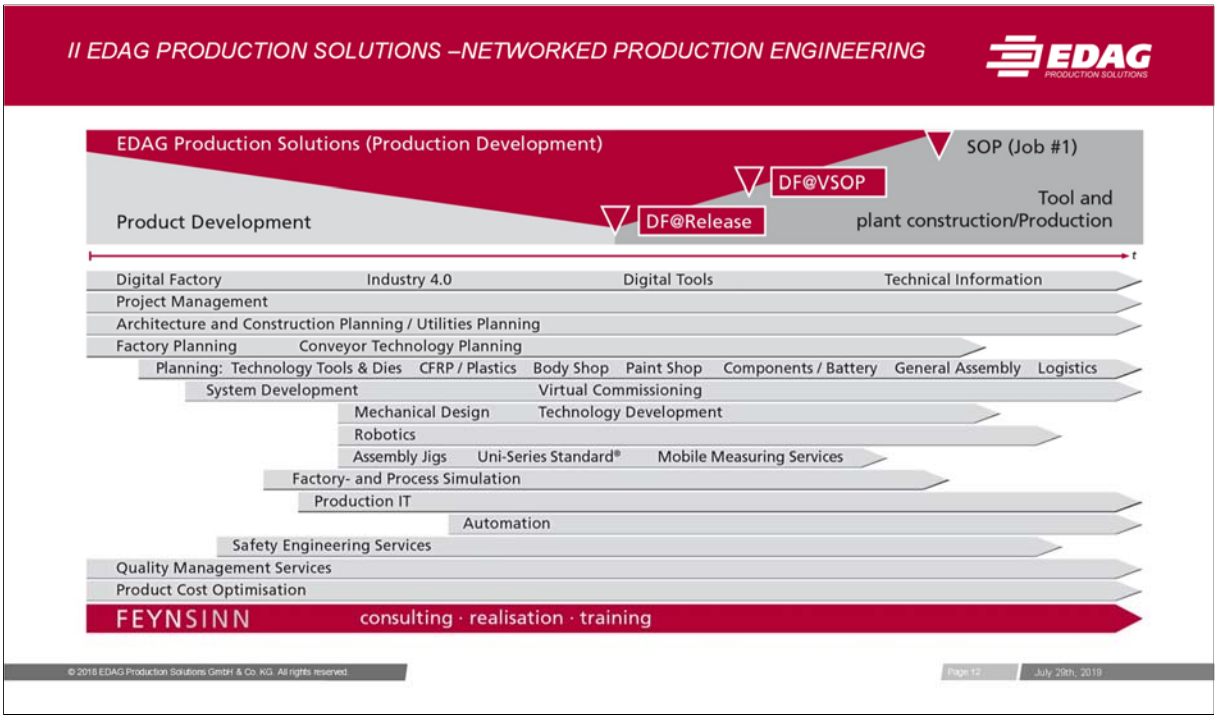
// EDAG PRODUCTION SOLUTIONS –NETWORKED PRODUCTION ENGINEERING
EDAG
PRODUCTION SOLUTIONS
EDAG Production Solutions (Production Development)
SOP (Job #1)
DF@VSOP
Tool and
plant construction/Production
Product Development
DF@Release
Digital Factory
Industry 4.0
Digital Tools
Technical Information
Project Management
Architecture and Construction Planning / Utilities Planning
Factory Planning
Conveyor Technology Planning
Planning: Technology Tools & Dies
CFRP / Plastics
Body Shop
Paint Shop
Components / Battery
General Assembly
Logistics
System Development
Virtual Commissioning
Mechanical Design
Technology Development
Robotics
Assembly Jigs
Uni-Series Standard®
Mobile Measuring Services
Factory- and Process Simulation
Production IT
Automation
Safety Engineering Services
Quality Management Services
Product Cost Optimisation
FEYNSINN
consulting · realisation · training
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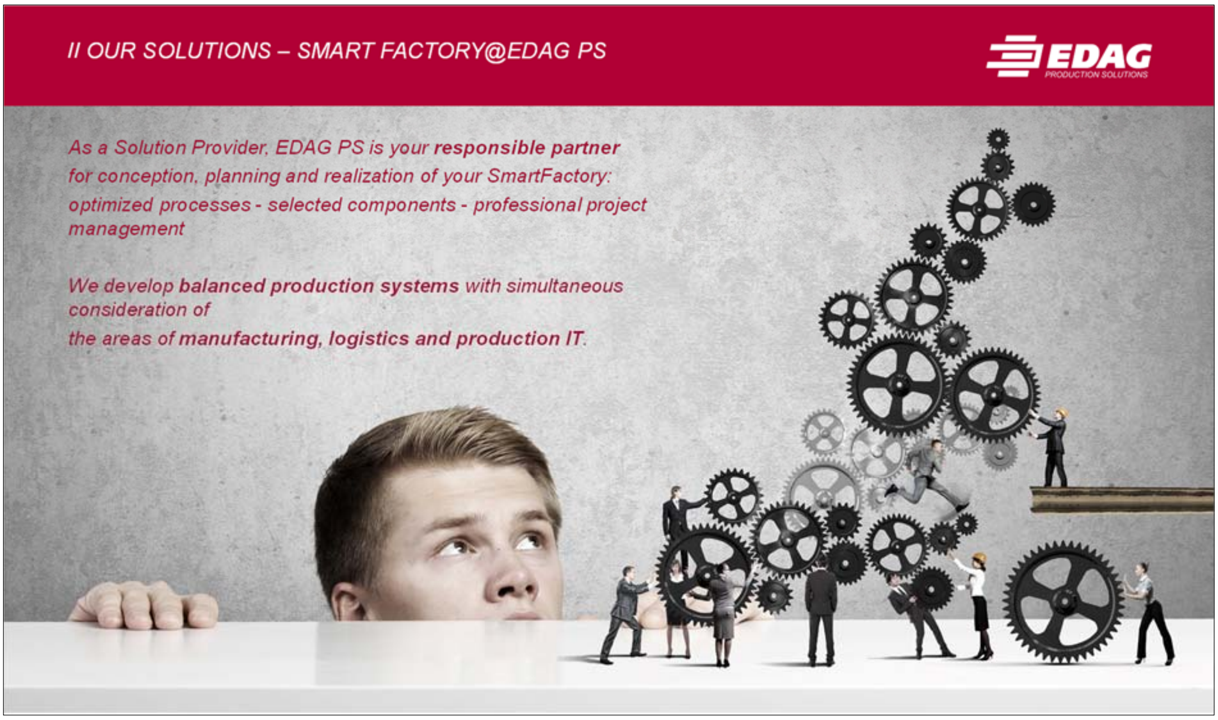
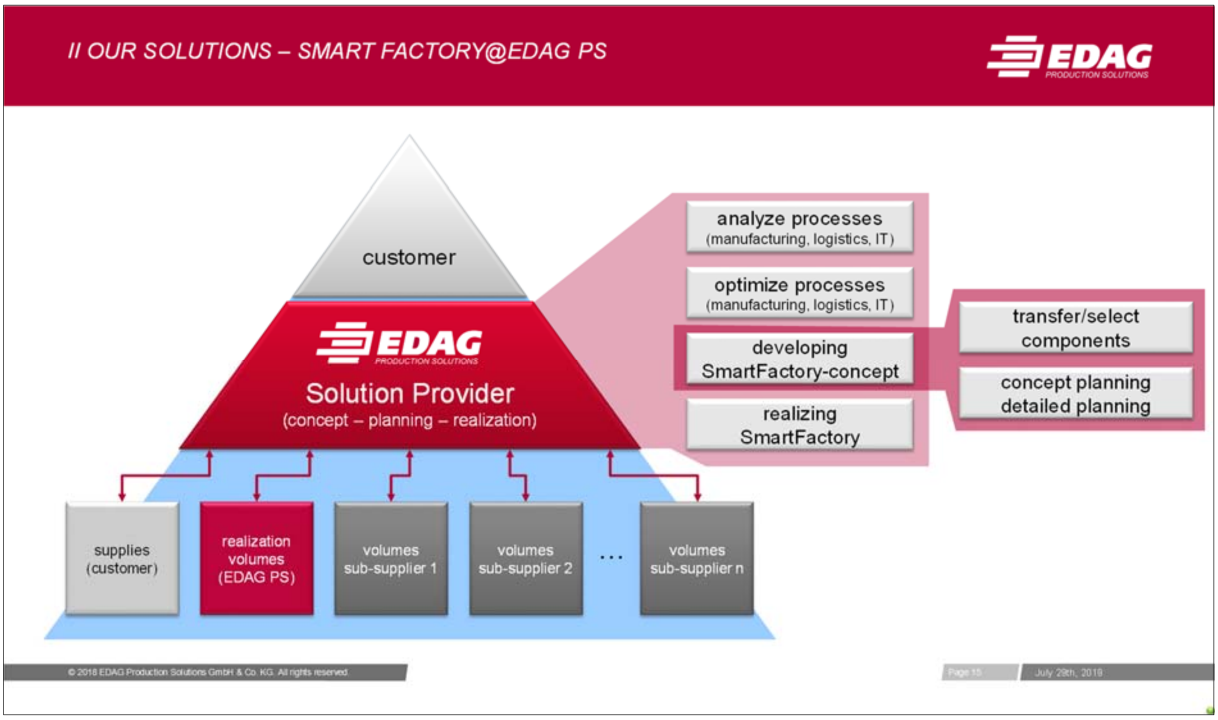

// OUR SOLUTIONS – SMART FACTORY@EDAG PS
EDAG
PRODUCTION SOLUTIONS
As a Solution Provider, EDAG PS is your responsible partner
for conception, planning and realization of your SmartFactory:
optimized processes - selected components - professional project
management
We develop balanced production systems with simultaneous
consideration of
the areas of manufacturing, logistics and production IT.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EDAG PRODUCTION SOLUTIONS
customer
EDAG PRODUCTION SOLUTIONS
Solution Provider
(concept – planning – realization)
analyze processes
(manufacturing, logistics, IT)
optimize processes
(manufacturing, logistics, IT)
developing
SmartFactory-concept
realizing
SmartFactory
transfer/select
components
concept planning
detailed planning
supplies
(customer)
realization
volumes
(EDAG PS)
volumes
sub-supplier 1
volumes
sub-supplier 2
…
volumes
sub-supplier n
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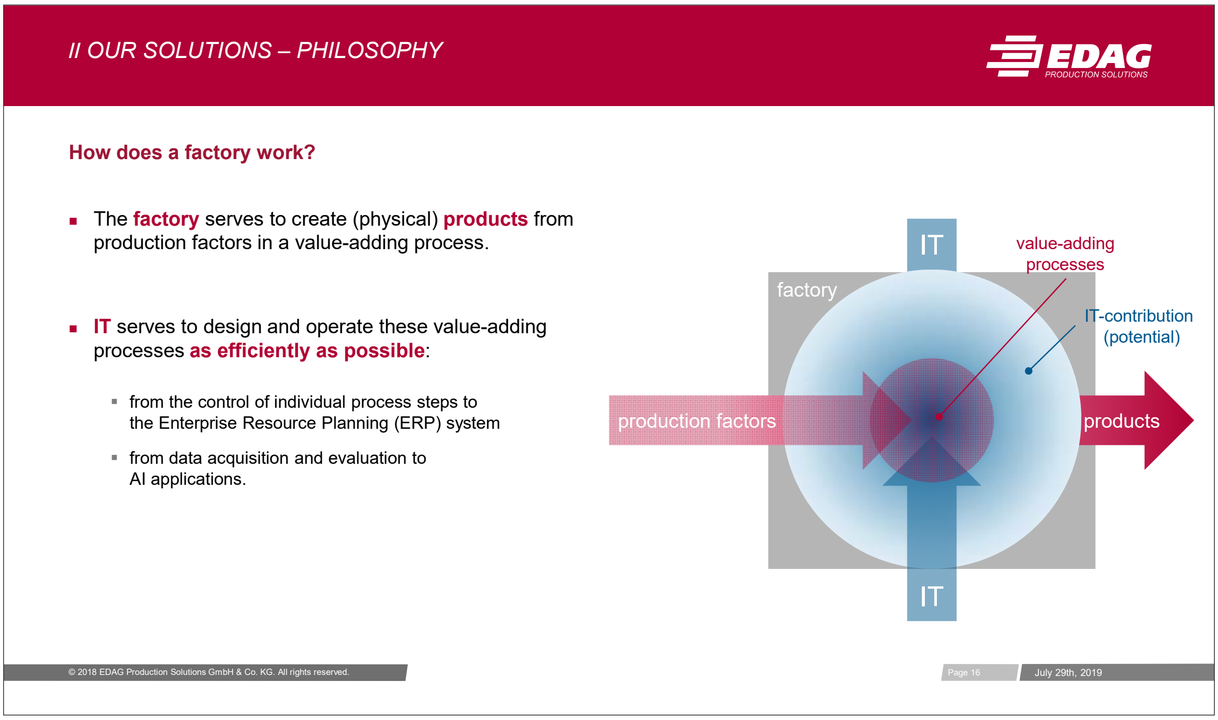
// OUR SOLUTIONS – PHILOSOPHY
EDAG PRODUCTION SOLUTIONS
How does a factory work?
The factory serves to create (physical) products from production factors in a value-adding process.
IT serves to design and operate these value-adding processes as efficiently as possible:
from the control of individual process steps to the Enterprise Resource Planning (ERP) system
from data acquisition and evaluation to AI applications.
IT
value-adding
processes
factory
IT-contribution
(potential)
production factors
products
IT
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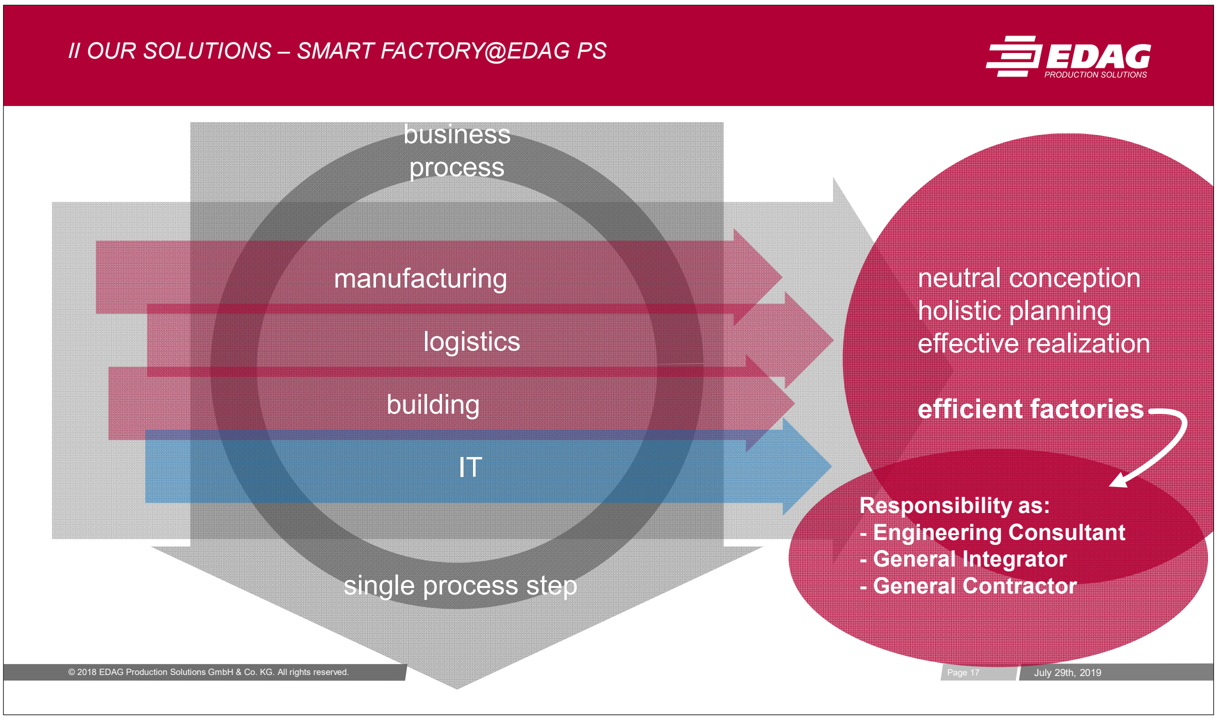
II OUR SOLUTIONS – SMART FACTORY@EDAG PS
EDAG
PRODUCTION SOLUTIONS
business process
manufacturing
logistics
building
IT
single process step
neutral conception
holistic planning
effective realization
efficient factories
Responsibility as:
- Engineering Consultant
- General Integrator
- General Contractor
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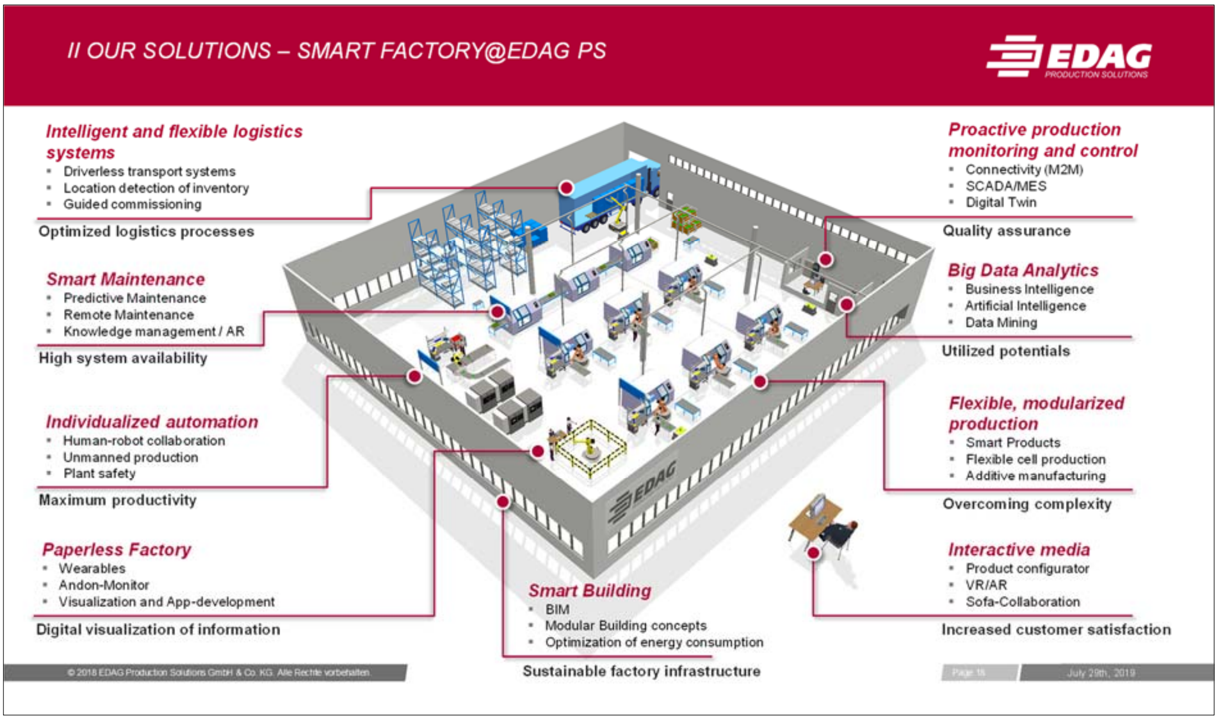
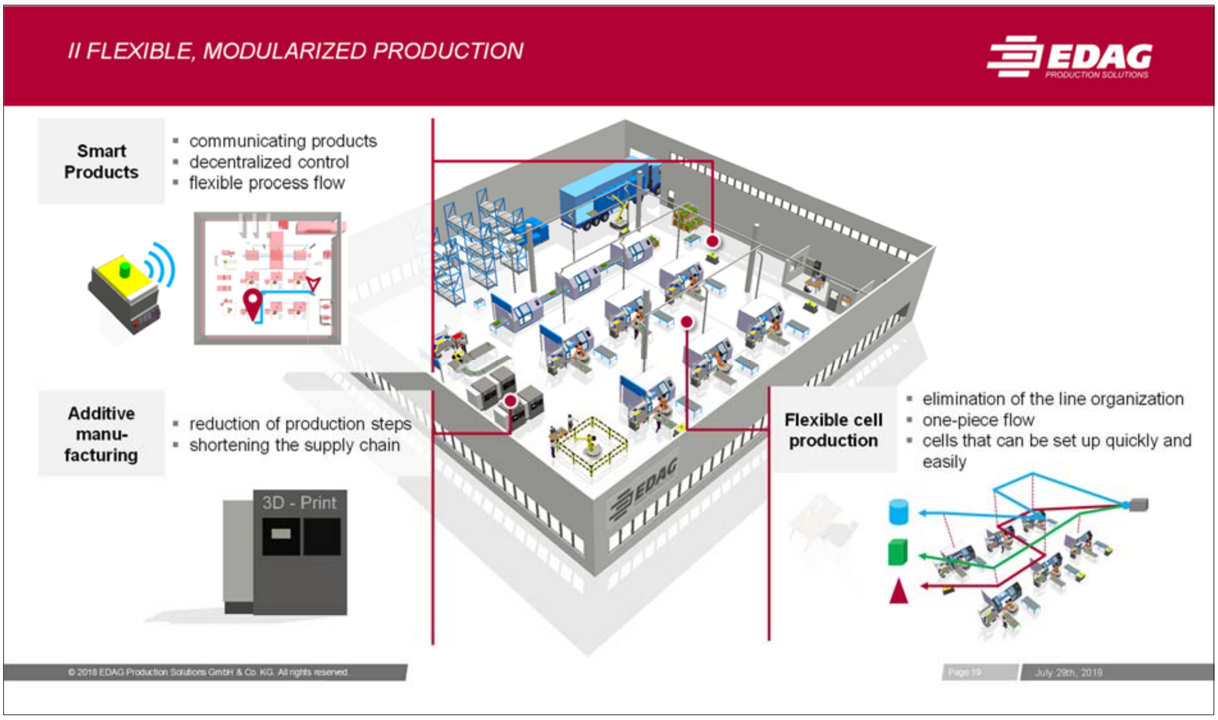

II OUR SOLUTIONS – SMART FACTORY@EDAG PS
EDAG
PRODUCTION SOLUTIONS
Intelligent and flexible logistics systems
Driverless transport systems
Location detection of inventory
Guided commissioning
Optimized logistics processes
Smart Maintenance
Predictive Maintenance
Remote Maintenance
Knowledge management / AR
High system availability
Individualized automation
Human-robot collaboration
Unmanned production
Plant safety
Maximum productivity
Paperless Factory
Wearables
Andon-Monitor
Visualization and App-development
Digital visualization of information
Smart Building
BIM
Modular Building concepts
Optimization of energy consumption
Sustainable factory infrastructure
Proactive production monitoring and control
Connectivity (M2M)
SCADA/MES
Digital Twin
Quality assurance
Big Data Analytics
Business Intelligence
Artificial Intelligence
Data Mining
Utilized potentials
Flexible, modularized production
Smart Products
Flexible cell production
Additive manufacturing
Overcoming complexity
Interactive media
Product configurator
VR/AR
Sofa-Collaboration
Increased customer satisfaction
July 29th, 2019


// FLEXIBLE, MODULARIZED PRODUCTION
EDAG
PRODUCTION SOLUTIONS
Smart Products
communicating products
decentralized control
flexible process flow
Additive manu-facturing
reduction of production steps
shortening the supply chain
3D - Print
Flexible cell production
elimination of the line organization
one-piece flow
cells that can be set up quickly and easily
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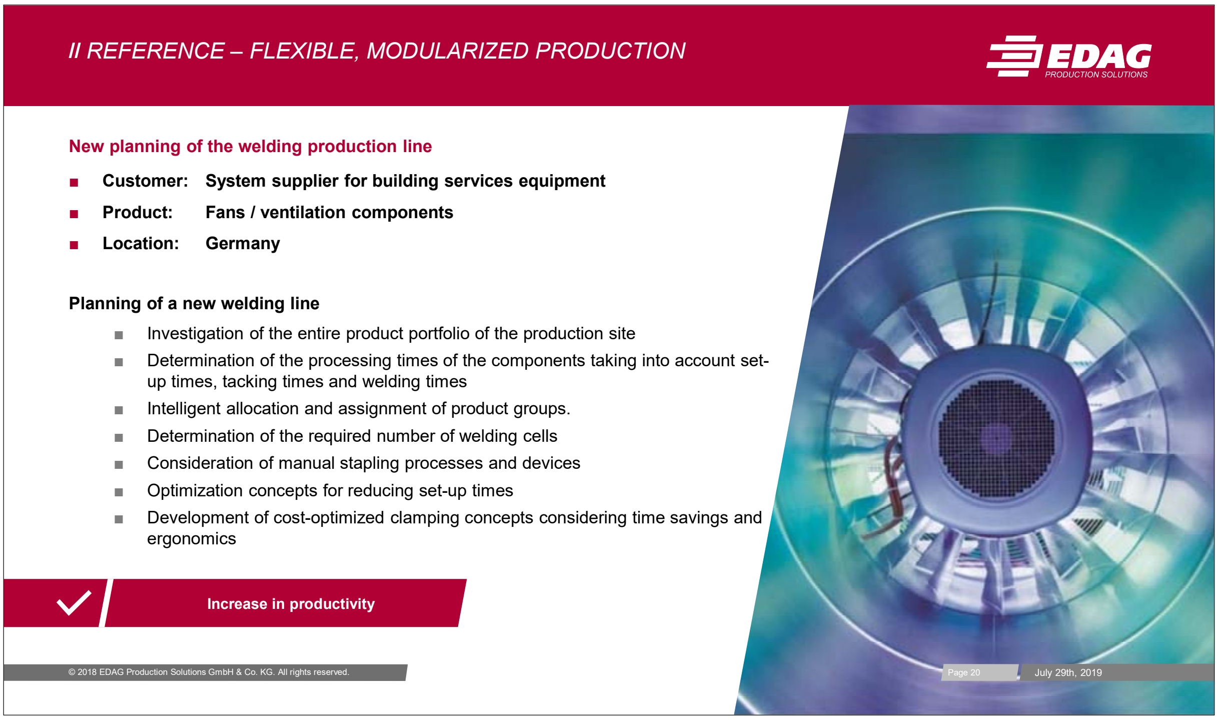
// REFERENCE – FLEXIBLE, MODULARIZED PRODUCTION
EDAG
PRODUCTION SOLUTIONS
New planning of the welding production line
Customer: System supplier for building services equipment
Product: Fans / ventilation components
Location: Germany
Planning of a new welding line
Investigation of the entire product portfolio of the production site
Determination of the processing times of the components taking into account set-up times, tacking times and welding times
Intelligent allocation and assignment of product groups.
Determination of the required number of welding cells
Consideration of manual stapling processes and devices
Optimization concepts for reducing set-up times
Development of cost-optimized clamping concepts considering time savings and ergonomics
Increase in productivity
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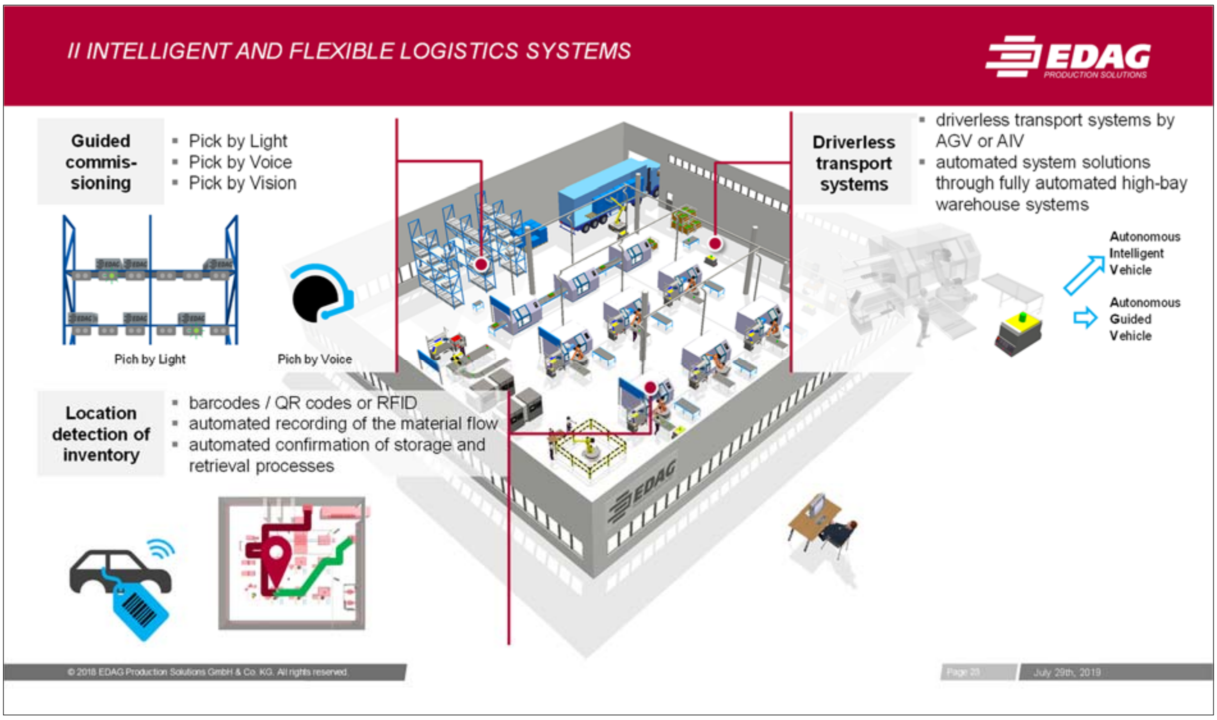
II INTELLIGENT AND FLEXIBLE LOGISTICS SYSTEMS
EDAG
PRODUCTION SOLUTIONS
Guided commis-sioning
Pick by Light
Pick by Voice
Pick by Vision
Pich by Light
Pich by Voice
Driverless transport systems
driverless transport systems by AGV or AIV
automated system solutions through fully automated high-bay warehouse systems
Autonomous Intelligent Vehicle
Autonomous Guided Vehicle
Location detection of inventory
barcodes / QR codes or RFID
automated recording of the material flow
automated confirmation of storage and retrieval processes
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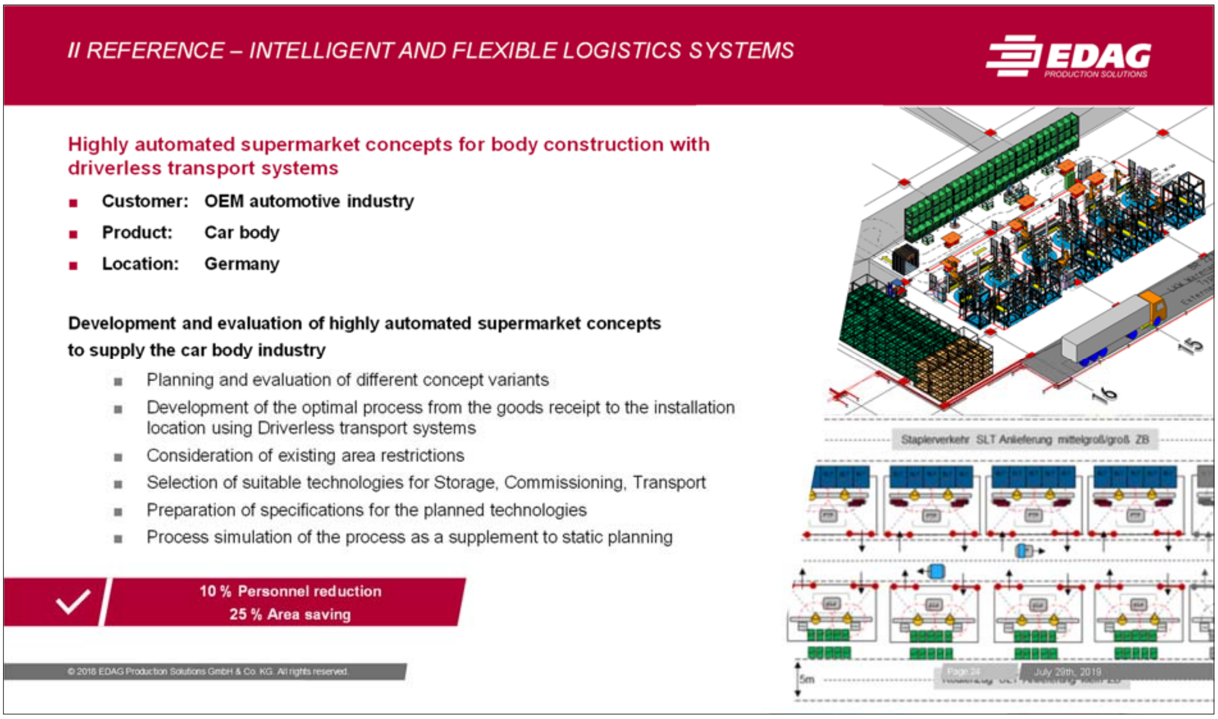
II REFERENCE – INTELLIGENT AND FLEXIBLE LOGISTICS SYSTEMS
EDAG
PRODUCTION SOLUTIONS
Highly automated supermarket concepts for body construction with driverless transport systems
Customer: OEM automotive industry
Product: Car body
Location: Germany
Development and evaluation of highly automated supermarket concepts to supply the car body industry
Planning and evaluation of different concept variants
Development of the optimal process from the goods receipt to the installation location using Driverless transport systems
Consideration of existing area restrictions
Selection of suitable technologies for Storage, Commissioning, Transport
Preparation of specifications for the planned technologies
Process simulation of the process as a supplement to static planning
10 % Personnel reduction
25 % Area saving
Staplerverkehr SLT Anlieferung mittelgroß/groß ZB
5m
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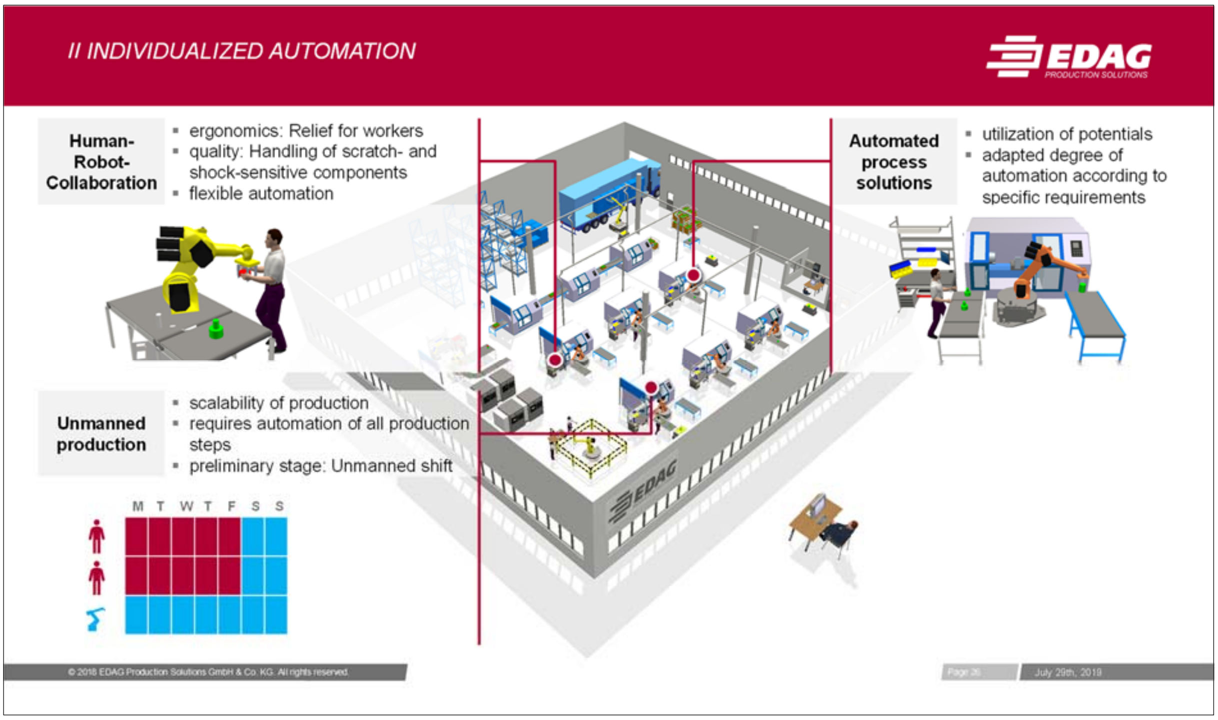
// INDIVIDUALIZED AUTOMATION
EDAG
PRODUCTION SOLUTIONS
Human-Robot-Collaboration
ergonomics: Relief for workers
quality: Handling of scratch- and shock-sensitive components
flexible automation
Automated process solutions
utilization of potentials
adapted degree of automation according to specific requirements
Unmanned production
scalability of production
requires automation of all production steps
preliminary stage: Unmanned shift
M T W T F S S
EDAG
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// REFERENCE – INDIVIDUALIZED AUTOMATION
EDAG
PRODUCTION SOLUTIONS
Concept planning for possibilities of human-robot collaboration in the assembly process
Customer: Automotive suppliers
Product: Passenger car interior fittings
Location: Germany
Activities
Identification of potential HRC-Applications and demonstration of HRC-Potentials
Development of concept alternatives for 3 HRC-Applications
Comparison of concept alternatives incl. costing and decision recommendation
Detailing of the selected concept planning incl. safety assessment, component selection and supplier recommendation
Increase in productivity
KUKA
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II REFERENCE – INDIVIDUALIZED AUTOMATION
EDAG PRODUCTION SOLUTIONS
Development of a media-less gripper
Customer: OEM automotive industry
Product: Passenger car component
Location: Germany
Planning and implementation of a HRC-workstation
Development of a media-less gripper for use with an HRC robot
Development of 3D printed parts for weight minimization
Conventional grippers cannot be used due to their weight
Integration of the HRC-workstation into a production station incl. safety concept and cycle time compliance
Simulation of the production line
Flexible adjustment of the degree of automation
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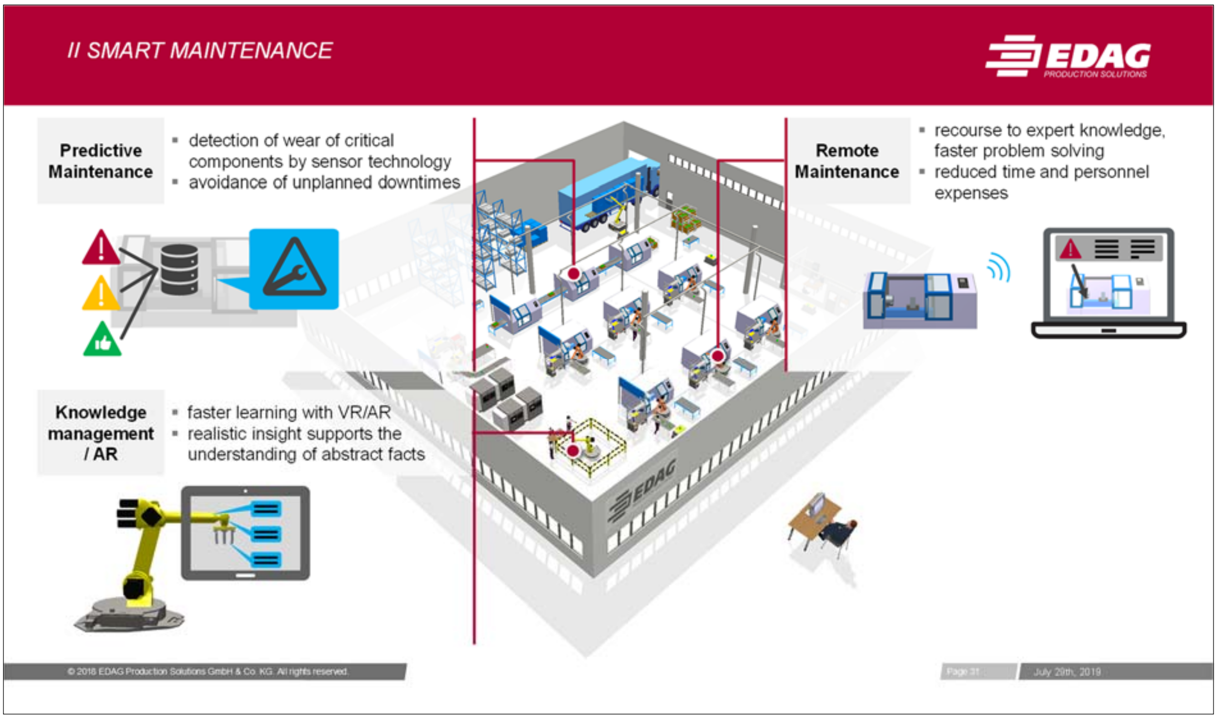
II SMART MAINTENANCE
EDAG PRODUCTION SOLUTIONS
Predictive Maintenance
detection of wear of critical components by sensor technology
avoidance of unplanned downtimes
Remote Maintenance
recourse to expert knowledge, faster problem solving
reduced time and personnel expenses
Knowledge management / AR
faster learning with VR/AR
realistic insight supports the understanding of abstract facts
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// REFERENCE – SMART MAINTENANCE

EDAG PRODUCTION SOLUTIONS

Predictive maintenance in automobile production

- **Customer: OEM automotive industry**
- **Product: Passenger car**
- **Location: Germany**

Implementation of a predictive maintenance solution for bodyshell construction

- Derivation of hypotheses from malfunction analysis
- Preparation of business case incl. value stream simulation
- Implementation of data connection to the cloud
- Programming and verification of hypotheses
- Optimization of hypotheses using machine learning algorithms
- Potential confirmation by pilot operation
- Rollout

✓ **Increased productivity and availability**

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// REFERENCE – SMART MAINTENANCE

EDAG PRODUCTION SOLUTIONS

Development of a modern maintenance system based on Smart Watches

- **Customer: OEM automotive industry**
- **Product: Vans**
- **Location: Worldwide**

Event-driven visualization of alarm messages on Smart Phone and Smart Watch

- Fast reactions to messages
- Direct acknowledgement of the message at the push of a button on the wrist
- Efficient working - no disturbance during activities
- Alarm filter and message history

✓ **Information availability**

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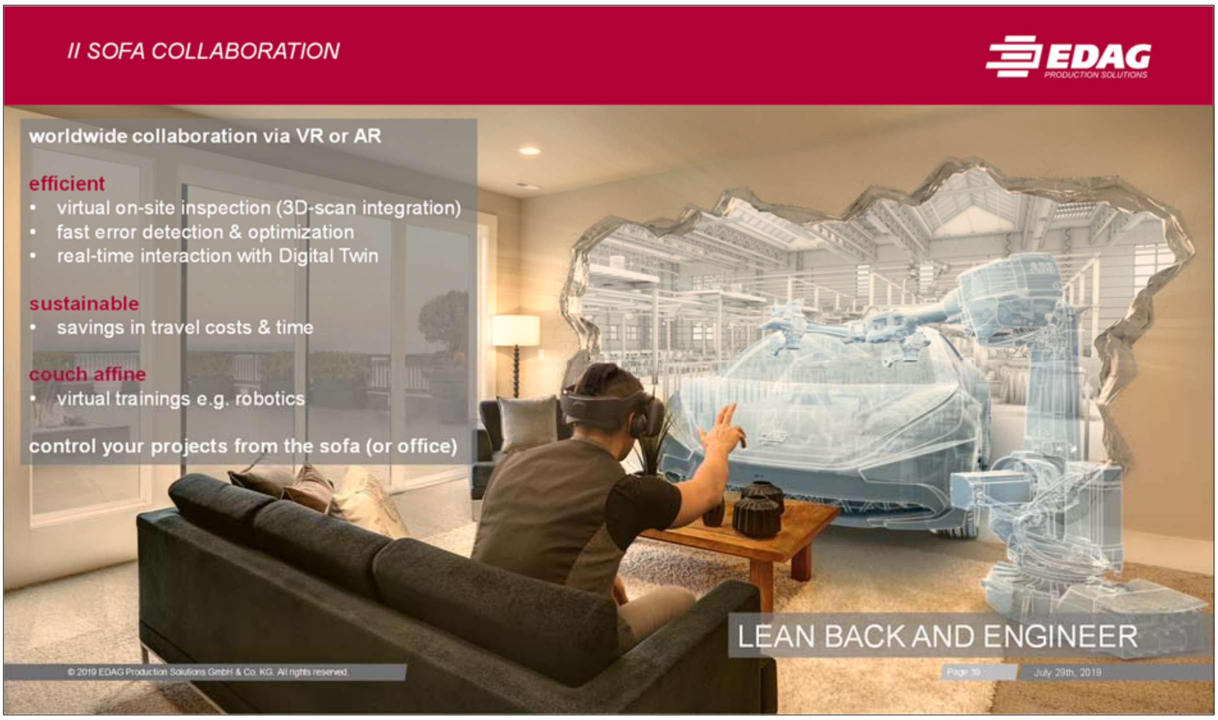
II SOFA COLLABORATION
EDAG
PRODUCTION SOLUTIONS
worldwide collaboration via VR or AR
efficient
• virtual on-site inspection (3D-scan integration)
• fast error detection & optimization
• real-time interaction with Digital Twin
sustainable
• savings in travel costs & time
couch affine
• virtual trainings e.g. robotics
control your projects from the sofa (or office)
LEAN BACK AND ENGINEER
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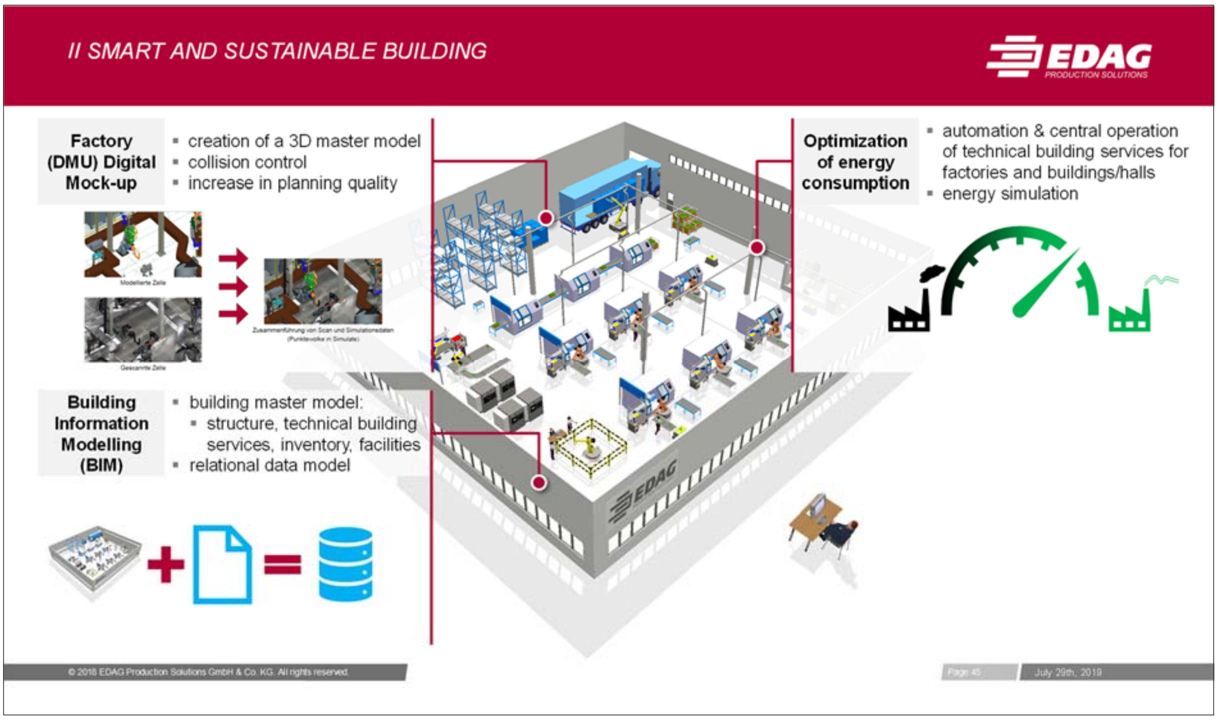
II JOIN VIRTUAL SCENES WORLDWIDE VIA VIRTUAL REALITY
EDAG
PRODUCTION SOLUTIONS
• controlling the virtual robot by a real teach pendant
• interaction with VR-participants
Avatar of a VR-participant
Avatar of the AR-operator
• virtual „presence" on site
• interaction with VR-participants and AR-operator
• via verbal communication
• via gestures
• via (hand-)written comments


// SMART AND SUSTAINABLE BUILDING
EDAG
PRODUCTION SOLUTIONS
Factory (DMU) Digital Mock-up
creation of a 3D master model
collision control
increase in planning quality
Building Information Modelling (BIM)
building master model:
structure, technical building services, inventory, facilities
relational data model
Optimization of energy consumption
automation & central operation of technical building services for factories and buildings/halls
energy simulation
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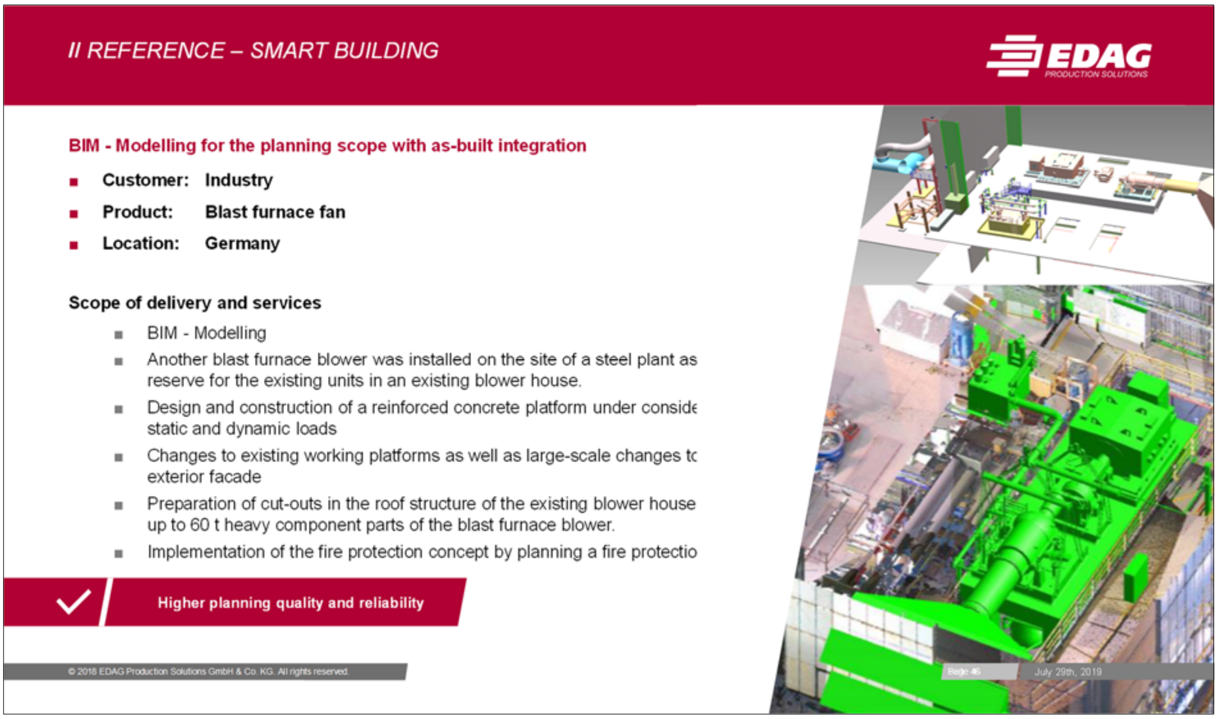
// REFERENCE – SMART BUILDING
EDAG
PRODUCTION SOLUTIONS
BIM - Modelling for the planning scope with as-built integration
Customer: Industry
Product: Blast furnace fan
Location: Germany
Scope of delivery and services
BIM - Modelling
Another blast furnace blower was installed on the site of a steel plant as reserve for the existing units in an existing blower house.
Design and construction of a reinforced concrete platform under conside static and dynamic loads
Changes to existing working platforms as well as large-scale changes tc exterior facade
Preparation of cut-outs in the roof structure of the existing blower house up to 60 t heavy component parts of the blast furnace blower.
Implementation of the fire protection concept by planning a fire protectio
Higher planning quality and reliability
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// CONCLUSIONS

EDAG PRODUCTION SOLUTIONS

- Our challenge as an engineering partner is to be able to provide
  - the right expertise
  - at the right time
  - in the right place
  - at all times

  and to take responsibility for it.

- In times of digital transformation, it is essential to take a holistic view of production systems:
  - from the assembly step to the business process
  - from logistics via manufacturing to production IT
  - from the building via the plant to the storage box.

- Digitization is an essential part of modern production systems
  - for increasing efficiency and quality
  - for sustainable production
  - ... and for a balanced work-life balance.

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EDAG PRODUCTION SOLUTIONS

MAKING IDEAS PERFORM

// WITH US, YOUR PROJECTS ARE IN THE BEST POSSIBLE HANDS.

Rainer Wittich
Chairman of the Board of Management
rainer.wittich@edag-ps.com

www.edag-ps.com

M.Sc. Celso Nogueira

Celso Nogueira was born in 1959 and studied Naval engineering at Escola Politécnica da Universidade de São Paulo, Brazil, where he received his diploma in 1981. He received the MSc. degree in Space Sciences & Orbital Mechanics at Instituto de Pesquisas Espaciais – INPE, S. J. dos Campos, Brazil in 1987. His dissertation was about Local Stress refinement in the Finite Element Method. From 1982 thru 1987 he worked at Instituto de Pesquisas Espaciais on the development of satellites, including a period working at SPAR Aerospace, Canada, from 1984 thru 1985, on a technology transfer program. He joined EMBRAER, S. J. Campos, Brazil, in 1987 to work on new carbon fiber aeronautical structures development and testing. Went back to satellite structures design and structural analysis from 1991 thru 1984 and in 1985 was put in charge of a multinational team of engineers, developing and testing aircraft structures at GAMESA Aeronáutica in Spain. Came back to Brazil in 2000, joining debis Humaitá (which was sold to T-Systems AG) where he held positions at Engineering and Manufacturing Department of the Systems Integration Division; he led multiple teams, simultaneously, working on Engineering and IT services areas, PLM, Numerical Simulation, Software Development, Systems Support and Sales. He has broad experience in the Aerospace and Automotive Industries, in development engineering, project/program management, people development and business development. Since 2018 he is working with SAVATec on business development and sales consulting on artificial intelligence, unsupervised self-learning and prescriptive control solution tools for predictive analytics: predictive maintenance, predictive quality, machinery control, capacity planning, logistics optimization and process efficiency

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SAVATec Eng & TI

Small services and consulting company in IT and engineering. SAVATec business is focused on helping companies navigate through the overwhelming sea of issues and opportunities represented by digital transformation and Industry 4.0 trends. Partnering with IS Predict GmbH, we bring to the Brazilian market the value proposition of the Predictive Intelligence solutions that have received several innovation awards in Europe, being the most recent the Innovation Award for Self-learning Artificial Intelligence, received during the European conference IDTEchEx in Berlin, 2019.

SAVATec

Artificial Intelligence improves Complex Production + Operation: Project examples from the shop floor

Abstract

More and more industry data is recorded. Data lakes are substantially growing. But, just having (Big) data does not yet realize a significant improvement in industrial processes. Thus, companies are increasingly focusing on getting insight out of their (large) data pools – with the help of Predictive Intelligence, the Self-Learning Artificial Intelligence Solution. Part I of the paper covers predictive maintenance in production: Reliable machinery is critical for production and operation processes. Failure leads to downtime of production lines. Un-supervised, self-learning algorithms analyzed data from critical processes and information on future failure, in machinery, allows for action before it actually occurs. Unplanned downtime is avoided. Part two covers predictive quality. The AI solution was used to get reliable fast results on root cause discovery for poor quality. Speed is essential as production runs 24/7. Complex root-cause findings were reduced from several days to hours, with transparency on disturbing factors.

Keywords

Artificial Intelligence; Self-learning; Cognitive Software Predictive Maintenance; Predictive Quality

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IS Predict GmbH | Member of Scheer Holding

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1 Introduction

Worldwide, businesses are increasingly exposed to cost pressures, quality requirements, unpredictability, and new processes complexities. Albeit the availability of data from their processes, machines and resource operation has also been on an increasing pattern, this availability of (Big) data does not easily, or readily, materializes into the hoped for improved efficiencies. Only turning Big Data into Smart Data, companies will be able to discover inefficiencies and disturbing factors in both the business and the technical processes. Predictive Intelligence is an un-supervised self-learning analysis, prediction, and control solution. Even in a complex process and dynamic data structures, it is possible to get foresighted recommendations for daily operations. Machine to machine communication allows direct process and machinery control – with proven efficiency increase. Dynamic simulation methods discover hidden optimization potentials. Disturbing factors are discovered early. In this way, inefficiencies can be avoided before they even occur.

These self-learning solutions count with cognitive robotic process automation (cRPA). A large number of complex processes cannot be described by rules because the influencing factors are constantly changing. These processes show high dynamics or the required knowledge for decision making is very complex. In these cases, the usual RPA BOTs do not suffice. Self-learning, cRPA BOTs are required, which are able to discover hidden and complex data patterns, even in Big Data or in, hardly, any data. A cognitive RPA BOT learns from executed processes, understands which steps lead to success (and when) and derives complex networks which allow for highly accurate predictions (predictive analytics) and for controlling processes in a predictive way (prescriptive analytics). Therefore, complex processes are automated in a dynamic and predictive manner.

These Predictive Intelligence solutions can be applied, successfully, in several areas, such as:

- **Industry 4.0 / Smart Production:**
  - Predictive maintenance;
  - Predictive quality and quality optimization;
  - Waste reduction, energy dispatching, and trading;
  - Logistics optimization, capacity planning;
  - Machinery control;
  - Process efficiency.
- **Smart Services:**
  - Demand-oriented planning, optimal resource utilization;

  - Communication analysis;
  - Optimized sales and service processes.
- **Smart Grid:**
  - Realizing the full potential of renewable energy usage;
  - More precise energy purchase and sale;
  - Predictive automated energy trading.
- **Smart Buildings:**
  - Predictive and adaptive building control.

This paper presents cases of Predictive Maintenance and Quality. Section 2 presents an overview of the solution. Section 3 presents the case on predictive maintenance, in production an operation (Part 1) and Section 4 the case on predictive quality in production (Part 2).

2 Solution Overview

The Self-Learning algorithms of the Artificial Intelligence Solution, Predictive Intelligence, represent the core of IS Predict standard software. In contrast with other AI approaches (i.e., Deep Learning), Predictive Intelligence gives transparency over which factors influence the processes in a positive or negative way. Thus, processes can be improved sustainably.

Due to its Self-Learning algorithms, the effort required on Data Scientists is kept to a minimum, basically in the project early phases. When the processes change, the software understands the future consequences of those changes, automatically. Therefore, no Data Scientist has to modify the Artificial Intelligence solution, any longer. This allows for reduced follow-up costs that usually are incurred while adapting an AI solution to changed processes. The Predictive Intelligence solution automates some time-consuming tasks which are normally executed by Data Scientists. Thus, it reduces not only the implementation costs for your AI solution but also the operating costs. In this way, the implemented AI solution gets scalable and can be used over the years, without hidden follow up costs.

The solution delivers highly accurate prediction even in complex processes and discovers hidden anomalies in the machine and human behavior. In addition, recommendations are given to avoid future inefficiencies. These recommendations are given to humans, i.e., machine operators in production or control is done without human interaction, thanks to “machine-to-machine” communication.

Depending on the analytical tasks and particular implementation, relevant solution modules are available and can be made of use. These modules encompass the following features:

- **Dynamic pattern discovery**
  In highly complex and dynamic data, hidden and multifaceted data patterns are discovered. High complexity can mean big data or data lake, but also hardly any data, i.e., gaps in data. Benchmarks have proven that Predictive Intelligence reaches significant, more accurate predictions in complex and dynamic data than state-of-the-art methods like Deep Learning, Neuronal Networks, Support Vector Machines, Regressions, etc. In addition, often, these said methods deliver satisfying results on learned data but are not reliable on unlearned data. Predictive Intelligence allows for equally good results on untrained data.

- **Anomaly detection**
  Complex data patterns are found, which happen in similar or changed ways before machinery runs inefficiently/fails or a poor quality item is produced. Those changing patterns can develop over weeks, months, or just within seconds or minutes. Predictive Intelligence detects anomalies and assesses them for criticality.

- **Influencing factor discovery**
  The available data is analyzed to assess their influence in causing machine inefficiency/failure or reduced quality. In this way – even out of data lakes – significant factors are discovered. Transparency leads to optimized process re-design. In addition, sensors are optimized, as attention is paid to relevant sensors, only, instead of gathering as much data as possible.

- **Failure prediction**
  For each machinery/equipment/installation, an inefficient operation or failure can be predicted with high accuracy. Downtime is minimized, and maintenance activities can be planned and managed in an optimized way. In addition, service technicians can be informed about which data causes future inefficiencies. Therefore, service technicians are guided to a particular component that will cause trouble in the future. Also, reduction in quality can be detected in advance.

  - **Predictive maintenance**
    Having future machinery problems discovered, machinery is always meeting quality requirements, and products can consistently meet the quality requirements.

  - **Predictive machinery control**
    Complex algorithms simulate variants in machine settings and control machinery in a predictive way, to allow for optimal quality. Alternatively, recommendations can be given to machine operators.

- **Root cause analysis**
  Disturbing factors can be discovered, early. This transparency enables sustainable process improvements.

- **Self-learning**
  - **Manage changes over time**
    Production processes are not static. Changes happen, again and again, e.g., production lines` utilization is changed, production items are changed, etc. This leads to different machinery usage, like heavier or lighter machine assignments, etc. Self-learning algorithms understand the dynamics of those changes and adopt the analyzed data patterns automatically. Thus, there is no need to engage Data Scientists, regularly, to adjust the mathematical models to the changed reality. Predictive Intelligence implements these adjustments, automatically.
  - **Enable scalability**
    In state-of-the-art methods, Data Scientists might be required to modify mathematical models for each individual machinery instance. However, Predictive Intelligence learns the individual context of each instance automatically. Thus, no Data Scientist has to adjust mathematical models for individual machinery instances.

3 Predictive Maintenance – production/operation (Part 1)

3.1 General

The Predictive Maintenance feature of the solution aims at reducing machinery downtime and optimizing technical services. High-class products require high-class production line management. Maintaining machinery based on pre-defined cycles and condition monitoring belongs to the past, see Figure 1.

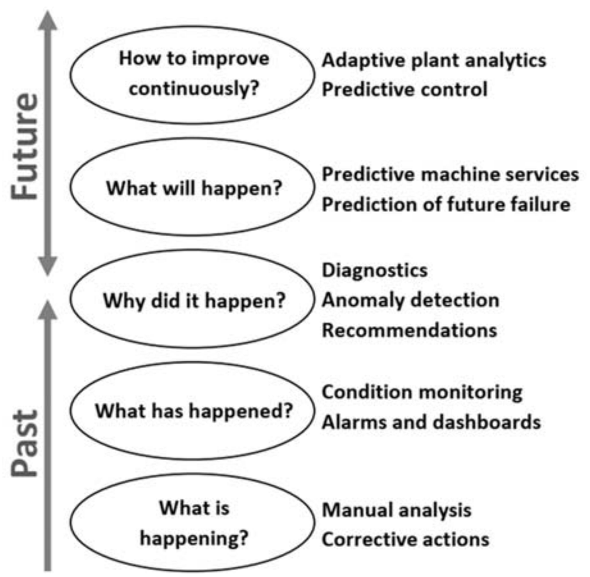


Figure 1: Future generation maintenance scenario

Next generation of maintenance is future-oriented: Predictive machine service and adaptive plant analytics. Only predictive and demand-oriented maintenance saves time and money. New self-learning algorithms can inject “predictive intelligence” in all relevant components. Both machinery operators and machinery producers can benefit from next-generation maintenance. New business models are created to offer added value services for predictive maintenance analytics, i.e., via the cloud.

3.2 Key Benefits

With Predictive Intelligence solution, for Predictive Maintenance, you can:

- Discover anomalies in machine behavior;
- Get transparency, which factors influence machine inefficiencies. In this way, you can optimize machine operation and sensor usage;
- Predict accurate machine failure and inefficiencies;
- Automatically adjust algorithms to understand changes in machine behavior (i.e., changed production and machinery utilization);
- Automatically roll out customized algorithms to your machinery instances.

3.3 Siemens Case– Predictive Maintenance in production

In car building, failure of critical machinery leads to the downtime of entire production lines. One minute of unplanned stand stills sums up to ca. 18,000 € in losses. To prevent a Car Body Press (Figure 2) from starting giving problems, Siemens introduced the utilization of the Predictive Intelligence solution in the shop-floor.

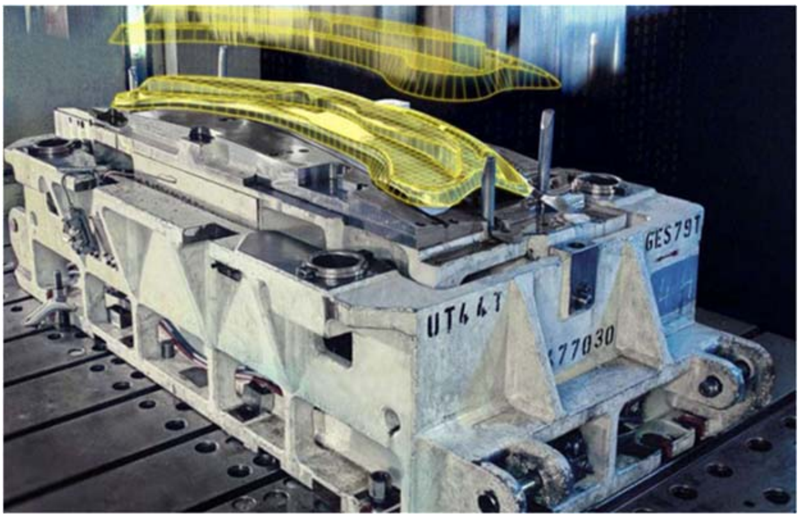


Figure 2: Car body press (pictorial)

Objectives:

- Change the presses maintenance scenario from Reactive/Break Fix and Proactive/Preventive to Proactive/Predictive;
- Early discovery of future quality problems, caused by tear and wear;
- Staying competitive in the future from a maintenance perspective, by:
  - Optimizing plant availability (24/7);
  - Reducing total cost of ownership;
  - Taking advantage of Digitalization.

Issues:

- Gears (Drive train) tear and wear and tooling misalignment (Orientation Station), see Figure 3;
- With the former procedure, it was not possible to understand how data can be used to predict press shutdowns, although metal press has been analyzed by both the data scientist and machine experts.

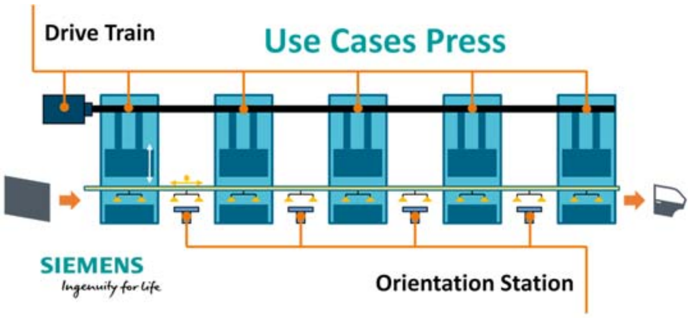


Figure 3: Schematic - Car body press line

Challenge:

- 6 Orientation stations with 42 toolsets each;
- Total of 252 individual contexts.

Approach:

- <u>Learn</u>, see Figure 4:
  - Offline data;
  - Discover data patterns that lead to problems.

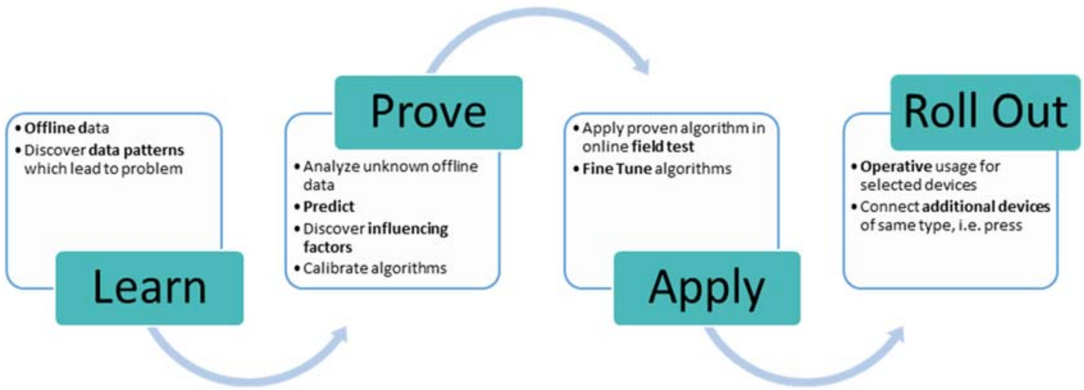


Figure 4: Approach - Car body press line

- <u>Prove</u>:
  - Analyze unknown, offline data;
  - Predict;
  - Discover influencing factors and calibrate algorithms.
- <u>Apply</u>:
  - Apply proven algorithm in the online field test;
  - Fine tune algorithms.
- <u>Roll-out</u>:
  - Operative usage for selected devices;
  - Connect additional devices of the same type, i.e., press

Solution:

- The Predictive Intelligence Solution allows for the discovery of disturbing factors that cause tear and wear and analyses the “health” of the machinery, making use of complex anomaly KPIs, Figure 5;

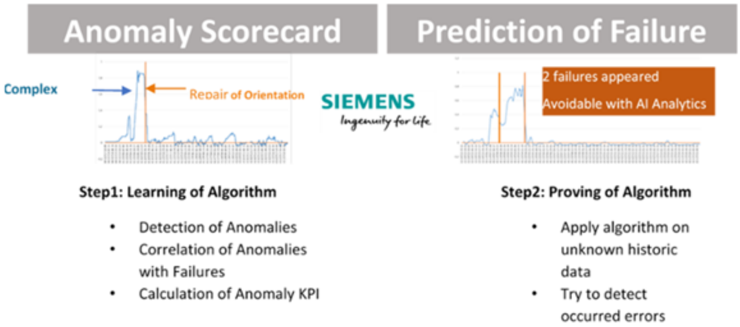


Figure 5: Solution - Car body press line

- Information on future press malfunction, also causing bad quality is obtained.

Outcome:

- Tear and wear can be assessed in a dashboard and failure predicted, see Figure 6;
- Prediction accuracy: verified models on unknown data > 99%.

Figure 6: Dashboard – Car body press line

3.4 NTT Case– Predictive Maintenance in operation

Failure Prediction for critical air-conditioning system, for the NTT Facilities Company. NTT Facilities is the "Building & Energy" professional company in the NTT Group; see Figure 7. In IT centers, the climate is critical for the well-functioning of servers and, thus, for all business processes.

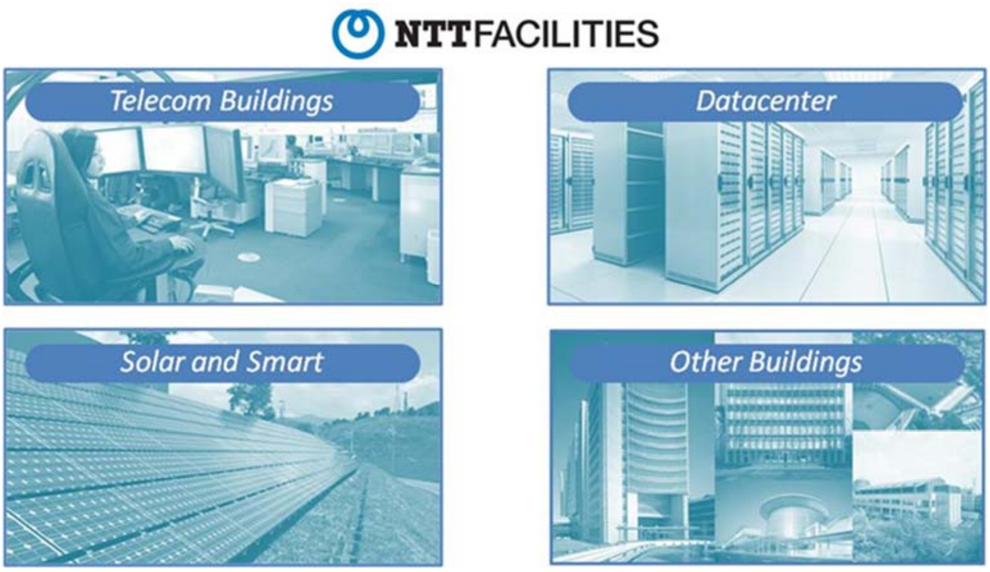


Figure 7: NTT Facilities – Business Segments

Objective:

- Failure Prediction for Air-Conditioning;
- Target: Critical Infrastructure inside Telecom, Figure 8;

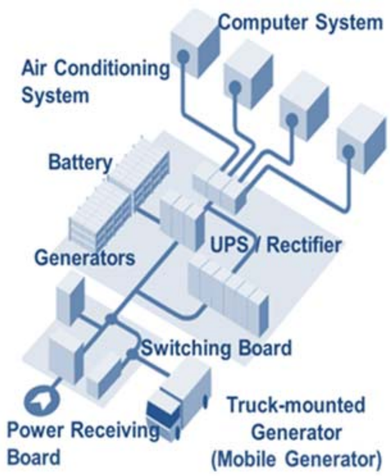


Figure 8: Target Infrastructure

- Target Component: Compressor, Figure 9.

Figure 9: Target Component

Issues:

- Replacing compressors before the actual end of a lifetime;
- Requiring installation of backup air-conditioning system (N+1);
- Sending in engineers, during the night, for emergency maintenance.

Outcome:

- Maximized compressors run time and decreased compressor replacement;
    - Decreased CAPEX.

- Backup unit avoided (N+0);
    - Decreased CAPEX.
- Sending in engineers, during the daytime, in a regular and organized manner;
    - Decreased OPEX.

4 Predictive Quality Improvements in production (Part 2)

4.1 General

Excellent production quality is paramount in any company. Time-consuming testing methods are usually executed for critical production steps and production batches. This normally covers only a few random samples to limit the involved time and inspection costs. Due to the small percentage of inspection samples, the possibility of having undetected low-quality products is considerable and may lead to further processing or recalling of products.

4.2 Key Benefits

By making use of the Self-learning Predictive Intelligence solution, it is possible to attain 100% quality inspection coverage, due to intelligent data analytics. Complex causes for reduced quality can be detected early in advance and, therefore, production processes can be improved sustainably. Machine operators can receive a recommendation for optimal quality results, or machinery can be controlled automatically without manual user interaction for the same token.

Table 1 presents the four levels that are considered for predictive quality optimization. Although those levels show a hierarchy, each optimization level is independent and capable of adding value.

Table 1: Quality Optimization Levels

Optimization Level	Objective	Problem	Added Value
# 1 Quality Prediction	Discover the quality of each relevant production process, e.g., executed by robots	Checks are time-consuming (e.g., ultrasonic inspection). Thus, only a fraction is randomly tested.	Quality checks for 100% of the production steps of relevant robots Manual inspection is only executed on those quality assessments which are near the borderline. Significant cost reduction of quality tests and at the same time, 100% test coverage
#2	Discover reasons for bad quality, e.g., an	Although production is exactly the same	Discovering complex disturbing factors

Root Cause Discovery	automotive supplier	(machinery, calibration, supplier material, etc.), sometimes, some machines deliver bad quality.	combinations Sustainable adjustment of the production process to avoid low quality
#3 Predictive Maintenance	Take early countermeasures, before batches of product are produced with low quality	Wear and tear causes low quality. Often, wear and tear are noticed when produced quality is bad. Then, ad hoc maintenance activities are required to stop low quality production	Discover wear and tear before it actually happens Recommend maintenance activities early in advance Execute maintenance when it best fits, in the production process High-quality production
#4 Predictive Machinery Control	Calibrate machinery automatically, in such a way that the required quality is produced, consistently	In particular, for production batch changes, it takes time to input correct machinery settings	Hardly any poor quality is produced due to automated machinery setting Note: Instead of automation, recommendation to the operator can be given

4.3 ZF Case – Predictive Quality

ZF plant in Saarbrücken, Germany, manufactures ca. 11,000 transmissions/day in 700 variants. Every transmission consists of up to 600 part numbers; see Figure 10. ZF introduced the Predictive Intelligence solution, and an AI project was started to get reliable + fast results on root cause discovery for poor quality. Speed is important as production runs 24/7. Complex root-cause findings can be reduced from several days to hours, using the self-learning Predictive Intelligence solution. Masses of complex data are analyzed to find reliable data patterns, giving transparency on disturbing factors.

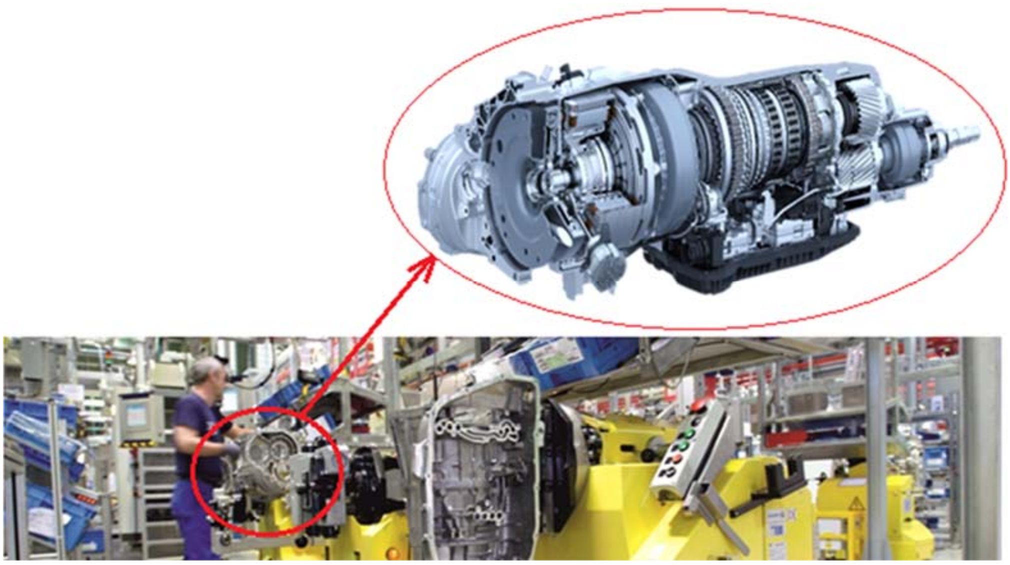


Figure 10: Transmission assembly line

Objectives:

- Improve production quality in complex variant processing;
- The target is to reduce waste in certain manufacturing domains by 20%.

Issues:

- Rejections and root cause findings have to be done with a huge effort over different manufacturing areas;
- Complexity is increased through the high mix of variants, variants of components and machining tool handling;
- Poor quality parts are still produced while the root cause analysis is running;
- Speed is important because production runs 24 hours / 7 days a week.

Challenges:

- Product Complexity, see Figure 11:
  - Every transmission consists of up to 600 parts;
  - 17 basic transmission types;
  - 700 variants.
- Process Complexity:
  - Various production lines;
  - Up to 50 machines for the same process step.

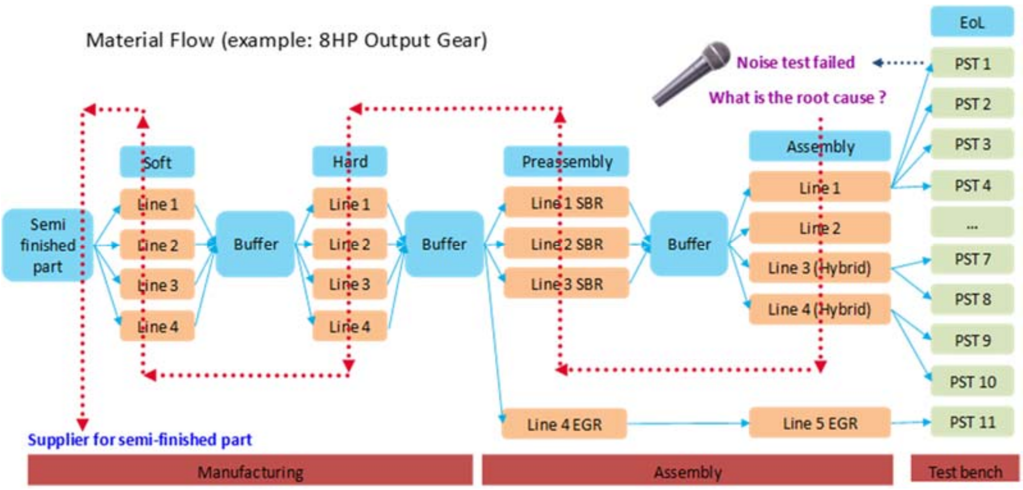


Figure 11: Assembly line complexity

Solution:

- Data to be processed for analytics:
  - Test bench:
    - Noise level measurements;
    - Acoustic test limit data;
    - Setups per test bench.
  - Pre-assembly and final assembly lines:
    - Genealogy data and its adjustment values;
    - Traceability data from suppliers;
    - Traceability data from in-house machines.
  - Manufacturing:
    - Same data type information than in assembly.
- Self-learning AI in the background: Continuous Learning.

Outcome:

- Interwoven data is continuously processed, see Figure 12;

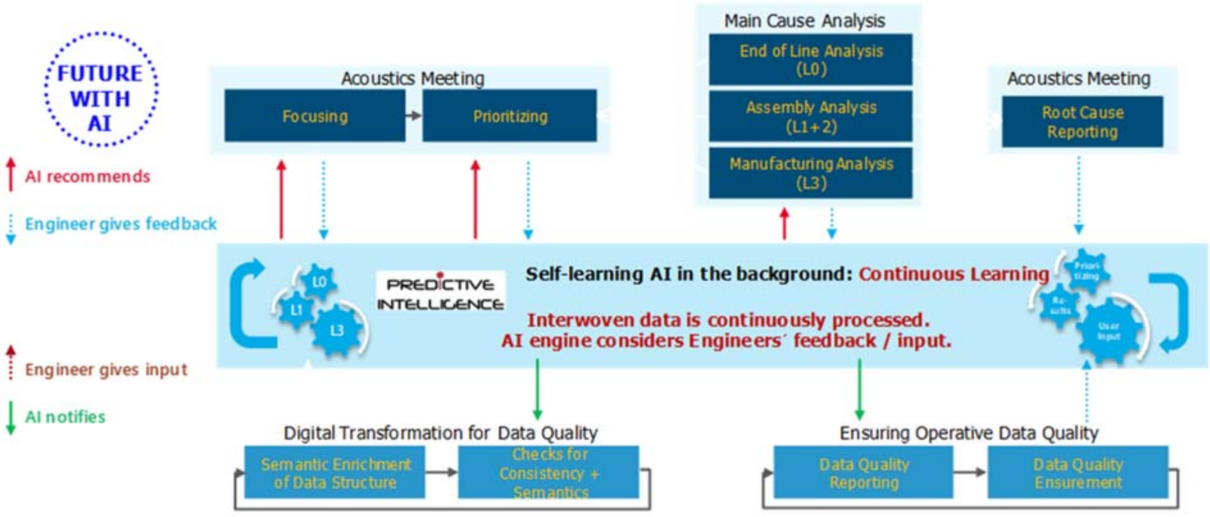
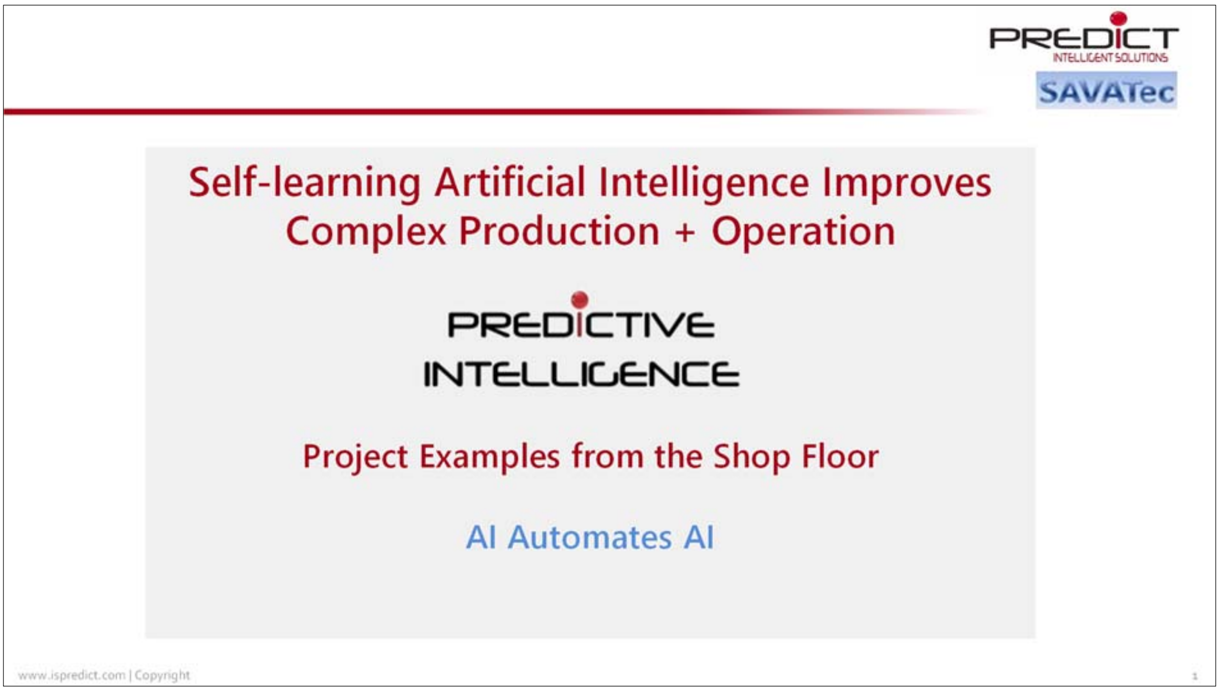


Figure 12: Future with Predictive Intelligence (AI)

- AI engine considers Engineers' feedback/input:
  - AI engine recommends / Engineering gives feedback;
  - Engineering give input / AI engine notifies
- Algorithms have been "told" how Data Scientist adapts models;

- Self-Learning learns 24/7 and adapts to changed processes for each individual instance;
- N^m changes nm are understood;
- Scalable solution for wide roll out.


PREDICT
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Self-learning Artificial Intelligence Improves
Complex Production + Operation
PREDICTIVE
INTELLIGENCE
Project Examples from the Shop Floor
AI Automates AI
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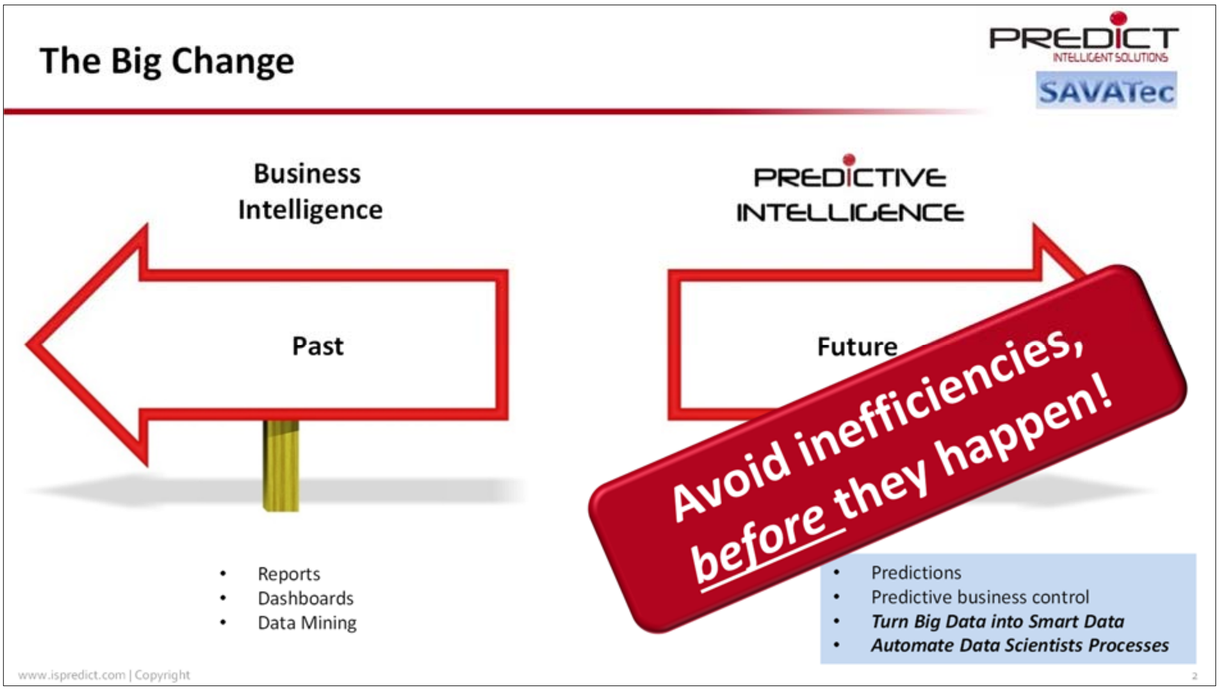
The Big Change
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Business
Intelligence
PREDICTIVE
INTELLIGENCE
Past
Future
Avoid inefficiencies,
before they happen!
Reports
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Predictions
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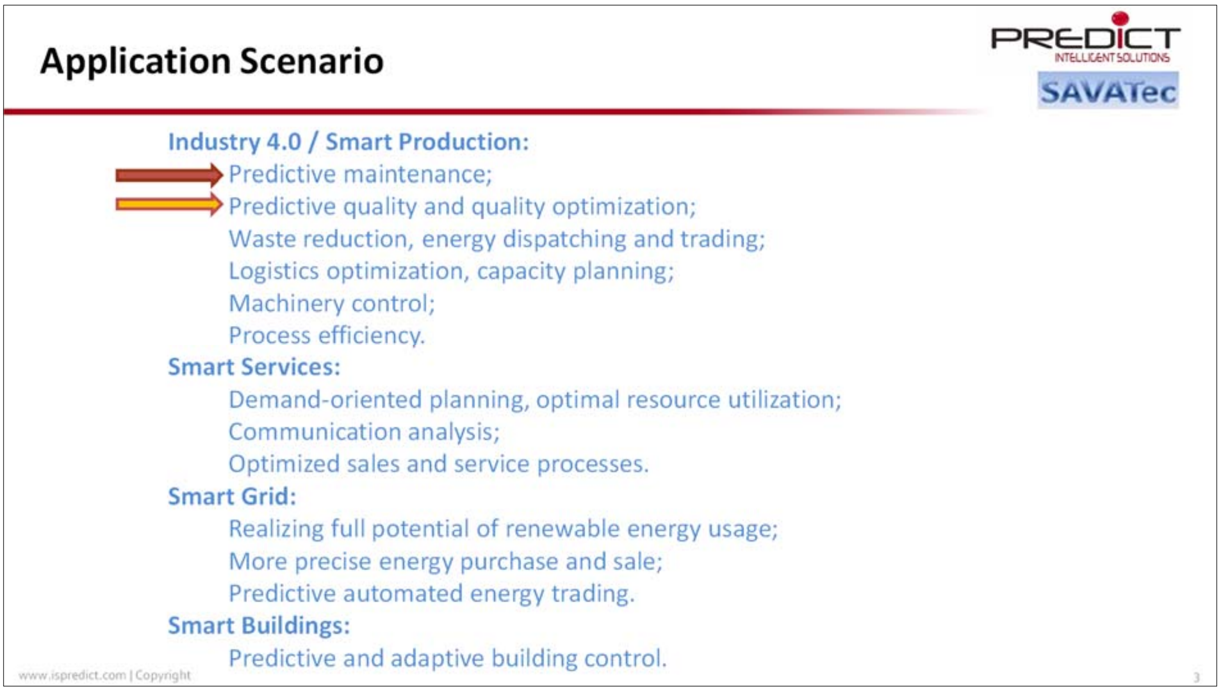
Application Scenario
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Industry 4.0 / Smart Production:
Predictive maintenance;
Predictive quality and quality optimization;
Waste reduction, energy dispatching and trading;
Logistics optimization, capacity planning;
Machinery control;
Process efficiency.
Smart Services:
Demand-oriented planning, optimal resource utilization;
Communication analysis;
Optimized sales and service processes.
Smart Grid:
Realizing full potential of renewable energy usage;
More precise energy purchase and sale;
Predictive automated energy trading.
Smart Buildings:
Predictive and adaptive building control.
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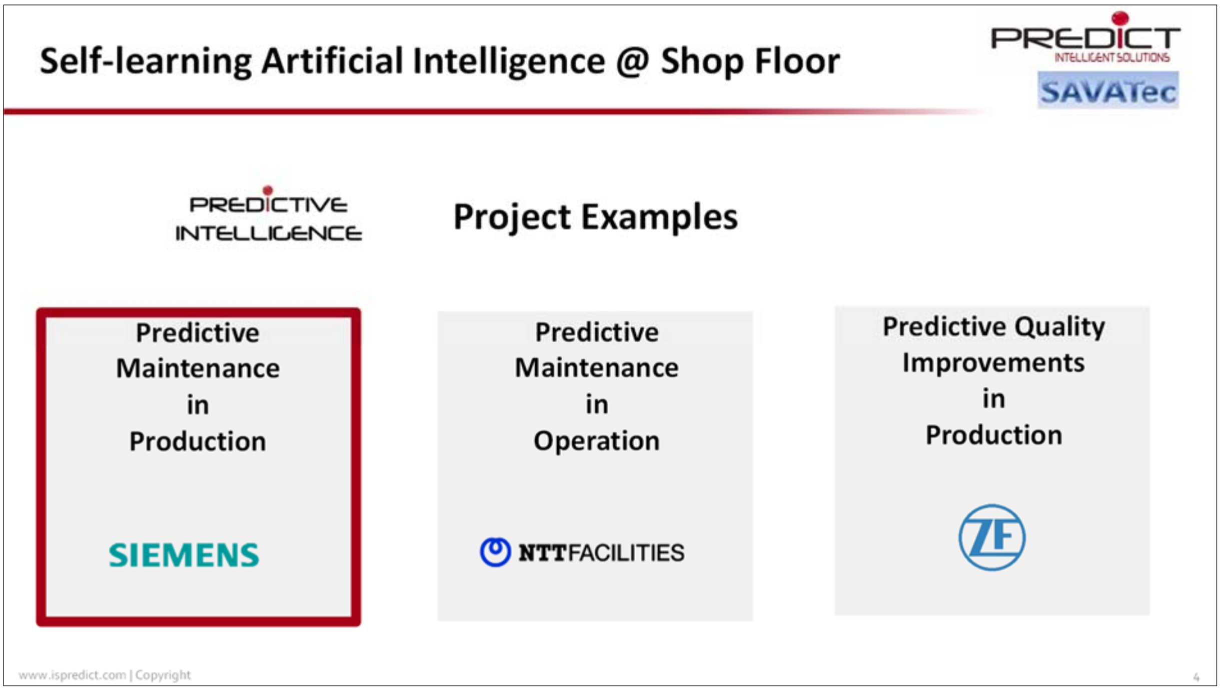
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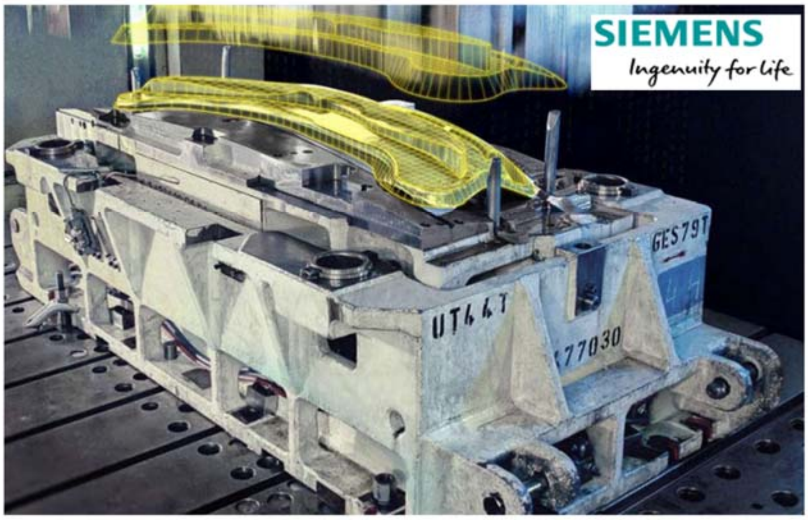
Predictive Maintenance in Production



 5

Predictive Maintenance in Production

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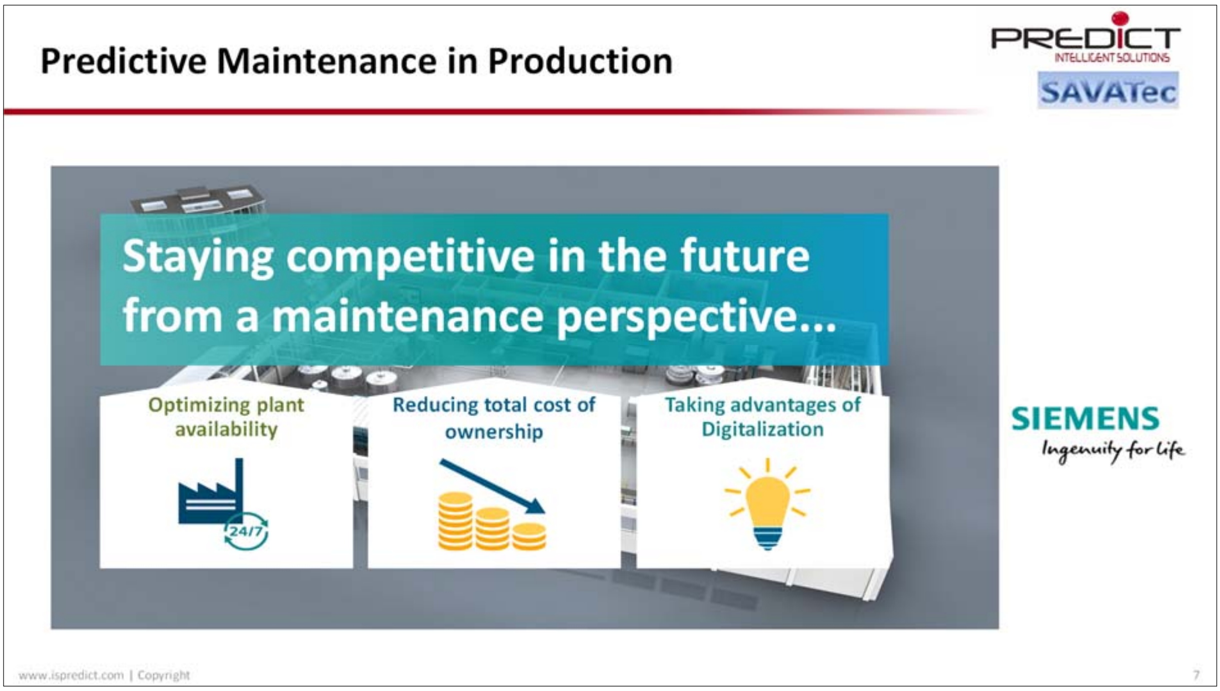
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Staying competitive in the future from a maintenance perspective...
Optimizing plant availability
24/7
Reducing total cost of ownership
Taking advantages of Digitalization
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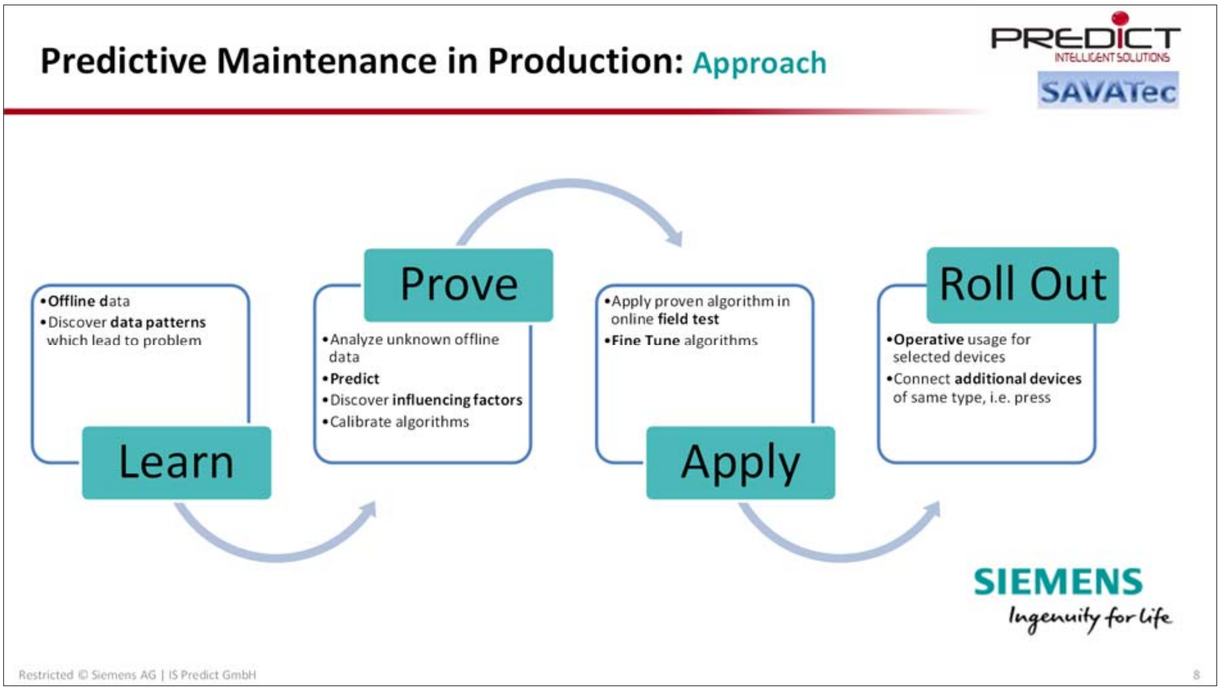
Predictive Maintenance in Production: Approach
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SAVATec
•Offline data
•Discover data patterns which lead to problem
Learn
Prove
•Analyze unknown offline data
•Predict
•Discover influencing factors
•Calibrate algorithms
•Apply proven algorithm in online field test
•Fine Tune algorithms
Apply
Roll Out
•Operative usage for selected devices
•Connect additional devices of same type, i.e. press
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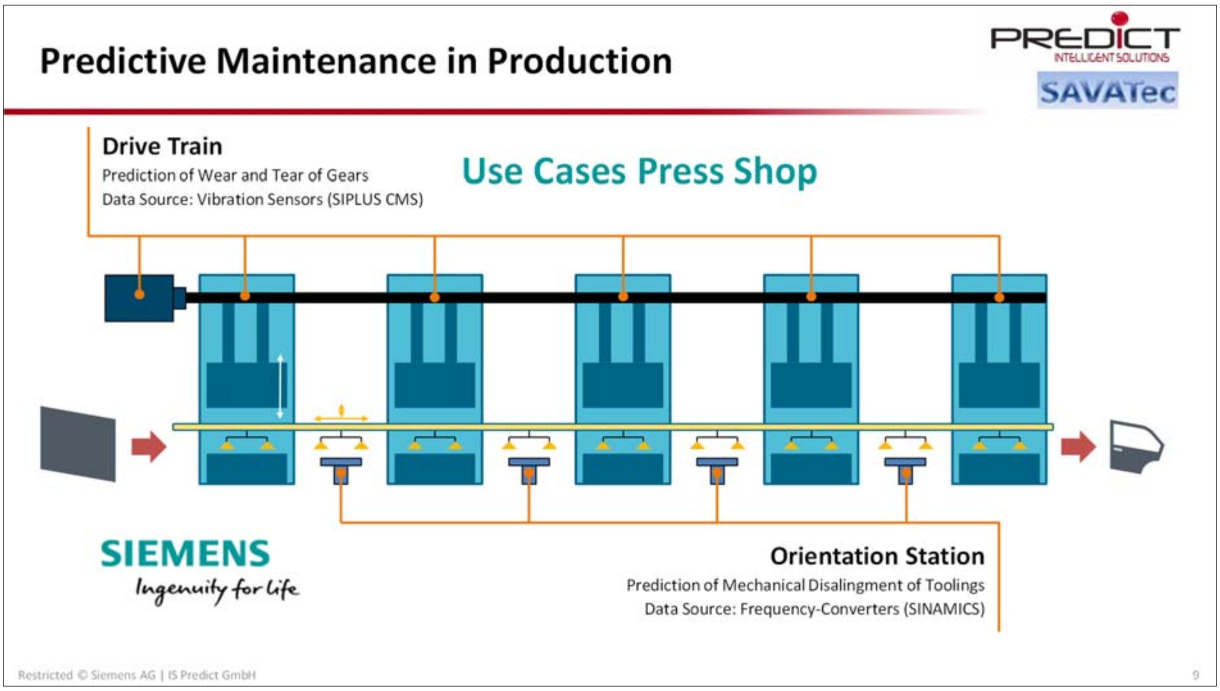
Predictive Maintenance in Production
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Drive Train
Prediction of Wear and Tear of Gears
Data Source: Vibration Sensors (SIPLUS CMS)
Use Cases Press Shop
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Orientation Station
Prediction of Mechanical Disalingment of Toolings
Data Source: Frequency-Converters (SINAMICS)
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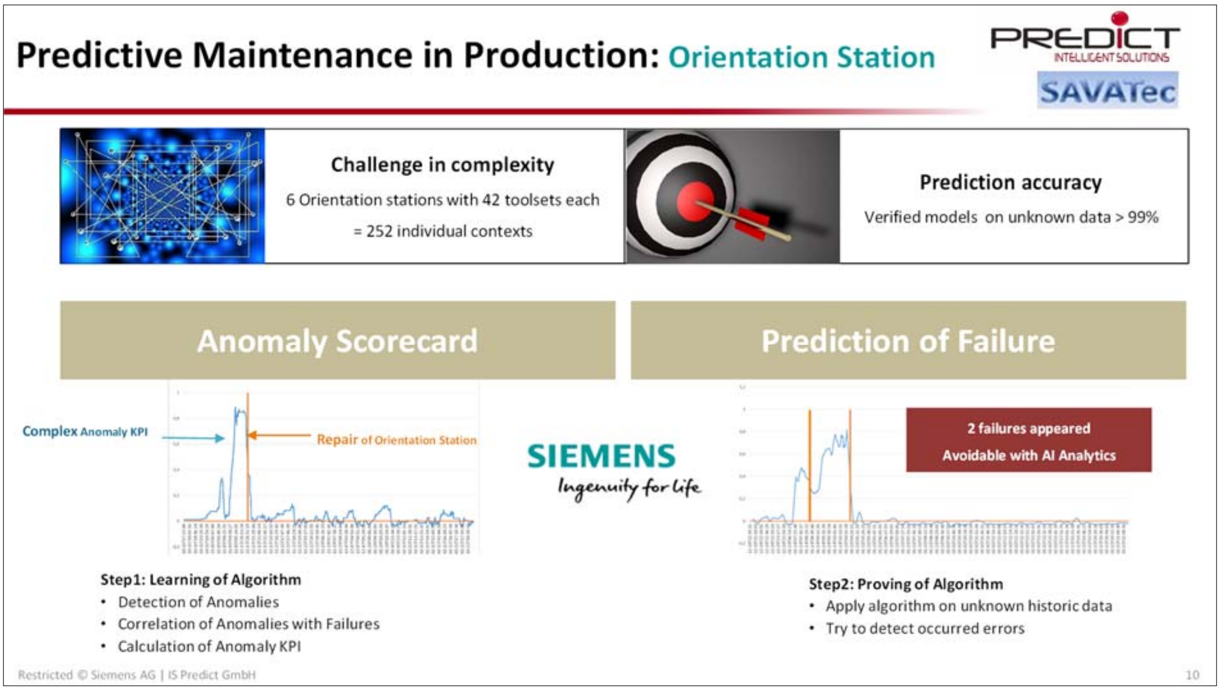
Predictive Maintenance in Production: Orientation Station
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SAVATec
Challenge in complexity
6 Orientation stations with 42 toolsets each
= 252 individual contexts
Prediction accuracy
Verified models on unknown data > 99%
Anomaly Scorecard
Prediction of Failure
Complex Anomaly KPI
Repair of Orientation Station
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Ingenuity for life
2 failures appeared
Avoidable with AI Analytics
Step1: Learning of Algorithm
• Detection of Anomalies
• Correlation of Anomalies with Failures
• Calculation of Anomaly KPI
Step2: Proving of Algorithm
• Apply algorithm on unknown historic data
• Try to detect occurred errors
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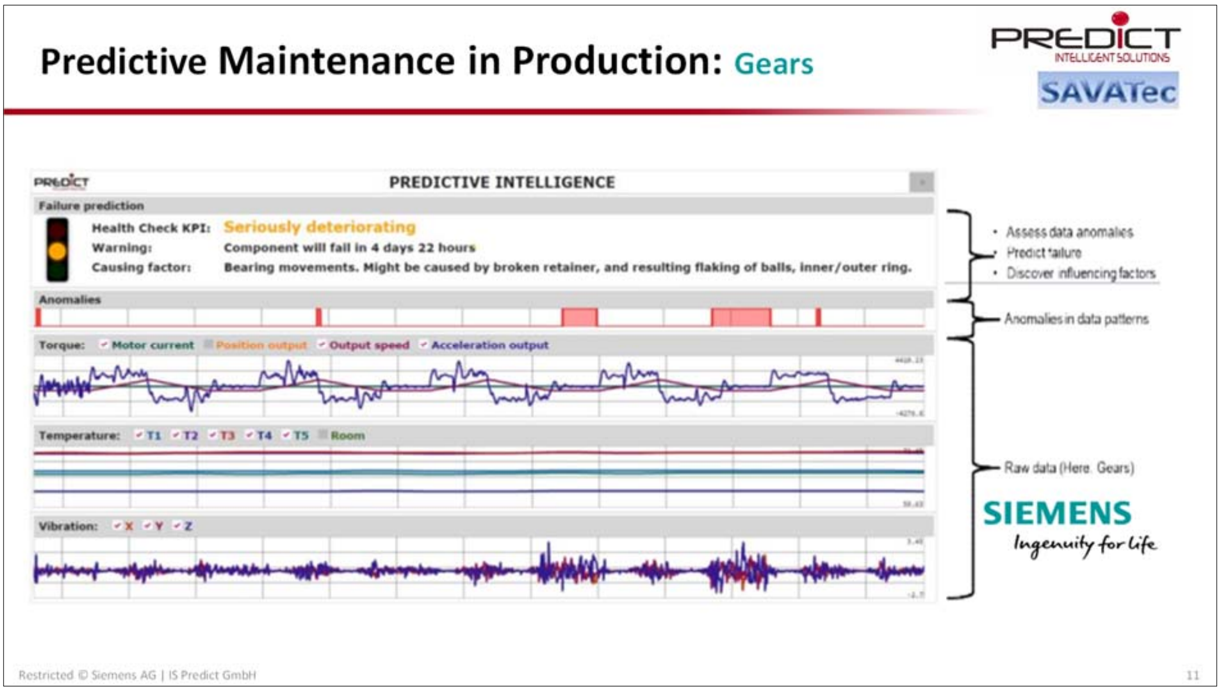
Predictive Maintenance in Production: Gears
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SAVATec
PREDICTIVE INTELLIGENCE
Failure prediction
Health Check KPI: Seriously deteriorating
Warning: Component will fail in 4 days 22 hours
Causing factor: Bearing movements. Might be caused by broken retainer, and resulting flaking of balls, inner/outer ring.
Anomalies
Torque: Motor current Position output Output speed Acceleration output
Temperature: T1 T2 T3 T4 T5 Room
Vibration: X Y Z
Assess data anomalies
Predict failure
Discover influencing factors
Anomalies in data patterns
Raw data (Here: Gears)
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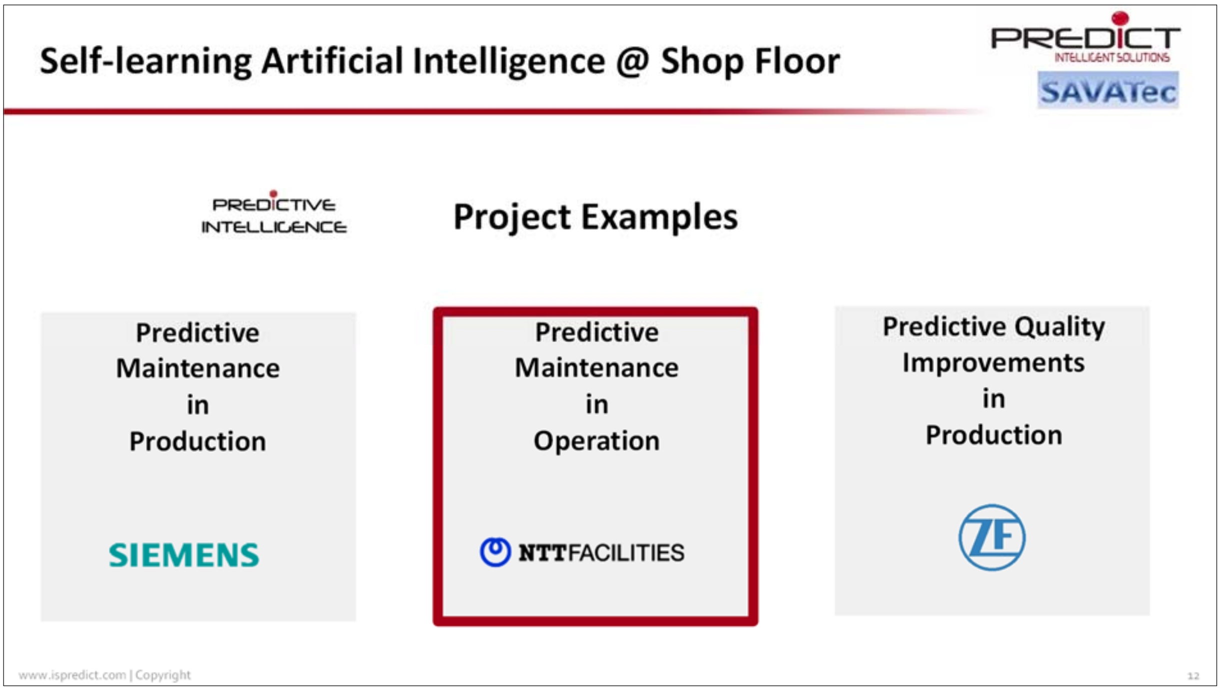
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Predictive Maintenance in Operation

PREDICT INTELLIGENT SOLUTIONS
SAVATec

Failure Prediction for Critical Air-conditioning System

NTT FACILITIES, INC.

"Building & Energy" company in NTT Group

NTTFACILITIES

13

Facility Segments

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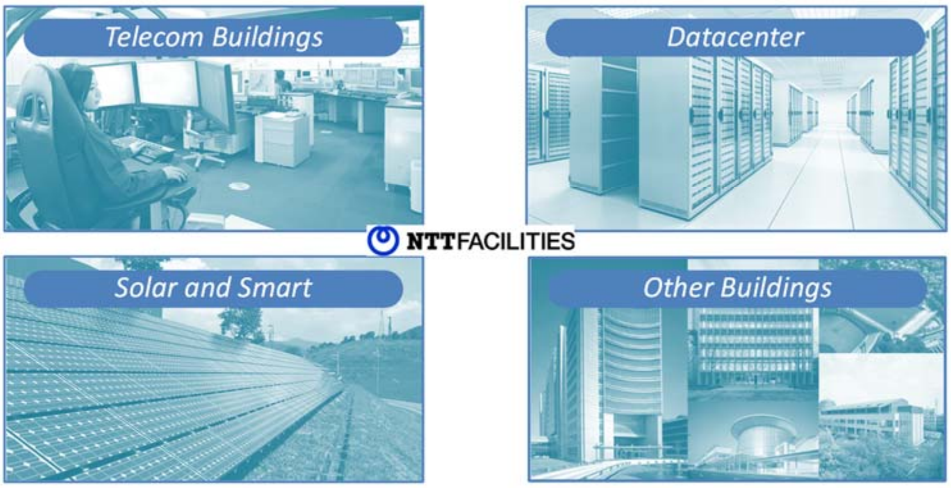
SAVATec



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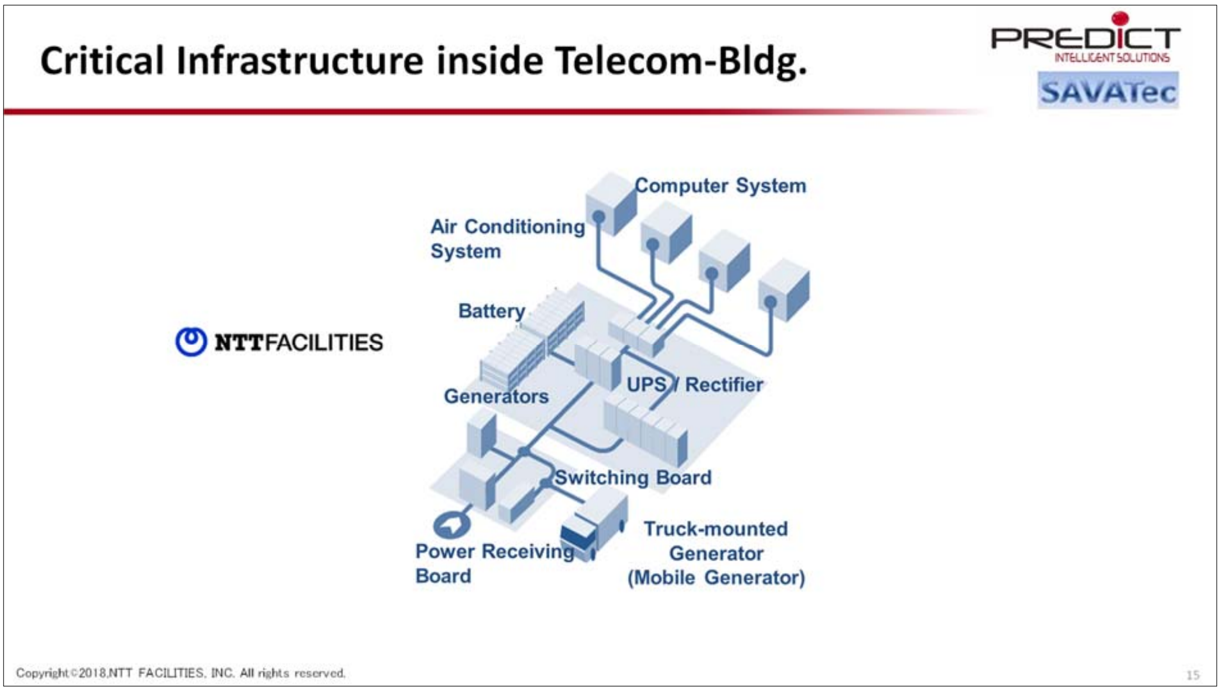
Critical Infrastructure inside Telecom-Bldg.
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SAVATec
NTTFACILITIES
Computer System
Air Conditioning System
Battery
Generators
UPS / Rectifier
Switching Board
Power Receiving Board
Truck-mounted Generator (Mobile Generator)
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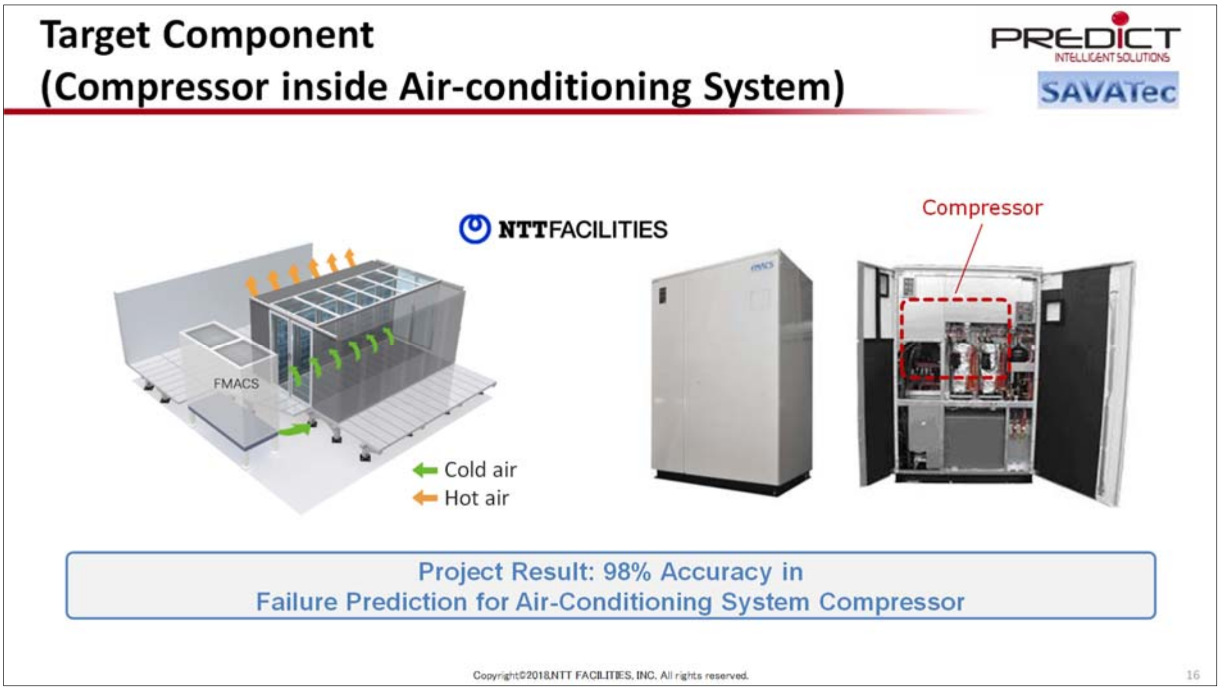
Target Component
(Compressor inside Air-conditioning System)
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SAVATec
NTTFACILITIES
Compressor
FMACS
Cold air
Hot air
Project Result: 98% Accuracy in
Failure Prediction for Air-Conditioning System Compressor
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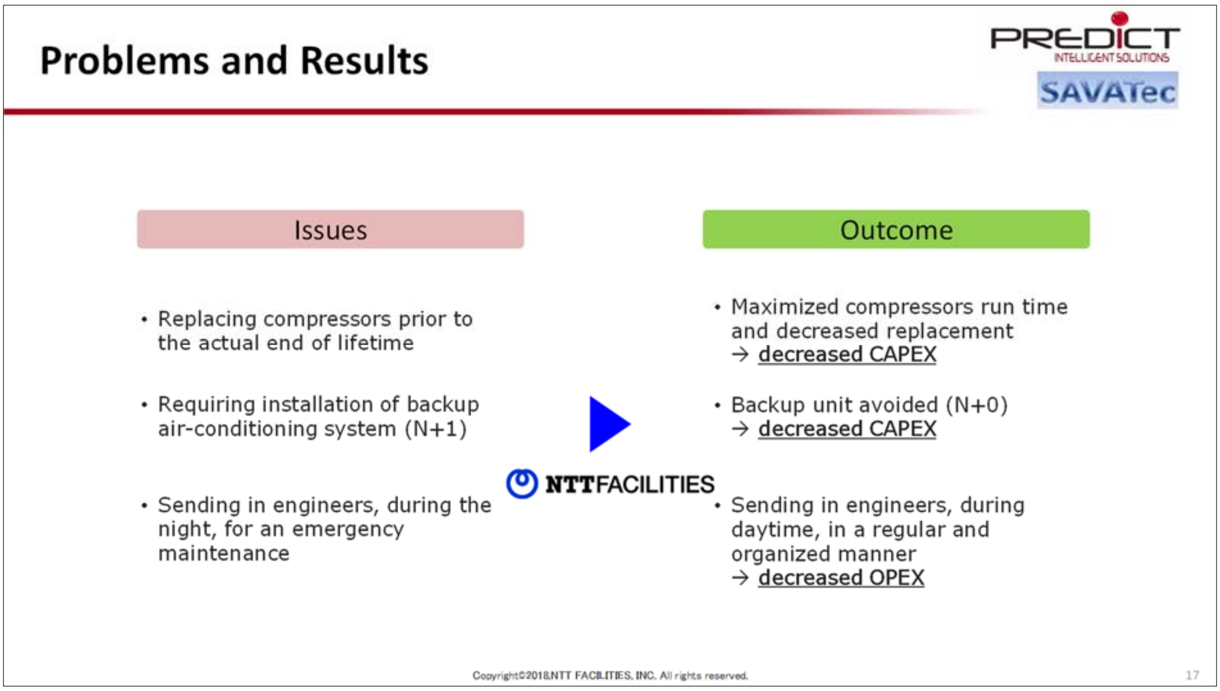
Problems and Results
PREDICT INTELLIGENT SOLUTIONS
SAVATec
Issues
Outcome
• Replacing compressors prior to the actual end of lifetime
• Requiring installation of backup air-conditioning system (N+1)
• Sending in engineers, during the night, for an emergency maintenance
NTT FACILITIES
• Maximized compressors run time and decreased replacement → decreased CAPEX
• Backup unit avoided (N+0) → decreased CAPEX
• Sending in engineers, during daytime, in a regular and organized manner → decreased OPEX
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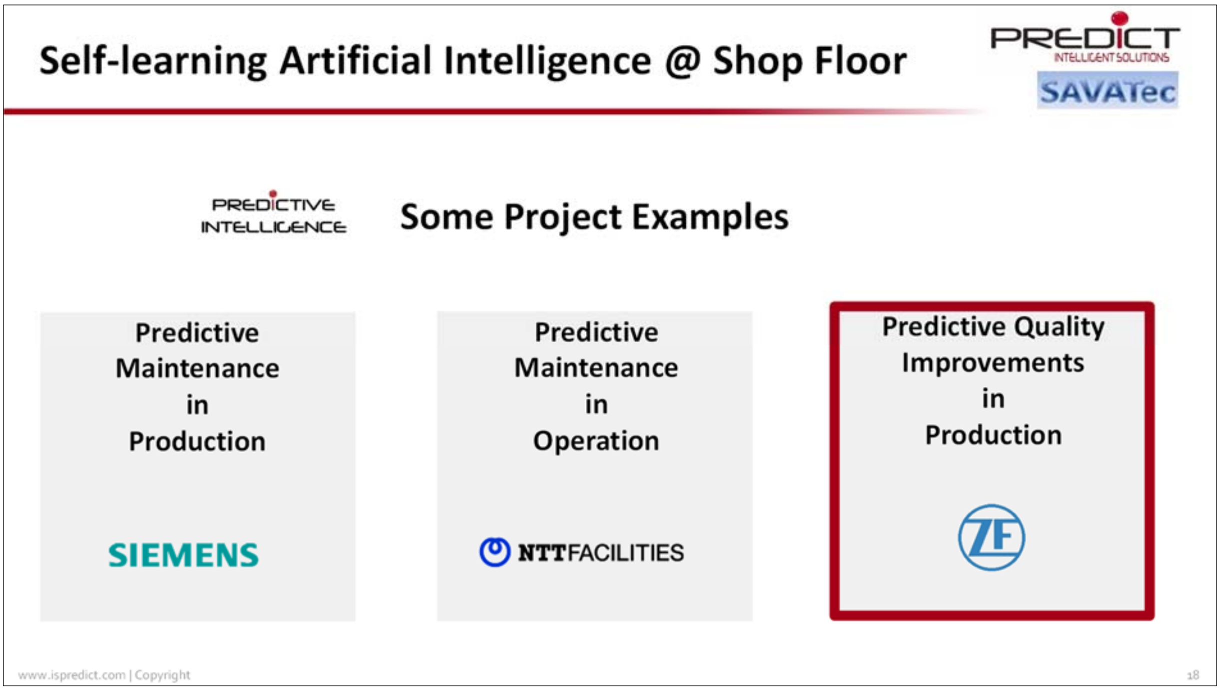
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ZF - CASE

PREDICT INTELLIGENT SOLUTIONS
SAVATec

Self-learning AI Improves Production Quality in Complex Variant Processing

8HP Transmission type and data processed for noise tests

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SAVATec

8 HP transmission type contents up to **600 parts**

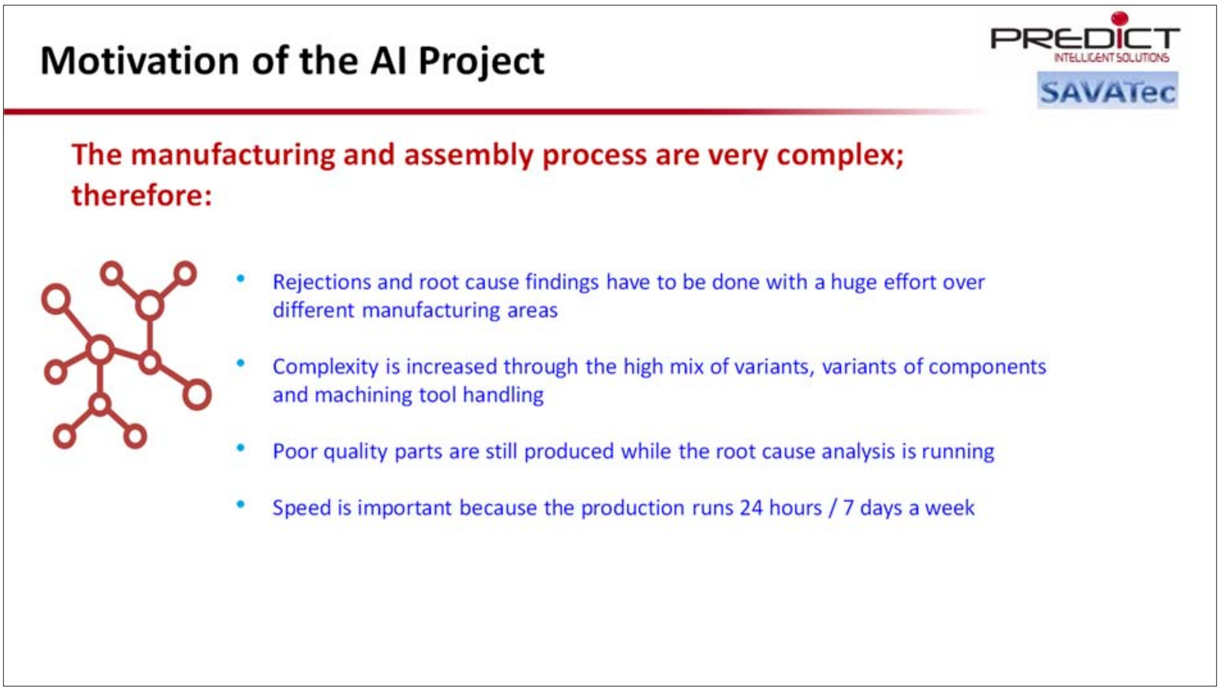
17 basic transmissions types in **700 Variants**

Data to be processed for analytics

Test bench
- Noise level measurements
- Acoustic test limit data
- Setups per test bench

Pre-assembly and final assembly
- Genealogy data and its adjustment values
- Traceability data from suppliers
- Traceability data from in-house machines

Manufacturing
- Same data type information than in assembly


Motivation of the AI Project
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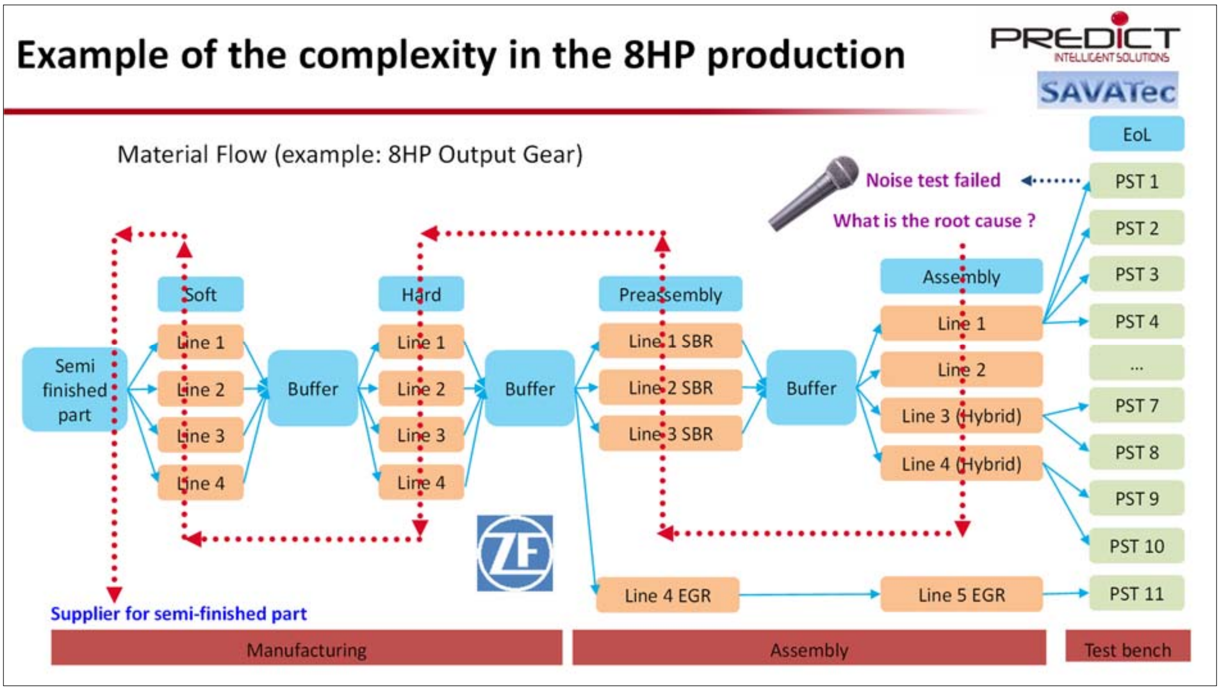
INTELLIGENT SOLUTIONS
SAVATec
The manufacturing and assembly process are very complex; therefore:
Rejections and root cause findings have to be done with a huge effort over different manufacturing areas
Complexity is increased through the high mix of variants, variants of components and machining tool handling
Poor quality parts are still produced while the root cause analysis is running
Speed is important because the production runs 24 hours / 7 days a week


Example of the complexity in the 8HP production
PREDICT
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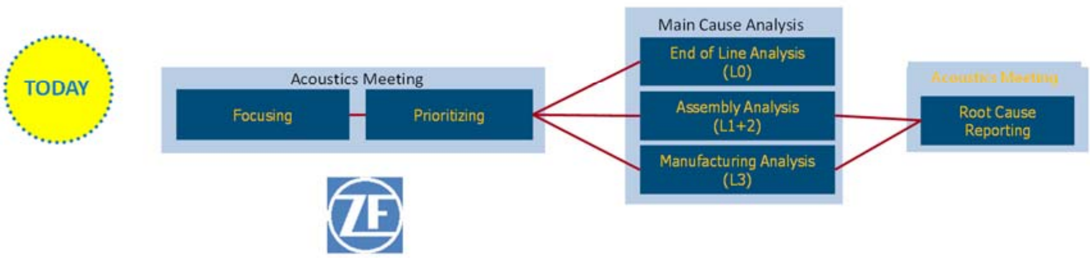
SAVATec
Material Flow (example: 8HP Output Gear)
Noise test failed
What is the root cause ?
Semi finished part
Soft
Line 1
Line 2
Line 3
Line 4
Buffer
Hard
Line 1
Line 2
Line 3
Line 4
Buffer
Preassembly
Line 1 SBR
Line 2 SBR
Line 3 SBR
Buffer
Assembly
Line 1
Line 2
Line 3 (Hybrid)
Line 4 (Hybrid)
Line 4 EGR
Line 5 EGR
EoL
PST 1
PST 2
PST 3
PST 4
...
PST 7
PST 8
PST 9
PST 10
PST 11
ZF
Supplier for semi-finished part
Manufacturing
Assembly
Test bench

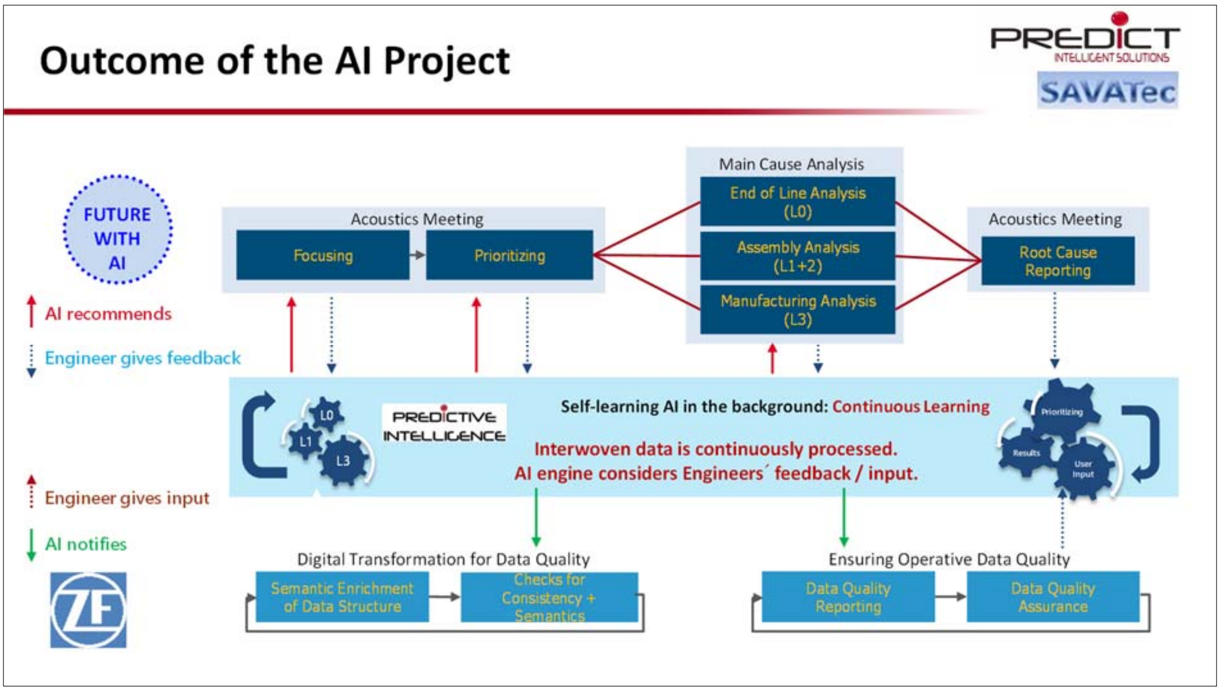
Motivation of the AI Project

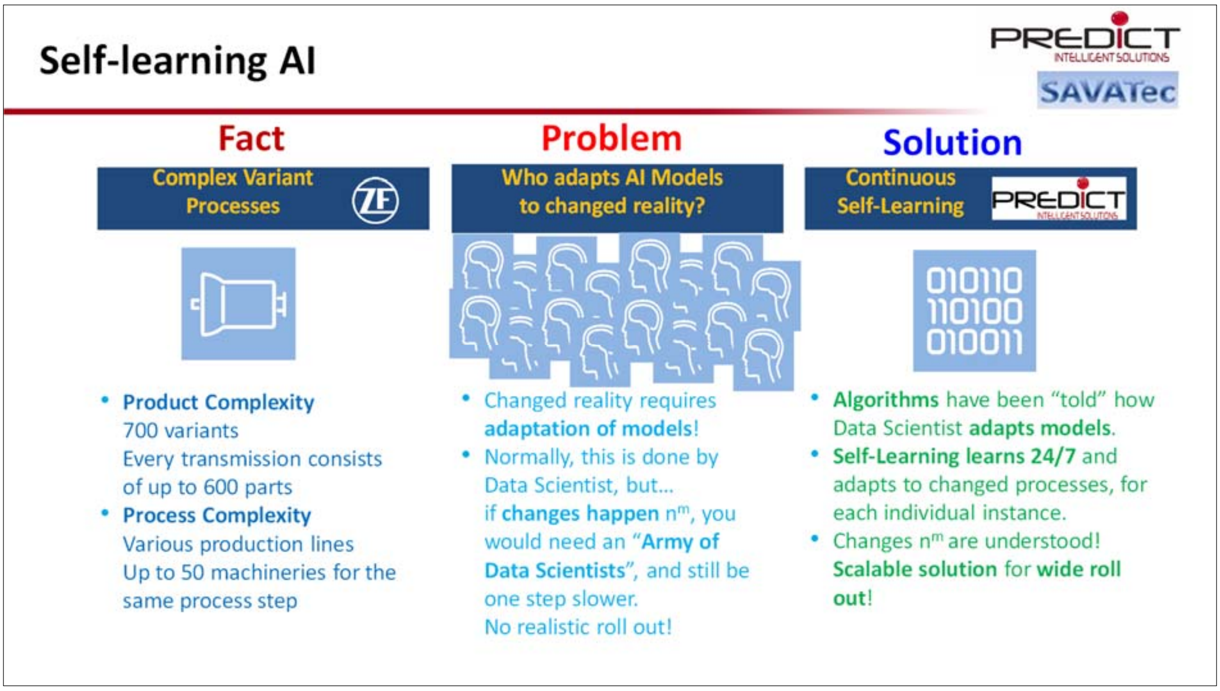
The target is to **reduce waste** in certain manufacturing domains **by 20%.** The **key success factor** is the **fast detection mechanism** within the production chain delivered **by AI**.

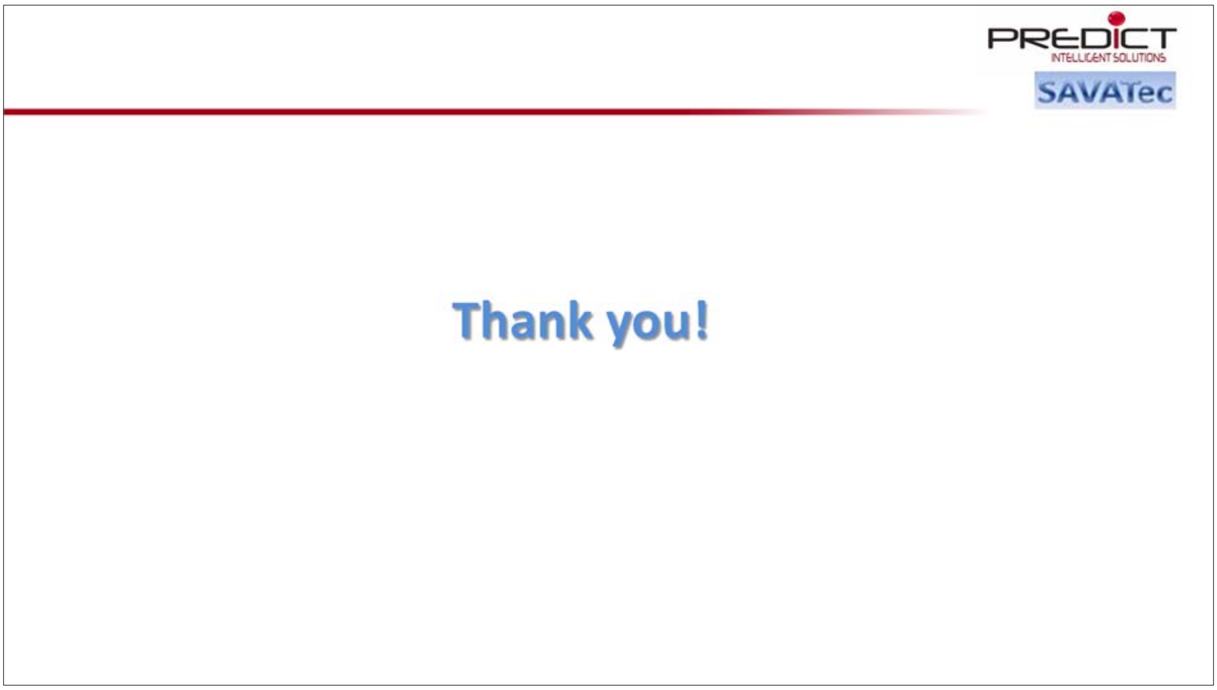
Involving an **experienced AI solution partner** with expertise in an AI solution, **proven on shop floor**.

Motivation of the AI Project (cont'd)




Outcome of the AI Project
PREDICT INTELLIGENT SOLUTIONS
SAVATec
FUTURE WITH AI
AI recommends
Engineer gives feedback
Engineer gives input
AI notifies
Acoustics Meeting
Focusing
Prioritizing
Main Cause Analysis
End of Line Analysis (L0)
Assembly Analysis (L1+2)
Manufacturing Analysis (L3)
Acoustics Meeting
Root Cause Reporting
PREDICTIVE INTELLIGENCE
Self-learning AI in the background: Continuous Learning
Interwoven data is continuously processed.
AI engine considers Engineers´ feedback / input.
L0
L1
L3
Prioritizing
Results
User Input
Digital Transformation for Data Quality
Semantic Enrichment of Data Structure
Checks for Consistency + Semantics
Ensuring Operative Data Quality
Data Quality Reporting
Data Quality Assurance


Self-learning AI
PREDICT INTELLIGENT SOLUTIONS
SAVATec
Fact
Complex Variant Processes
Problem
Who adapts AI Models to changed reality?
Solution
Continuous Self-Learning
PREDICT
010110
110100
010011
• Product Complexity
700 variants
Every transmission consists of up to 600 parts
• Process Complexity
Various production lines
Up to 50 machineries for the same process step
• Changed reality requires adaptation of models!
• Normally, this is done by Data Scientist, but...
if changes happen n^m, you would need an "Army of Data Scientists", and still be one step slower.
No realistic roll out!
• Algorithms have been "told" how Data Scientist adapts models.
• Self-Learning learns 24/7 and adapts to changed processes, for each individual instance.
• Changes n^m are understood!
Scalable solution for wide roll out!


PREDICT
INTELLIGENT SOLUTIONS
SAVATec
Thank you!

Eng. Ricardo Teixeira Ávila

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Sabó Indústria e Comércio de Autopeças S/A

Founded 80 years ago, innovative Sabó has sites in São Paulo capital and Mogi Mirim. Has a subsidiary in Argentina and holds a minor participation in Germany KACO. In Brazil, has 1.100 employees. From 1939, produces oil seals, gaskets and sealing systems for the automotive industry as global strategic supplier of GM, VW, among others. Received more than 200 awards and certifications as world technologies leader in engine sealing. Yet in 2012 speed up competitiveness through leverage methods and resources with its European plants. Modernization drivers include sustaining the production capacity (machinery and people reachness) over the road map plan while reducing labor, machines and lay-out occupation, by improving first time quality, and tooling solutions. Latest years Brazilian strong economic crisis and recession have directly affected the business working capital. Efforts on Lean and Industry 4.0 are key to reduce the needed cash flow to the business while producing components for fossil fuel, hybrid and electric powered vehicles.

Advanced Manufacturing: Enabling Industry 4.0 Solutions in Lean Operation Design and Management

Abstract

The fourth Industrial Revolution has promoted relevant impact on operations of Sabó - Brazilian multinational manufacturer. In this article we will explore the path that followed Sabó while crossing innovation borders in data management, about its processes and product portfolio, when yet mature, multinational and already 70 years of existence, it realized itself with the Brazilian operations technologically lagged and just a few enjoying cycles of installing methods and tools of management: lacked a true north and a road map. There was a basic deficiency to win – modernize in an environment in which the return on investment was slower, in competition with other units of the group. In the evolution of the text, it will be noted that the Brazilian units absorbed with adequate intensity the concepts of return on employed capital and accelerated strategies in the gemba (where the value is generated) to stimulate consensus and validate alternatives to maximize and anticipating success. We will conclude with the understanding of the importance of positioning the company as an user empowering 4.0 technology, not as an alternative explorer and / or solution provider, aligning its choices with the business and the evolution of the markets in which operate. This clear perception has been key to offering the best solutions to Sabó customers, ensuring business sustainability and respect for people, evolving in the facility that drives its plan to transform the Brazilian operation.

Keywords

Industry 4.0; Manufacturing strategy; Advanced Manufacturing; Digitalization; Shop Floor Automation; Artificial Intelligence; Analytics; Lean Development; Virtual Reality; Augmented Reality; Real time supervising; Autonomous Supply-chain

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1 Introduction – Sabó History and Highlights

Sabó was founded approximately 80 years ago, by José Sabó. Since its beginning, the company has stood out as an innovative enterprise always investing in research activities.

In the state of São Paulo it has an industrial park with a constructed area of 52,000 m2. In 2005, inaugurated a modern factory in the town of Mogi Mirim also state of São Paulo. It has a subsidiary in Argentina and holds a currently minor participation in the company KACO, based in Germany. In our country, it has approximately 1,100 employees.

Figure 1: Sabó São Paulo production site

Sabó produces oil seals, gaskets and sealing systems for the automobile industry. The company has widened its activities to different countries and has conquered different awards and certifications. Currently, besides supplying to large carmakers and the spare parts market, it is the Brazilian representative acknowledged as the global strategic supplier of companies such as GM, VW, among others.

Figure 2: Sabó products and markets

It is already producing components related to hybrid vehicles and is prepared to supply products for the future electric cars, thus contributing to the environment sustainability.

The company history begins in 1939 when José Sabó begins to produce chains for carriages. In 1944, with the difficulties caused by World War II, the company starts to produce oil seals demanded by the truck engines.

In the decade of 1950, the company made the movement of importing modern machinery and sponsored the first one thousand miles of Brazil, the traditional motor car race on the Interlagos race track in São Paulo-SP.

At the beginning of the ‘60s, always attending events of the automobile industry, it participates as exhibitor in the First Automobile Trade Show. In 1965, launched laboratories for product testing, focusing on oil seals.

From 1970 and on, the company becomes an international enterprise producing oil seals for the German brand Opel (company which belonged to the General Motors Group) and delivered technology to an important German auto parts Company.

Later on in the decade of 1980, the company received an award for being one of the best suppliers of the Opel Group. It began the ‘90s receiving the “Quality Excellence Award” of Isuzu Motors from Japan.

International consolidation was remarkably achieved through incorporating, in 1992, “Todaro” and ”Wol”, oil seals manufacturers in Buenos Aires, Argentina, and in 1993 the German company “Kaco”. The latter, invigorated by Sabó, became the “Premium” supplier of Volkswagen, Daimler, BMW, GM, Bosch, ZF, among others. In 1997, it inaugurated its subsidiary in Hungary.

The company accessed the new century enlarging its installations in Hungary and in Argentina. In 2005, it inaugurated its modern plant in Mogi Mirim. To crown its international growth it inaugurates, in 2007, a plant in the United States (North Carolina) in order to directly supply to the American carmakers and inaugurates, in 2009, a plant in the Chinese market (Wuxi).

Figure 3: Sabó Mogi Mirim production site

The company has always stood out by its advanced technology having received more than 200 awards and quality certifications. It is world leader in vehicles dynamic-sealing technologies.

In 2008, due to having been assessed as Level 4 in Governance by the IFC-International Finance Corporation (financial branch of the World Bank), it obtained important financing in US dollars. This loan, which allowed entering into the Chinese and North American markets, made it possible for the company to achieve one billion *reais* worth of annual turnover. Indeed, the net revenues which in 2002 amounted to US$ 150 million increased in 2008 to US$ 400 million.

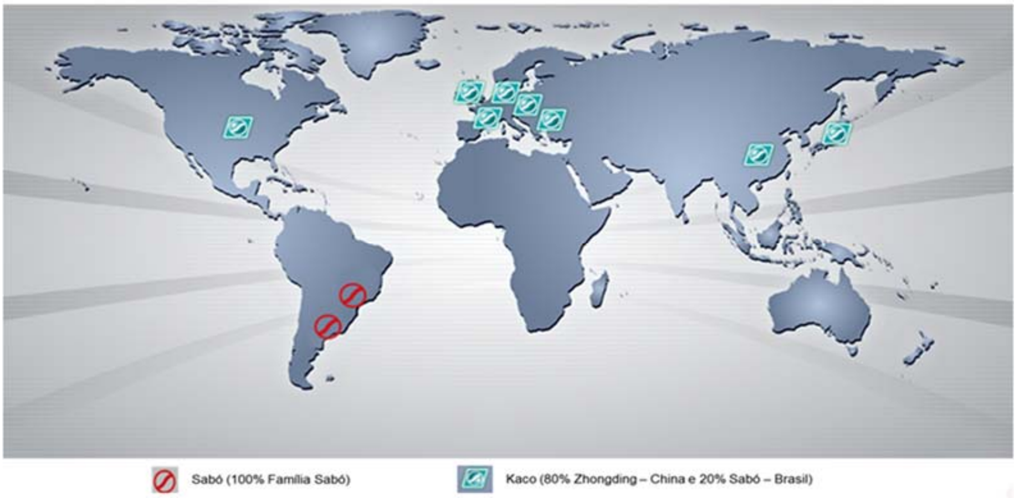

Figure 4: SABÓ and KACO Global Presence

In the last quarter of 2008, with the worldwide financial crisis, revenues dropped by approximately 35%. The consequence was the need of reducing costs and face higher obstacles to comply with the amortization of the debt. In 2014, Sabó sold 80% of its Kaco shares to the Chinese company Zhongding Europe GMBH; thus, the company substantially reduced its indebtedness.

The latest years have also been marked by the strong economic crisis and the recession which have ravaged the country directly affecting the company's business activities with a reduction in the turnover in the Brazilian automobile market and a decrease in profit margins. Due to this scenario, the company stressed its working capital and competitive efforts on Lean and Industry 4.0 have been a big focus and the way to increase inventory turns while reducing the needed cash flow to the business.

Yet in 2012 Sabó took its way to speed up the competitive efforts at Mogi Mirim plant in order to leverage the methods and resources in comparison to its European plants. Was noticed high potential related to the load and unload components at the rubber vulcanization main processes plus the need of quality improvements and best service supplies on maintenance.

Started to design the Modernization of Mogi Mirim plant keeping in mind the drivers of sustaining the vulcanization capacity over the road map plan (machinery and people) while reducing the job stations and the absolute number of employees: strategy involves automation and first time quality in general plus quick answers to any turbulences. Sabó's CEO and Industrial Director stablished a goal in terms of the amount of old equipment which could be de-activated each week. Sabó cumulated 18 years working with Lean Technology and started arguing, studying and implementing its pillars and some proof of concepts on Industry 4.0 from 2013 on. The modernization is currently on track through elimination of old equipment and through adding smart devices, tools and machinery which can really innovate and disrupt the regular processes.

Figure 5: Sabó Mogi Mirim internal facilities

2 Advanced Manufacturing Commitment – Enabling Industry 4.0 Solutions on the Design and Management of the Lean Operation for the Sealing Industry

Currently attending the major automotive global players locally and worldwide plus the aftermarket demands, Sabó exports from its Brazilian sites more than 20% from 7 million parts produced per year. The supply chain basis is considered as important as its internal operations to reach the high quality level of the hard- technological products on static and dynamic sealing Sabó produces. Some of the involved suppliers depend on running leased tooling developed and owned by Sabó. Special tooling are designed and built through the collected competences of its engineering team and have maturely being used in internal core activities and processes.

The vulcanization of rubber is the principal core competence but is yet very important the dominium of special receipts and formulas applied to prepare the rubber batches from powder as it is so well focused the termination of the products while including automatic trimming, inspection, handling, assembling and packaging. From packaging to the distribution, competitive solutions are also required: providing services to customers – meaning original equipment suppliers or Tiers (OEs), and aftermarket distributors (AM). The complex tributary business environment moved Sabó and the AM customers to structure the business in a way that Sabó reaches the deliveries to each subsidiary from the distributors in different Brazilian states so far performing more than 500 diverse points of sales.

Digitalization and advanced manufacturing tools have proved key resources to boost competitiveness to both high volume and low volume parts to several applications in the dynamic oil seals and the static sealing gaskets. In Sabó large portfolio experience there are manufacturing lines and cells driven production to attend light and heavy vehicles, four or two wheels, off-road vehicles, truck and buses, considering engines, gears and rub wheels, for instance. Also Sabó plants have been delivering solutions to the white goods appliances, agricultural machines and to the small mechanical tools important markets.

2.1 Competitiveness Approach and Profitability Focus Considering Industry 4.0 and Smart Manufacturing Technologies Availability

Industry 4.0 has been presented as a recent big world wave and introduced in each nation with different nicknames – in Germany it is named as *Industrie 4.0*; in United States it is the Smart Manufacturing; in China is the Made in China 2025; in Japan the big governmental program is the Industrial Value Chain Initiative; in India the Make in India; in French the program is the *Industrie du Futur*; In Brazil we have some movements from the Industries National Confederation (CNI) and Evaldo Loti Institute (IEL) and the Entrepreneurs Movement to the Innovation (MEI) whose approach has raised the flag of Brazil 2027. The Brazilian Industrial Development Agency (ABDI) on the other hand prefers to adopt and stimulate the Industry 4.0 already so known in the world. The last has its strategy very closely connected to the Commercial and Industrial Development Ministry (MDIC) which have mainly worked on stimulate the industry movement in a route to a "more productive Brazil".

In this way it is understood by the Ministry the need to better organize the production sites considering basic stability and lean techniques plus basic automation to command individual workstations and machines as well and which matches the boundaries of the previous generation of technology (Industry 3.0) in the same way as the basic robots application approaches. Sure such an approach is seeding the land to open space to more advanced technologies from the Industry 4.0 – so far connecting several and different work stations, command those through an unique smart system and collecting data in real time performing analytics with some complex mathematics algorithmic and providing auto-correction and auto-supervising to the work cell.

The complete framework of the Industry 4.0 up to the moment should include the application of system integration, industrial internet of things (IIoT), engineering simulations, additive manufacturing, cloud computing, augmented and virtual reality, big data, cyber security, and autonomous and collaborative robots (named as cobots).

Sabó has been evolving the lean techniques application through its processes for the last 18 years. From the more recent years, the maturity of its Supply Chain has increased and is continually focusing the goal of an Autonomous Supply Chain really making use of the system integration, big data, cloud computing, IIoT among others, always to boost "agility". Agile is the name of the game! This is the big substantive to keep in mind when arguing about the Industry

4.0 as defend the VDI 4000 guidelines (*richtlinie* in Germany) – VDI is the German Association of Engineers (or the *Verein Deutscher Ingenieure*). Connecting Industry 4.0 initiatives and smart work stations to the ERP (Enterprise Resource Planning system) is key. Sabó has been working with the German R3/ SAP system since 1999 and has it as an important solution to deal with its portfolio.

Sabó has in Brazil more than 4000 part numbers in production. Some like 40% of them work every month but yearly all of those have inventory turns. The reality of Sabó Mogi Mirim plant includes 800 distinct part numbers.

One of the R3/ SAP modules in rich application at the Sabó manufacturing sites is the COPA module to better manage the Cost Profits Analyses in several different clusters like per account manager, per region, per customer, per cost center, and others. From excellence in managing the portfolio profitability and competitiveness Sabó has been driving its priorities and project management on implementing Industry 4.0 resources. The bright is on considering itself as an important user not as a developer, as well as to exercise several proof of concepts in line with its competitive demands, not running to the technology only because of its disruptive nature. Dexterity on the use and outstanding skills on applying the Industry 4.0 resources and pillars is an important choice Sabó made.

Presented the Sabó portfolio the reader can access the footprint with large volumes and low volumes demands. The transition to move the large volumes cells to the newest technologies is hard working in terms of risks and commitments, but the kind of transition to deal with the low volumes cells is not so different – must take advantage of customizing techniques and new resources. Mass customizing is still very new in this automotive marketing sales – Sabó has faced lower and lower volumes to attend special needs to very old vehicles (Sabó Classics) and to imported vehicles in low scale which still have not local manufactured parts (Sabó Imports). Low volumes techniques can remember us handicraftsmen so capable to produce single parts batches, but imagine digitalization additive manufacturing and others connecting the processes to speed-up the process and drive the line to connect the customer, the manufacturer, the raw material and , why not, to guarantee the circular economy through recycling.

The nomination Industry 4.0 so far is a choice that justifies itself from understanding the very initially known manufacturing processes. Industry 1.0 now is understood as the work of the isolated handicraftsmen working to attend the neighborhood. Industry 2.0 is understood as the Taylorism which splits standardized work in small stations and drives repetitive tasks through a manufacturing chain. Industry 3.0 is finally understood as robotization and automation of the work stations spread in a factory, plus the adding of numeric control commands (CNC) or programmable logic controller (PLC) to the same stations. From that point, the connection, digitalization and next generation resources are conceived as Industry 4.0.

2.2 Creating a Long Term Approach to the Industry 4.0 Strategies and Providing Identity to the Internal Program: The A3 Project

In 2012 Sabó set a new competitive agenda at its facilities in Mogi Mirim. There were several opportunities to leverage the technologies available in the manufacturing process in comparison to the European plants of the group. A big amount of benchmarking visits were made since the 90s among Sabó and Kaco, but all of those were concentrated in specific research and development (R&D) projects- an holistic approach was in lack. Up to the moment Sabó Mogi Mirim plant had 712 employees and the productiveness was set very lower than its potential. So Sabó sent the Industrial Director and a Technology Manager to execute a new two weeks benchmarking in five different industrial sites – spread in Germany, Austria and Hungary.

The visits raised lots of important points which were organized in a complete book later shared with Sabó shareholders, directors, managers, coordinators and supervisor. Important items worked in the backstage to guarantee quick reaction and support to the operation plus well succeed implementation of new technologies in the factory but one from those took special attention: there was not segregate structure to deal with process design and development in contrast with the structure encharged for maintenance of the current processes. In Brazil, Sabó often faced arguing regarding the trouble the maintenance structure had to maintain the "not robust enough" solutions from the R&D team, on the other hand the last complained about how disturbing were the repetitive efforts to teach the maintenance people and providing their absorbing of the new techs due to "lower competences" or "lack of commitment".

Tackling the scenario, Sabó's choice was build a frame where it emphasized the timeline to paste the learned technologies from Europe (from the beginning the initiative was going to copy and paste) in a way to take care about internal knowledge and commitment. Questions to answer while in the road were: "how to manage the human talents in the long term?"; "how to perpetuate the learning process?"; "how to obtain external support from the government and sector skilled entities to review Sabó's internal people soft and hard skills?"; "which would be the new required professional certifications standards?". From the start the board of directors understood the competence of Project Management as an outstanding resource to reach its goals.

As premises were spotted developments of Proof of Concepts (PoC) and initiatives that could impact and create enthusiasm to stimulate commitment and people engagement. The intention was to answer a general question about from where to start: Sabó chose to organize that non-dependent of the customer or the contribution margin or the age of the processes and machines, but instead of it was considered the potential to overcome obstacles and engage creating rebounding waves effects. Different points a little bit far from one another were selected as well as 10 different strategic programs to deal with the Industry 4.0 scope. Among the strategic programs there were 47 lines of action and initiatives.

The strategic programs were:

- Collaborative robots (cobots);
- Innovations over the rubber compound preparation;
- Energetic efficiency;
- Internal supply routes modernization;
- Manufacturing Execution System (MES) and real-time management;
- Mobile devices;
- Big-data and cloud computing applications over the Product Lifecycle Management (PLM);
- Flexibility to prototype and/ or attending low volumes;
- Product portfolio innovations;
- Other processes innovations

In 2016 was built an A3 Project (as recommended by Lean experts and considering the shape and size of a paper sheet) where Sabó drew a road-map with the prioritized items to reach a 2024 scenario. Important partnerships were raised and closed to perform required research and development plus supporting the implementation – government agencies, scientific and academic institutes, service suppliers, small and micro businesses companies complete the innovation ecosystem for Sabó.

2.3 Understanding the Overall Industry 4.0 – A3 Plan to Boost Rhythmic and Sequence on the Competitiveness Efforts

Since its foundation Sabó had an innovative soul over the processes and was in the 90's that took the decision of stop internally developing new machines and devices. Before that, had even had a business unit whose name was SAMAPRE (*Sabó Máquinas de Precisão* or Sabó Precision Machines). Competences as Project Management came from there and when closing the business unit Sabó moved to keep the main specialists in machines design, laser inspections, electronic engineers and others. In the very beginning of the subsequent decade, Sabó stablished a team to rethink and organize new protocols, work instructions and standards over the Integrated Supply Chain Management. Digitalization started to be focused. Decentralized systems were buried while growing up the R3/ SAP reach. Also the Integrated Development Flow to deliver high technology and quality over new products and processes was rethought and drawn with new protocols and standards. Simultaneous engineering and fast decision making was stimulated leaning the indirect structure and eliminating barriers previously noticed in the company organization chart. Those topics were dealt with while advancing with the Total Predictive Maintenance (TPM) and the Lean Management pillars implementation. Too many troubles were faced on the way: mainly was the challenge of diverse processes and product lines considering a so vertically integrated process flow. Then Sabó made some important choices, set and reinforced its core business and core competences. Processes not considered among the core were outsourced or discontinued and eliminated their competition in terms of investments and management attention. It took around 10 years to prepare the business frame. Meanwhile people got prepared and used to Change Management and frantically working on lean principles – making mistakes, fast learning and correcting.

When joining this current decade, Sabó Brazil representatives were in Germany, Austria and Hungary as stated before. New resources were demanded to be absorbed in South America facilities and to finance was challenging. The cheapest and most reachable financial resources were committed with the operational cash flow in the shape of materials inventory. In the defense of agility and improving the lean management, Sabó team tackled the speeding up of inventory turns to reduce the amount of capital locked in the cash flow. Implementing new assets while and from improving the productivity of employed capital was key.

Value stream mapping, A3 management, one piece flow, heijunka box, kanban system, standardized work, lean leadership, “go & see” approach and strategies like those become commonplace. Mentoring managers, supervisors, engineers and technicians through the production chain in daily basic routines is part of the picture. Technology availability put lights on first time quality and turn easier conquered new certifications. Laser inspections, the warehouse management system, fast response, and IIoT devices among others open space to new business opportunities and to dream further. Being predictive in quality includes treating data through analytics and machine learning. All the Brazilian plants Sabó has were prepared to offer robust Wi-Fi spread in the plant layout, facing potential interferences from the running assets. Cloud computing is present for more than five years.

Always thinking two different mainstreams and respecting the reality from each one of the markets Sabó plays, meaning Aftermarket or Original Equipment, currently there are activities and PoCs on:

- Mobile APP to people management;
- Energetic efficiency;
- Shared economy;
- E-Commerce;
- Mobility;
- Electronic kanban;

- QR Codes;
- Paperless factory;
- Profitability management;
- Algorithmic applications;
- Big data;
- Commissioning;
- 3D Scanning;
- Laser manufacturing;
- Additive manufacturing;
- Mass customizing;
- Biometrics and Traceability;

…those organized among the strategic programs.

3 Obtained Results – Smart Solutions in Practice, Quantifying or Qualifying the Deliveries

More than a half of the Mogi Mirim plant layout was turned free after redrawing and executing the new designs of manufacturing cells in leaner value stream maps enriched with fast response sensors and smart devices. Now there is open space to grow up. More than 40 old technology machines were deactivated and only six new ones were bought, keeping the same net installed capacity. Quality scrap rate improved 60% and OEE (overall equipment efficiency) improved 45% in five years. Electric power consumption to run the net installed capacity decreased nearly 40% in the same timeframe. Medium time to repair (MTTR) the machines moved from nine to five hours and are still improving. Medium time between failures moved from 300,5 hours to 590 hours.

The unavailability of the equipment when scheduled to work moved from 8% to less than 3%. Job stations were reduced to a half from the original and more than 30% of the balance are still working in the plant due to new business conquering from a more competitive position. New businesses are being reached increasing the market share to current developed product and also by speeding-up the development process to new products and services, offering new and special solutions to the customers in both attended markets.

3.1 High Volume Oil Seal Manufacturing Cell as the Initial Proof of Concept

By changing the main vulcanization concept process from compress molding to the injection molding and from single injection nozzle to multiple injection nozzles, Sabó implemented regular and repetitive good results and stabilized the tasks to finish the work in process components. Celebrating results, the number of cavities to vulcanize at the same cycle were incremented step by step till fulfill the machine main plate, adding technologies over the cold runner blocks. Was reachable and executed full automation to load and unload the components while connecting post processes till the packaging in a single line, without overflow transferring from a transportation box to another.

One can realize step solutions in the middle of the process flow, connecting conveyor belts, adding sensors, empowering the integrated systems to qualify the produced goods and make decisions from previous set conditions. Real-time data is collected and offered. Previous scenario was a manufacture line with 15 job stations per shift. Now it is a manufacturing cell with a half employee per shift (sharing the new workstation concept with a different cell which crosses the flow). The new workstation concept is focusing not a single machine but instead a small ecosystem of connected machines that “talk to each other” creating and exchanging data, making decisions – next step is on track and one of the non-disclosure agreements, which matches different partnerships, is preparing the system to learn, predict and self-adjust.

Optimism is related to the fact that this manufacturing cell is quite similar to the great majority of the others dispersed around the factory. Multiplying the solutions is an in progress activity. The load and unload process considers automated feeders and a cobot plus conveyor belts. Cobots were implemented taking into consideration new labor safety resources as well area scanners and track designs plus programming the cobots itself. Cobots are friendly but the finger grips can injure depending on what they collide.

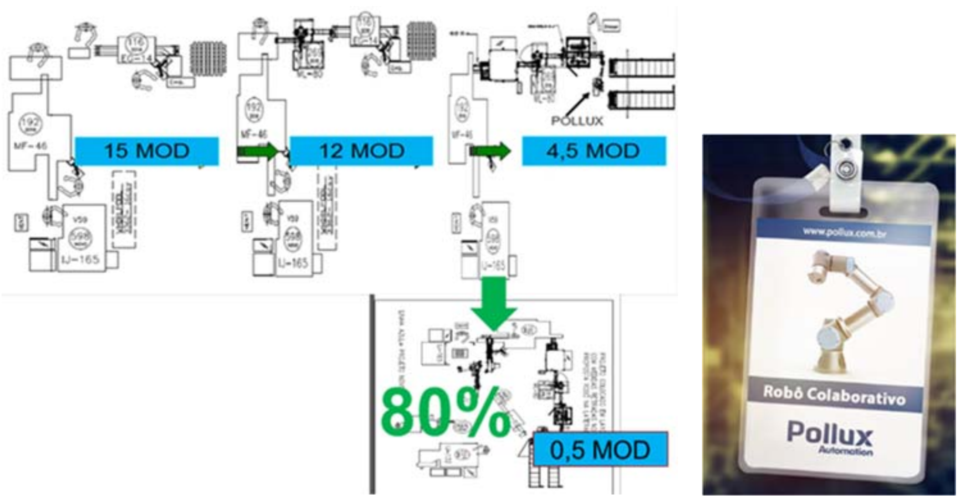

Figure 6: Manufacturing cell with cobots

3.2 Virtual Simulation and Digital Twins in Parallel to Augmented Reality – Exposing the Team to Learn and Deeply Understand When to Consider Each

Productiveness advances are often requiring new designs of manufacturing cells and reviewing the layouts to reorganize transformed processes. Flexible workstations and quick connectors to supply compressed air, vacuum, energy and water as examples are always suggested best practices, but well developing a plan and deeply studying alternative solutions can drive to better and quick results. Digitalization of the process flows is an important new trend. After managing the digital construction of mirrored resources one can promote small and sensitive changes to evaluate the impacts in a free from risk environment and while the real manufacturing cell is generating value to the stakeholders, so far without causing turbulences under the manufacturing. Sabó has been using the virtual simulation or the digital twin mainly to develop new products and processes manufacturing cells. Even during the acquisition of assets we can exercise and predict the effects and opportunities of alternative layouts.

A complete work cell was drawn to simulate an important crankshaft output flange sealing system. From it we could make synchronic movements searching for the better speed to set as takt. We could confirm the best solution to guarantee quality and lean costs plus simulate turning shifts strategies to the employees. Also the connection to the feeding supply routes: when and how often to deliver package cartons? When and how often to take and to move finished goods away from the cell? When and how often to bring raw material to the cell? (Virtual simulation experiences can explore the senses without connections to the real world).

Those are specific questions not so tightly connected to the use of the second focused resource: augmented reality. This last technological opportunity explore digital data, media or sensors extracting data in connection to the real world – a person can point a device to recognize special signs or plug-ins over images taken in real-time from the real available manufacturing site. In this case Sabó is taking advantage from augmented reality to train people who are driven to new or changed job stations. Several times only written standardized process flow and work instructions cannot be considered enough to train people. Through repetition and discipline, with slow movements to be followed, focus people can speed-up their learning curve. This is the case Sabó has: pointing a mobile to a standardized work sheet an employee can access a small media with the standard process being performed by a colleague or an actor having narratives to explain it step by step and including why not doing it in different sequence.

Other uses are not experienced yet in the plant but have been explored with specialists and through benchmarking, turning possible to an auditor or inspector, for instance, capture data metrics from the process, just pointing the mobile – such a technology adds virtual information to the real world. Sabó is evaluating the use of that.

Figure 7:Sabó virtual reality simulation and augmented reality initiatives

3.3 Other Smart Solutions in Practice Including but Non-Limited to Additive Manufacturing, Laser Manufacturing and Biometrics Traceability

A collection of new technologies has been spotted as “smart” due to add disruptive potential and/or the analytics matching artificial intelligence when connected to the PLM, MES systems or the ERP itself. The additive manufacturing already in large use at Sabó is mainly focusing three different workflows: rapid prototyping, complex devices constructions in line with designing review for robustness, and maintenance spare parts construction. Moreover, printers are giving space to creativity and permitting Sabó people to exceed their regular stream tasks to reach completely out of box solutions to daily commercial and industry challenges in an environment and spirit of a start-up. In the same root IIoT and IoT (internet of things spread applied), new sensors, and some handcraft tools are stimulating the spirit.

It’s already common place to hear people sharing experiences like reaching robust solutions or amplifying medium time between failures in equipment due to the shift from steel components to plastic printed alternatives – meaning some still high frequency calls to substitute components are pointed to designs in need to be improved. When making in steel and the original design the parts use to receive some subtractive adjustments at the most, and maybe that’s not enough. Sometimes the correct approach demanded complex previous design changes, scalable approving before formalize an order to buy and ask a different designed part to an external supplier – non comparable with the flexibility reach when one can print, test and proof, reprint and perform data final adjustment in the end of the process with the production cell in rhythm. Finishing parts machines and devices, like trimming, “go/no go” devices, manipulators, closing and calibration stations among others have taken advantages from printing solutions at Sabó.

Recently Sabó people have studied coupling components and eliminating them from the spare parts warehouse. Several machined steel coupling can be substituted by printed plastic solutions and can even reach longer life in use.

Product Engineering considers to design and deliver prototypes in plastic to get easier and quick communication with customers. Promoting co-engineering between the original equipment manufacturer teams and Sabó's one can realize that even mature engineers are not so fast to evaluate 2D drawings, or even 3D exposed on a screen in applications different from daily practices. Sabó's solutions are very technical demanding and to guarantee target results engineers from both sides took too many meetings cross-evaluating designing changes – now it's different.

By receiving new demands in 3D, Sabó team can immediately print. In some minutes or hours at the most, meetings can be set and both sides people can better connect the ideas while touching and easily moving the part. During the last three years 40% of the new businesses were got by boosting time to market with printed prototypes – some are part of Sabó portfolio because of the speed to present its ideas and the way to argue about the solutions. Not only the product prototype but also the manufacturing tool prototype can be printed and it was a differential in design for manufacturing demonstrated capabilities to get the business.

Single products have been changed to complex and with great value added systems from some years but it is already noticed the accelerated movement now available with the printers.

Figure 8: Sabó 3D printers and printed prototypes

Laser manufacturing is another advanced manufacturing important solution and Sabó is developing two disruptive initiatives matching the new resource. Those will increase the portfolio which for some years had only laser to perform the inspections. The flexible current capabilities and knowledge on laser manufacturing can deliver alternative potency gun and peripheral resources to adjust and provide the real need in a very repetitive and robust process. Traceability is one of the applications, but there are lots. Finishing the parts with laser manufacturing can offer a free from debris process. Additive manufacturing or subtractive manufacturing can be combined with 5 axles or more axles special CNCs machines and permit to build a part or a tool in a single bench assembling, so far eliminating set-up loses or work-in-process.

Direct labor has been stimulated to commit and make use of creativeness to support the manufacturing flow. It's challenging to do that while keeping updated standardized work and parts or components designs in the engineering system. Also the company has to take care about the labor capabilities matrix and provide training and safety instructions. Sabó has some PoCs on biometrics to guarantee skilled people performing activities.

Fast response is an important pillar and fast communication, help chain and escalation is also a frequent improved process. Data science, analytics and IoT have been explored at Sabó. Technicians and engineers have developed small wireless boxes to perform calling leaders to action and improve spot verification workstations and regular control plan inspections.

Portfolio profitability has been managed by unit, account manager, cost center and other clusterization alternatives through the R3/SAP system and specifically by COPA (Cost Profit Analyses) resource. Very few companies in the world have maturely implemented such tool and have discipline to manage – what Sabó chooses to perform in weekly bases. Easily its managers can point what products, processes, customer's account are matching 80% of the contribution margin and results. From that Sabó has a strategy of open and manage activities in deeply approach to the 20% of products and processes that match those 80% of results. It's there where a visitor can see real time OEE management, TPM running, laser inspections, real-time Pareto suspect parts analyses, and more complete predictive maintenance approach management through the ERP.

Yet, digitalization is applied to manage headcount demands, to follow power and water consumption in real time, to follow any legislation, law publications, adjusted government regulations, connected to Sabó business, as is applied to ask and generate reimburse activities to support out of the company expenses faced by Sabó employees. Internal people are getting involved to daily activities through smartphones applicatives to communicate their demands to the social security, to organize their fuel expenses when traveling and others.

Moreover LPPD meetings, product development innovations, testing lab facilities are supervised and supported through digitalization. Sabó made a decision from 2017 to start a new Lean Project which was the Lean Product and Processes Development (LPPD) – is understood as an important trend to impact the simultaneous engineering workflows, responsiveness of the process, agile methods practices and trade-off curves to guarantee robust design and stimulate innovation while shortening next developments cycles and time-to-market.

Focus is on developing knowledge modules instead of single and completely isolated product solutions. Knowledge modules can be accessed repetitive times on a virtual shelf and stand-up meetings are practical, concrete and conducted in lean environment – the Obeyas to deliver expected results. Modernization, at the end, includes manufacturing, project designs, methods and management demands and the Industry 4.0 and lean administration practices are key.

4 Sabó Sharing of Its Experienced Journey

Notwithstanding only passing through installing some initiatives from the Industry 4.0 and adding updated technologies to its in maturation lean system, Sabó recognizes in good faith some potential contribution to benchmarking as it emerges like concernment to other companies – especially those still managed under a familiar structure of shareholders, closed companies, maybe small and medium businesses. Sabó is stimulating their suppliers and some similar businesses, institutes and academic partnerships in an easygoing but persistent manner.

From where to start? What are the main attention points? What are the main obstacles under the digital manufacture scope? What are the main lessons learned? What is new regarding the 4.0 programs? Which challenges are predicted to be tackled in the near future?

4.1 From Where to Start? What are the Main Attention Points?

Think about your own business challenges and problems. Think about them individually. Perform a deep evaluation over the value chain of your business priorities and put your focus on be lean. Develop project management skills and competences. Afterwards take some time to perform a self-assessment through the VDMA model, which is spotted by VDI 4000 (Readiness Model) (available at: https://www.industrie40-readiness.de/?lang=en). Taking this mainstream, connect your business and collaborate!

VDMA is an entity with presence in Brazil since 2013. There are four main themes that define their approach: “Creating the entrepreneurship future”; “Net thinking, net actions”; “Technologies to the associates and customers”; “Europe and the world” – that is one possible and rich connection to experience.

Engaging to an innovative ecosystem is very important to not start from a blank sheet of paper. Several low cost or cost free seminars, webinars, papers and communities can be accessed to better align industrial businesses with the main trends. Local leadership can review the “Manifesto ABDI 4.0” through Youtube (https://www.youtube.com/?gl=BR&hl=PT).

Choose to enlarge your thoughts, starting from tiny while going fast!

Yet in Brazil evaluate to engage VDI Seminars and Roadshows, SAE Brazil Advanced Manufacturing Congress – Connected Industrial Operations panel, Businesses mobilization for the innovation - MEI Programs, *Inova Sindipeças* Seminars, and to follow CNI and ABDI initiatives.

Federal and State Governments calls also are working to organize and create a positive wave to transform the industry perspective. Industry intellectual property institute INPI, the “S” system (Senai, Sebrae), FINEP and EMBRAPII are working to add synergy on this sense.

Disruptive businesses are blowing up. The A.I. report (Artificial Intelligence report) and Aachen University I4.0 Maturity Index shall be downloaded to stimulate your thoughts.

In Portuguese and from Brazil is already available the Connectivity Diagnoses to be reach surfing the internet. The "*Programa Brasil mais Produtivo* (B+P)" is also important to be known and evaluated. Access http://www.industria40.gov.br/

In summary, be attentive to several innovation publishing and calls and develop your own strategic plan to implement digital technologies. Once again, choose to enlarge your thoughts, starting from tiny while going fast. Harvest results and speed-up.

4.2 What are the Main Obstacles Under the Digital Manufacture Scope?

Sabó has realized the obstacles related to education and technical training of its crew. Somehow understands it in need to be plural and flexible and is running to seed that.

Tools and technologies availability are under challenging also, and the often question is the crossroad which guides the team to research and develop or just research to buy and adopt.

Once speed and agile are part of the drivers, the decision making and authority verges must be studied and sometimes reviewed to not intimidate group or individuals work.

Credibility, sponsorship and support can boost the process while on the other hand "complex of inferiority" – so common in Brazilian industrial sites nowadays – can retreat. Human resilience is required when failing to take the opportunity of fast learning and succeed in a near future.

Communication protocols and information technologies are key and step by step every company will face the deal of thinking the workstations through the value chain and demand internet protocols to increment the data access and analyses. What and how to integrate the production flow? Future seems to include autonomous supply chain and vertical and horizontal integrations are and will be more and more required, connecting even further away than each company borders.

Lots have been presented about User eXperience (UX as globally referenced) but mainly the approach is dedicating studies over customer experiences. Industrial companies moving their businesses to be digital have to put attention on their employees acceptation to newest tools and resources. Friendly environments over the applicative tools, nice and quick answers, pre-filled fields and system guessing to start fulfill reports are enjoyable, like it is a well-designed size of screen, size of fonts, color and shape of graphics for instance. Those suggest proof of concepts and pilots tasks before going massive and that is the better alternative.

Still Sabó's experience recommend to take care about digital security. A robust Wi-Fi system will be demanded even available at the shop facilities where it can face machinery interferences and signal shadows. Risks of malware and data stealing is truth recognizable.

As basics a very fine backup program over the CLPs and CNCs is mandatory to take care of software protection. Moreover it is recommended to segregate portals and level of access with frequent risk review. If a company does not have full or enough competences on that should firm a partnership with a service providers who will be charged about it and following the trends (like blockchain which is spreading up).

4.3 What are the Main Sabó's Lessons Learned?

- Simplicity and robustness can be present in the same side of the coin and lean practices drive your business to be enriched on the road. Each individual business has its particular factors with potential to move the process to an agile perspective.
- Integration and collaboration development, working in nets are important fuels to the Industry 4.0 strategy and should include the supply chain, the training centers and the technology competence centers (academic institutions and others).
- Starting small, fast harvesting and going further can mean resources multiplying.
- Analytic intelligence is a true north and each single company needs to recognize the relevance of the data it produces. Running the production, empowering data analytics and crossing variables and results can move the company to produce just golden batches.
- When arguing about modernization, an enterprise still need to accept considering to abandon old methods, practices and assets. It's more regarding deactivating old resources than to bring new machines and assets with heavy financial commitments. Experiences bring up situations of newest equipment and resources showing even lower productiveness results due to neighboring than to the olds in which the labor is accustomed to operate. Sometimes the newest equipment concentrates the overcapacity while the older are fully occupied.
- Small devices can be connected to robust machinery to boost their capabilities mainly related to collecting data and interface connections. So, communication and interfaces aren't strong arguments to justify new assets investments.
- To eliminate process stations goods or work-in-process transshipments is the preferential movement. It can amplify the inventory turns and improve the capital expenditure productiveness with lower cash flow demand.
- Traceability, product safeness and customer protection are all empowered through the current available technologies on advanced manufacturing.

4.4 What is New Regarding the 4.0 Programs?

There will be published a collection of drivers to the Industry 4.0 conceived as VDI 4000 (*Richtlinie* 4.0) in Germany at the end of 2019. Recommendation is to pay attention in this movement.

Sustainability, ecology and social inclusion have been stimulated and can receive different and better resources through current available solutions. Advanced manufacturing thinkers have been provoked with green patents stimulus and Circular Economy is advancing to stimulate companies to recover their consumed goods in order to reprocess those and get them as raw materials to the same or different nature of products.

The brightness under analytics and artificial intelligence is the power of current system to treat non-structured data. Considering this, a company can be surprised about the richness their own data can provide when correctly organized and supported.

Miniaturization is yet expanding without known limits. Every business is and will be hardly affected.

Additive manufacturing and laser manufacturing are improving fast and more applications blow up every day. Adding micro-layers of polymers or even steel materials printers and similar resources are reaching very complex shapes and offering solutions that are moving to eliminate any kind of rework after printing as they have improved to have alternative materials prepared to offer same physical and chemical properties obtained through conventional manufacturing processes. Though laser techniques we are accessing very special techniques non limited to metallic powder deposition and additive manufacturing as well, and special finishing and cutting techniques without debris and without the need of special tools to be kept with sharped faces.

Mass customization as the process of delivering wide-market goods and services which are modified to satisfy a specific customer's need is getting its arena. Mass customization is a marketing and manufacturing technique which combines the flexibility and personalization of custom-made products with the low unit costs associated with mass production. Other names for mass customization include made-to-order or built-to-order. It allows a customer to design certain features of a product while still keeping costs closer to that of mass-produced products. In some cases, the components of the product are modular. This flexibility allows the client to mix-and-match options to create a semi-custom final product. Reducing more and more the manufacturing processes batches is a big trend and the process tools and methods should be reviewed often and in very short term.

Start-up companies and new businesses acceleration centers ecosystems are contributing and performing a great positive impact on researching and bringing to market all of these and others technologies. A regular company can offer its structure and business field plus real problems and difficulties to be a test bed – a real environment to develop and refine their solutions. Fastness on it can guarantee cheaper access and/or even business partnership to create larger visibility and business opportunities.

4.5 Which Challenges are Predicted to be Tackled in the Near Future?

The quality of a company product tends to be strictly connected to data protection and solutions. Risks can move to be more demanding on information, maybe hackers invasion, than to the product performance while in regular regime.

Natural resources consuming optimization and energetic efficiency are polarizing diverse initiatives and called smart solutions. Smart equipment, smart factories, smart communities, smart cities, smart countries and a smart gear can be thought – everything running under supervising and with self corrective actions in need. Smart grids are collecting data, performing analytics, suggesting interferences and optimizing everywhere. Competitive balances will be more and more exposed and the trend is equalizing. Social impact will suggest consortium even among competitors.

The autonomous supply-chain will strongly impact the indirect labor supervising the production flows. Electronic Data Interchanging will be shot straight from the point of use and without human interference as well as the correspondent bill of landing and other fiscal and physical controls, connecting business chains. In such an environment the survivor of some small and micro-businesses is challenging – even more than it was until the moment. They need to reinvent their business as well.

In the auto-industry the openness to the deconstruction and construction of current and pretty new products and services is already required. One needs to answer what is the real vocation it has. How to deal with the digital marketing? Deeply know your business, your market and your customer, and make it with proximity – evaluate and make choices regarding Business-to-Business (B2B) practices or Business-to-Consumer (B2C) practices.

A company will be facing larger problems to retain or to attract human talents. Called digital-native talents are biased to leap from a current responsibility to others more often. How to keep their spirit alive but still satisfying and keeping them?

Internal communication, endo-marketing, social media conviviality are part of the business and will lead the companies to diverse attitudes and programs.

In order to guarantee access to the best funding alternatives, your business depends on having some connections to investors and special agencies. Integration is the way and to be kept as the preferred choice is also challenging.

Problems will remain present and the speed of each business to solve them is what differentiates and highlights an enterprise among the others. Being a fast learner is a goal. Precise diagnoses, clear and concrete action plans are recommended practices.

Knowledge expansion and acquiring new knowledge modules which could be combined in some future know-how gaps is a trend. In Brazil there are CT&Is (Innovation and Technology Centers) where are concentrated external modules of knowledge and the potential to speed-up ones journey. The Lean Enterprises Institute (LEI) and the *Lean Institute Brasil* (LIB) are spreading up the Obeya good practices to stimulate innovation, trade-off curves, design thinking and innovation shops (garage). The "Inova" Programs are a source of good practices as well (*Sindipeças* and MEI).

Integrative patents registering and due dates in Brazil have to change and leverage with good practices around the world. In Brazil scientific discovers aren't prized and protected as they are in different countries.

Servicefication is another trend, which means that manufacturing industries buy, produce and sell more and more services. Some equipment manufacturers for instance can sell a product and also deliver a 24 hours service desk on it, adding electronic data room of the usual problems and best solutions and even an easy access to a spare parts center. Parts manufactures are selling technical assistance and traceability as examples. Adding services can gain access to better contribution margins.

Global insertion and internationalization are also important. "Globalization, considered by many to be the inevitable wave of the future, is frequently confused with internationalization, but is in fact something totally different. Internationalization refers to the increasing importance of international trade, international relations, treaties, alliances, etc. International, of course, means between or among nations. The basic unit remains the nation, even as relations among nations become increasingly necessary and important. Globalization refers to global economic integration of many formerly national economies into one global economy, mainly by free trade and free capital mobility, but also by easy or uncontrolled migration. It is the effective erasure of national boundaries for economic purposes." As refers https://www.globalpolicy.org/component/content/article/162/27995.html in the GPF - Global Policy Forum.

In the end, a Company needs to keep and sustain an agenda to the future, reviewing it in regular basis.

5 Conclusion

The extreme rhythm of the 4th industrial revolution has suggested agile methods to manage Sabó operations as it has been demanded over all the global industries. Lean concept and tools can seed the ground to prepare the administrator to better understanding their businesses value chain and to make robust solutions available to their customers.

Production digitalization can speed-up data mining, boost analytics and provide the advantages of the artificial intelligence. The transition to Digital Production is a big journey and a company needs to make important choices along the way. Even the nature of the business can be changed. Flexible solutions connected to the manufacturing lines can guarantee multiple alternatives are easily accepted by the crew and developing people keeps being a huge effort – now matching the digital native generation.

Preparing people, exploring vocational boundaries and getting access to diverse market, customers and tools without losing a true north and growing up the business. Sabó made this choice. As an important user not a developer, Sabó is getting advantages from the new advanced manufacturing tools to increase its contribution margin, market share and getting additional relevance in the global market while revising its financial structure to face the new era.

Sharing resources and efforts is mandatory and Sabó is integrating vertically and horizontally with others businesses and institutions to reduce the weight of its business: being light and slim on assets but robust in solutions offerings is demanded.

In this article was presented some important points taken at the Industrial Strategy from Sabó as well as some results, experiences and insights. As a Brazilian company, familiar structured business, the case can demonstrate how possible it is to similar businesses perform a growing business moving to professional management and accessing important markets while facing disruptive technologies access challenges in contrast with other major companies resources and capabilities.

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"Manufatura Avançada:
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Diretor Industrial
São Paulo, 10 de Outubro 2019
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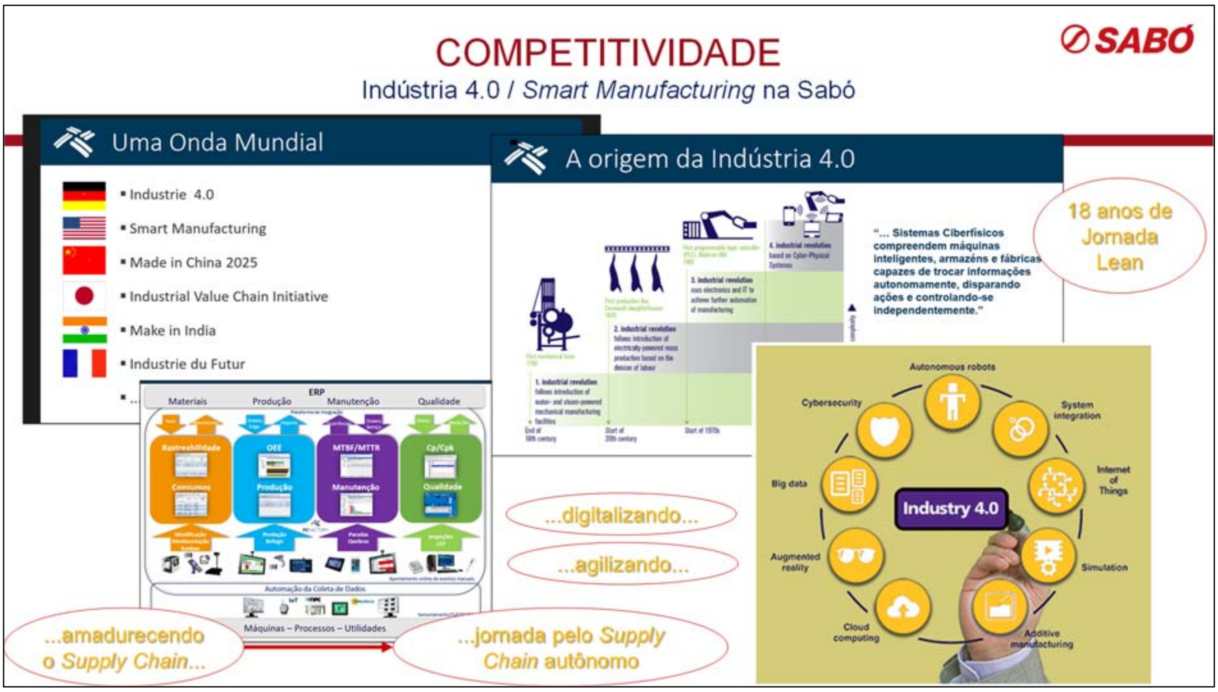
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Entidades e Governo nos apoiando na revisão de habilidades e perfis dos colaboradores
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• Eficiência Energética (2);
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Estoque, Separ. e Confer.
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Mobilidade
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QR codes
Fábrica sem papel
Rentabilidade
• Negócios Core;
• Fortalecimento Cadeias Suprimentos e Distribuição
2003 à 2012
2012 à 2015
2015 à 2019
SAMAPRE
SIM
KeyFile
SAE
CAD CAE CAM
Consolidação GICL (Gestão Integrada da Cadeia Logística)
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BM "MM300" Alemanha
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Big Data
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"Leituras" em tempo real
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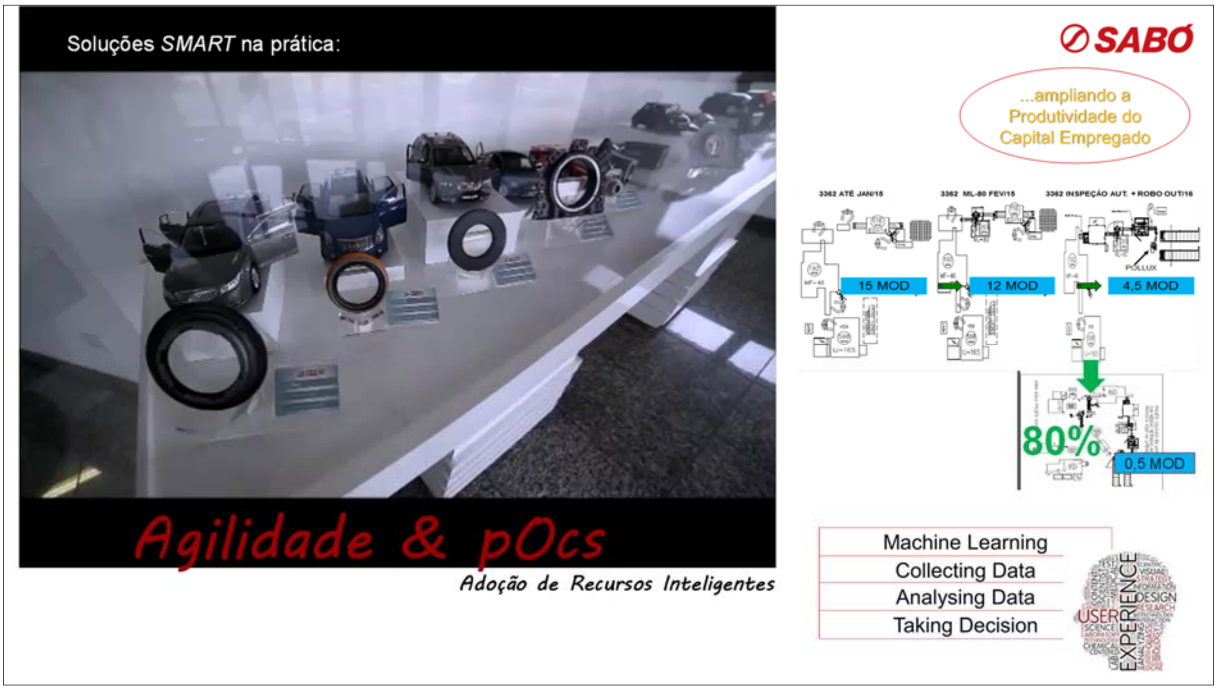
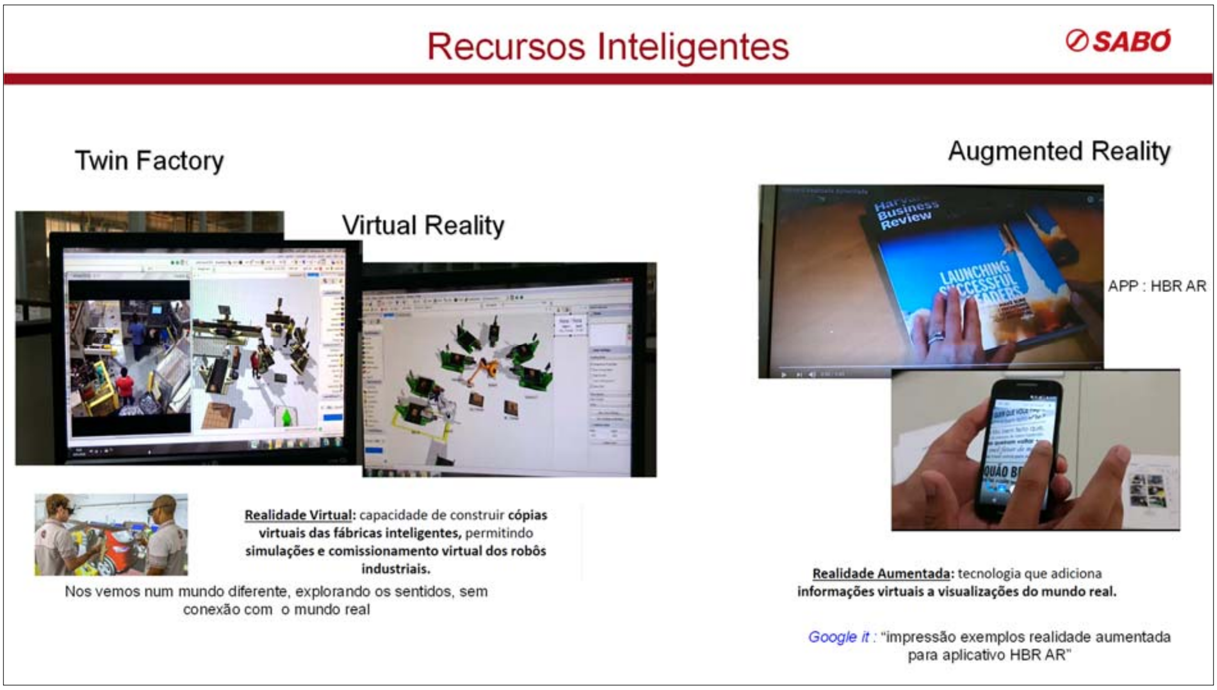
Customização em Massa
Biometria e Rastreabilidade


Soluções SMART na prática:
SABÓ
...ampliando a Produtividade do Capital Empregado
15 MOD
12 MOD
4,5 MOD
80%
0,5 MOD
Agilidade & pOcs
Adoção de Recursos Inteligentes
Machine Learning
Collecting Data
Analysing Data
Taking Decision
USER EXPERIENCE


Recursos Inteligentes
SABÓ
Twin Factory
Virtual Reality
Augmented Reality
APP : HBR AR
Realidade Virtual: capacidade de construir cópias virtuais das fábricas inteligentes, permitindo simulações e comissionamento virtual dos robôs industriais.
Nos vemos num mundo diferente, explorando os sentidos, sem conexão com o mundo real
Realidade Aumentada: tecnologia que adiciona informações virtuais a visualizações do mundo real.
Google it : "impressão exemplos realidade aumentada para aplicativo HBR AR"


Recursos Inteligentes
SABÓ
Laser Manufacturing
3D Printing – Additive Manufacturing
Biometria, Segurança do Trabalho & Capacitação


Recursos Inteligentes
SABÓ
OEE & Digitalização x Tempo Real (MES)
Gestão dos intervalos entre falhas, para reparo e de indisponibilidade de máquinas
100% Digital, 100% no ERP
e, ainda, explorando o enxuto, o digital, o ágil….
Rentabilidade COPA;
LPPD & Inovações Produto e Processo; Monitoramento Lab. Funcional;
Inspeção a laser & Pareto de defeitos em tempo real;
APPs e Portal do RH;
Consumo e perdas energéticas em tempo real;
Legis & regulações;
Automação na geração de reembolsos

Competitividade & Qualidade intimamente ligadas!

SABÓ

- Gestão de Projetos e de Tecnologia nos Processos:....*road map*
- Simulações, comissionamento, predição, prototipagem
  - ✓ errar rápido e corrigir => aprender em alta velocidade
- Algoritmos, inteligência artificial, *analytics*
  - ✓ aperfeiçoando, customizando
- Agilidade... suporte à operação em tempo real e com dispositivos móveis
  - ✓ meios novos x tradicionais;
  - ✓ estabilidade dos ativos, resposta rápida, trabalho padronizado, monitoramento regular,
    - TPM (*Total Predictive Maintenance*),
    - OEE (*Overall Equipment Efficiency*)
    - Auditoria Escalonada;
    - Coaching
- Modernização de Projetos, Métodos, Gestão....
  - ✓ projeto dos produto, processo, ferramentais, controles,...
  - ✓ método nas operações, movimentações, embalagens;
  - ✓ fluxo da informação e gestão de dados + rastreabilidade

...capabilidade, gestão de risco, PFMEA, poka-yokes;
...Manufatura Avançada !
...giros rápidos de inventário, baixos *lead times*.

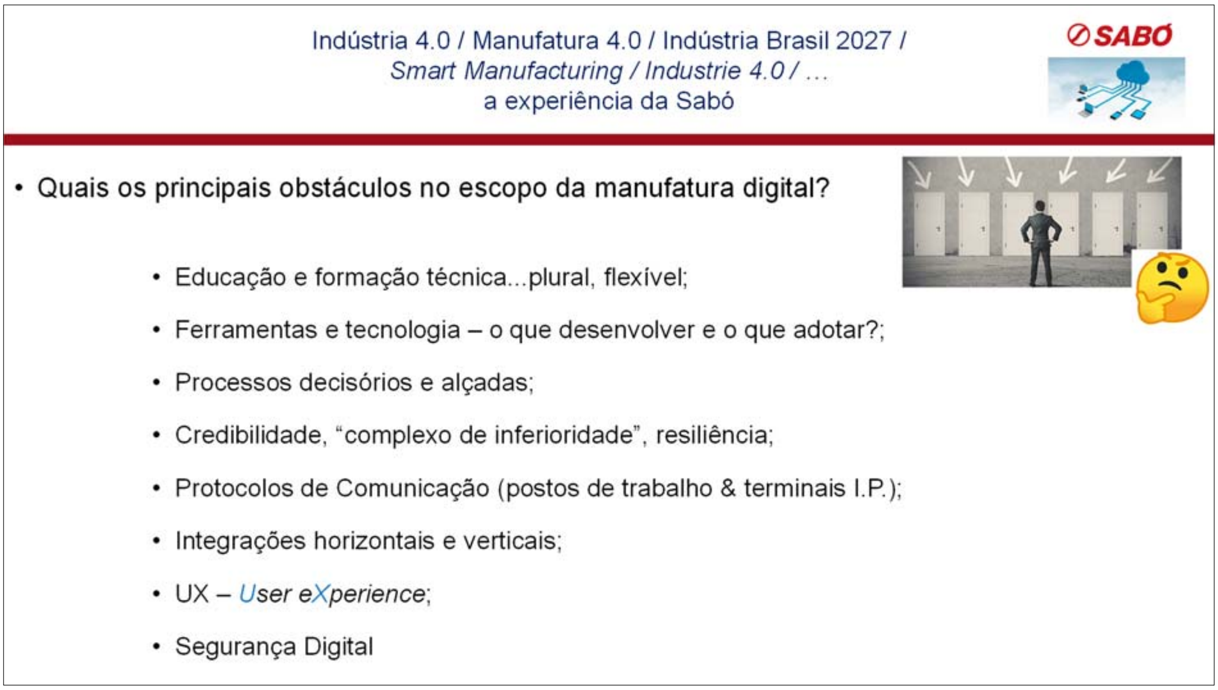
Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 / *Smart Manufacturing / Industrie 4.0 / ...* a experiência da Sabó

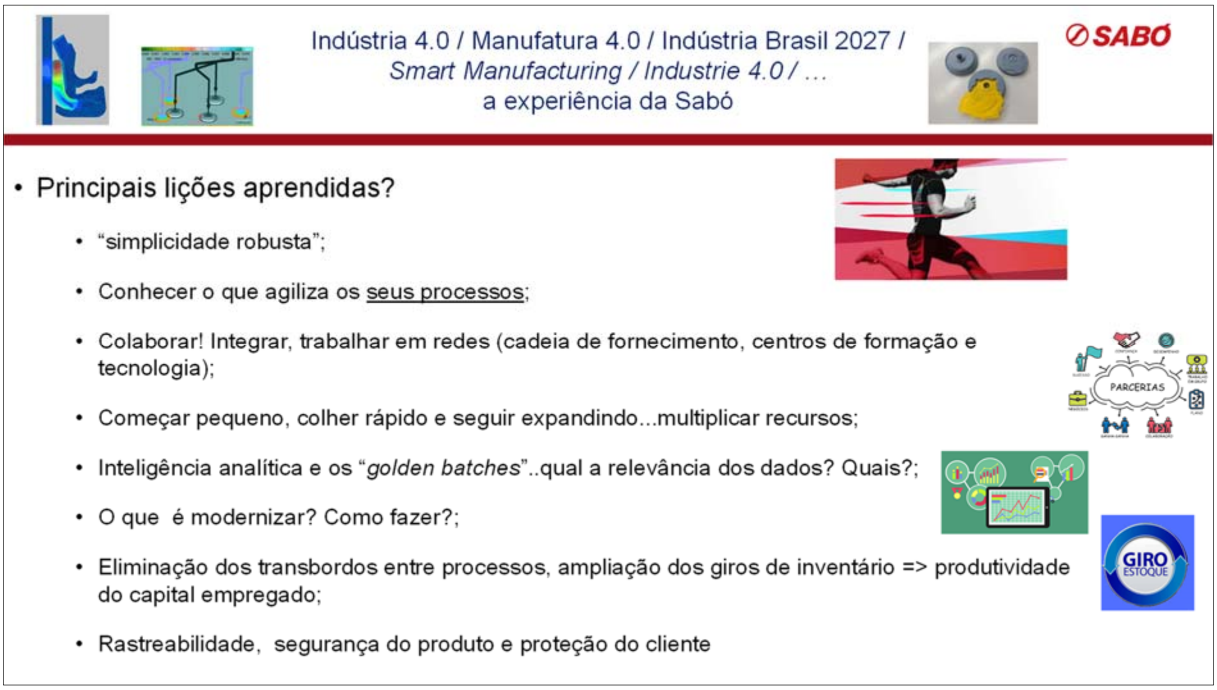
Indústria 2027

SABÓ

- Por onde começar? Quais os principais pontos de atenção?
- Quais os principais obstáculos no escopo da manufatura digital?
- Principais lições aprendidas?
- O que há de novo nos programas 4.0 ?
- Quais desafios a enfrentar nos próximos anos?


Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 /
Smart Manufacturing / Industrie 4.0 / …
a experiência da Sabó
SABÓ
• Por onde começar? Quais os principais pontos de atenção?
Pense grande, comece pequeno, ande rápido!
• VDI Webinars, Roadshows ; Simpósios de Produção ;
• Congressos de Manufatura Avançada SAE;
• Programas de Imersão MEI, intercâmbios internacionais;
• Download A.I. report;
• Download do "I4.0 Maturity Index" da Aachen University;
• Diagnóstico de conectividade;
• Programa "Brasil mais Produtivo" (B+P);
• Editais de Inovação;
• Desenvolva um plano estratégico para implementação de Tecnologias Digitais.
Colha resultados, e acelere!
VDI Associação de Engenheiros Brasil-Alemanha
SAE BRASIL
CNI
PAINEL OPERAÇÕES INDUSTRIAIS CONECTADAS 17/Out/19
MEI MOBILIZAÇÃO EMPRESARIAL PELA INOVAÇÃO
ABDI
Propriedade Industrial
INPI
Finep
SEBRAE
SENAI PELO FUTURO DO TRABALHO
EMBRAPII
⇒ Quais os problemas / desafios reais de seus processos (individuais) ?
⇒ Conhece seus mapas de valor ? *Be lean!*
⇒ Desenvolva competências na Gestão de Projetos;
⇒ Autoavaliação: modelo da VDMA destacado pela VDI 4000 (*Readiness Model*)
https://www.industrie40-readiness.de/?lang=en
⇒ Conecte-se! Colabore!
http://www.industria40.gov.br/
No YouTube : "Manifesto ABDI 4.0"


Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 /
Smart Manufacturing / Industrie 4.0 / …
a experiência da Sabó
SABÓ
• Quais os principais obstáculos no escopo da manufatura digital?
• Educação e formação técnica...plural, flexível;
• Ferramentas e tecnologia – o que desenvolver e o que adotar?;
• Processos decisórios e alçadas;
• Credibilidade, "complexo de inferioridade", resiliência;
• Protocolos de Comunicação (postos de trabalho & terminais I.P.);
• Integrações horizontais e verticais;
• UX – *User eXperience*;
• Segurança Digital


Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 /
Smart Manufacturing / Industrie 4.0 / ...
a experiência da Sabó
SABÓ
• Principais lições aprendidas?
• "simplicidade robusta";
• Conhecer o que agiliza os seus processos;
• Colaborar! Integrar, trabalhar em redes (cadeia de fornecimento, centros de formação e tecnologia);
• Começar pequeno, colher rápido e seguir expandindo...multiplicar recursos;
• Inteligência analítica e os "*golden batches*"..qual a relevância dos dados? Quais?;
• O que é modernizar? Como fazer?;
• Eliminação dos transbordos entre processos, ampliação dos giros de inventário => produtividade do capital empregado;
• Rastreabilidade, segurança do produto e proteção do cliente
PARCERIAS
GIRO
ESTOQUE


Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 /
Smart Manufacturing / Industrie 4.0 / ...
a experiência da Sabó
SABÓ
• O que há de novo nos programas 4.0 ?
• Diretriz (*Richtlinie*) VDI 4000 a ser publicada ao fim de 19 na Alemanha;
• Sustentabilidade – ecologia, inclusão social, ... Inclusive incentivos a patentes verdes;
• Acesso à soluções de inteligência analítica (tratamento de dados não estruturados);
• Expansão das miniaturizações;
• Evolução da manufatura aditiva e manufatura a laser;
• Customização em massa;
• Contribuição dos ecossistemas de *start-ups* e aceleradoras
PATENTES
VERDES
MAKE IT YOURS
startups
IDEAS


Indústria 4.0 / Manufatura 4.0 / Indústria Brasil 2027 /
Smart Manufacturing / Industrie 4.0 / …
a experiência da Sabó
SABÓ
Indústria 2027
• Quais desafios a enfrentar nos próximos anos?
• Qualidade & Segurança (Blockchain, ….);
• Otimização do uso de recursos naturais & eficiência energética;
• Supplly-chain autônomo & evolução do iiOt;
• Sobrevivência das PMEs brasileiras;
• Desconstrução e reconstrução de produtos e serviços – qual a sua vocação?
• convivio com o MKT Digital … conheça seu mercado, seu cliente…B2B ? B2C?
• Atração, retenção de nativos digitais;
• Comunicação interna, Endomarketing, convívio com mídias sociais;
• Acesso a fomentos … integrar-se;
• Precisão de diagnóstico e propostas de ação
• Expandir fronteiras de conhecimento, integrar-se à Academias e Centros de Tecnologia e Inovação (CT&I)
• Inovar através dos Obeyas, das Garagens, Design Thinking;
• Programas Inova (MEI, Sindipeças, …)
• Prazo e integração internacional para registros de patentes;
• Servicificação;
• Internacionalização, inserção global;
• Criar e manter uma agenda de futuro.
Future
2027
Principais Linhas
PATENTED


SABÓ
Obrigado!

Wellington Moscon

Wellington Moscon, Bacharel em Sistemas de Informação com mais de 14 anos de experiência em TI, atuou em grandes empresas e multinacionais de Telecom, Serviços em TI e no setor Bancário. Atualmente é CEO da startup GoEPIK que possui plataforma proprietária para atender aos desafios da indústria 4.0, através do uso de tecnologias habilitadoras como realidade aumentada, voz, visão computacional, machine learning entre outras. A plataforma funciona num modelo SaaS que permite às indústrias autonomia total no uso e aplicação em seus processos. A GoEPIK tem como sócios o Grupo Porto Seguro, Plug&Play Tech Center e Fundo Primatec.

wellington@goepik.com.br

Integração horizontal da cadeia de valor na Indústria 4.0

Resumo

Prover soluções inteligentes e digitais para obter visibilidade em tempo real e integração junto a fornecedores, distribuidores e clientes pode representar um aumento expressivo no faturamento e redução de custos em sua indústria. Neste case iremos abordar os fatores que podem levar uma empresa da indústria automotiva de remanufatura a aumentar em 700% o seu faturamento através da digitalização de processos e utilização de tecnologias habilitadoras da indústria 4.0.

Palavras-chave

Industria 4.0; Horizontalização; Tecnologias Habilitadoras; Integração; Fábrica Inteligente.

Autores

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1 O papel da logística em nossas vidas

Comprar frutas na feira mais próxima de sua casa, poder escolher as que possuem a melhor aparência e em seguida pagar por estas em dinheiro ou cartão é trivial, já em outro cenário você pode realizar uma compra on-line de um par de sapatos utilizando seu cartão de crédito por meios seguros, com um prazo de entrega aceitável e no endereço que você escolher e isso pode parecer mais um exemplo óbvio e até banal de nosso cotidiano. Mas não se engane, não existe nada óbvio ou banal na cadeia de suprimentos que garante que esses produtos cheguem até você, muitos elementos precisam estar alinhados através de uma rede eficiente para que as situações exemplificadas aconteçam.

Na indústria esses exemplos não são diferentes, as empresas de manufatura com frequência precisam ter acesso a um número de suprimentos específico, com características muito específicas, em quantidades precisas, dentro de um prazo e qualidade também muito restritos. Erros na garantia de atendimento de qualquer um destes itens levam a problemas em alguma etapa da cadeia podendo ser, por exemplo, na etapa de produção, operações, marketing, vendas ou até mesmo entrega.

O gerenciamento da rede de suprimentos envolve um espectro maior e mais abrangente do que a cadeia de suprimentos, pois pode estar relacionado a atividades adicionais como desenvolvimento de produtos, rastreabilidade em rede, marketing e muito mais. O propósito final da integração horizontal é fornecer ao cliente, de maneira eficiente, o produto adquirido.

Um sistema logístico não consiste apenas do fluxo de materiais, componentes e produtos que são processados e distribuídos aos clientes, mas também inclui fluxos de suprimentos em cadeia de peças de reposição para produtos que já foram entregues.

O sistema deve contemplar fluxos de retorno de produtos excedentes, defeituosos e até mesmo embalagens. É cada vez mais importante que o sistema de logística atue como uma rede de fornecimento e não esteja confinado somente aos limites da própria organização. As empresas em geral não fazem parte de uma única cadeia de suprimentos, ao contrário, elas fazem parte de várias cadeias de suprimento, uma rede de cadeia de suprimentos.

É importante que as organizações cultivem interfaces e interações contínuas com seus *stakeholders*, objetivando maior integração e velocidade de resposta para expandir sua compreensão quanto a mudanças no ambiente negocial além de proatividade para atender e gerar demanda no mercado. É imprescindível buscar ou manter um posicionamento competitivo no mercado visando melhoria da marca e satisfação de clientes, colaboradores e acionistas.

Buscar inovação relevante a toda cadeia de valor da organização através de ferramentas de gestão e tecnologias habilitadoras da transformação digital / Indústria 4.0, que permitam a rápida experimentação e otimização de processos. É de extrema importância para a empresa se tornar perene.

Uma estratégia promissora de transformação digital ou Indústria 4.0 deve levar em consideração fatores tecnológicos, culturais, organizacionais e um profundo entendimento da cadeia de valor. Empresas que estão dedicando seu tempo para compreender e implementar estratégias digitais vem sendo extremamente bem-sucedidas como é o caso da Domino's Pizzaria.

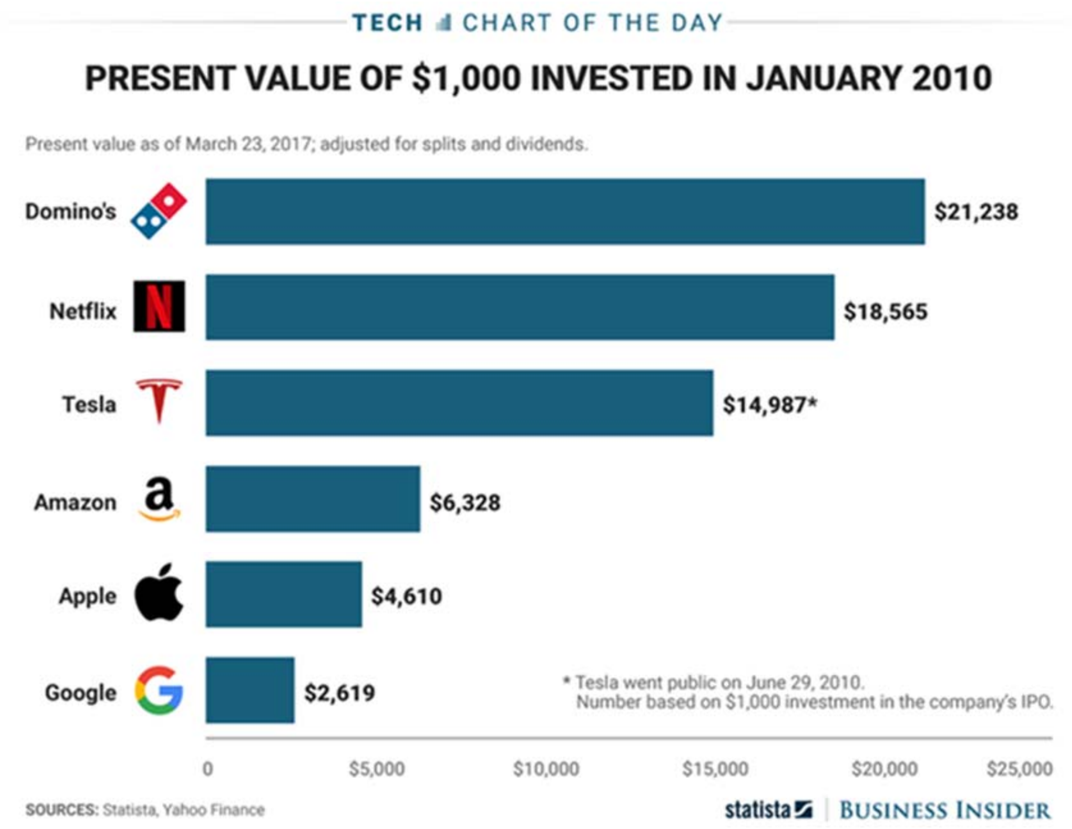


Figura 1: Valor presente dos investimentos em janeiro de 2010

2 Oportunidades da Integração Horizontal 4.0

A Indústria 4.0 se fundamenta especificamente em fábricas inteligentes que serão capazes de não apenas agendar a produção e manutenção de máquinas, como também serão capazes de realizar ajustes autônomos, garantindo assim alta disponibilidade e adequação da linha de produção à demanda do mercado, desta forma tornando as organizações mais competitivas, lucrativas e o ambiente de trabalho menos exaustivo.

Figura 2: Linha de produção Renault, utilização de tecnologia de realidade aumentada para garantia de qualidade

Para garantir ganhos reais de produtividade, disponibilidade e qualidade é imprescindível que não somente conceitos de verticalização sejam implementados, mas também conceitos relacionados a horizontalização da cadeia de valor. O fluxo de informações deve fluir naturalmente, sem perdas, ao longo de toda cadeia de valor, envolvendo fornecedores, parceiros e clientes, com o intuito de disponibilizar uma grande massa de informações. Em conjunto com o uso de tecnologias como *Machine Learning*, *Analytics* e KPIs bem definidos, as informações geradas auxiliam de maneira inteligente no processo de tomada de decisão.

Em linhas gerais, as organizações já possuem grande quantidade de informação ou dados, o grande desafio está no formato em que estes são usualmente armazenados. Os meios de armazenamento com frequência são planilhas e fisicamente em papel, desta forma fornecendo muito pouca ou nenhuma informação que auxilie no processo de tomada de decisão. Estamos falando de uma enorme massa de dados que é subutilizada, e quando utilizada, alimenta somente ao ciclo vicioso da retroatividade e da burocracia do papel.

A Indústria 4.0 faz uso intensivo de dados e tecnologias de forma estratégica e busca a eliminação de meios que dificultam ou inibem o uso de dados como o já citado anteriormente, papel. A abordagem horizontal foca na integração de sistemas, desenvolvimento ou utilização de tecnologias que proporcionam visibilidade em tempo real, integração entre áreas de negócio e possibilita que dados gerados por clientes, fornecedores ou parceiros sejam utilizados para melhorar a proposta de valor do produto ou serviço ofertado e pode ser vista como uma grande oportunidade para utilizar informações de maneira inteligente como auxiliando no processo de compreensão de dores e/ou oportunidades latentes em toda cadeia de valor bem como gerando inteligência analítica para aumentar a assertividade no processo de tomada de decisão.

As empresas inteligentes farão uso de tecnologias que proporcionem integração em tempo real de colaboradores, fornecedores, máquinas, equipamentos, clientes, pós-venda e inclusive integração vertical entre as áreas de manutenção, segurança da saúde, treinamento, qualidade, entre outras.

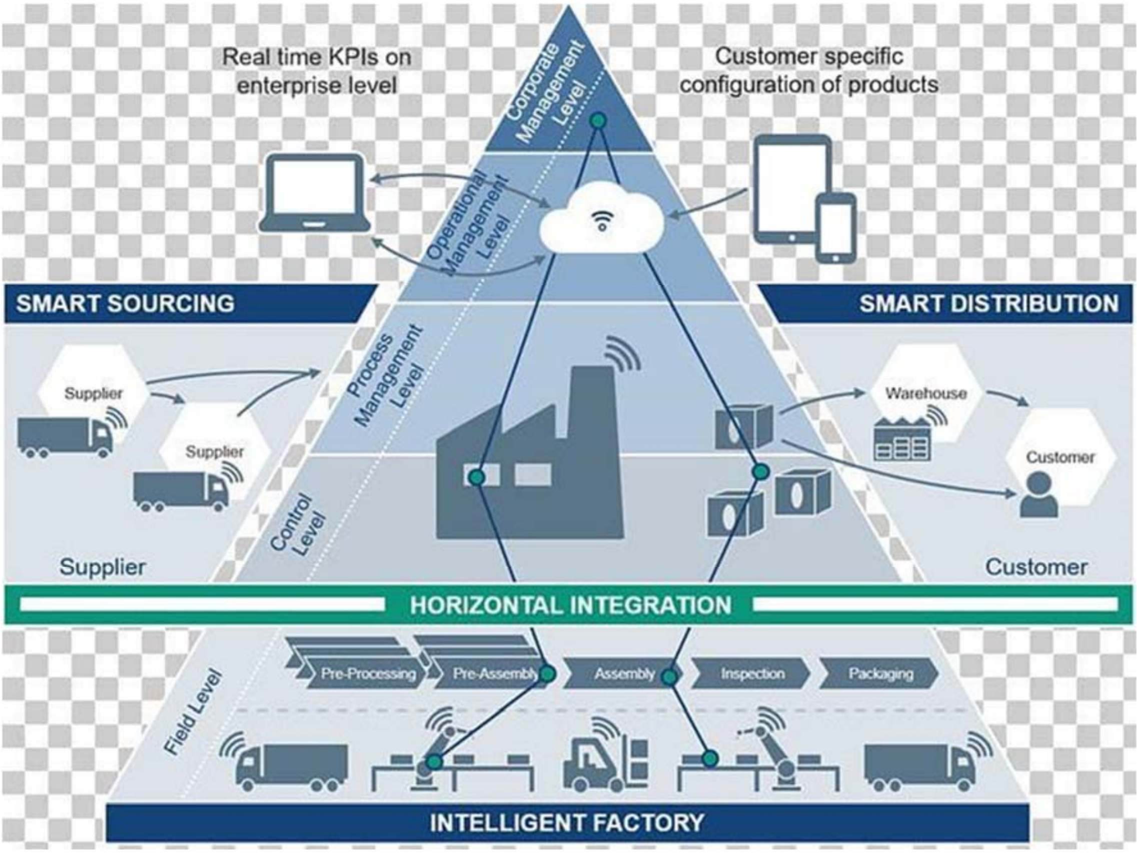


Figura 3: Integração horizontal e vertical

3 Plataforma GoEPIK aplicada ao fluxo de pós-venda

A Plataforma GoEPIK é simples, flexível e hiper customizável. Atende a desafios em diferentes indústrias e tamanhos de negócio – tudo em um único lugar, em tempo real, com autonomia e flexibilidade. As empresas conseguem de maneira autônoma criar soluções para Indústria 4.0 ou transformação digital sem a necessidade de programação ou infraestrutura de TI possibilitando assim que tecnologias de ponta sejam aplicadas instantaneamente pelas mais diversas áreas como por exemplo, manutenção, qualidade, montagem, treinamento, segurança do trabalho, pós-venda, entre outras, e que os processos que fazem uso destas tecnologias estejam prontamente disponíveis para execução através de smartphone, tablet, óculos de realidade aumentada, smartband ou Web.

Nosso cliente, que atua no setor de remanufatura, tinha o grande desafio de ampliar sua base de parceiros, distribuidores e oficinas em todo Brasil de maneira escalável garantindo que a qualidade das avaliações de caixa de câmbio para remanufatura fossem realizadas com alta qualidade e que todos os interessados (caminhoneiros, oficinas, distribuidores, pós-venda, engenheiros e logística) recebessem prontamente informações customizadas sobre cada etapa do processo.

O processo de avaliação das caixas de câmbio avariadas era realizado via formulário impresso abrindo espaço para erros frequentes na validação de qualidade das caixas o que em seguida levava a perdas financeiras expressivas. Alguns dos fatores que contribuem para que essas perdas aconteçam são estimativas erradas para recuperação das caixas com base no preenchimento de formulário impresso enviado pelo distribuidor ou oficina, tempo dispendido entre o distribuidor informar sobre a disponibilidade de uma caixa de câmbio em bom estado e a coleta desta, além do custo com logística reversa nos casos em que as caixas eram avaliadas erroneamente.

Para solucionar este desafio o cliente escolheu a Plataforma GoEPIK. Esta plataforma permite criar workflows que enviam notificações em tempo real via Push, E-mail ou SMS. Os processos suportam o uso de tecnologias como Realidade Aumentada, Captura de Imagens e Vídeos, Captura de Áudio para reconhecimento de ruídos, que são enviados para auditoria. O cálculo e avaliação da caixa de câmbio são executados por diferentes interessados a medida que as etapas avançam dentro do workflow. Exemplificando o cenário, a oficina é agora orientada através de processos disponibilizados em aplicativo a como proceder e avaliar corretamente a caixa de câmbio, a inteligência contida no aplicativo avalia se o nível da caixa é A, B ou C e essa avaliação é enviada em seguida para a distribuidora.

A distribuidora por sua vez, através de um clique, encaminha a avaliação a empresa de remanufatura que decide por aceitar ou não a caixa, em caso de aceite uma notificação é enviada à distribuidora para que insira o número da nota fiscal da caixa e tão logo isso aconteça o processo de logística para coleta da caixa é iniciado. Antes de iniciar de fato o processo de remanufatura, um engenheiro utilizando a mesma tecnologia de processos realiza uma nova avaliação e o sistema imediatamente confere se existem divergências entre as avaliações e reajusta o nível da caixa e seu valor de venda, ao final da remanufatura o ciclo de vida da caixa de câmbio passa a ser monitorado via identificação única através de QR Code. Todos são informados assim que o processo de remanufatura é encerrado e em seguida o processo de logística para entrega da nova caixa de câmbio é realizado.

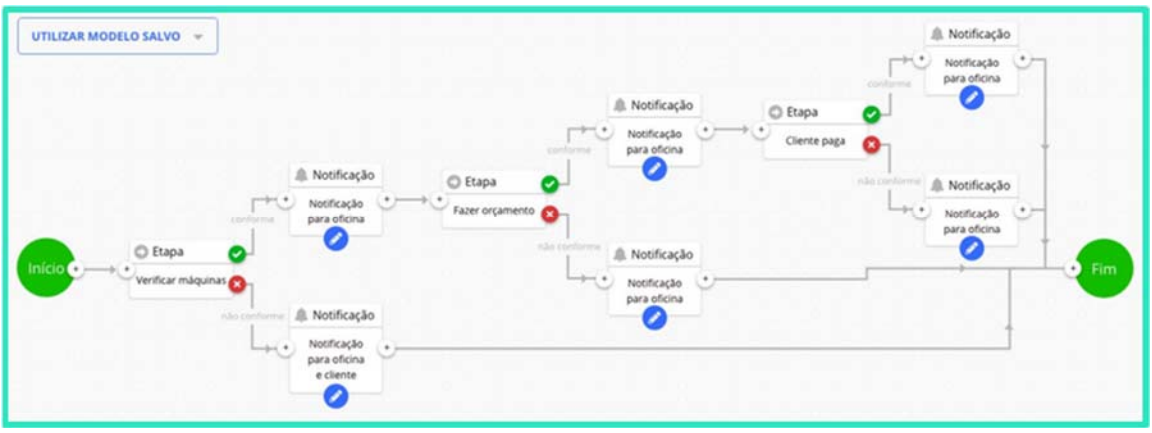


Figura 4: Exemplo de aplicação da Plataforma GoEPIK

4 Conclusão

Os ganhos relacionados a integração horizontal por meio de tecnologia são inúmeros e permitem a organização ter acesso a dados em tempo real e acelerar seu processo de compreensão da cadeia e tomada de decisão. Escalar rapidamente a solução e realizar ajustes no fluxo de trabalho ou processo e poder replicar estes ajustes instantaneamente aos parceiros traz flexibilidade, confiabilidade de dados e diminui o tempo de resposta a mudanças. A expectativa de aumento nas vendas neste caso de sucesso é de 700% para o ano de 2020.

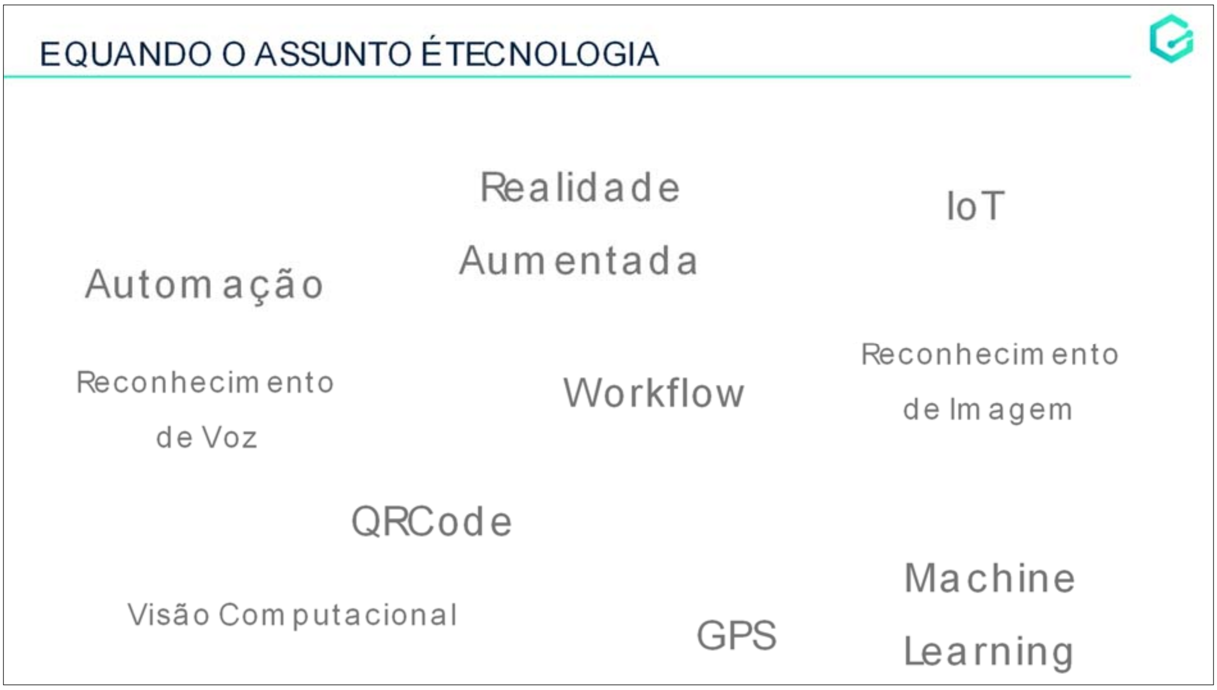

GoEPIK
A PLATAFORMA DA
INDÚSTRIA 4.0


TRAJETÓRIA
14 anos em TI
Há 9 anos
Há 2 anos
GVT
vivo
HSBC
Global Technology
TIVIT
GoEPIK


RECONHECIMENTOS
100 STARTUPS TO WATCH 2019
100 open startups
LIGA VENTURES
StartOut Brasil
OUSE SER GLOBAL
PLUGANDPLAY
Silicon Valley in a Box
PRÊMIO DE STARTUPS
Brasil-Alemanha
BUSINESSFRANCE
BIND4.0
STARTUP! BASQUE INDUSTRY 4.0 ACCELERATOR PROGRAM
STARTUP AWARD BRASIL 2017
EDP STARTER
STARTUPS CONNECTED
Connecting challenges to innovative solutions


PRINCIPAIS CLIENTES
cebrace
MAXION
EATON
Powering Business Worldwide
Gyproc SAINT-GOBAIN
SAINT-GOBAIN
grupo boticário
Braskem
CNH INDUSTRIAL
DOVER FUELING SOLUTIONS
ambev
RENAULT
Garrett ADVANCING MOTION
brf
weber quartzolit
TEK BOND
Telhanorte
BRASILIT SAINT-GOBAIN
MINERAÇÃO JUNDU
comgas
ANDRADE GUTIERREZ
Mondelēz International
Heineken open your world
Ipiranga


O DESAFIO DE QUALQUER EMPRESA
PESSOAS
PROCESSOS
TECNOLOGIAS


E QUANDO O ASSUNTO É TECNOLOGIA
Realidade Aumentada
IoT
Automação
Reconhecimento de Voz
Workflow
Reconhecimento de Imagem
QRCode
Visão Computacional
GPS
Machine Learning

ALGUMAS DORES E DESAFIOS

Pessoas

- Equipe de TI sobrecarregada;
- Áreas de negócios dependem da TI;

Processos

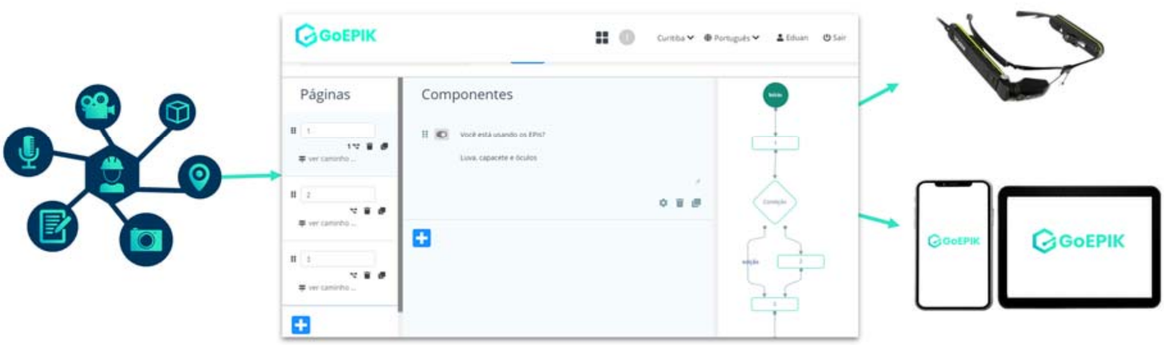
- Muitas vezes em papel ou Excel;
- Não integrados;

Tecnologia

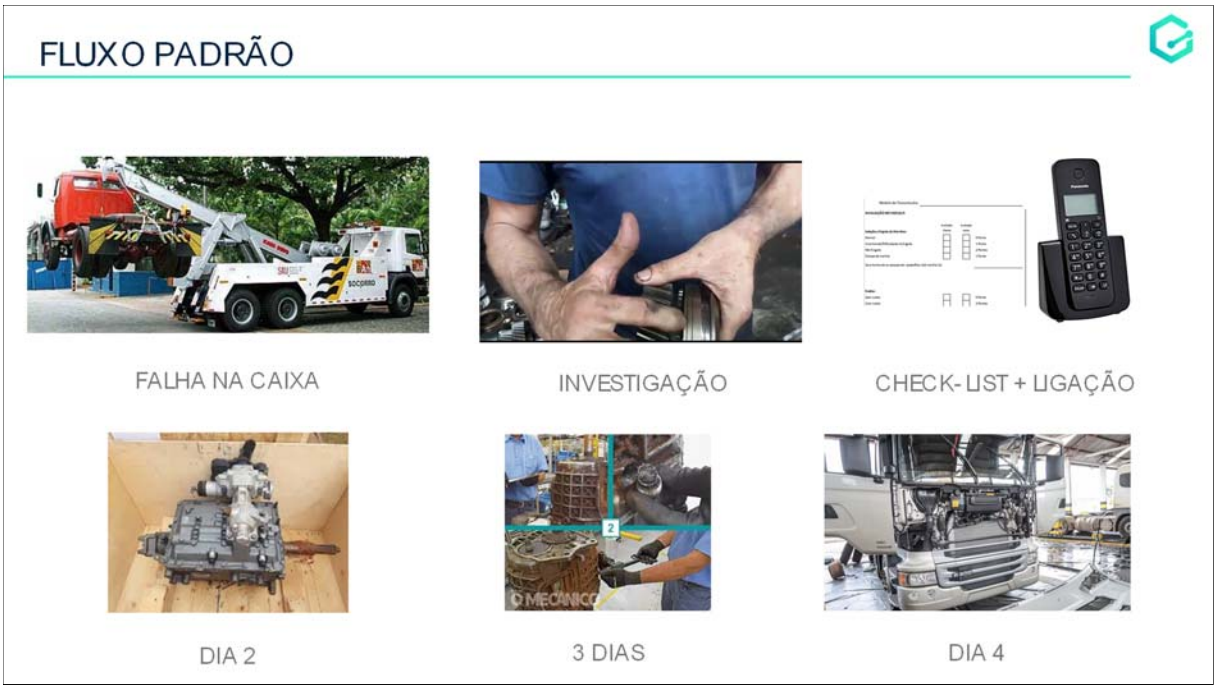
- O ROI não é garantido;
- Para as PMEs o custo pode ser inviável;

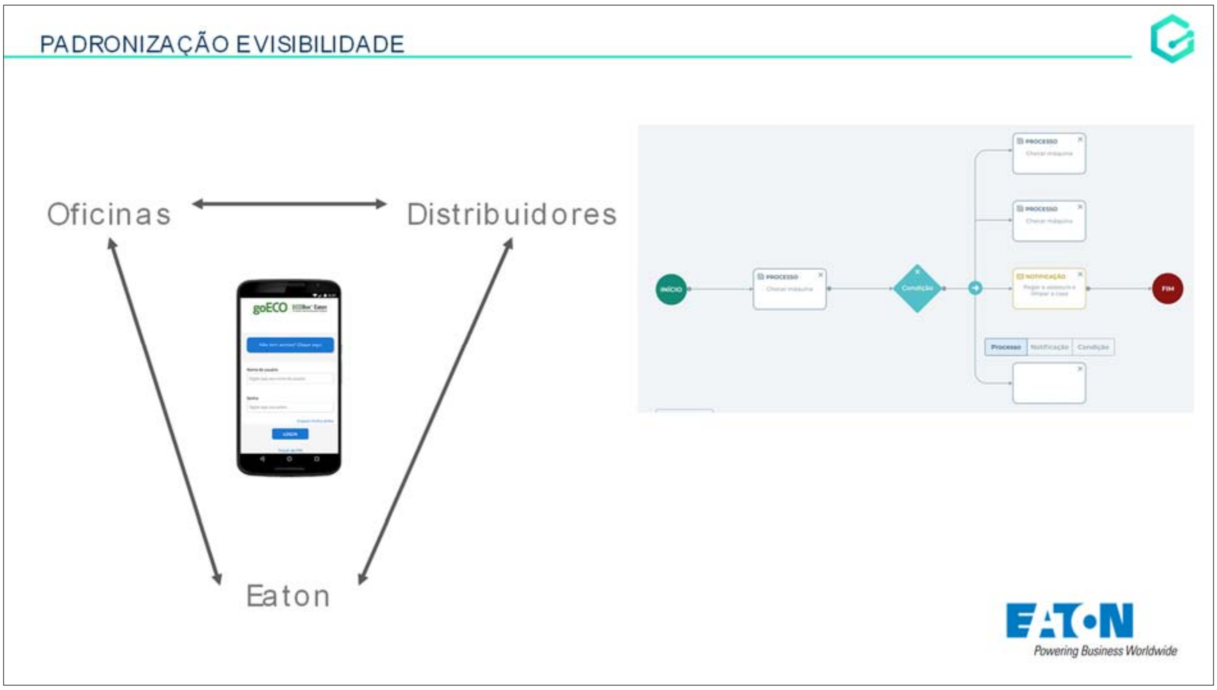
GO DIGITAL - INDÚSTRIA 4.0 SEM SOBRECARREGAR A TI

PESSOAS + AUTONOMIA EM TECNOLOGIA + PROCESSOS = TRANSFORMAÇÃO DIGITAL




AUTONOMIA EVISIBILIDADE
GoEPIK
12
Nome do Usuário
Idiomas
Sair
Cadastros
Epiks
Gestão de Processo
Gráficos
QR Code
Quantidade de execuções
Pendente
Andamento
Realizado
Atrasado
Visualização Gráfico
Dados Detalhados
90 Pessoas
231 Execuções
Número de Execuções
100
80
60
40
20
0
Jan
Fev
Mar
Abr
Mai
Jun
Jul
Ago
Set
Out
Nov
Dez
Mês
Manutenções
35
Equipamentos em falta
10 ÓCULOS
20 CAPACETES
15 BOTAS
Planos de Ação
10
Problemas mecânicos
05


FLUXO PADRÃO
FALHA NA CAIXA
INVESTIGAÇÃO
CHECK- LIST + LIGAÇÃO
DIA 2
3 DIAS
DIA 4


PADRONIZAÇÃO E VISIBILIDADE
Oficinas
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INÍCIO
Condição
FIM
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Powering Business Worldwide


FLUXO DIGITAL
FALHA NA CAIXA
INVESTIGAÇÃO
FOTO, VÍDEO E ÁUDIO
RECEBE AVALIAÇÃO
CAFEZINHO - 15 MINUTOS
NOVA CAIXA


O QUE MUDA?
PRATICIDADE
TRANSPARÊNCIA COM O CONSUMIDOR FINAL
PADRONIZAÇÃO
AMPLIAÇÃO DE ATUAÇÃO
AUMENTO DE FATURAMENTO
CUSTOS DE LOGÍSTICA NA AUTORIZADA
CUSTOS DE LOGÍSTICA NA EATON


O DESAFIO DE QUALQUER EMPRESA
PESSOAS
PROCESSOS
TECNOLOGIAS

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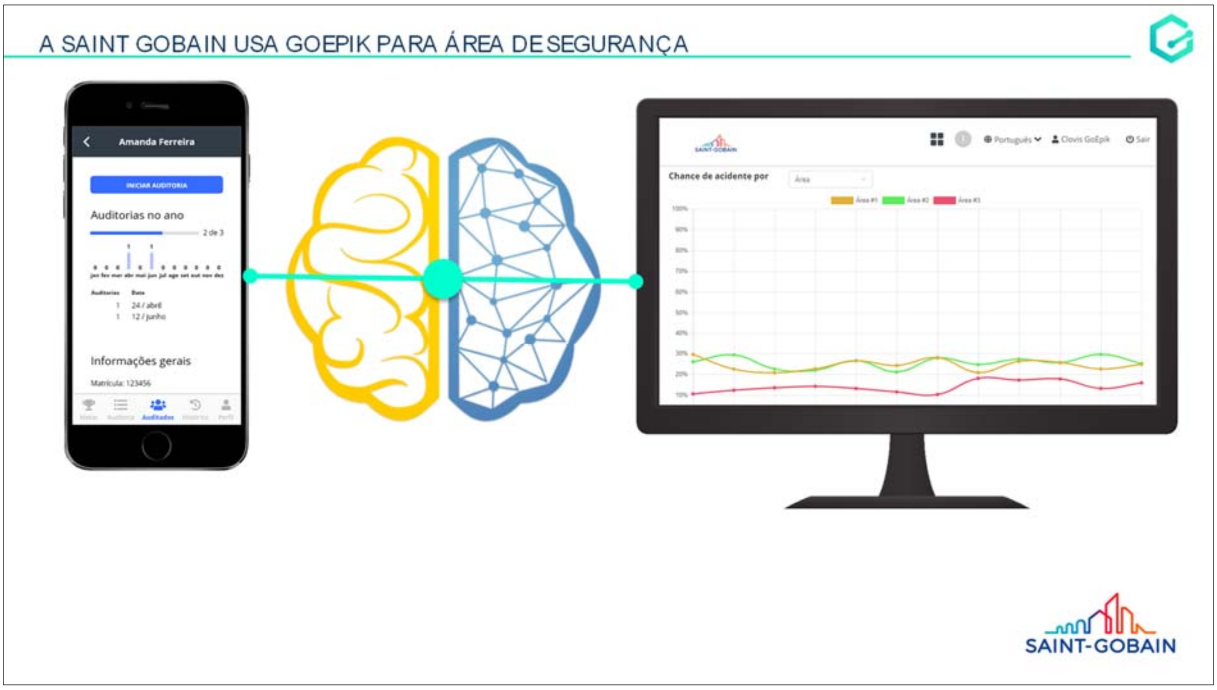
RENAULT
Passion for life

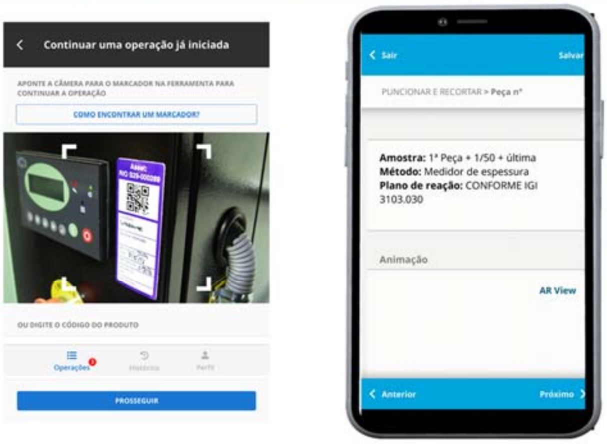

A RENAULT USA GOEPIK TAMBÉM PARA MANUTENÇÃO DE MÁQUINAS
goEPIK
paixão
verificar se ao apertar o botao o mesmo vai gerar uma parada imediata da mesa elevatória
PRONTO
RENAULT
Passion for life


A SAINT GOBAIN USA GOEPIK PARA ÁREA DE SEGURANÇA
Amanda Ferreira
INICIAR AUDITORIA
Auditorias no ano
2 de 3
Informações gerais
Matrícula: 123456
Chance de acidente por
SAINT-GOBAIN

O BOTICÁRIO USA GOEPIK PARA MANUTENÇÃO REMOTA

grupo boticário

A MAXION USA GOEPIK PARA GUIAR OPERADORES DURANTE O SETUP DE MÁQUINA



IOCHPE - MAXION


A EPSON USA GOEPIK PARA SABER EM TEMPO REAL A CONDIÇÃO DAS IMPRESSORAS
m²
DASHBOARD
PRINTED
59m
Temperature variation
Printer status
Working
EPSON
EXCEED YOUR VISION

Resumo e Transparências

Summary and Slides

Prof. Dr.-Ing. Eberhard Abele

Study of Mechanical Engineering at Stuttgart University of Technology. Researcher and Department Leader at the *Fraunhofer Institut für Produktionstechnik und Automatisierung* (IPA). Management functions in a German automotive supply company as Head of Production Planning and Head of Special Purpose Machine Tool. In the same company Head of Production Technology and Technical Director. Since 2000 Director of the Institute of Production Management, Technology and Machine Tools (PTW) at TU Darmstadt.The PTW is working with a staff of about 90 persons in the areas: Additive manufacturing, Machine Tools and Machine Tools Spindles, Optimising Energy Consumption in Machine Tools, Production Organisation and Lean Management, *Industrie 4.0*. About 200 international publications in the fields of additive manufacturing, cutting, automation, robotics, machine tools, production management. Founder of the learning factories “CIP” and “ETA” at the campus of TU Darmstadt. Member of acatech and CIRP fellow. President of the German Academic Society for Production Technologies (WGP) during 2016/2017.

abele@ptw.tu-darmstadt.de

PTW, TU Darmstadt

The Institute of Production Management, Technology and Machine Tools (PTW) is one of the leading German research institutes for production technology. It is directed by Prof. Dr.-Ing. Eberhard Abele and Prof. Dr.-Ing. Joachim Metternich. Currently about 65 associate researchers focus their work on innovations along the manufacturing value chain. This includes the development of machine components and cutting tools, technologies for high-speed machining, energy efficient machine tools, additive manufacturing processes and production management. As pioneer, the PTW opened in 2007 its own learning factory CiP on the campus of the Technische Universität Darmstadt. In 2016 another Factory ETA opened which addresses the energy efficiency of the machines as well as the storage of energy and the energetic linkage of the machines and the factory building.

Energy efficiency and flexibility in Production

Abstract

Climate change has brought along a variety of changes in the global energy landscape. Population growth and development are resulting in a steady increase in energy needs with consumption more than doubling since 1980. The German energy transition "Energiewende", in which renewable energy sources play a central role, requires disruptive transformations of the energy grid. With the industry sector remaining one of the most significant energy consumers in Germany, it is inevitable to bring big industrial changes in order to reach climate goals set in the Paris Agreement and German climate policy through energy efficiency and waste heat reduction measures. Moving towards a greener energy mix with large shares of wind and solar power means more decentralized and volatile energy systems. This poses challenges to the current energy infrastructure and urgently calls for an increase in energy flexibility in addition to energy efficiency. The ETA Factory (Energy Technologies and Applications in Production) is one of six research groups under the Institute of Production Management, Technology and Machine Tools at TU Darmstadt. With over 20 interdisciplinary research associates, the ETA Factory is involved in research projects striving towards energy and resource efficiency as well as energy flexibility in production. For a practical edge, the ETA Factory participates in transferring know-how and technologies into the industry through workshops, factory tours and university courses. In regards to energy efficiency, ETA sets itself apart from traditional approaches by aiming towards factory optimization in a more holistic sense. This incorporates all the factory sub-systems such as production machines, process chains, infrastructure and the factory building as opposed to an isolated optimization of each sub-system. Efforts towards energy flexibility in cooperation with other research institutions and industrial partners have so far brought along successes in large-scale energy flexibilization (e.g. in aluminium electrolysis) in addition to insights into further energy flexibility potentials in other energy intensive industries.

Keywords

Production; Energy efficiency; Energy flexibility.

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M.Sc. M.Sc. Ghada Elserafi
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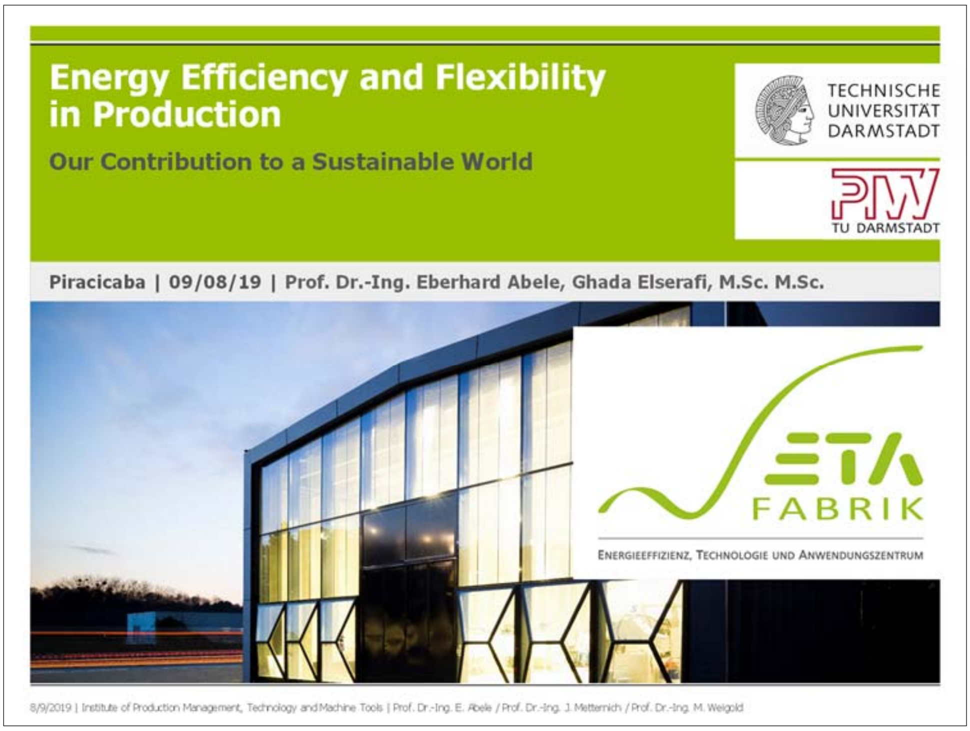
g.elserafi@ptw.tu-darmstadt.de


Energy Efficiency and Flexibility in Production
Our Contribution to a Sustainable World
TECHNISCHE UNIVERSITÄT DARMSTADT
PTW
TU DARMSTADT
Piracicaba | 09/08/19 | Prof. Dr.-Ing. Eberhard Abele, Ghada Elserafi, M.Sc. M.Sc.
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Energieeffizienz, Technologie und Anwendungszentrum
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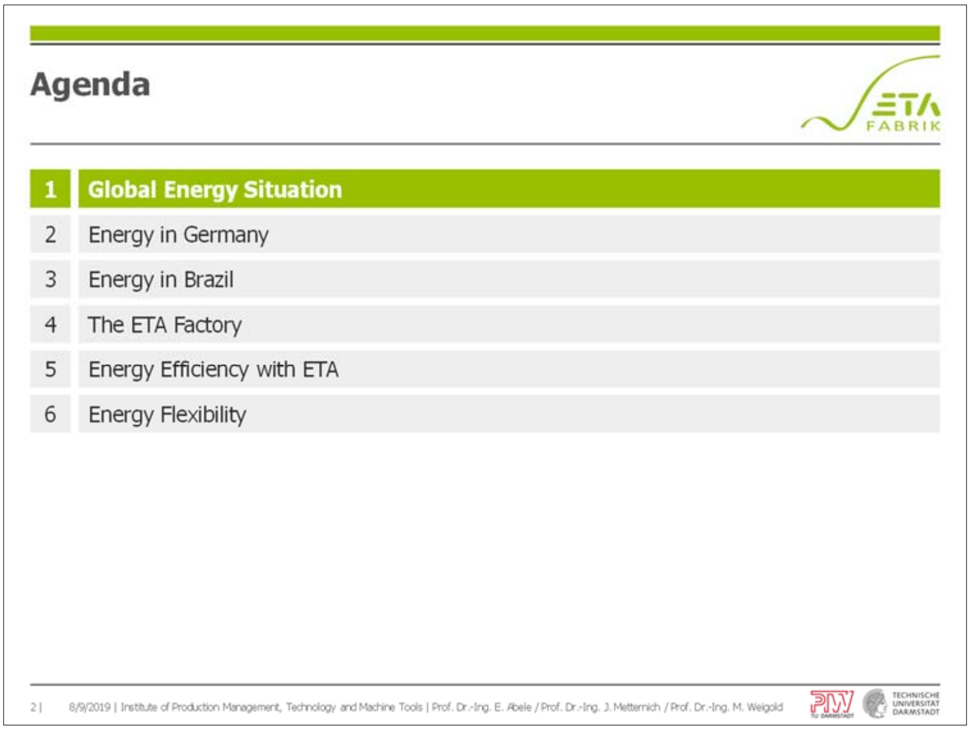
Agenda
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1 Global Energy Situation
2 Energy in Germany
3 Energy in Brazil
4 The ETA Factory
5 Energy Efficiency with ETA
6 Energy Flexibility
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Welcome
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Energy is so important.
If you don't have it, don't bother with rock and roll.
- Yoko Ono
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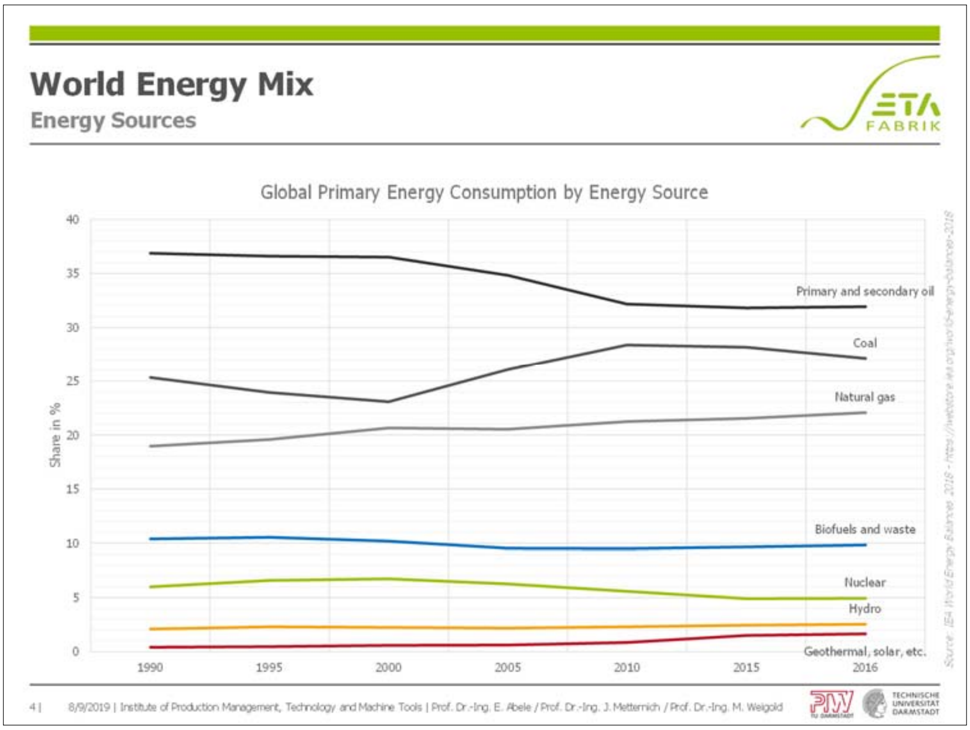
World Energy Mix
Energy Sources
ETA FABRIK
Global Primary Energy Consumption by Energy Source
Share in %
40
35
30
25
20
15
10
5
0
1990
1995
2000
2005
2010
2015
2016
Primary and secondary oil
Coal
Natural gas
Biofuels and waste
Nuclear
Hydro
Geothermal, solar, etc.
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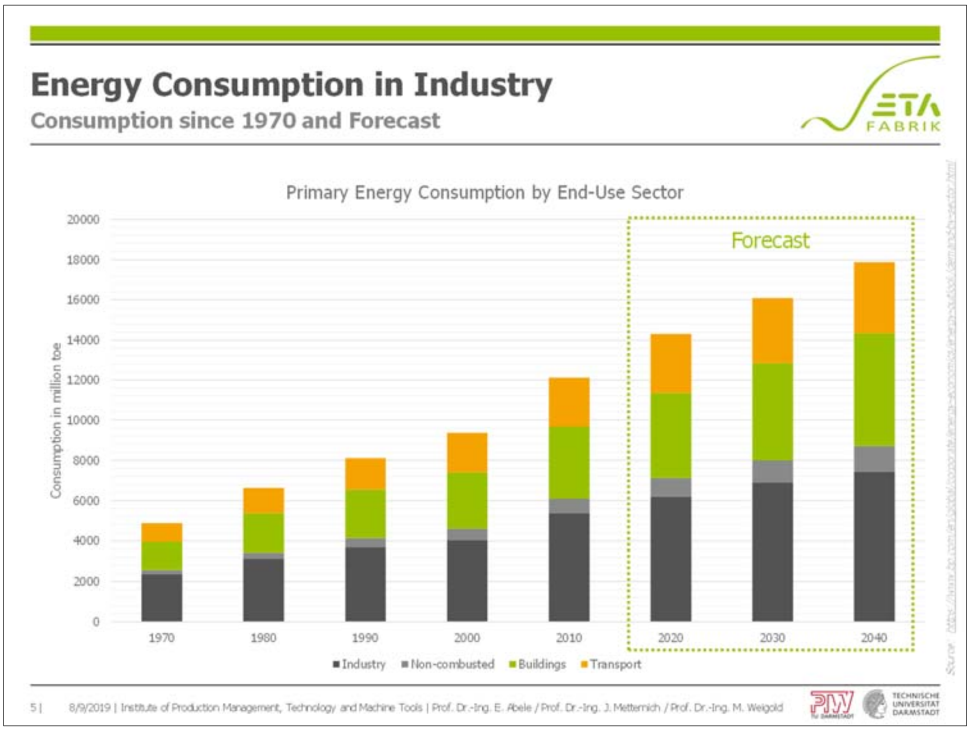
Energy Consumption in Industry
Consumption since 1970 and Forecast
ETA FABRIK
Primary Energy Consumption by End-Use Sector
Consumption in million toe
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1970
1980
1990
2000
2010
2020
2030
2040
Forecast
Industry
Non-combusted
Buildings
Transport
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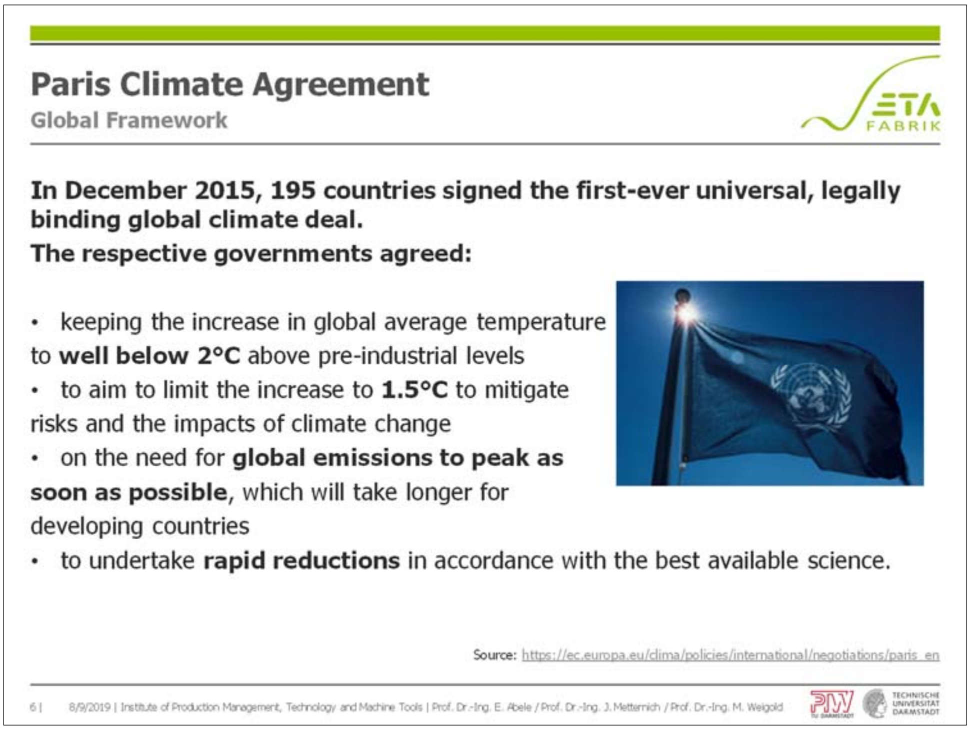
Paris Climate Agreement
Global Framework
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In December 2015, 195 countries signed the first-ever universal, legally binding global climate deal.
The respective governments agreed:
• keeping the increase in global average temperature to well below 2°C above pre-industrial levels
• to aim to limit the increase to 1.5°C to mitigate risks and the impacts of climate change
• on the need for global emissions to peak as soon as possible, which will take longer for developing countries
• to undertake rapid reductions in accordance with the best available science.
Source: https://ec.europa.eu/clima/policies/international/negotiations/paris_en
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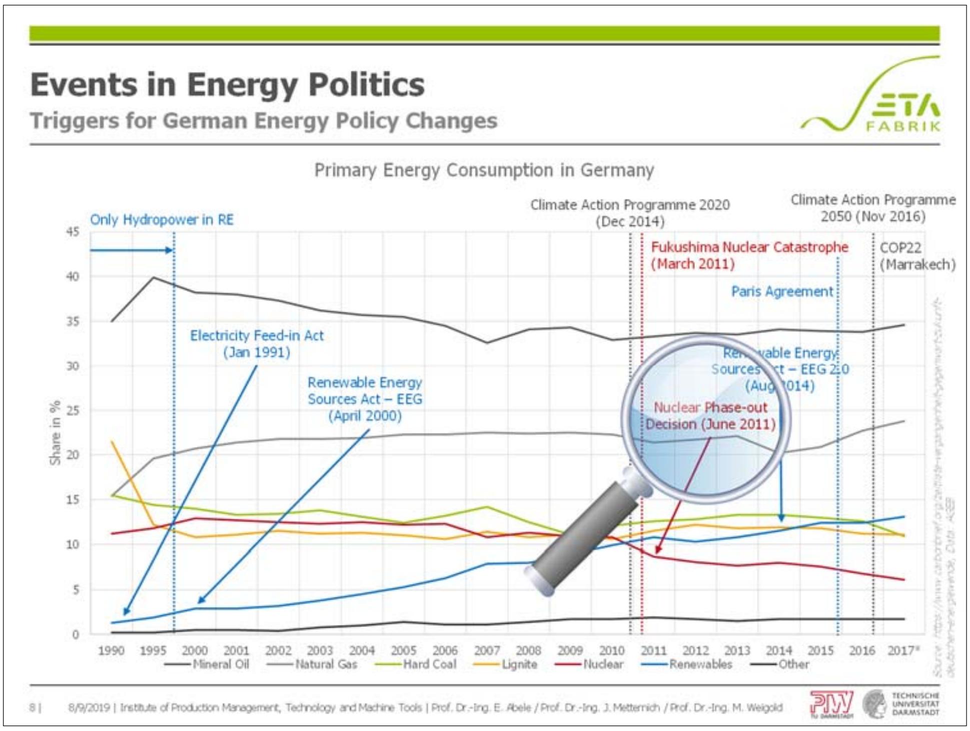
Events in Energy Politics
Triggers for German Energy Policy Changes
ETA FABRIK
Primary Energy Consumption in Germany
Only Hydropower in RE
Climate Action Programme 2020 (Dec 2014)
Climate Action Programme 2050 (Nov 2016)
Fukushima Nuclear Catastrophe (March 2011)
COP22 (Marrakech)
Paris Agreement
Electricity Feed-in Act (Jan 1991)
Renewable Energy Sources Act – EEG (April 2000)
Nuclear Phase-out Decision (June 2011)
Share in %
45
40
35
30
25
20
15
10
5
0
1990 1995 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017*
Mineral Oil
Natural Gas
Hard Coal
Lignite
Nuclear
Renewables
Other
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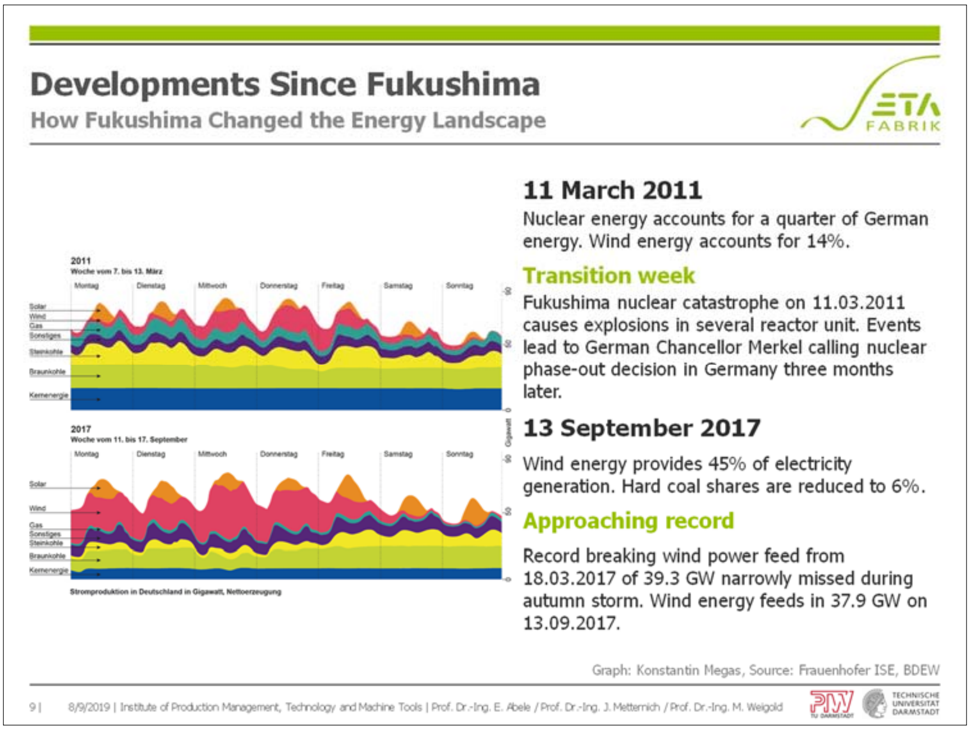
Developments Since Fukushima
How Fukushima Changed the Energy Landscape
ETA FABRIK
2011
2017
11 March 2011
Nuclear energy accounts for a quarter of German energy. Wind energy accounts for 14%.
Transition week
Fukushima nuclear catastrophe on 11.03.2011 causes explosions in several reactor unit. Events lead to German Chancellor Merkel calling nuclear phase-out decision in Germany three months later.
13 September 2017
Wind energy provides 45% of electricity generation. Hard coal shares are reduced to 6%.
Approaching record
Record breaking wind power feed from 18.03.2017 of 39.3 GW narrowly missed during autumn storm. Wind energy feeds in 37.9 GW on 13.09.2017.
Graph: Konstantin Megas, Source: Fraunhofer ISE, BDEW
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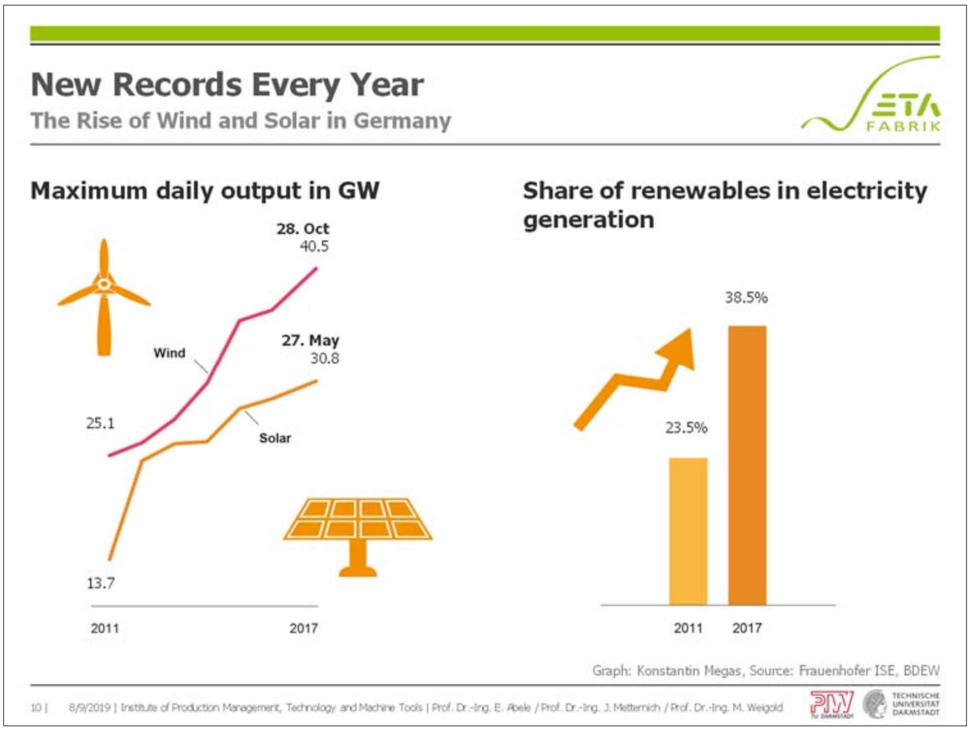
New Records Every Year
The Rise of Wind and Solar in Germany
ETA FABRIK
Maximum daily output in GW
28. Oct
40.5
Wind
27. May
30.8
25.1
Solar
13.7
2011
2017
Share of renewables in electricity generation
38.5%
23.5%
2011
2017
Graph: Konstantin Megas, Source: Fraunhofer ISE, BDEW
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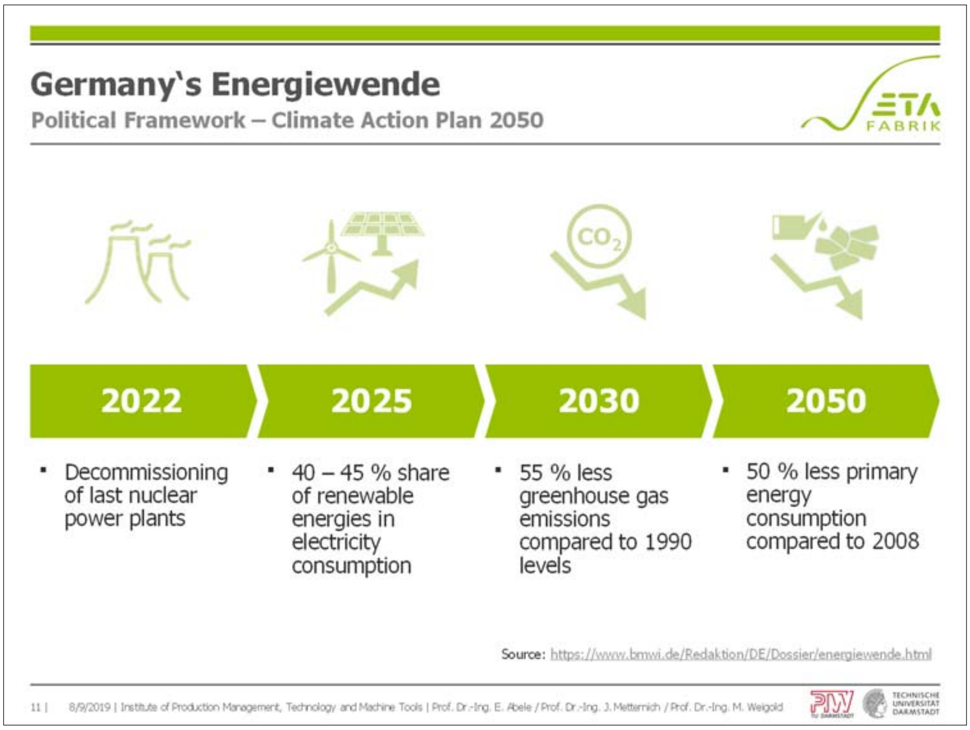
Germany's Energiewende
Political Framework – Climate Action Plan 2050
ETA FABRIK
CO2
2022
2025
2030
2050
Decommissioning of last nuclear power plants
40 – 45 % share of renewable energies in electricity consumption
55 % less greenhouse gas emissions compared to 1990 levels
50 % less primary energy consumption compared to 2008
Source: https://www.bmwi.de/Redaktion/DE/Dossier/energiewende.html
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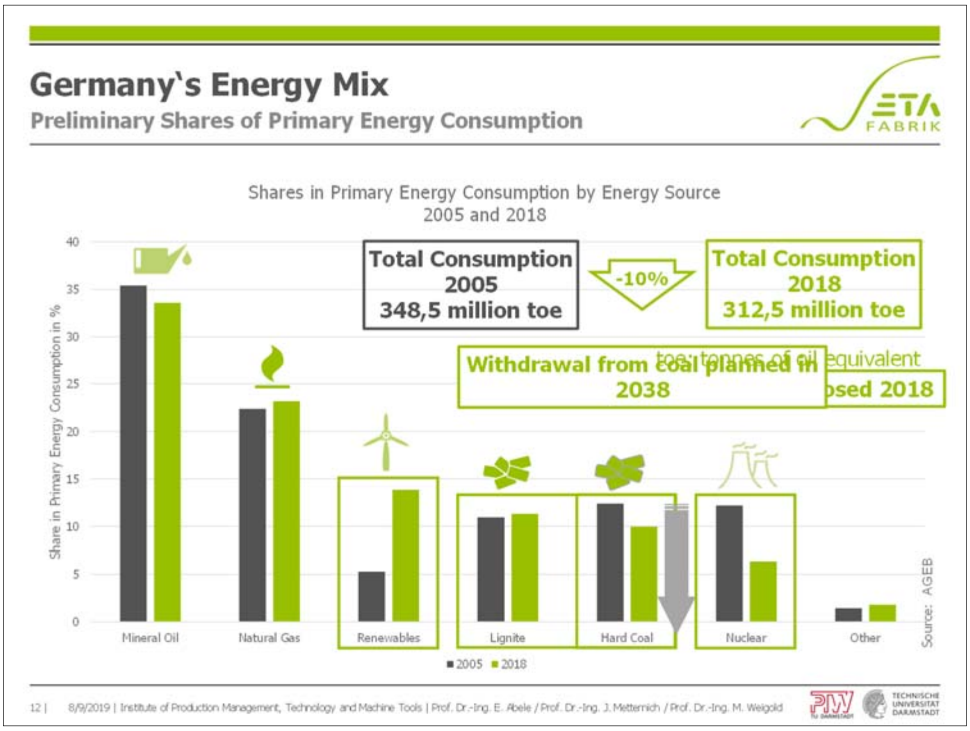
Germany`s Energy Mix
Preliminary Shares of Primary Energy Consumption
ETA FABRIK
Shares in Primary Energy Consumption by Energy Source
2005 and 2018
Total Consumption 2005
348,5 million toe
-10%
Total Consumption 2018
312,5 million toe
toe: tonnes of oil equivalent
Withdrawal from coal planned in 2038
psed 2018
Share in Primary Energy Consumption in %
40
35
30
25
20
15
10
5
0
Mineral Oil
Natural Gas
Renewables
Lignite
Hard Coal
Nuclear
Other
2005
2018
Source: AGEB
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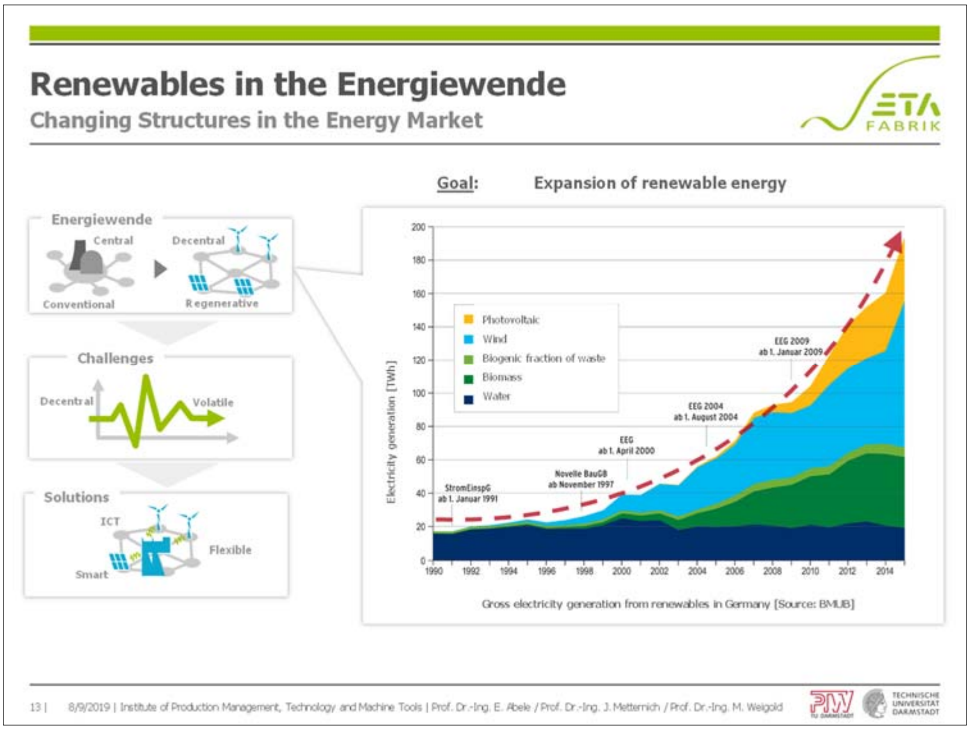
Renewables in the Energiewende
Changing Structures in the Energy Market
ETA FABRIK
Goal: Expansion of renewable energy
Energiewende
Central
Decentral
Conventional
Regenerative
Challenges
Decentral
Volatile
Solutions
ICT
Flexible
Smart
Photovoltaic
Wind
Biogenic fraction of waste
Biomass
Water
Electricity generation [TWh]
EEG 2009 ab 1. Januar 2009
EEG 2004 ab 1. August 2004
EEG ab 1. April 2000
Novelle BauGB ab November 1997
StromEinspG ab 1. Januar 1991
Gross electricity generation from renewables in Germany [Source: BMUB]
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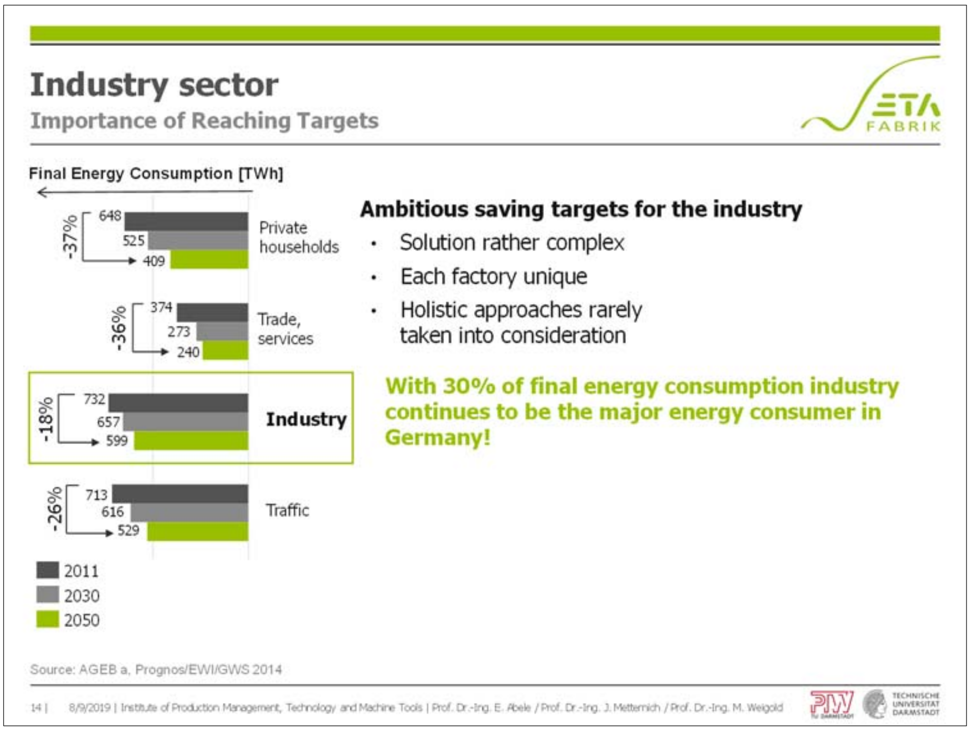
Industry sector
Importance of Reaching Targets
ETA FABRIK
Final Energy Consumption [TWh]
-37%
648
525
409
Private households
-36%
374
273
240
Trade, services
-18%
732
657
599
Industry
-26%
713
616
529
Traffic
2011
2030
2050
Ambitious saving targets for the industry
Solution rather complex
Each factory unique
Holistic approaches rarely taken into consideration
With 30% of final energy consumption industry continues to be the major energy consumer in Germany!
Source: AGEB a, Prognos/EWI/GWS 2014
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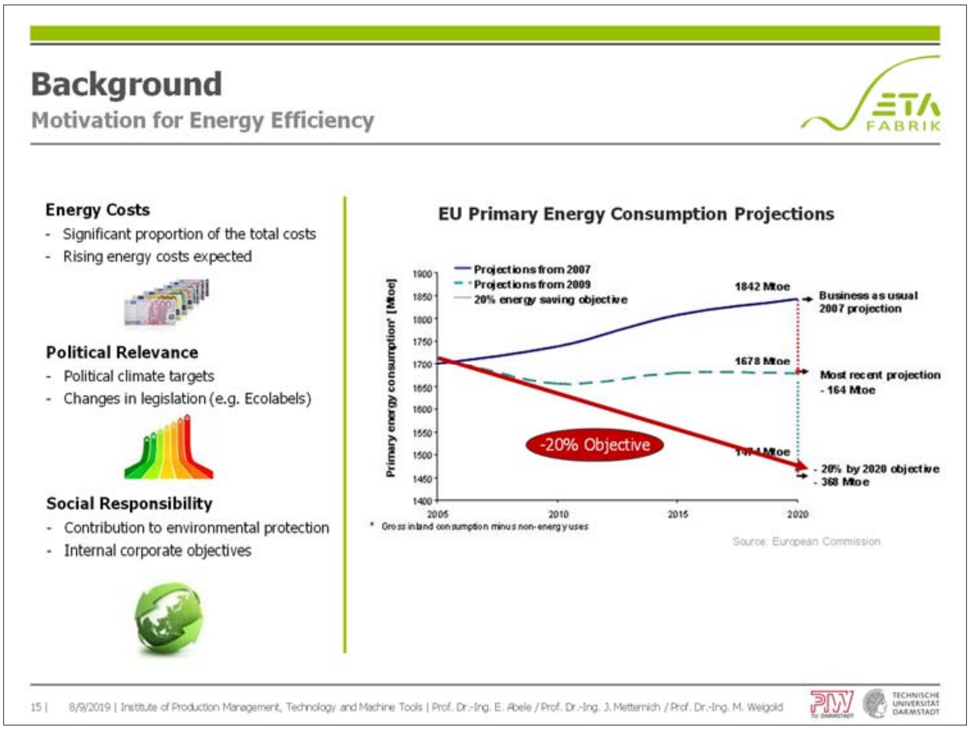
Background
Motivation for Energy Efficiency
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Energy Costs
- Significant proportion of the total costs
- Rising energy costs expected
Political Relevance
- Political climate targets
- Changes in legislation (e.g. Ecolabels)
Social Responsibility
- Contribution to environmental protection
- Internal corporate objectives
EU Primary Energy Consumption Projections
Projections from 2007
Projections from 2009
20% energy saving objective
Primary energy consumption* [Mtoe]
1842 Mtoe
Business as usual 2007 projection
1678 Mtoe
Most recent projection - 164 Mtoe
-20% Objective
- 20% by 2020 objective - 368 Mtoe
2005
2010
2015
2020
* Gross inland consumption minus non-energy uses
Source: European Commission
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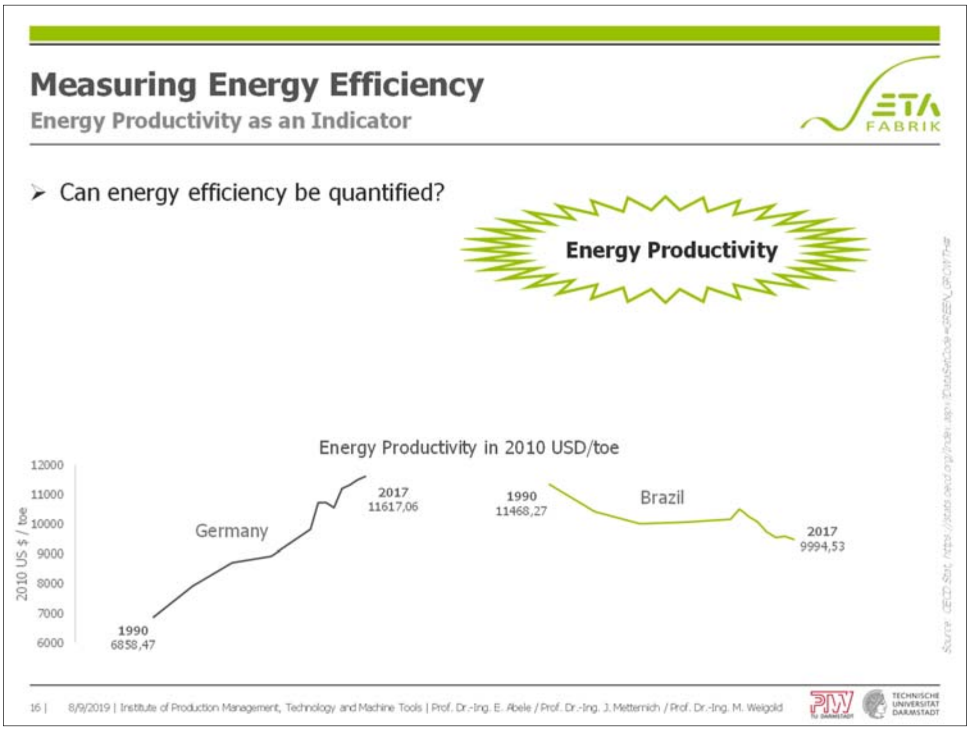
Measuring Energy Efficiency
Energy Productivity as an Indicator
ETA FABRIK
Can energy efficiency be quantified?
Energy Productivity
Energy Productivity in 2010 USD/toe
2010 US $ / toe
12000
11000
10000
9000
8000
7000
6000
Germany
1990
6858,47
2017
11617,06
Brazil
1990
11468,27
2017
9994,53
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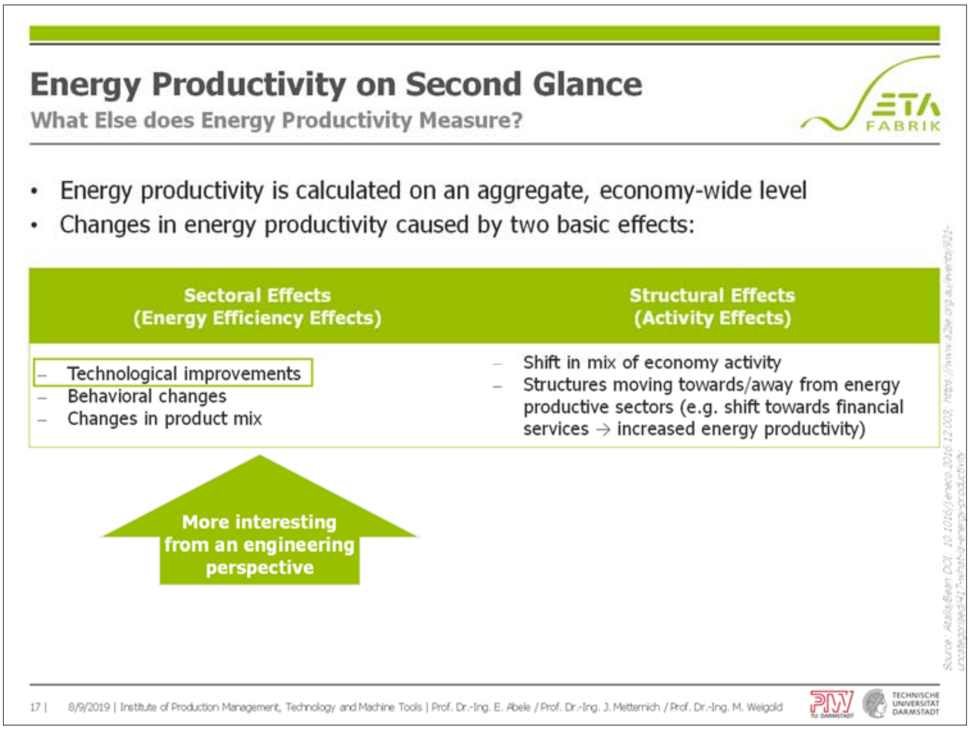
Energy Productivity on Second Glance
What Else does Energy Productivity Measure?
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Energy productivity is calculated on an aggregate, economy-wide level
Changes in energy productivity caused by two basic effects:
Sectoral Effects (Energy Efficiency Effects)
Structural Effects (Activity Effects)
– Technological improvements
– Behavioral changes
– Changes in product mix
– Shift in mix of economy activity
– Structures moving towards/away from energy productive sectors (e.g. shift towards financial services → increased energy productivity)
More interesting from an engineering perspective
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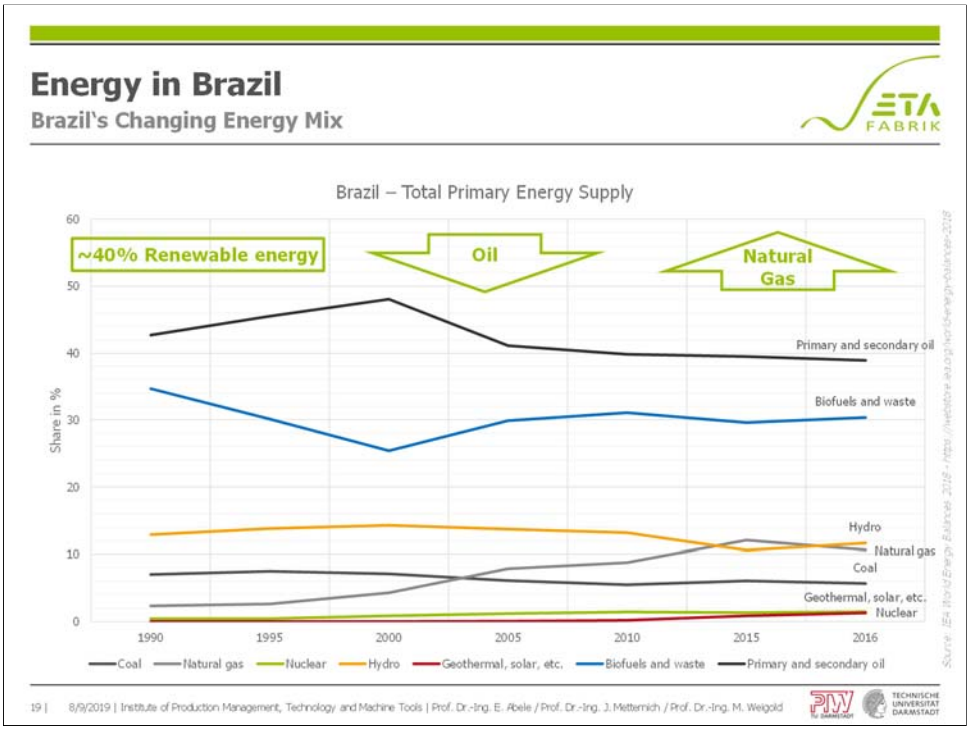
Energy in Brazil
Brazil's Changing Energy Mix
ETA FABRIK
Brazil – Total Primary Energy Supply
~40% Renewable energy
Oil
Natural Gas
Share in %
Primary and secondary oil
Biofuels and waste
Hydro
Natural gas
Coal
Geothermal, solar, etc.
Nuclear
1990
1995
2000
2005
2010
2015
2016
Coal
Natural gas
Nuclear
Hydro
Geothermal, solar, etc.
Biofuels and waste
Primary and secondary oil
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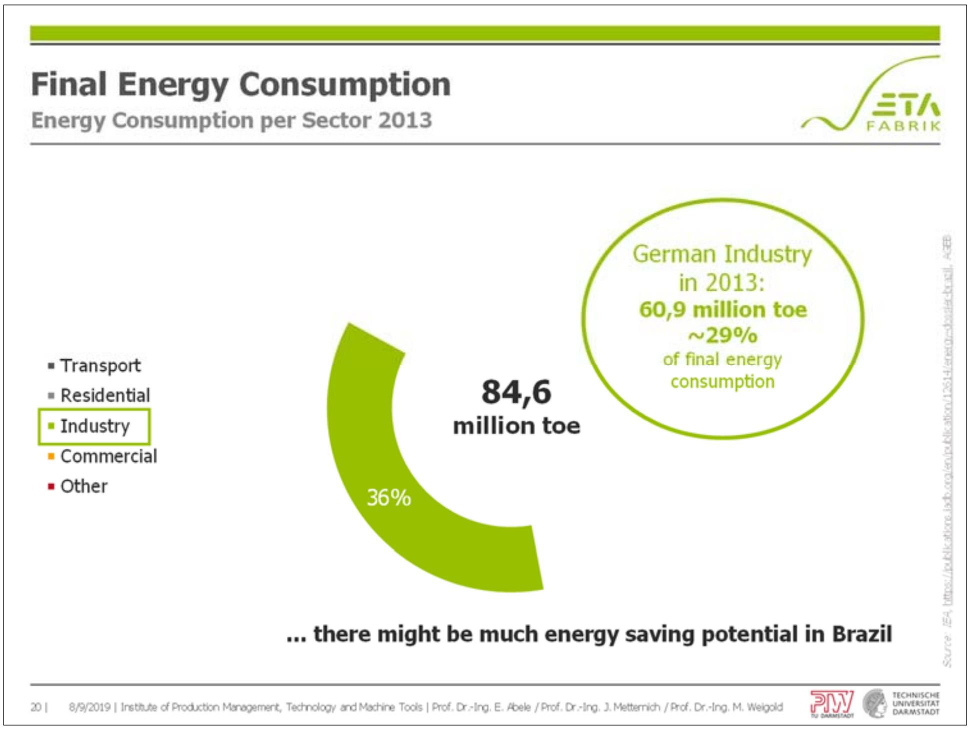
Final Energy Consumption
Energy Consumption per Sector 2013
ETA FABRIK
Transport
Residential
Industry
Commercial
Other
84,6
million toe
36%
German Industry
in 2013:
60,9 million toe
~29%
of final energy
consumption
... there might be much energy saving potential in Brazil
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The ETA Factory
Background
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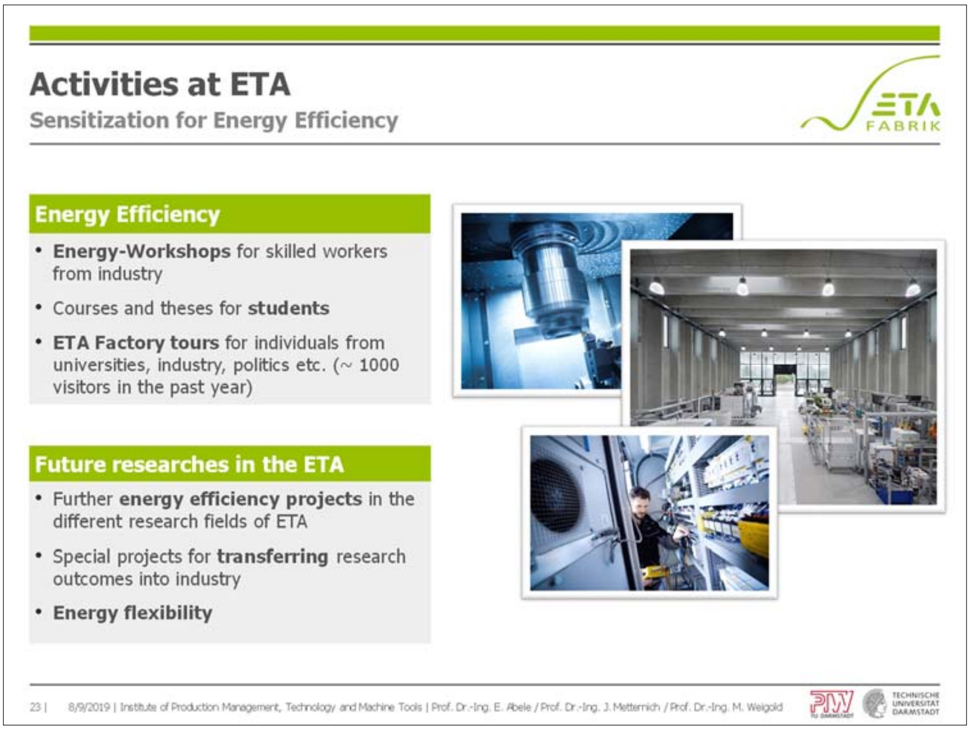
Activities at ETA
Sensitization for Energy Efficiency
ETA
FABRIK
Energy Efficiency
• Energy-Workshops for skilled workers from industry
• Courses and theses for students
• ETA Factory tours for individuals from universities, industry, politics etc. (~ 1000 visitors in the past year)
Future researches in the ETA
• Further energy efficiency projects in the different research fields of ETA
• Special projects for transferring research outcomes into industry
• Energy flexibility
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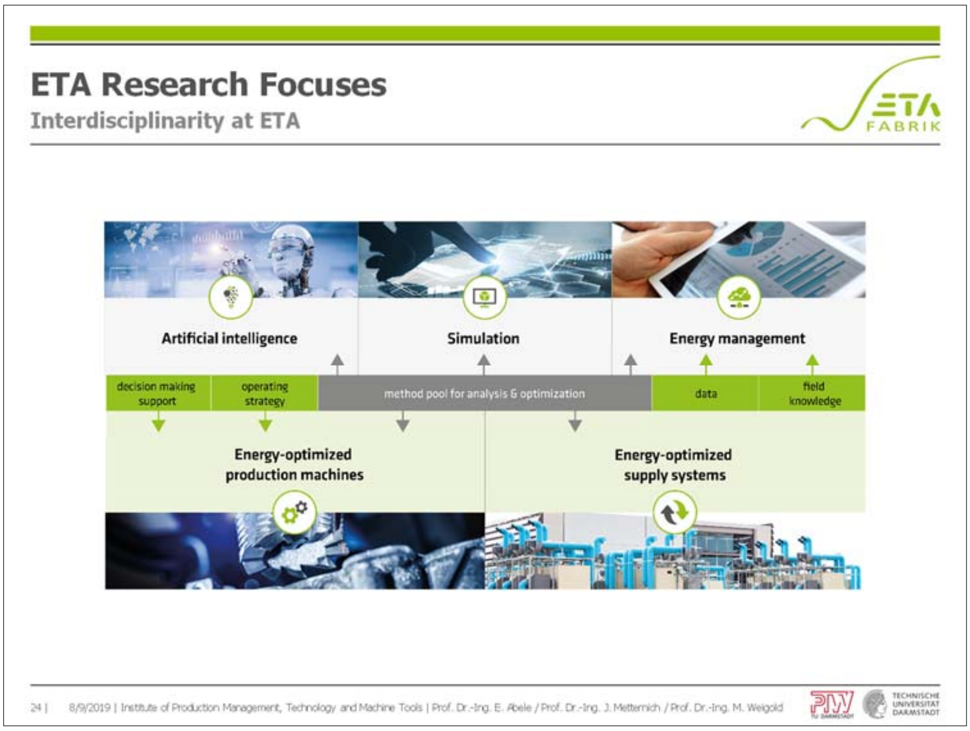
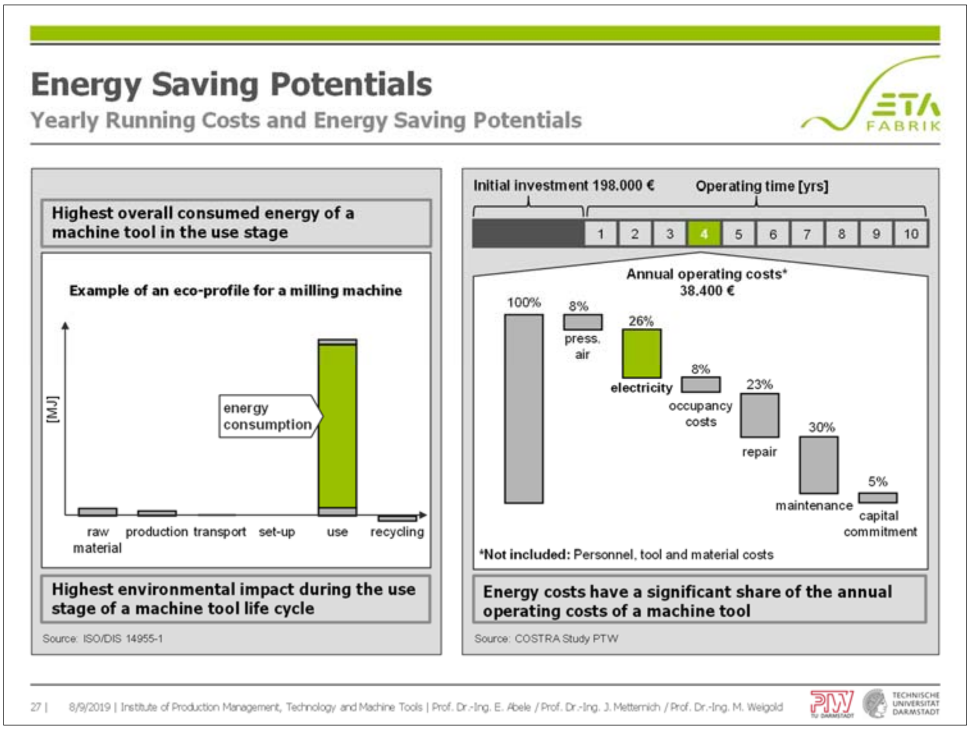

ETA Research Focuses
Interdisciplinarity at ETA
ETA FABRIK
Artificial intelligence
Simulation
Energy management
decision making support
operating strategy
method pool for analysis & optimization
data
field knowledge
Energy-optimized production machines
Energy-optimized supply systems
24 | 8/9/2019 | Institute of Production Management, Technology and Machine Tools | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich / Prof. Dr.-Ing. M. Weigold


Energy Saving Potentials
Yearly Running Costs and Energy Saving Potentials
ETA FABRIK
Highest overall consumed energy of a machine tool in the use stage
Example of an eco-profile for a milling machine
[MJ]
energy consumption
raw material
production
transport
set-up
use
recycling
Highest environmental impact during the use stage of a machine tool life cycle
Source: ISO/DIS 14955-1
Initial investment 198.000 €
Operating time [yrs]
1 2 3 4 5 6 7 8 9 10
Annual operating costs* 38.400 €
100%
8%
press. air
26%
electricity
8%
occupancy costs
23%
repair
30%
maintenance
5%
capital commitment
*Not included: Personnel, tool and material costs
Energy costs have a significant share of the annual operating costs of a machine tool
Source: COSTRA Study PTW
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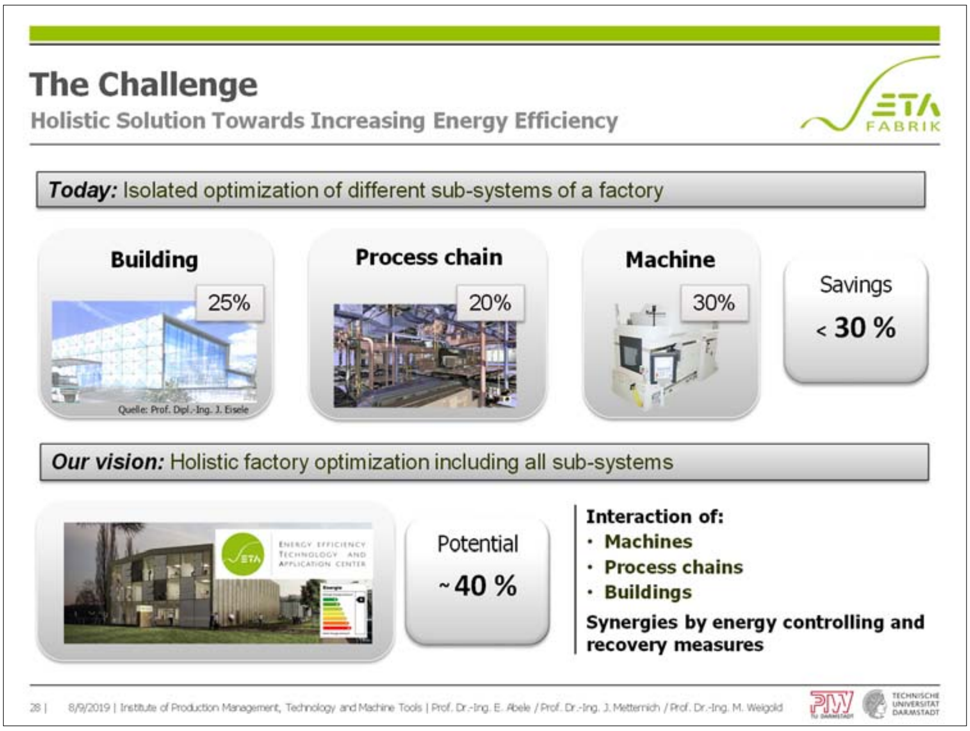
The Challenge
Holistic Solution Towards Increasing Energy Efficiency
ETA FABRIK
Today: Isolated optimization of different sub-systems of a factory
Building
25%
Quelle: Prof. Dipl.-Ing. J. Eisele
Process chain
20%
Machine
30%
Savings
< 30 %
Our vision: Holistic factory optimization including all sub-systems
Energy efficiency Technology and Application Center
Potential
~ 40 %
Interaction of:
• Machines
• Process chains
• Buildings
Synergies by energy controlling and recovery measures
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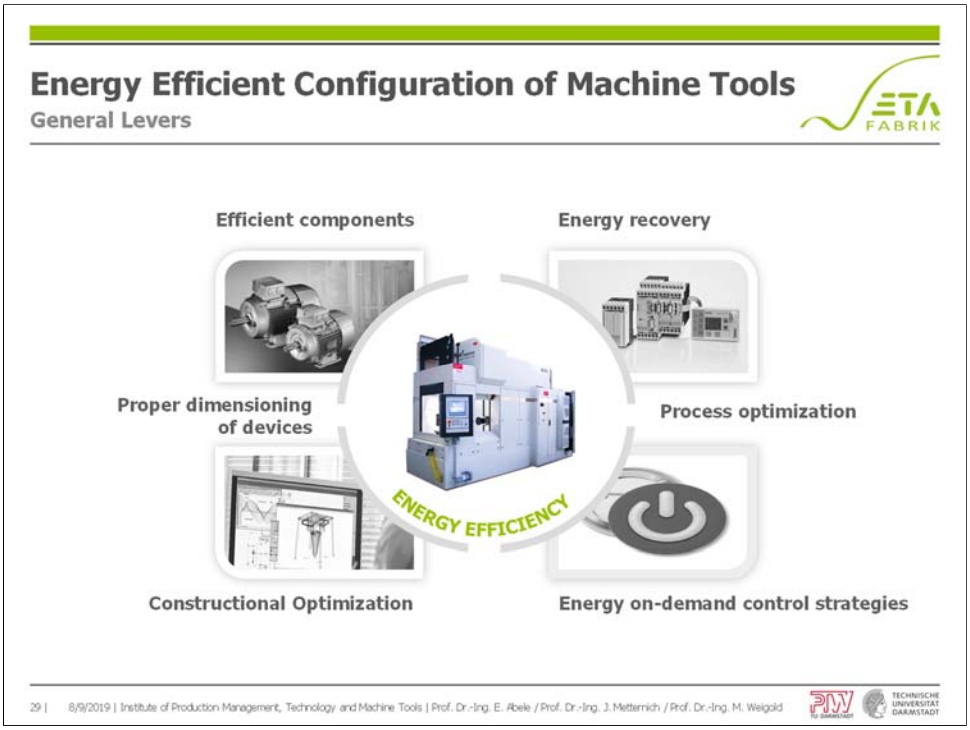
Energy Efficient Configuration of Machine Tools
General Levers
ETA FABRIK
Efficient components
Energy recovery
Proper dimensioning of devices
Process optimization
Energy Efficiency
Constructional Optimization
Energy on-demand control strategies
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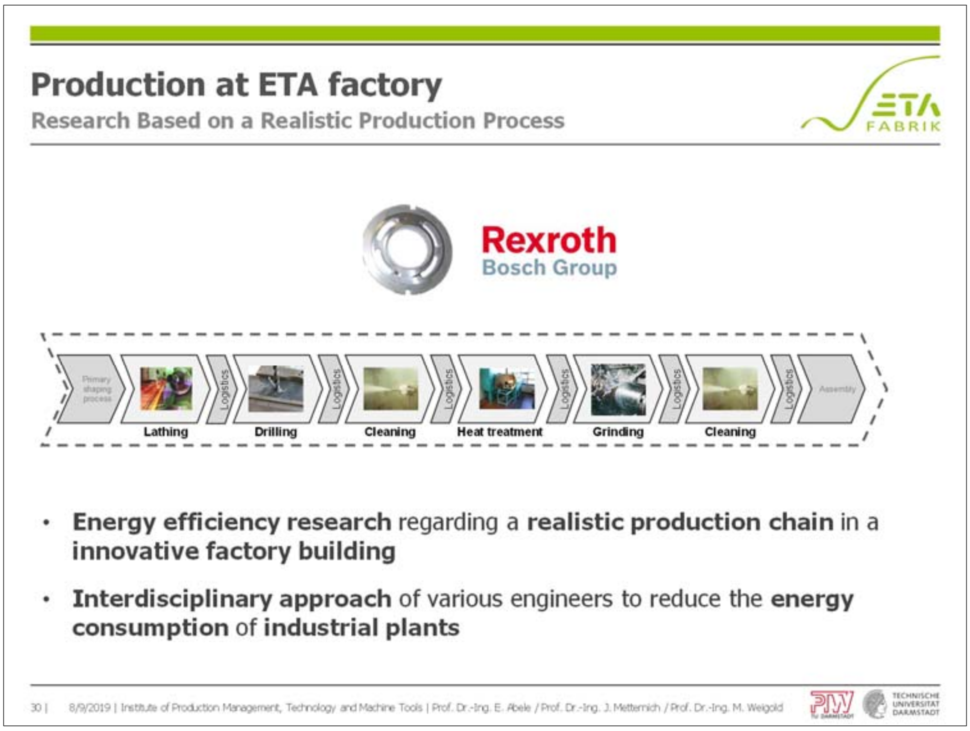
Production at ETA factory
Research Based on a Realistic Production Process
ETA FABRIK
Rexroth
Bosch Group
Lathing
Drilling
Cleaning
Heat treatment
Grinding
Cleaning
Logistics
Energy efficiency research regarding a realistic production chain in a innovative factory building
Interdisciplinary approach of various engineers to reduce the energy consumption of industrial plants
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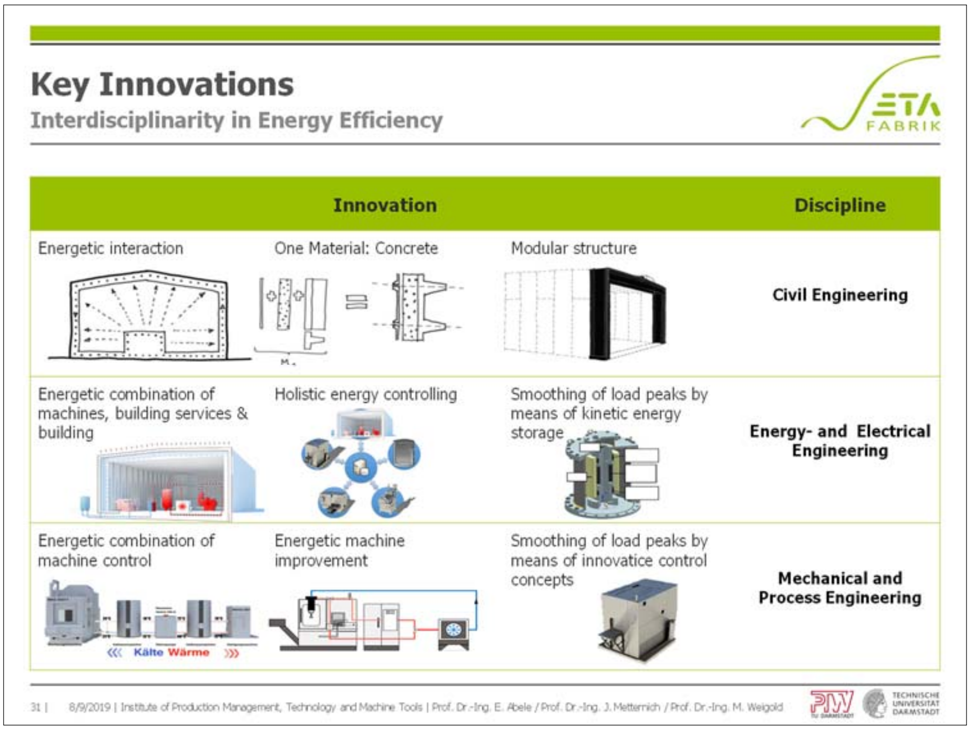
Key Innovations
Interdisciplinarity in Energy Efficiency
ETA FABRIK
Innovation
Discipline
Energetic interaction
One Material: Concrete
Modular structure
Civil Engineering
Energetic combination of machines, building services & building
Holistic energy controlling
Smoothing of load peaks by means of kinetic energy storage
Energy- and Electrical Engineering
Energetic combination of machine control
Kälte Wärme
Energetic machine improvement
Smoothing of load peaks by means of innovatice control concepts
Mechanical and Process Engineering
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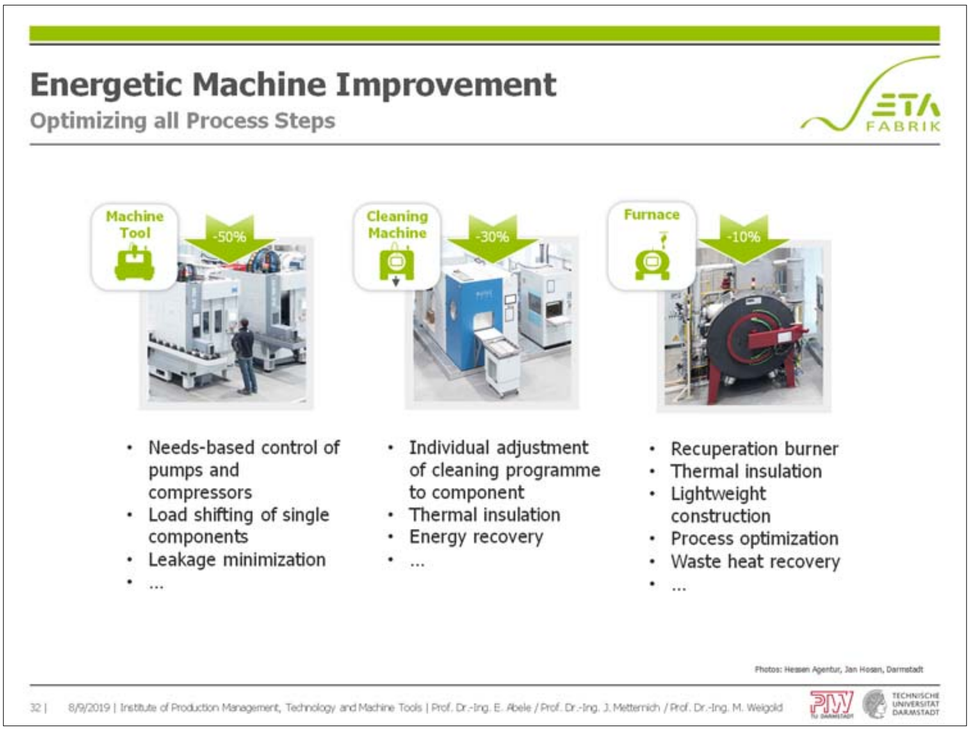
Energetic Machine Improvement
Optimizing all Process Steps
ETA FABRIK
Machine Tool
-50%
Cleaning Machine
-30%
Furnace
-10%
• Needs-based control of pumps and compressors
• Load shifting of single components
• Leakage minimization
• ...
• Individual adjustment of cleaning programme to component
• Thermal insulation
• Energy recovery
• ...
• Recuperation burner
• Thermal insulation
• Lightweight construction
• Process optimization
• Waste heat recovery
• ...
Photos: Hessen Agentur, Jan Hosan, Darmstadt
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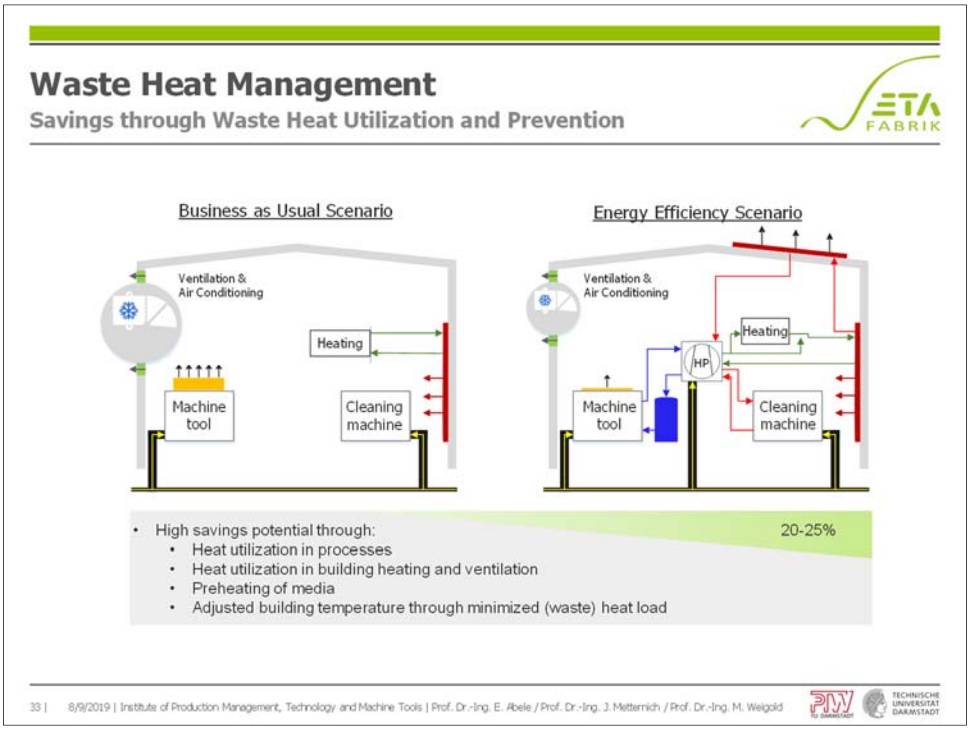
Waste Heat Management
Savings through Waste Heat Utilization and Prevention
ETA FABRIK
Business as Usual Scenario
Ventilation & Air Conditioning
Heating
Machine tool
Cleaning machine
Energy Efficiency Scenario
Ventilation & Air Conditioning
Heating
HP
Machine tool
Cleaning machine
• High savings potential through:
• Heat utilization in processes
• Heat utilization in building heating and ventilation
• Preheating of media
• Adjusted building temperature through minimized (waste) heat load
20-25%
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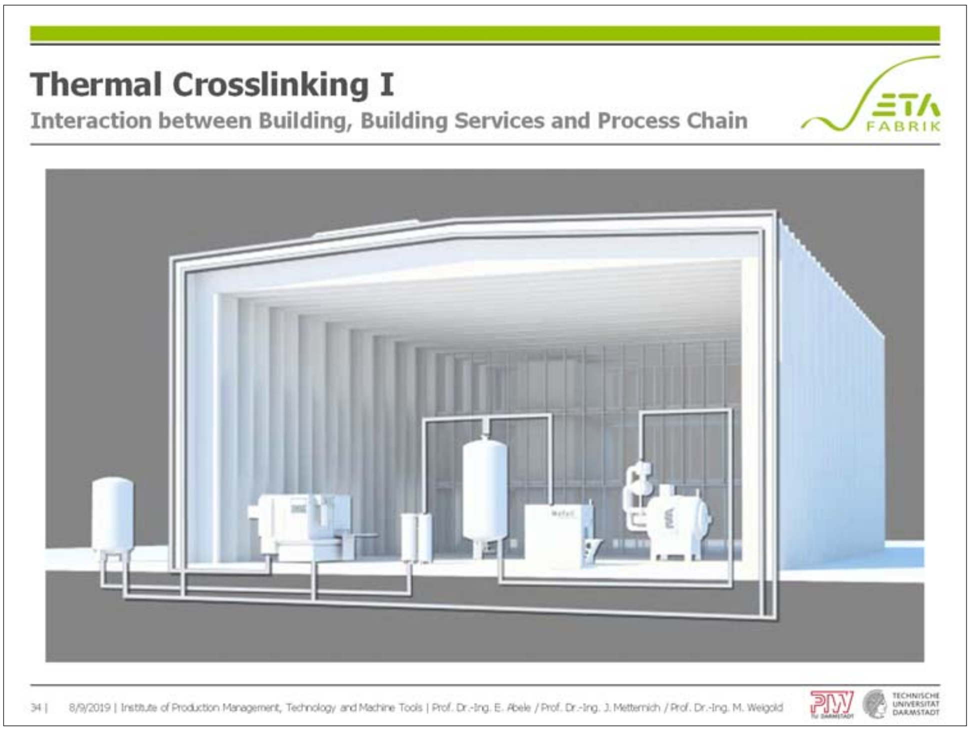
Thermal Crosslinking I
Interaction between Building, Building Services and Process Chain
ETA FABRIK
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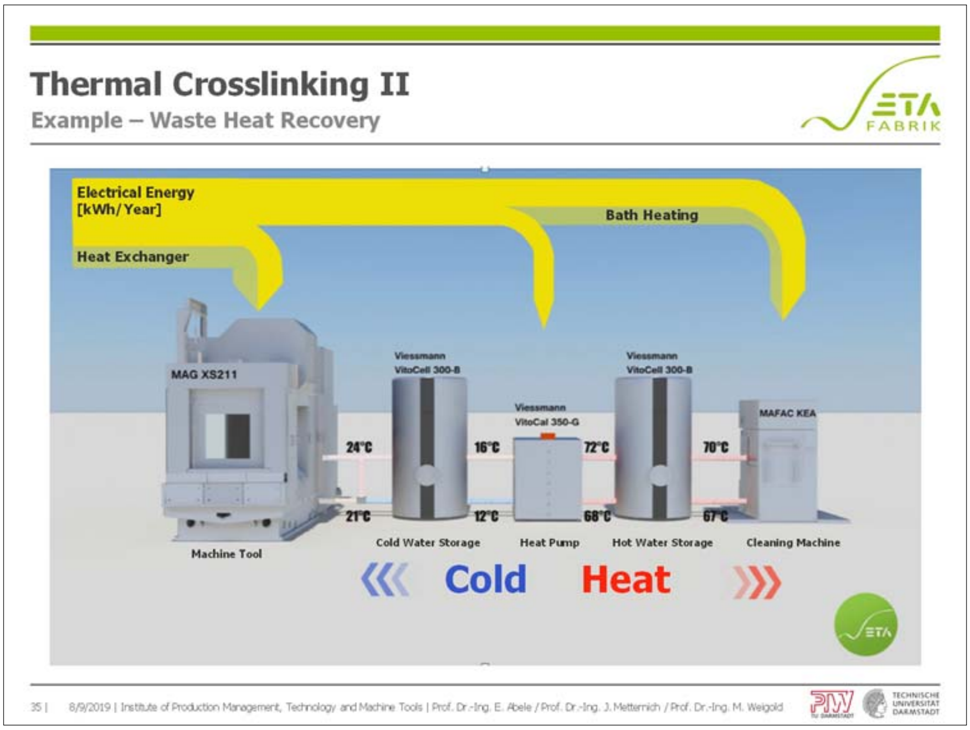
Thermal Crosslinking II
Example – Waste Heat Recovery
ETA FABRIK
Electrical Energy [kWh/Year]
Bath Heating
Heat Exchanger
MAG XS211
Viessmann VitoCell 300-B
Viessmann VitoCal 350-G
Viessmann VitoCell 300-B
MAFAC KEA
24°C
16°C
72°C
70°C
21°C
12°C
68°C
67°C
Cold Water Storage
Heat Pump
Hot Water Storage
Cleaning Machine
Machine Tool
Cold
Heat
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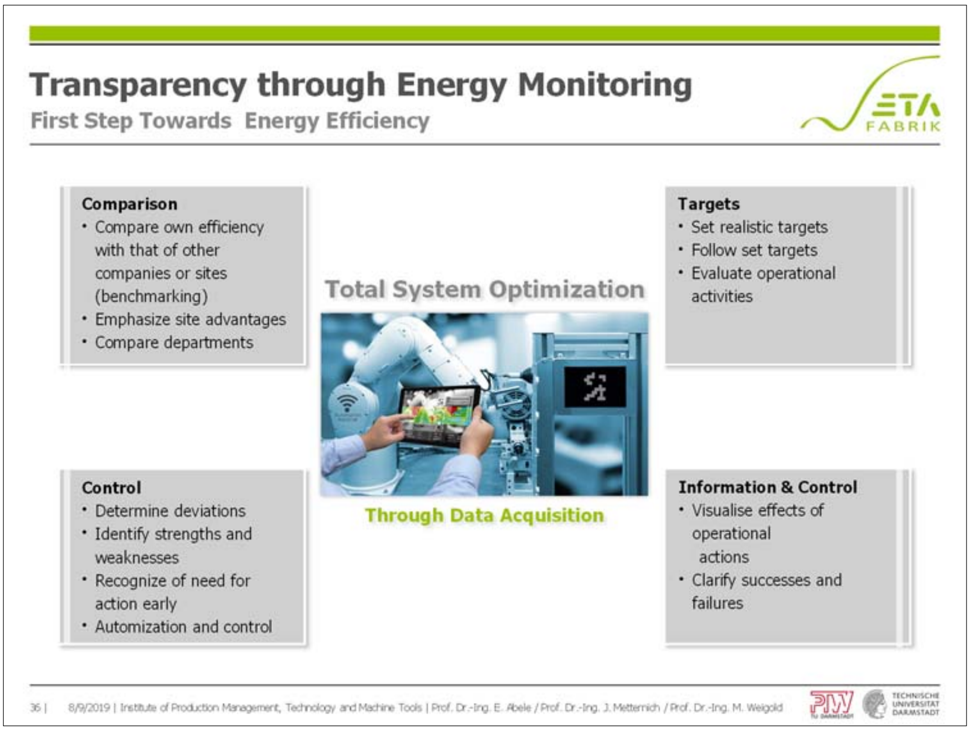
Transparency through Energy Monitoring
First Step Towards Energy Efficiency
ETA FABRIK
Comparison
• Compare own efficiency with that of other companies or sites (benchmarking)
• Emphasize site advantages
• Compare departments
Targets
• Set realistic targets
• Follow set targets
• Evaluate operational activities
Total System Optimization
Through Data Acquisition
Control
• Determine deviations
• Identify strengths and weaknesses
• Recognize of need for action early
• Automization and control
Information & Control
• Visualise effects of operational actions
• Clarify successes and failures
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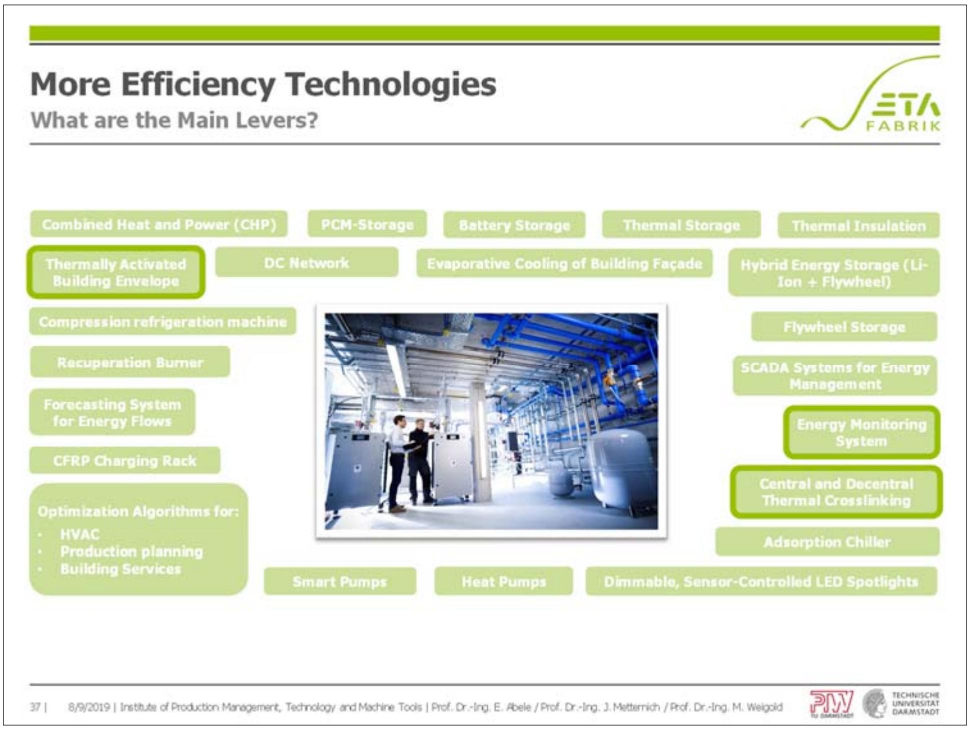
More Efficiency Technologies
What are the Main Levers?
ETA FABRIK
Combined Heat and Power (CHP)
PCM-Storage
Battery Storage
Thermal Storage
Thermal Insulation
Thermally Activated Building Envelope
DC Network
Evaporative Cooling of Building Façade
Hybrid Energy Storage (Li-Ion + Flywheel)
Compression refrigeration machine
Flywheel Storage
Recuperation Burner
SCADA Systems for Energy Management
Forecasting System for Energy Flows
Energy Monitoring System
CFRP Charging Rack
Central and Decentral Thermal Crosslinking
Optimization Algorithms for:
• HVAC
• Production planning
• Building Services
Adsorption Chiller
Smart Pumps
Heat Pumps
Dimmable, Sensor-Controlled LED Spotlights
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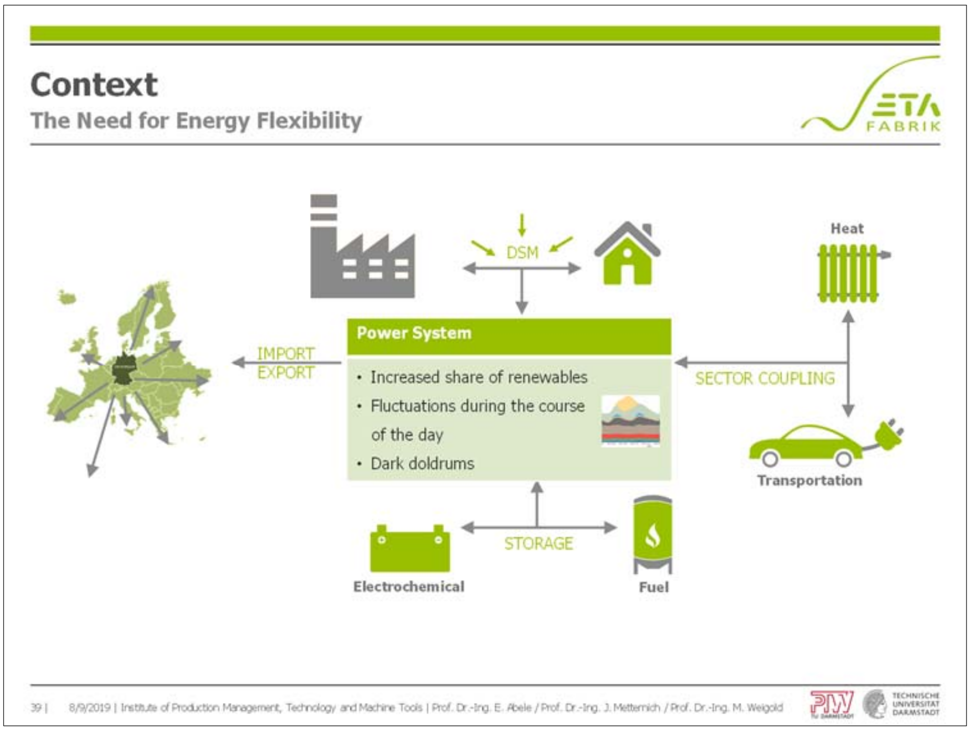
Context
The Need for Energy Flexibility
ETA FABRIK
DSM
Heat
IMPORT
EXPORT
Power System
• Increased share of renewables
• Fluctuations during the course of the day
• Dark doldrums
SECTOR COUPLING
Transportation
STORAGE
Electrochemical
Fuel
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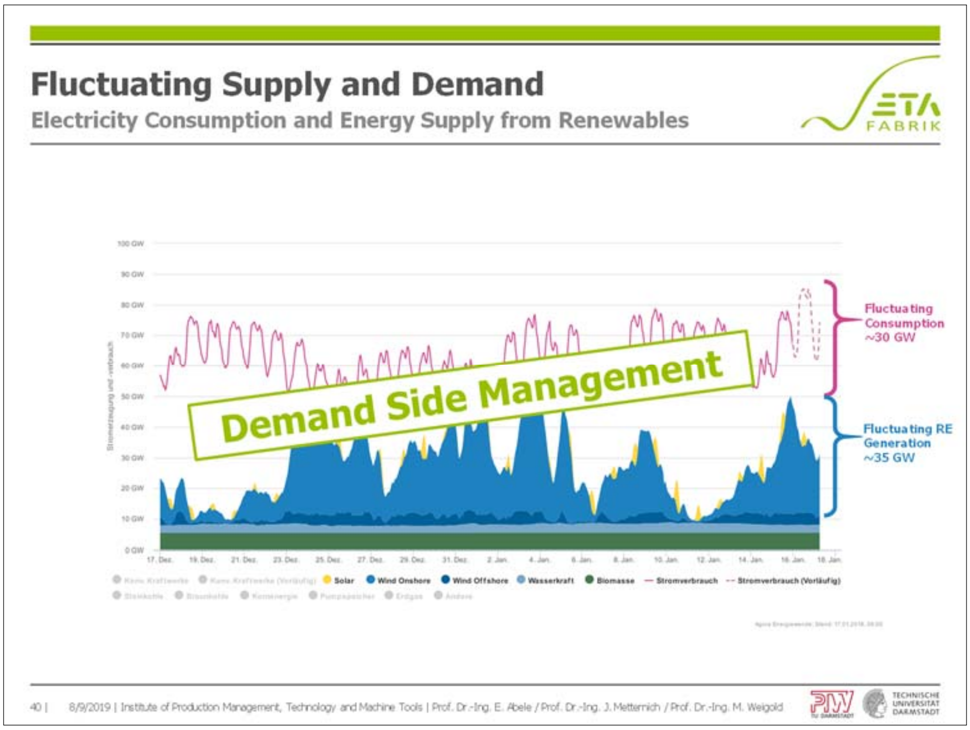
Fluctuating Supply and Demand
Electricity Consumption and Energy Supply from Renewables
ETA FABRIK
100 GW
90 GW
80 GW
70 GW
60 GW
50 GW
40 GW
30 GW
20 GW
10 GW
0 GW
17. Dez. 19. Dez. 21. Dez. 23. Dez. 25. Dez. 27. Dez. 29. Dez. 31. Dez. 2. Jan. 4. Jan. 6. Jan. 8. Jan. 10. Jan. 12. Jan. 14. Jan. 16. Jan. 18. Jan.
Solar
Wind Onshore
Wind Offshore
Wasserkraft
Biomasse
Stromverbrauch
Stromverbrauch (Vorläufig)
Demand Side Management
Fluctuating Consumption ~30 GW
Fluctuating RE Generation ~35 GW
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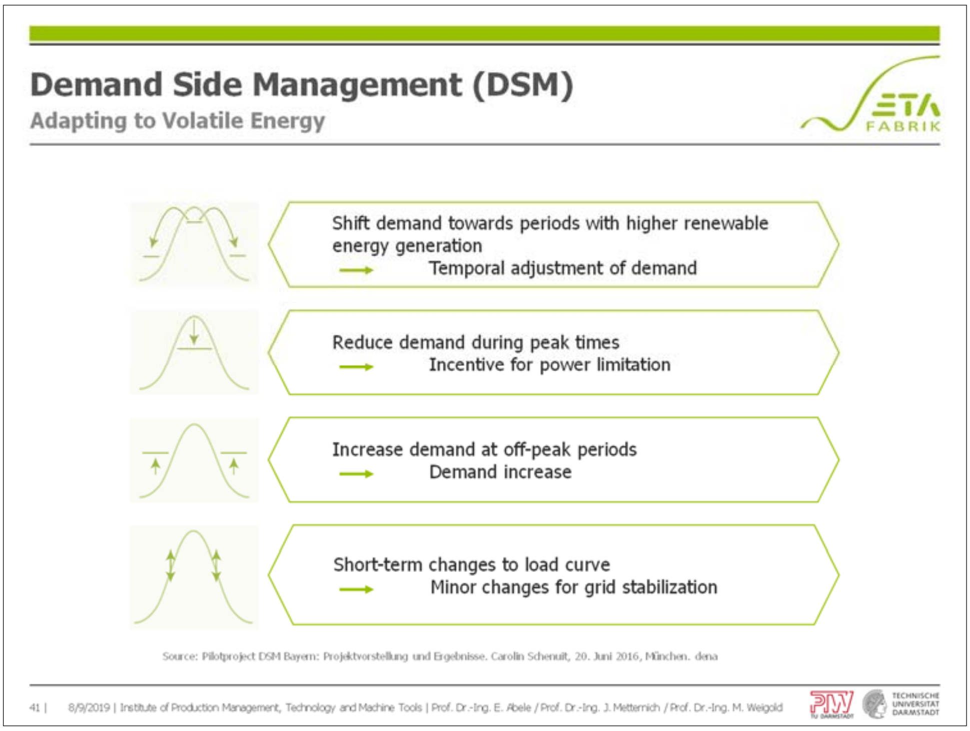
Demand Side Management (DSM)
Adapting to Volatile Energy
ETA FABRIK
Shift demand towards periods with higher renewable energy generation
Temporal adjustment of demand
Reduce demand during peak times
Incentive for power limitation
Increase demand at off-peak periods
Demand increase
Short-term changes to load curve
Minor changes for grid stabilization
Source: Pilotprojekt DSM Bayern: Projektvorstellung und Ergebnisse. Carolin Schenuit, 20. Juni 2016, München. dena
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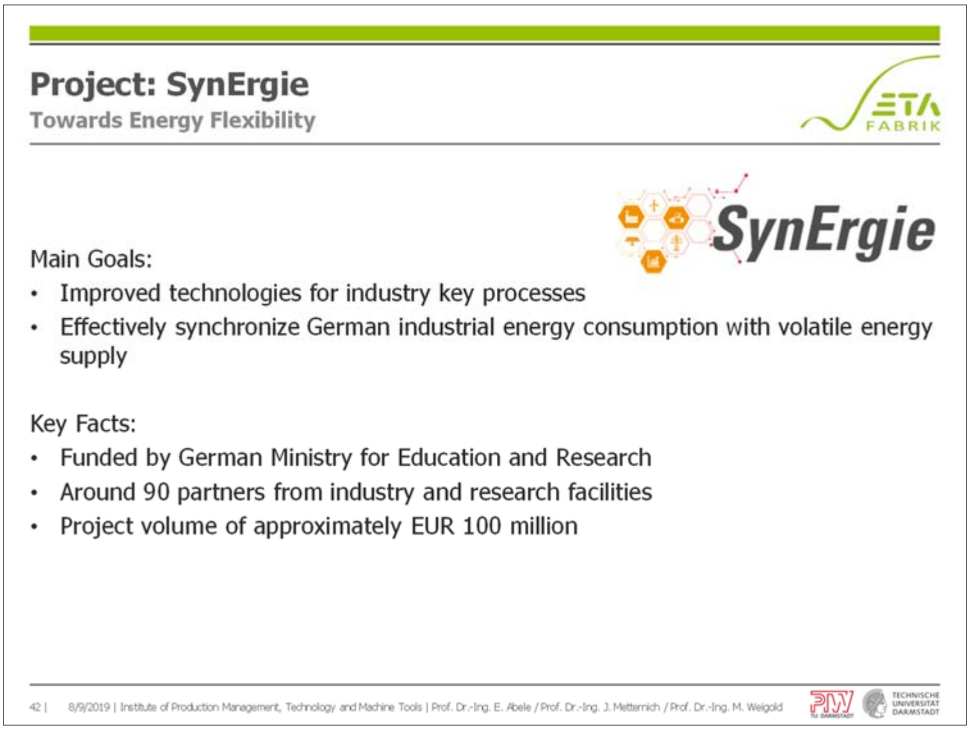
Project: SynErgie
Towards Energy Flexibility
ETA FABRIK
SynErgie
Main Goals:
• Improved technologies for industry key processes
• Effectively synchronize German industrial energy consumption with volatile energy supply
Key Facts:
• Funded by German Ministry for Education and Research
• Around 90 partners from industry and research facilities
• Project volume of approximately EUR 100 million
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Project Outcome
FLEX-Electrolysis
ETA FABRIK
• Can this process be flexibilized?
FLEX-Electrolysis
German aluminum manufacturer
trímet
Aluminum electrolysis line
Source: TRIMET Aluminium SE
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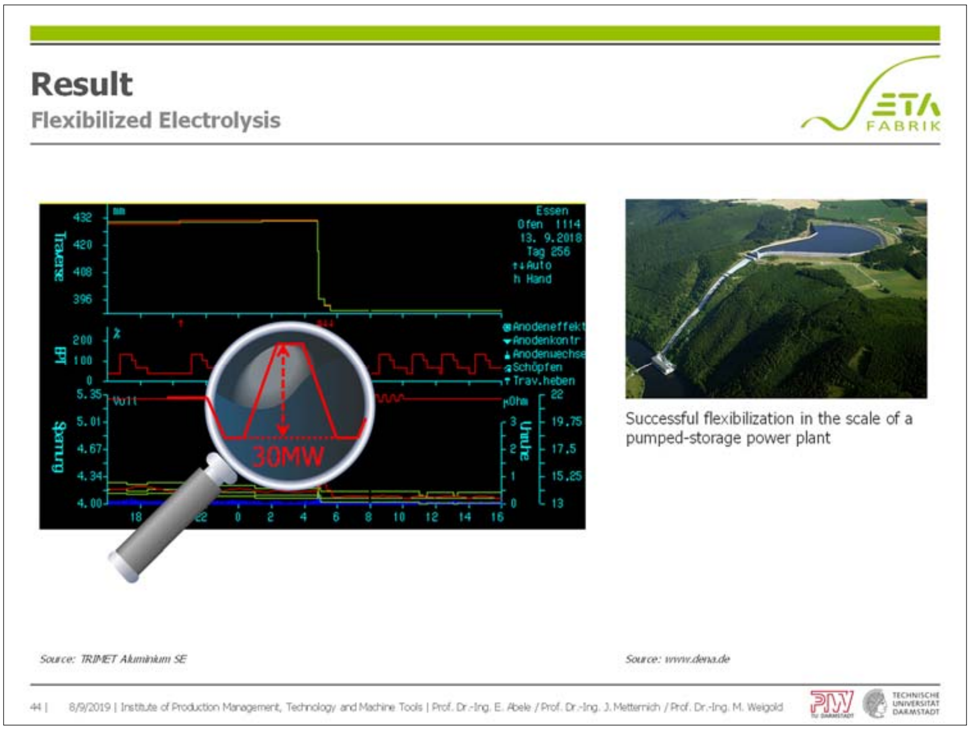
Result
Flexibilized Electrolysis
ETA FABRIK
30MW
Successful flexibilization in the scale of a pumped-storage power plant
Source: TRIMET Aluminium SE
Source: www.dena.de
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Dr. Paulo César Rezende de Carvalho Alvim

É Engenheiro Civil, formado pela Universidade Federal do Rio de Janeiro, Mestre em Ciência da Informação, formado pela Universidade de Brasília. 1982 a 1984 foi analista de projetos das áreas de transporte e energia. 1985 a 1986, foi analista técnico da Secretaria de Tecnologia Industrial do MIC, atuando nas áreas de energia e tecnologia industrial básica. 1987 a 1989 foi Técnico do CEBRAE, atuando nas áreas de apoio tecnológico aos pequenos negócios e superintendente da área de modernização e cooperação técnica. 1989 a 1990 foi Secretário Geral Adjunto do MEC. 1990 foi técnico da FINEP, atuando na área de apoio a consultoria nacional. 1990 a 1992 Coordenação de modernização tecnológica da Secretaria de Ciência e Tecnologia da PR, atuando as áreas de prospecção tecnológica, PBQP e PACTI. 1992 foi Secretário Adjunto de Governo do Governador do DF/ GDF. 1993 foi Secretário Adjunto de Ciência, Tecnologia e Meio Ambiente do GDF. 1994 a 1995 foi Presidente da FAP-DF. 195 foi técnico da FINEP, atuando na área de negócios internacionais de tecnologia. 1996 a 1997 foi Vice-Diretor do IBICT. 1998 a 2000 foi Chefe de escritório da FINEP em Brasília. 2000 a 2002 foi Diretor do Departamento de Setores Intensivos em Mão-de-obra da Secretaria de Desenvolvimento da Produção do MDIC. 2002 a 2019, foi analista III do Sebrae Nacional, onde exerceu as funções de Gerente de Acesso a Tecnologia e Inovação, Gerente de Agronegócios, Gerente de Acesso a Mercados, Gerente de Acesso a Mercados e Serviços Financeiros, Coordenador do CRAB, Assessor da Diretoria, analista da Unidade de Cultura Empreendedora, além das participações como Conselheiro dos CDE dos Sebrae PA, AC, RO, RJ e MG e como representante do Sebrae em Conselhos e Fóruns nacionais e internacionais. Atualmente é Secretário Nacional de Empreendedorismo e Inovação do Ministério da Ciência, Tecnologia, Inovações e Comunicações – MCTIC.

Ministério da Ciência, Tecnologia, Inovações e Comunicações – MCTIC.

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL

Indústria Avançada e IoT

Keywords

Indústria 4.0; IoT; Mapeamento 4.0.

Dr. Paulo César Rezende de Carvalho Alvim
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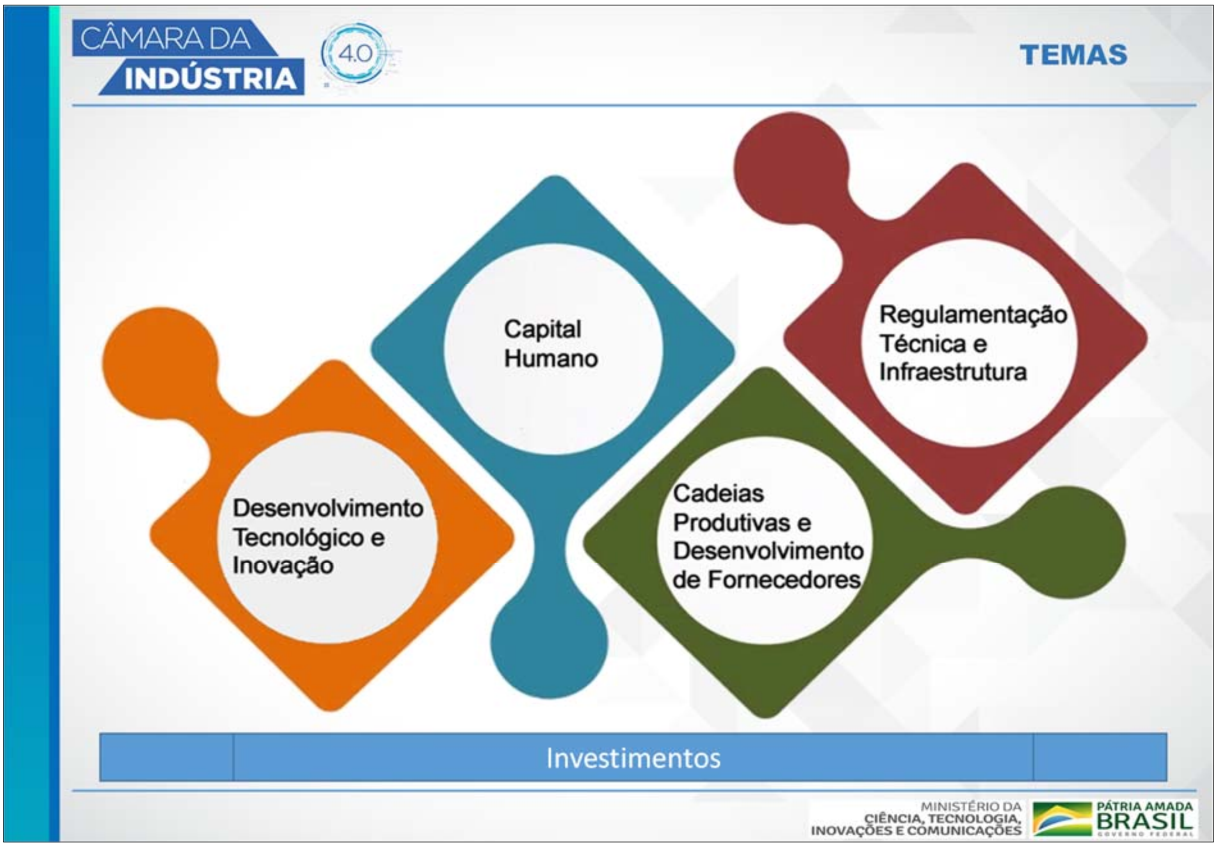
IOT
Social Network
Social Network
IoT.B
PLANO NACIONAL DE
INTERNET DAS COISAS


Plano Nacional de IoT
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL
GOVERNO FEDERAL
Quatro ambientes priorizados
Cidades
Saúde
Rural
Indústrias
• BNDES Pilotos IoT - 45 MM
• FINEP IoT - 1,5 BI
• EMBRAPII - Programa IoT/Manufatura 4.0 – 8 MM
• ANATEL – Consulta Pública para regulamentação de IoT
• UIT – Contribuição brasileira aprovada para padronização de dispositivos de IoT
Aspiração
"Acelerar a implantação da Internet das Coisas como instrumento de desenvolvimento sustentável da sociedade brasileira, capaz de aumentar a competitividade da economia, fortalecer as cadeias produtivas nacionais e promover a melhoria da qualidade de vida"
Horizontais – 60 ações
Capital Humano
Inserção Internacional
Viabilidade Econômica
Ciência, Tecnologia & Inovação
Regulatório, Segurança & Privacidade
Infra de Conectividade & Interoperab.


CÂMARA DA
INDÚSTRIA
4.0
Câmara Brasileira da Indústria 4.0
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL


CÂMARA DA
INDÚSTRIA
4.0
A CÂMARA
Formalizada em 3 de abril de 2019
Conselho Superior, Secretaria Executiva e Grupos de Trabalho (GT)
Câmara Brasileira da Indústria 4.0
Coordenação: Ministério da Ciência, Tecnologia, Inovações e Comunicações – MCTIC e Ministério da Economia – ME
Instituições governamentais, acadêmicas e empresariais
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL


CÂMARA DA INDÚSTRIA 4.0
TEMAS
Capital Humano
Regulamentação Técnica e Infraestrutura
Desenvolvimento Tecnológico e Inovação
Cadeias Produtivas e Desenvolvimento de Fornecedores
Investimentos
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
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CÂMARA DA INDÚSTRIA 4.0
Composição
SECRETARIA EXECUTIVA
CONSELHO SUPERIOR
Membros
MCTIC ME CNI FINEP CNPq BNDES ABDI SEBRAE EMBRAPII
GRUPOS DE TRABALHO (POR TEMAS)
Desenvolvimento Tecnológico e Inovação (Coordenação: MCTIC)
1 ABDI 2 ABIMAQ 3 ABINEE 4 ABIPTI 5 ANPEI 6 ANPROTEC 7 BNDES 8 CNI 9 CONFAP 10 EMBRAPII 11 FINEP 12 MCTIC 13 ME 14 P&D Brasil 15 SENAI 16 CNPq 17 SEBRAE 18 ABStrartups 19 Abramat 20 Abisemi 21 GS1 Brasil 22 ABIA 23 BRASSCOM 24 CAESenado
Capital Humano (Coordenação: MCTIC)
1 ABRUEM 2 ANDIFES 3 CAPES 4 CNI 5 CNPq 6 CONIF 7 CRUB 8 MCTIC 9 ME 10 MEC 11 SENAI 12 ABDI 13 ABES 14 ABO2O 15 AEA 16 Eletros 17 ABIA 18 CAESenado
Cadeias Produtivas e Desenvolvimento de Fornecedores (Coordenação: ME)
1 ABDI 2 ABIMAQ 3 ABINEE 4 ABIQUIM 5 ABIT 6 Anfavea 7 BNDES 8 CNI 9 FINEP 10 MCTIC 11 ME 12 SEBRAE 13 SENAI 14 ABES 15 Abiplast 16 Abisemi 17 ABStrartups 18 AEA 19 Eletros 20 Sindipeças 21 GS1 Brasil 22 ABIA 23 CAESenado
Regulação, Normalização Técnica e Infraestrutura (Coordenação: ME)
1 ABII 2 ABIMAQ 3 ABINEE 4 ABNT 5 ANATEL 6 BNDES 7 BRASSCOM 8 CNI 9 CNPq 10 FINEP 11 INMETRO 12 MCTIC 13 ME 14 SinditeleBrasil 15 SOFTEX 16 ABDI 17 Abramat 18 ABO2O 19 VDI-Brasil 20 MBC 21 GS1 Brasil 22 ABIA 23CAESenado
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL


CÂMARA DA INDÚSTRIA 4.0
PLANO DE AÇÃO DA CÂMARA BRASILEIRA DA INDÚSTRIA 4.0
Objetivo:
Ser um instrumento indutor do uso de conceitos e práticas relacionados à Indústria 4.0, visando o aumento da competitividade e produtividade das empresas brasileiras, contribuindo para inserção do Brasil nas cadeias globais de valores.
Período: 2019 - 2022
Deverá ser avaliado e revisado periodicamente considerando os resultados da implementação de suas ações e iniciativas e oportunidades de melhoria. Novas ações e iniciativas poderão ser incorporadas.
Desafios:
Aumentar a competitividade e produtividade das empresas brasileiras;
Melhorar a inserção do Brasil nas cadeias globais de valor;
Introduzir o uso de tecnologias da Indústria 4.0 nas pequenas e médias empresas;
Garantir instrumentos para que soluções de empresas de base tecnológica, startups e integradoras possam ser ofertadas e disponibilizadas diretamente às empresas;
Assegurar estabilidade e volume de recursos a custo adequado para implementação de iniciativas para a Indústria 4.0;
Identificar e desenvolver soluções para a Indústria 4.0 adequadas às empresas do parque produtivo brasileiro; e
Evitar a sobreposição de esforços de instituições públicas e privadas para solucionar necessidades e demandas da Indústria 4.0 no Brasil.
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
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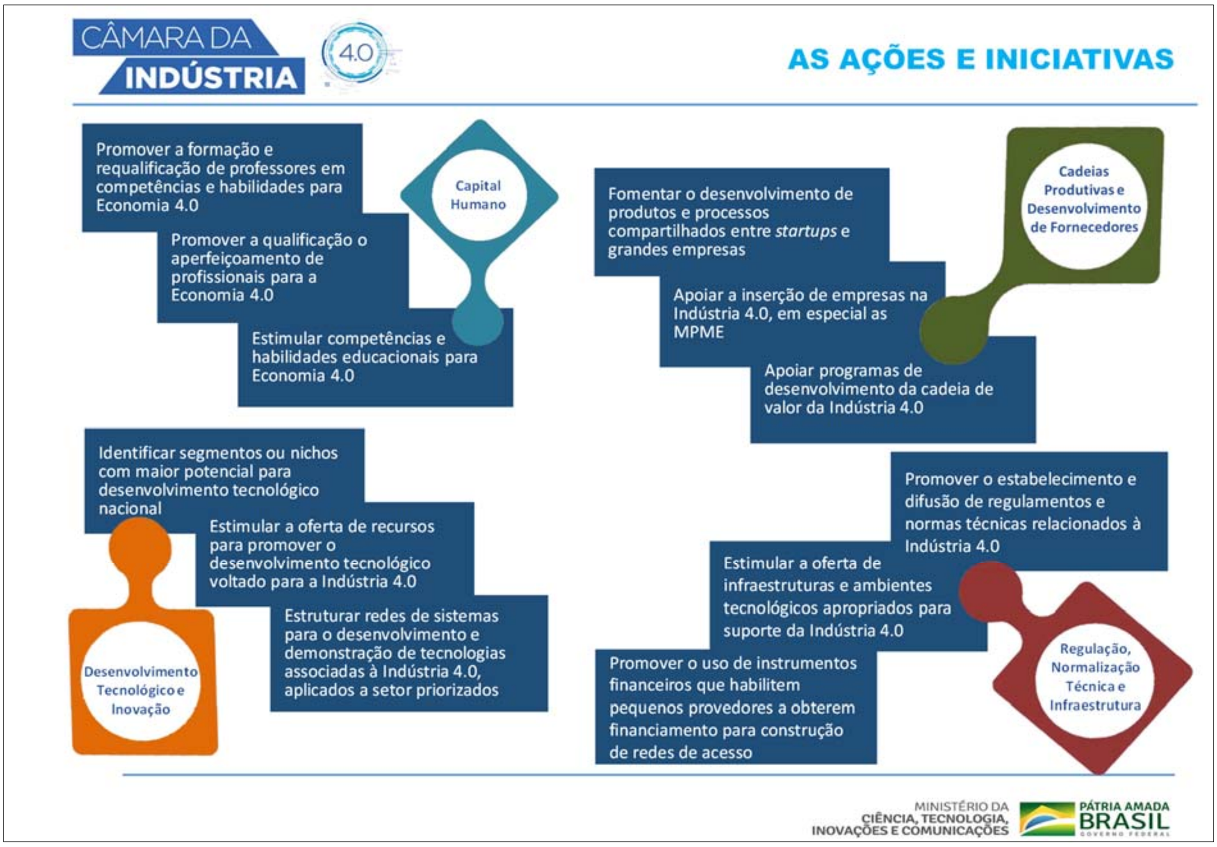
CÂMARA DA INDÚSTRIA 4.0
AS AÇÕES E INICIATIVAS
Capital Humano
Promover a formação e requalificação de professores em competências e habilidades para Economia 4.0
Promover a qualificação o aperfeiçoamento de profissionais para a Economia 4.0
Estimular competências e habilidades educacionais para Economia 4.0
Cadeias Produtivas e Desenvolvimento de Fornecedores
Fomentar o desenvolvimento de produtos e processos compartilhados entre startups e grandes empresas
Apoiar a inserção de empresas na Indústria 4.0, em especial as MPME
Apoiar programas de desenvolvimento da cadeia de valor da Indústria 4.0
Desenvolvimento Tecnológico e Inovação
Identificar segmentos ou nichos com maior potencial para desenvolvimento tecnológico nacional
Estimular a oferta de recursos para promover o desenvolvimento tecnológico voltado para a Indústria 4.0
Estruturar redes de sistemas para o desenvolvimento e demonstração de tecnologias associadas à Indústria 4.0, aplicados a setor priorizados
Regulação, Normalização Técnica e Infraestrutura
Promover o estabelecimento e difusão de regulamentos e normas técnicas relacionados à Indústria 4.0
Estimular a oferta de infraestruturas e ambientes tecnológicos apropriados para suporte da Indústria 4.0
Promover o uso de instrumentos financeiros que habilitem pequenos provedores a obterem financiamento para construção de redes de acesso
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
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CÂMARA DA INDÚSTRIA 4.0
RESULTADOS
MAPEAMENTO 4.0
Iniciativas para ciência, tecnologia e inovação
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Iniciativa do Ministério da Ciência, Tecnologia, Inovação e Telecomunicações (MCTIC) e do Serviço Nacional de Aprendizagem Nacional (SENAI-DN)
93 iniciativas cadastradas em todo o Brasil
Finep
Inovacred
4.0
Linha de crédito para financiar projetos de Indústria 4.0 nas áreas de internet das coisas, computação em nuvem, big data, segurança digital, manufatura digital, integração de sistemas, robótica avançada e inteligência artificial
R$200 milhões de recursos disponível às empresas
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PÁTRIA AMADA BRASIL


Plano Nacional de IoT
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
PÁTRIA AMADA BRASIL
CÂMARA DO AGRO 4.0
• Câmara do Agro 4.0 lançada em 15 de agosto de 2019
• Primeira reunião dos GTs em out/2019
• Objetivos:
• expansão da internet no campo; aumento de produtividade;
• fomento a tecnologias e serviços inovadores; e
• posicionamento do Brasil como exportador de soluções de Internet das Coisas (IoT) para a agricultura
• Impacto preliminar em 2025 ~US$ 5 a 21 bilhões

Plano Nacional de IoT

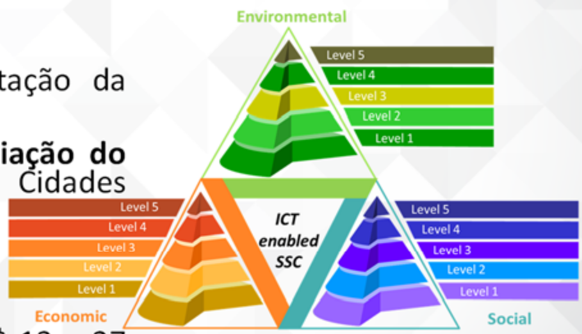
CÂMARA DA SAÚDE 4.0

- Lançamento da Câmara da Saúde 4.0 até nov/2019
- Status atual: alinhamento do Acordo de Cooperação Técnica entre MCTIC e MS (CONJUR dos ministérios)
- Objetivo: Contribuir para a ampliação do acesso à saúde de qualidade no Brasil por meio da criação de uma visão integrada dos pacientes, descentralização da atenção à saúde, e da melhoria de eficiência das unidades de saúde
- Impacto preliminar em 2025 ~US$ 5 a 39 bilhões

Plano Nacional de IoT

CÂMARA DAS CIDADES 4.0 – CIDADES INTELIGENTES

- Lançado o Programa Brasileiro de Cidades Inteligentes
- Instituir a Câmara de Cidades 4.0
- Publicar Decreto de Regulamentação da Câmara
- Regulamentar o **Modelo de Avaliação do Nível de Maturidade** das Cidades Inteligentes
- Nivelar as Cidades
- Certificar as Cidades
- Impacto preliminar em 2025 ~US$ 13 a 27 bilhões

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Prof. Dr. Eng. Gustavo D. Donatelli

Prof. Donatelli was born in 1957, in the city of Buenos Aires, Argentina. His career is related to mechanical sciences and technologies since 1976, when finished secondary-level studies in the Henry Ford Technical School. In 1984, he received his Mechanical Engineering diploma by the National Technological University of Argentina. After working in industry several years, he moved to Brazil and joined the Metrology and Automation Lab of Federal University of Santa Catarina, obtaining the Doctor Engineer diploma in 1999. His career in the private sector started already in 1977 and run in parallel to the engineering studies and doctoral research, building professional experience in mechanical design, tool design and construction, machining, metrology and quality. His relationship with CERTI Foundation dates from 1995, first as a researcher and consultant, then as Technical Manager. In 2009, he became Director of the Metrology and Instrumentation Center, leading a team of 45 researchers and technicians. Since 2002 he is part-time professor of the Laboratory of Metrology and Automation of the University of Santa Catarina, where is advisor of MSc and PhD theses devoted to 3D metrology, industrial computed tomography, quality engineering and asset integrity management.

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CERTI Foundation - Metrology and Instrumentation Center

CERTI Foundation is a non-profit and self-sustained institution devoted to science, technology and innovation, located in the city of Florianópolis, Santa Catarina State. The Metrology and Instrumentation Center (CMI) provides metrology services, training consultancy to the Brazilian industry and participates in R&D programs on quality engineering and integrity management, dimensional engineering and 3D metrology, instrumentation, automation and testing.

Metrology and Instrumentation in the Age of Industry 4.0 – Opportunities and Challenges

Abstract

A relevant characteristic of Industry 4.0 is the extensive use of internet of things (IoT), sensors and actuators to connect physical assets with their digital twins, creating collaborative entities known as cyber-physical systems (CPS). In this context, the role of production metrology goes beyond to the traditional application of measuring product characteristics to evaluate their conformity with specifications or to decide on process adjustments. It becomes a key enabling technology. The presentation will explore the two-way relationship that production metrology has with the Industry 4.0 paradigm. On the one hand, as a key provider of data to support descriptions, diagnostics, predictions and prescriptions on the fly. On the other hand, as a process that can benefit by the cyber-physical approach to reach higher levels of performance and reliability at an affordable cost. Two examples will be provided to illustrate the delivered concepts, one from the aircraft manufacturing industry and other from offshore oil & gas production.

Keywords

Metrology; Industry 4.0; Cyber-physical systems.

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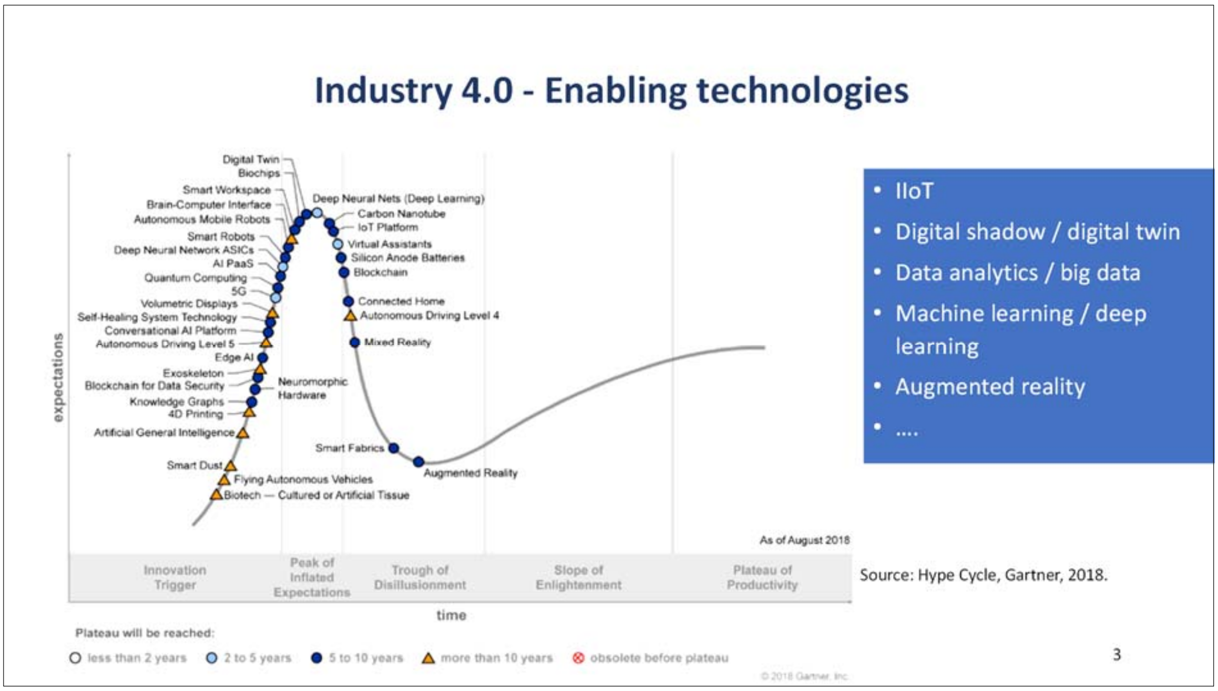
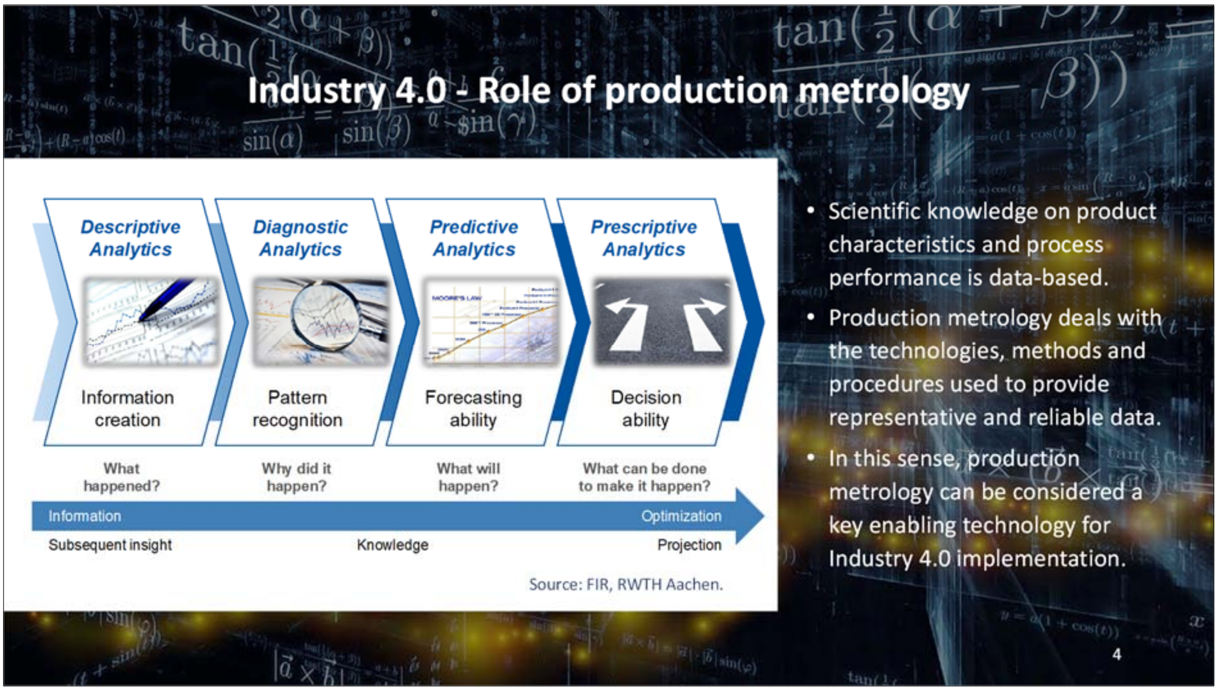
Metrology and Instrumentation in the Age of Industry 4.0 – Opportunities and Challenges
Gustavo Daniel Donatelli, Pablo Rosa, Thiago Fernandes, Tiago Muner Zíllio
Fundação CERTI – Centro de Metrologia e Instrumentação


Industry 4.0 - Enabling technologies
Digital Twin
Biochips
Smart Workspace
Brain-Computer Interface
Autonomous Mobile Robots
Smart Robots
Deep Neural Network ASICs
AI PaaS
Quantum Computing
5G
Volumetric Displays
Self-Healing System Technology
Conversational AI Platform
Autonomous Driving Level 5
Edge AI
Exoskeleton
Blockchain for Data Security
Knowledge Graphs
4D Printing
Artificial General Intelligence
Smart Dust
Flying Autonomous Vehicles
Biotech — Cultured or Artificial Tissue
Deep Neural Nets (Deep Learning)
Carbon Nanotube
IoT Platform
Virtual Assistants
Silicon Anode Batteries
Blockchain
Connected Home
Autonomous Driving Level 4
Mixed Reality
Neuromorphic Hardware
Smart Fabrics
Augmented Reality
expectations
As of August 2018
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Plateau will be reached:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau
IIoT
Digital shadow / digital twin
Data analytics / big data
Machine learning / deep learning
Augmented reality
....
Source: Hype Cycle, Gartner, 2018.
3


Industry 4.0 - Role of production metrology
Descriptive Analytics
Diagnostic Analytics
Predictive Analytics
Prescriptive Analytics
Information creation
Pattern recognition
Forecasting ability
Decision ability
What happened?
Why did it happen?
What will happen?
What can be done to make it happen?
Information
Optimization
Subsequent insight
Knowledge
Projection
Source: FIR, RWTH Aachen.
Scientific knowledge on product characteristics and process performance is data-based.
Production metrology deals with the technologies, methods and procedures used to provide representative and reliable data.
In this sense, production metrology can be considered a key enabling technology for Industry 4.0 implementation.
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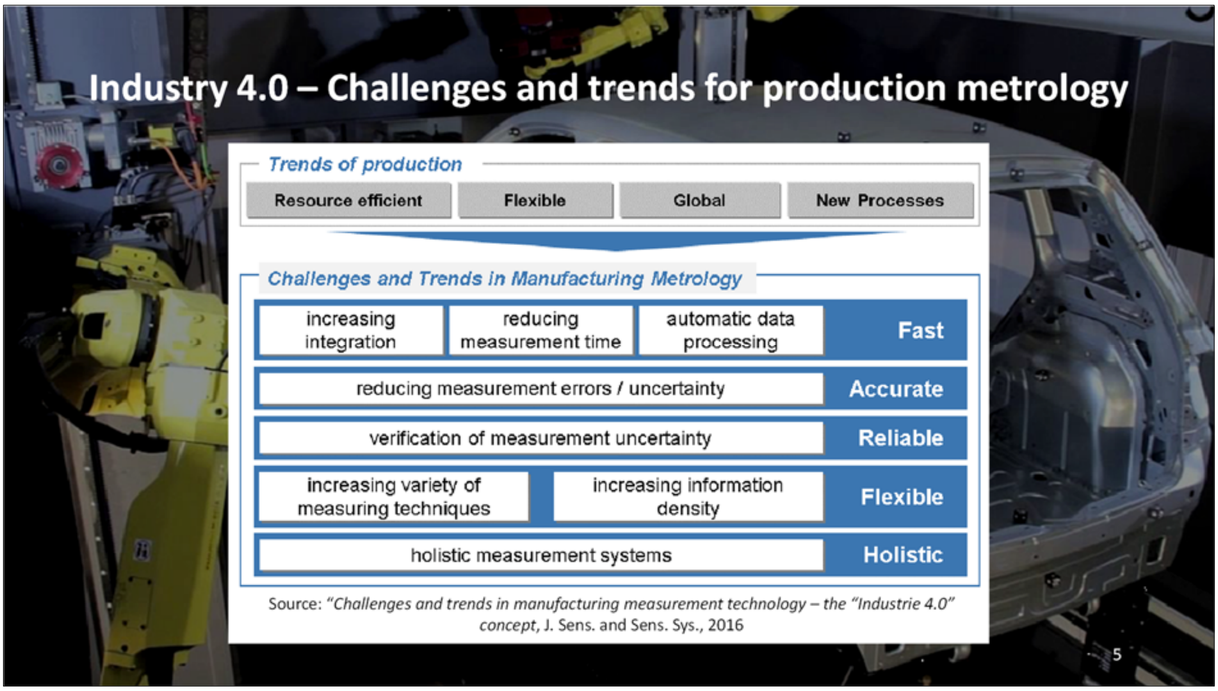
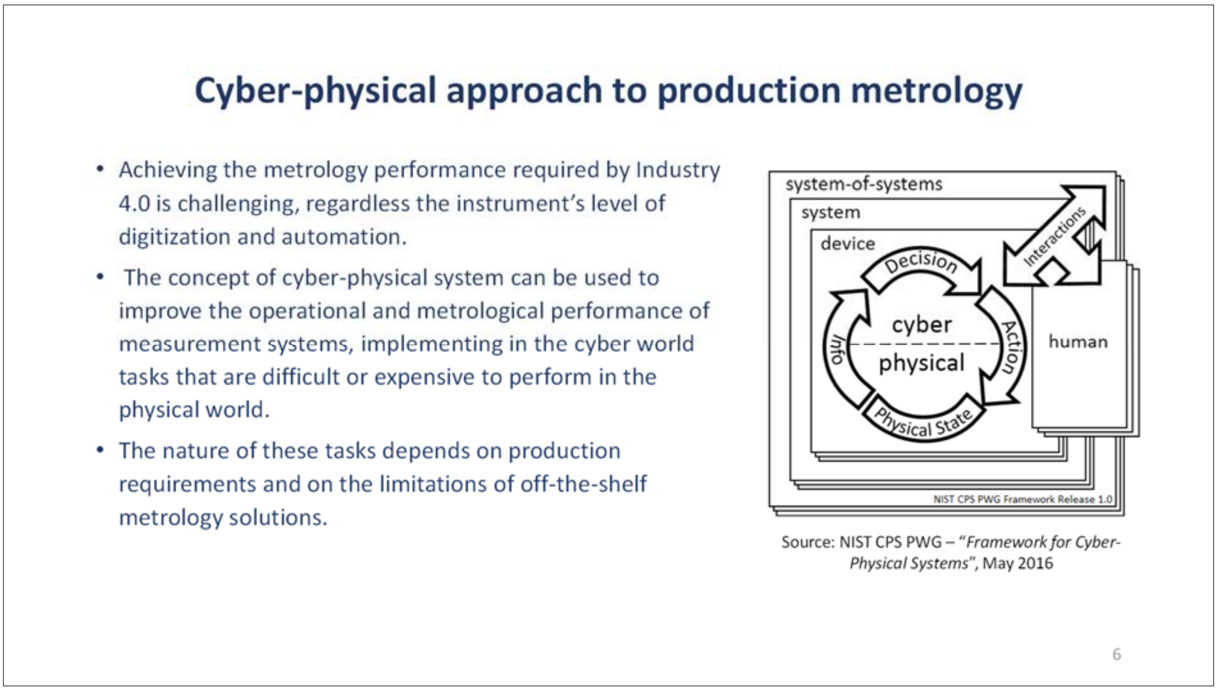
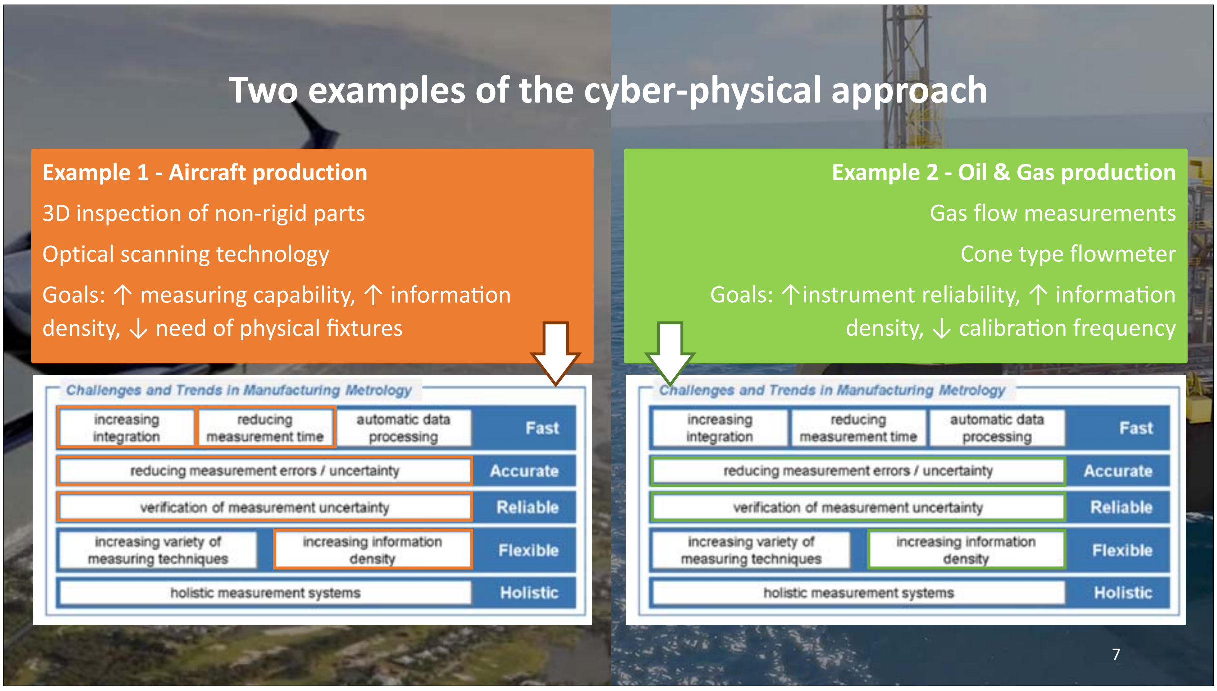

Industry 4.0 – Challenges and trends for production metrology
Trends of production
Resource efficient
Flexible
Global
New Processes
Challenges and Trends in Manufacturing Metrology
increasing integration
reducing measurement time
automatic data processing
Fast
reducing measurement errors / uncertainty
Accurate
verification of measurement uncertainty
Reliable
increasing variety of measuring techniques
increasing information density
Flexible
holistic measurement systems
Holistic
Source: "Challenges and trends in manufacturing measurement technology – the "Industrie 4.0" concept, J. Sens. and Sens. Sys., 2016
5


Cyber-physical approach to production metrology
• Achieving the metrology performance required by Industry 4.0 is challenging, regardless the instrument's level of digitization and automation.
• The concept of cyber-physical system can be used to improve the operational and metrological performance of measurement systems, implementing in the cyber world tasks that are difficult or expensive to perform in the physical world.
• The nature of these tasks depends on production requirements and on the limitations of off-the-shelf metrology solutions.
system-of-systems
system
device
Decision
Interactions
cyber
physical
Info
Action
Physical State
human
NIST CPS PWG Framework Release 1.0
Source: NIST CPS PWG – "Framework for Cyber-Physical Systems", May 2016
6


Two examples of the cyber-physical approach
Example 1 - Aircraft production
3D inspection of non-rigid parts
Optical scanning technology
Goals: ↑ measuring capability, ↑ information density, ↓ need of physical fixtures
Example 2 - Oil & Gas production
Gas flow measurements
Cone type flowmeter
Goals: ↑instrument reliability, ↑ information density, ↓ calibration frequency
Challenges and Trends in Manufacturing Metrology
increasing integration
reducing measurement time
automatic data processing
Fast
reducing measurement errors / uncertainty
Accurate
verification of measurement uncertainty
Reliable
increasing variety of measuring techniques
increasing information density
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Challenges and Trends in Manufacturing Metrology
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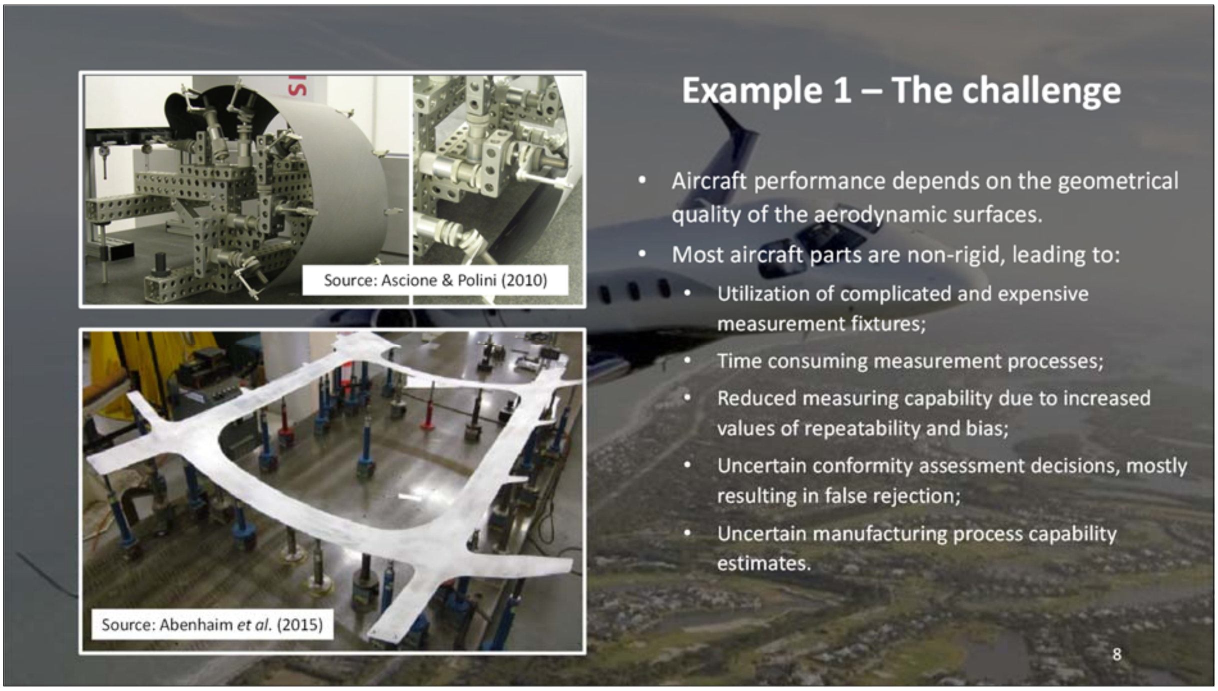
holistic measurement systems
Holistic
7


Example 1 – The challenge
Source: Ascione & Polini (2010)
Source: Abenhaim et al. (2015)
• Aircraft performance depends on the geometrical quality of the aerodynamic surfaces.
• Most aircraft parts are non-rigid, leading to:
• Utilization of complicated and expensive measurement fixtures;
• Time consuming measurement processes;
• Reduced measuring capability due to increased values of repeatability and bias;
• Uncertain conformity assessment decisions, mostly resulting in false rejection;
• Uncertain manufacturing process capability estimates.
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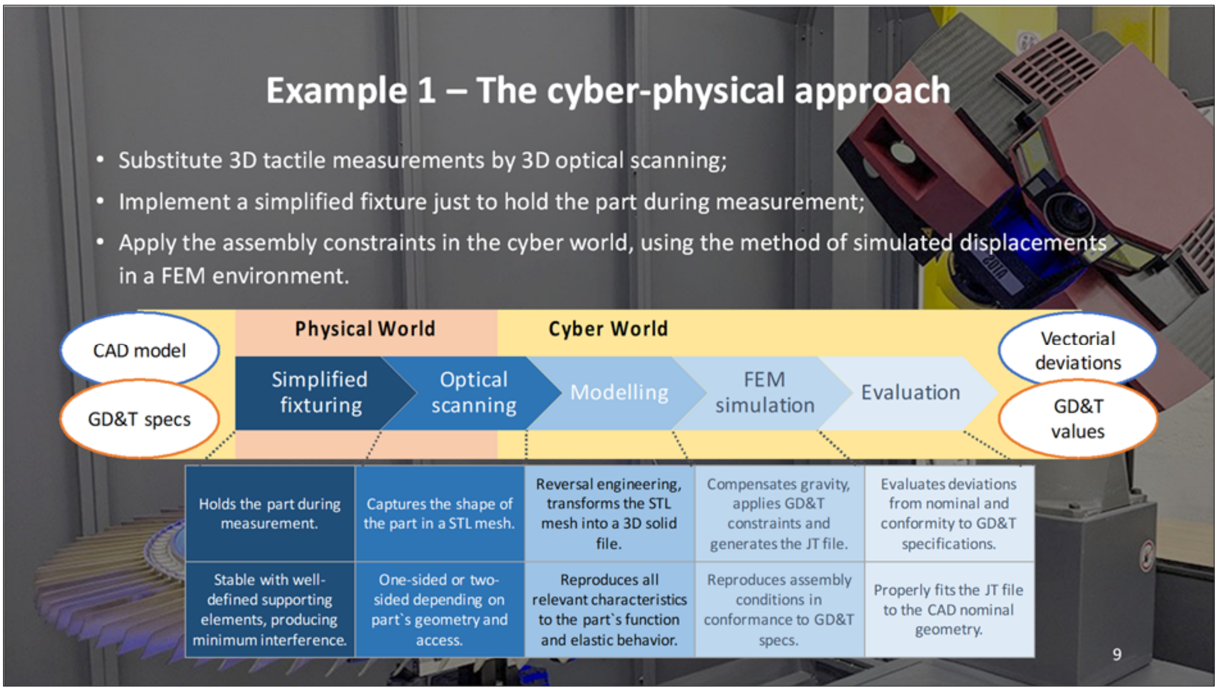
Example 1 – The cyber-physical approach
• Substitute 3D tactile measurements by 3D optical scanning;
• Implement a simplified fixture just to hold the part during measurement;
• Apply the assembly constraints in the cyber world, using the method of simulated displacements in a FEM environment.
CAD model
GD&T specs
Physical World
Cyber World
Simplified fixturing
Optical scanning
Modelling
FEM simulation
Evaluation
Vectorial deviations
GD&T values
Holds the part during measurement.
Captures the shape of the part in a STL mesh.
Reversal engineering, transforms the STL mesh into a 3D solid file.
Compensates gravity, applies GD&T constraints and generates the JT file.
Evaluates deviations from nominal and conformity to GD&T specifications.
Stable with well-defined supporting elements, producing minimum interference.
One-sided or two-sided depending on part`s geometry and access.
Reproduces all relevant characteristics to the part`s function and elastic behavior.
Reproduces assembly conditions in conformance to GD&T specs.
Properly fits the JT file to the CAD nominal geometry.
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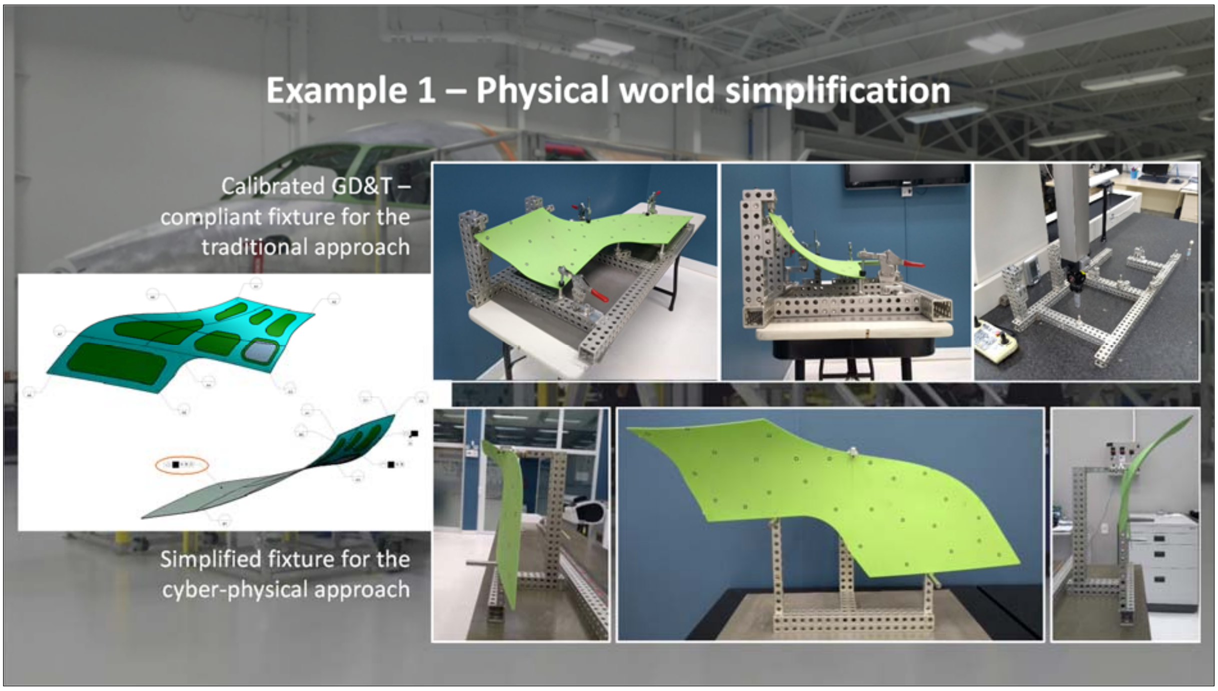
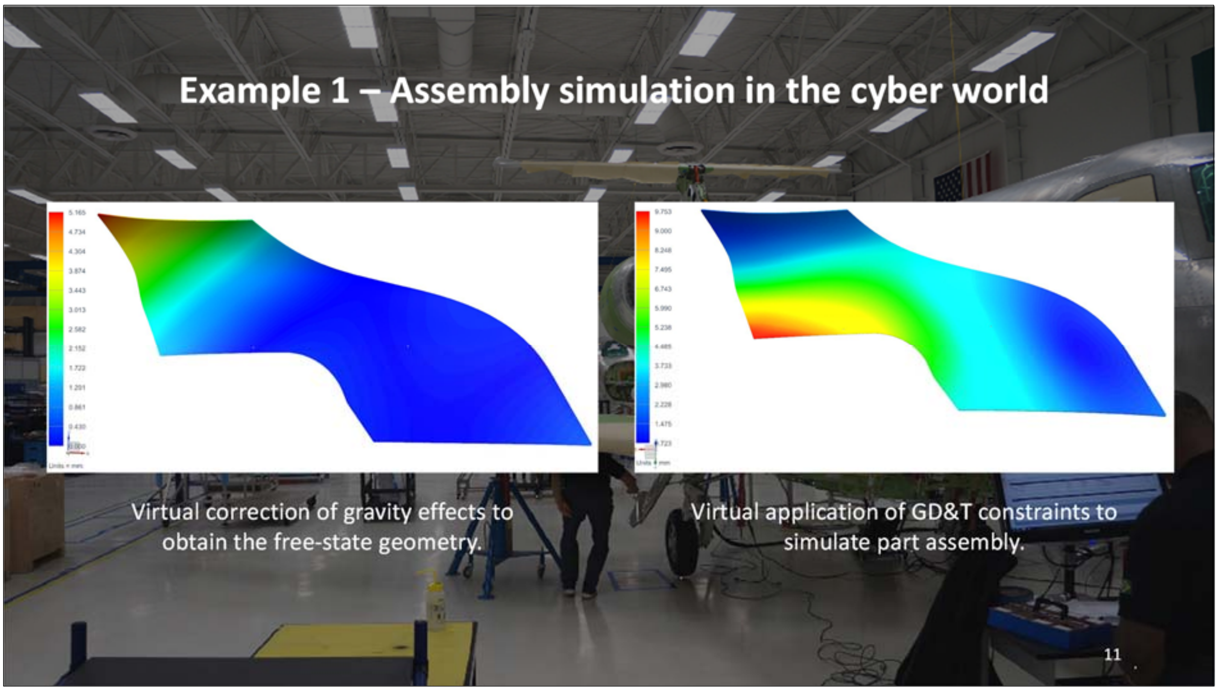

Example 1 – Physical world simplification
Calibrated GD&T – compliant fixture for the traditional approach
Simplified fixture for the cyber-physical approach


Example 1 – Assembly simulation in the cyber world
Virtual correction of gravity effects to obtain the free-state geometry.
Virtual application of GD&T constraints to simulate part assembly.
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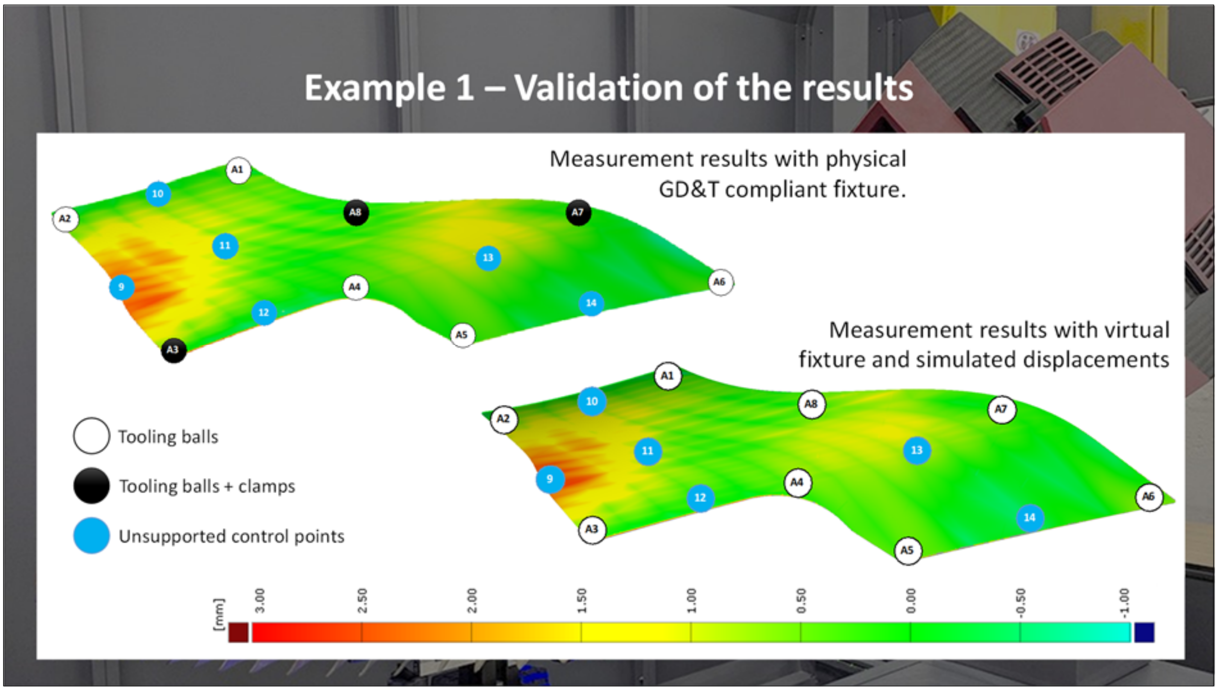
Example 1 – Validation of the results
Measurement results with physical GD&T compliant fixture.
Measurement results with virtual fixture and simulated displacements
Tooling balls
Tooling balls + clamps
Unsupported control points
[mm]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00


Example 1 – Benefits, opportunities and challenges
Direct benefits
• Reduced data acquisition time;
• Enhanced metrological performance;
• Reduced CAPEX and OPEX with measurement fixtures.
Opportunities
• Improved GD&T, closely representing functional and assembly conditions (ex. line or area datums);
• Bonus information obtained in the cyber-world at no extra cost (ex. assembly-induced stresses);
• Digital shadow of the product available to support manufacturing and assembly decisions.
Challenges
• Traceability to the international standards cannot be proved using physical standards.
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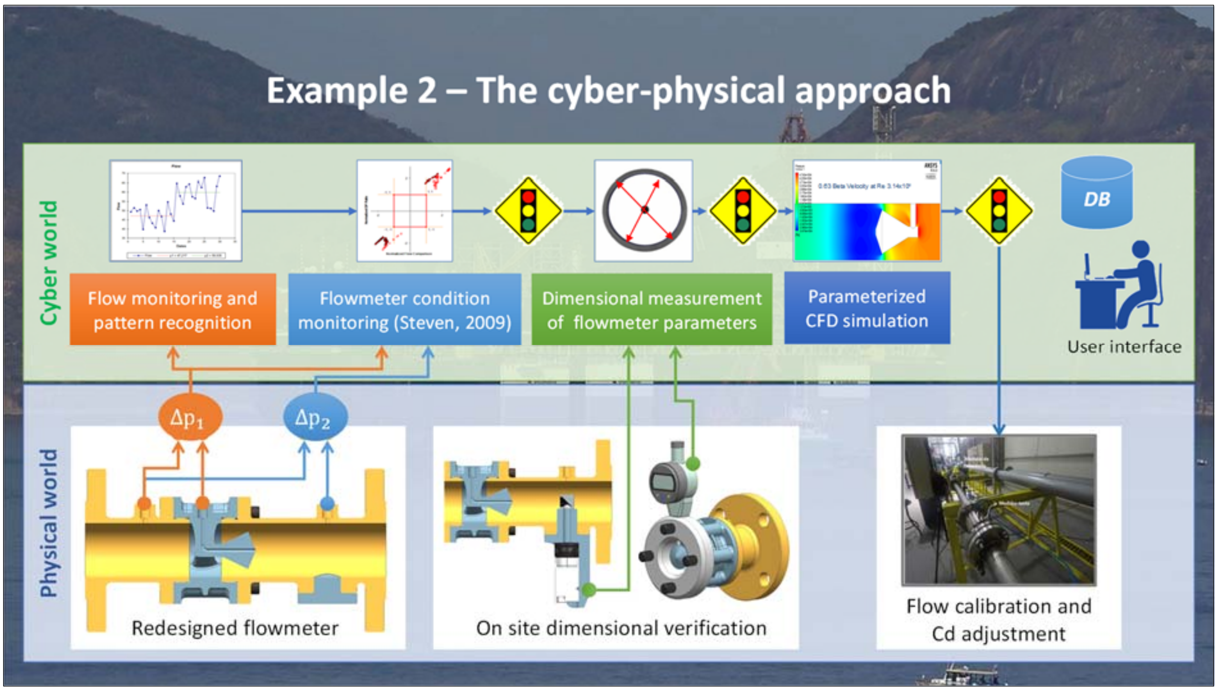
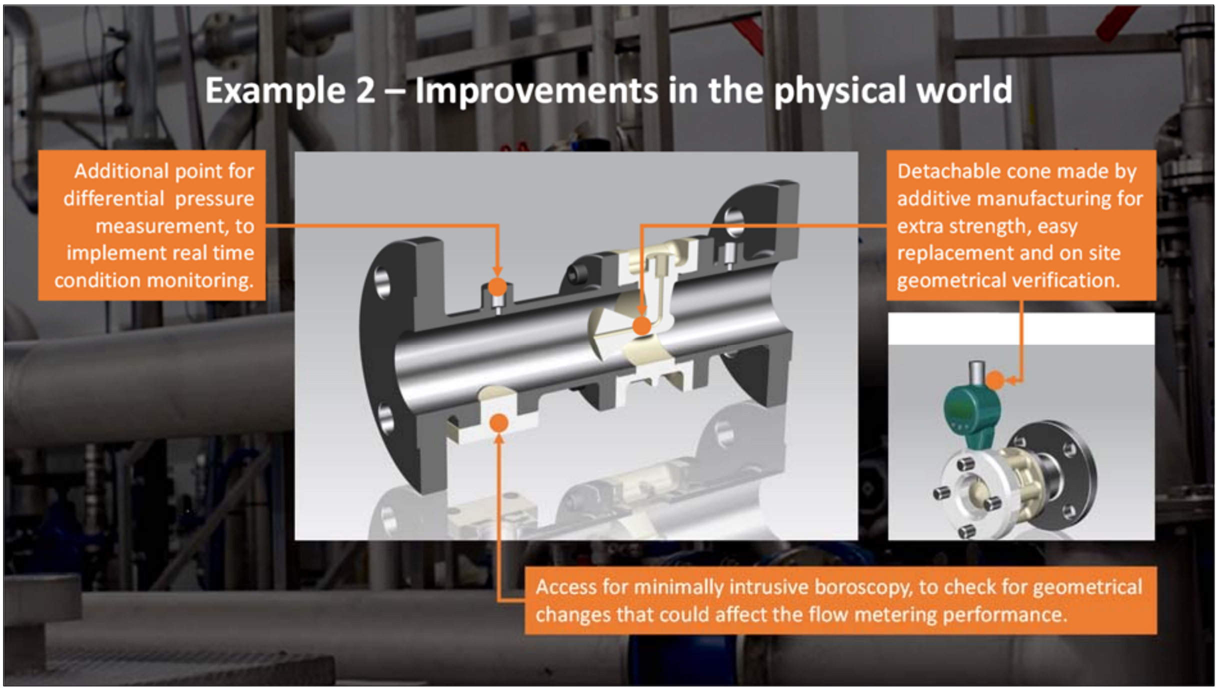
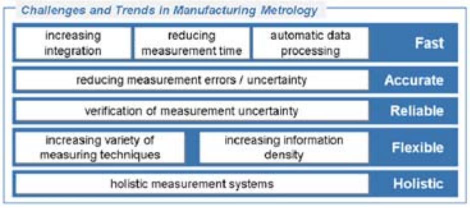
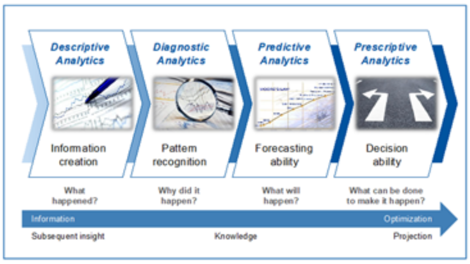
Example 2 – The challenge
• The cone-type flowmeter has relevant advantages:
• Robust, without removable parts;
• Applicable for several fluids in a broad Reynolds range;
• Reduced head loss.
• Metrological performance not known for all operating conditions (ex. wet gas).
• Calibration in flow lab expensive and time demanding, requires decommissioning the cone meter.
• Geometrical verification possible, but not easy to perform on site.


Example 2 – The cyber-physical approach
Cyber world
Flow monitoring and pattern recognition
Flowmeter condition monitoring (Steven, 2009)
Dimensional measurement of flowmeter parameters
Parameterized CFD simulation
DB
User interface
Physical world
Δp1
Δp2
Redesigned flowmeter
On site dimensional verification
Flow calibration and Cd adjustment


Example 2 – Improvements in the physical world
Additional point for differential pressure measurement, to implement real time condition monitoring.
Detachable cone made by additive manufacturing for extra strength, easy replacement and on site geometrical verification.
Access for minimally intrusive boroscopy, to check for geometrical changes that could affect the flow metering performance.

Concluding remarks





- The cyber-physical approach could led to the development of measurement systems with enhanced capabilities, able to attend the needs of Industry 4.0.
- The examples showed that the cyber-physical approach could be used to support the quality of the data delivered by the measurement system and to reduce the measurement and data processing time.
- The development and continual updating of task-specific data bases (i.e. digital shadows) make possible reliable diagnostics, predictions and prescriptions about the product, the production process and the measurement system itself.
- More efforts are needed to systematize this approach.

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Thank you for the attention!
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Patrocínio

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