Profit per hour as target process control parameter for resource productive manufacturing systems enabled by big data analytics and industry 4.0 infrastructure

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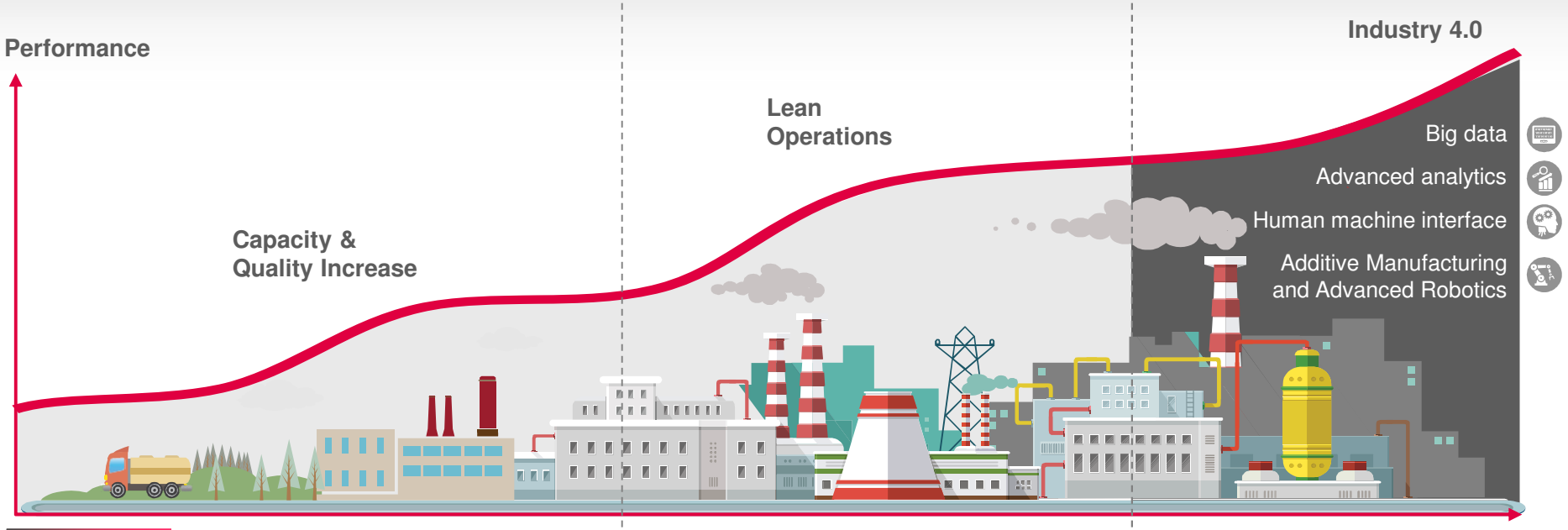
"The **search for the one objective** is essentially a search **for a magic formula** that will **make judgement unnecessary**. But the attempt to replace judgement by formula is always irrational; **all the can be done is to make judgement possible** by narrowing its range and the available alternatives, giving it clear focus a sound **foundation in facts and reliable measurements** of the effects and validity of actions and decisions."[1]

1 Drucker, Peter (1955) – The practice of management, Chapter 7: The Objectives of a Business, p.59

Objectives for today´s discussion

- **Motivation**
- Research focus, questions & hypotheses
- State of the art & literature review
- Next steps

Industry 4.0 is impacting operations through disruptive technologies including big data and advanced analytics

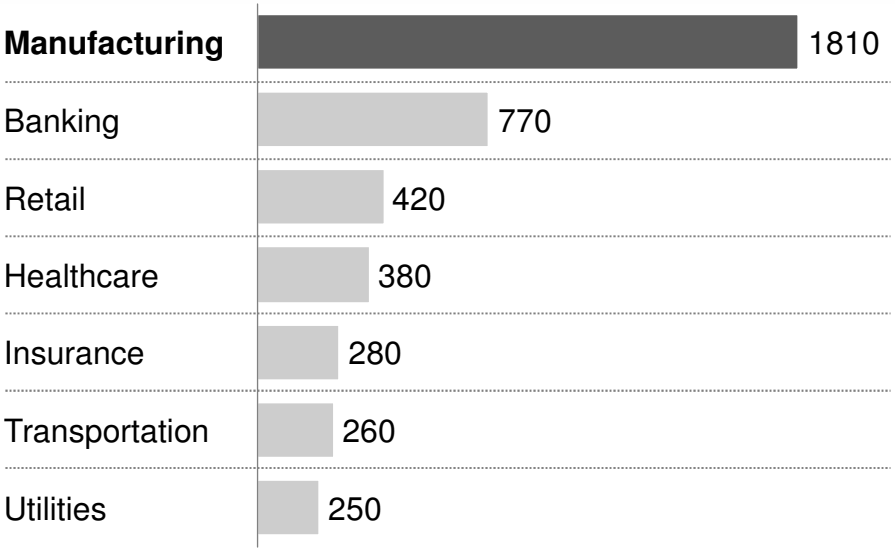


	Capacity & Quality Increase	Lean Operations	Industry 4.0
Trend	▪ Customer expectations and demand increase	▪ Cost pressure from low cost countries through globalization	▪ Acceleration of technological advancements[1]
Need	▪ Sufficient product quality and supply	▪ Empowering the entire organization to continuously improve	▪ Enabling the people to do even more value-added work through technology
Resolution	▪ Production network planning, automation, TQM and TPM	▪ Incorporation of Lean principles	▪ New technical solutions and increased skills requirements

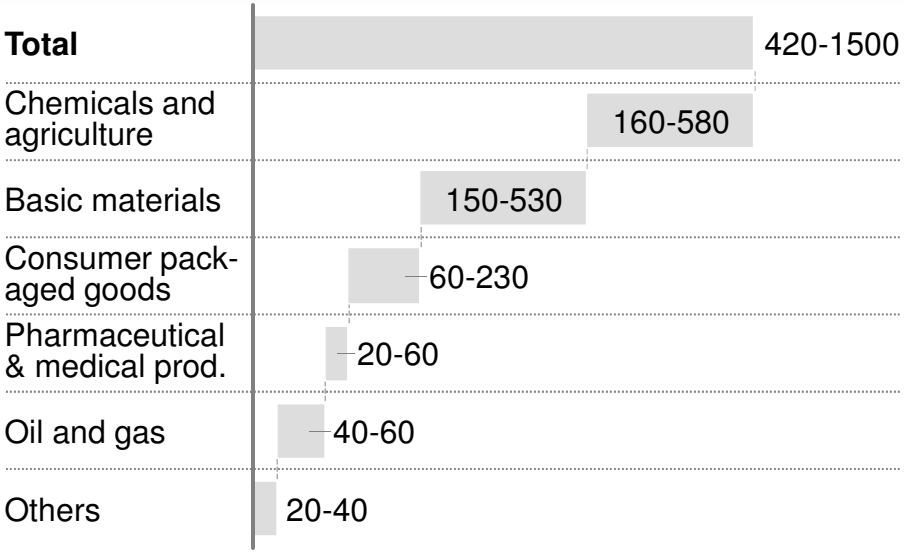
1 Cheaper storage, increasing computing power, cloud technology, affordable sensors, reliable data transmission, machine learning

For manufacturing industries there is considerable value to be captured…

Manufacturing produces more data than any other industry[1], Annual new data stored by sector, 2010, Petabyte



Potential economic impact from productivity improvements in manufacturing by 2025, USD bn[2]



In the factories, value from the **Internet of Things** would arise chiefly from **productivity improvements**, including **10 to 20 percent energy savings**[2]

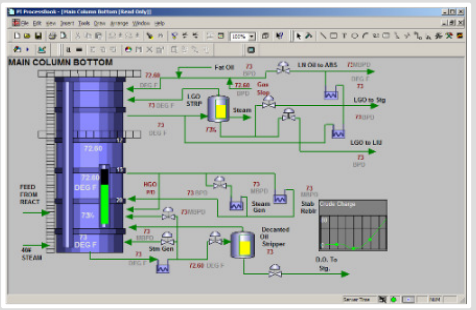
1 IDC (2015), 2 MGI (2015)

…and process industries are not starting from zero with data utilization and industrial automation

A

Data generation and harvesting has been done for many years with sensors

B



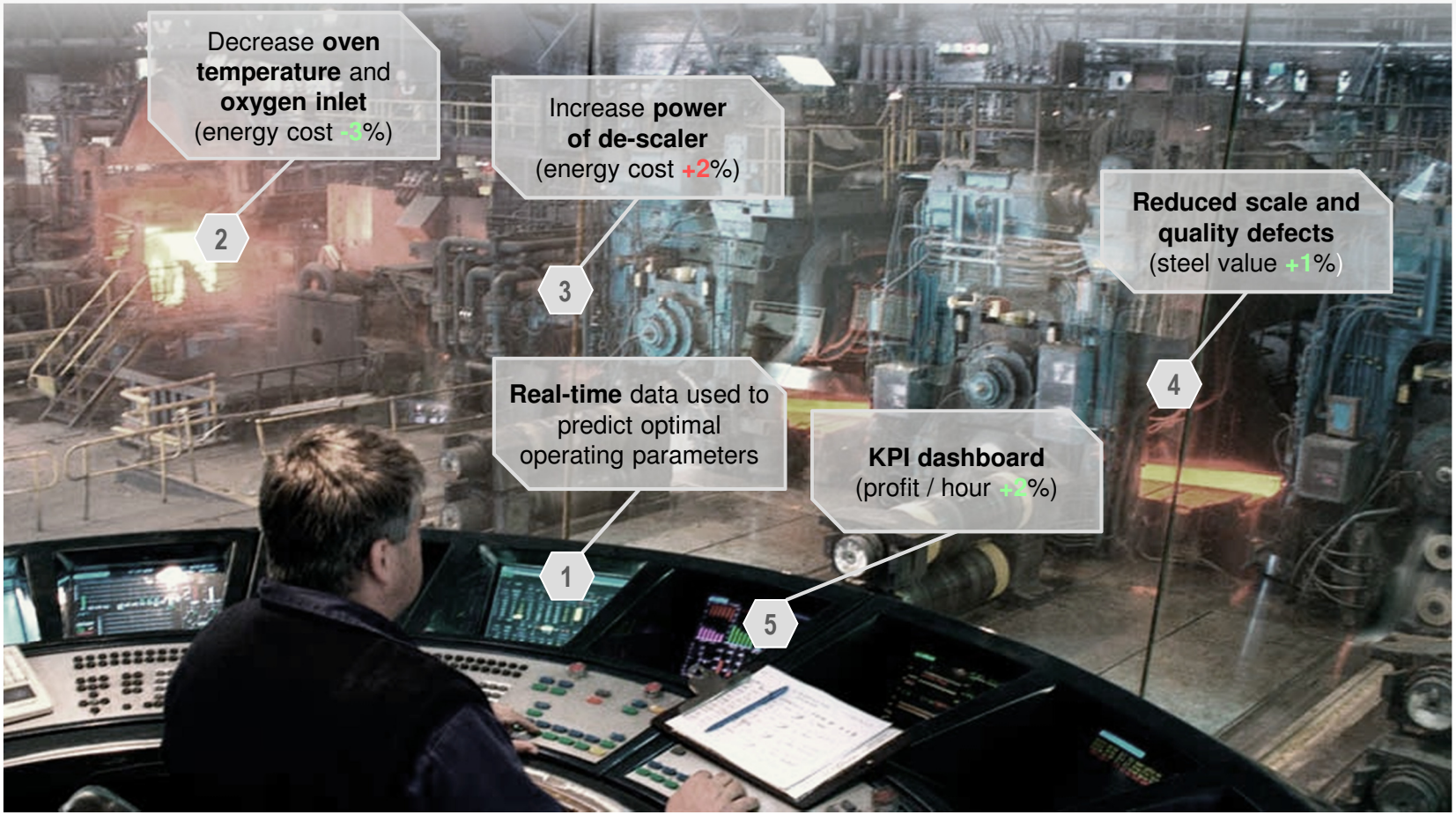
Data structuring and illustration happens already e.g. PI (Process information) systems

C

Automated decision-making is being done via Advanced Process Control systems

The goal: Enabling smart operational decision making to optimize for profit per hour in a volatile environment

ILLUSTRATIVE



Advise the control room operator and process engineers on the optimal settings to maximize profit

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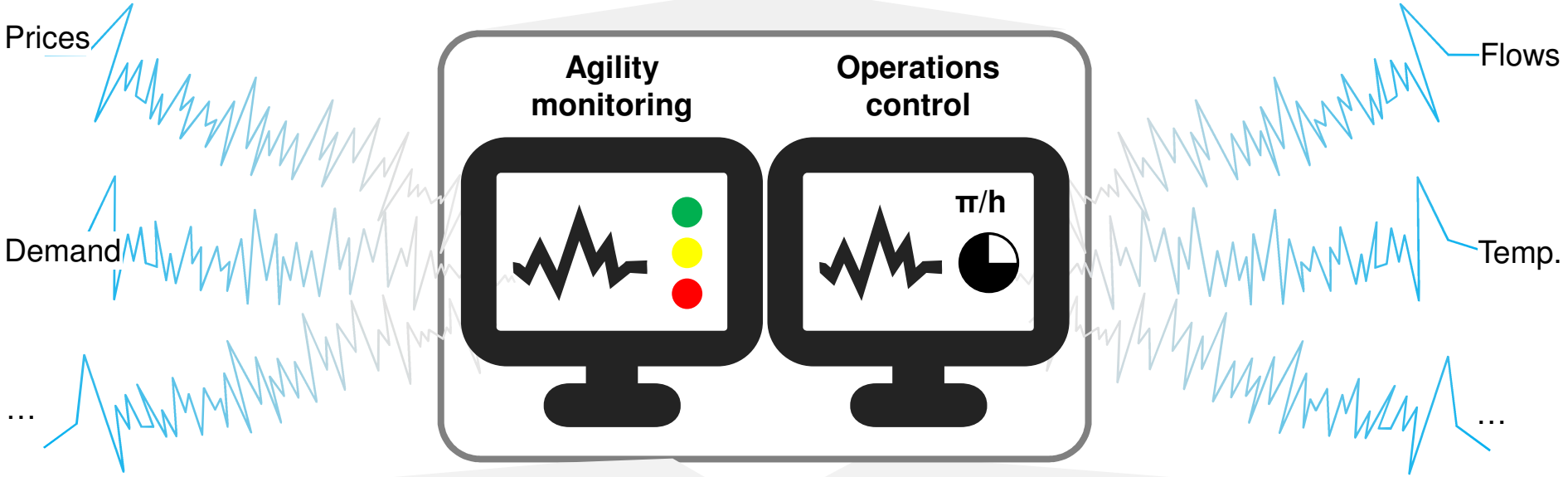
How to optimize operations for maximum profitability using a profit per hour management approach

External focus (Markets, supply network,…) | **Internal focus** (Manufacturing system)

Volatility | **Agility strategy** | **Operations**



Research in progress by agility working group[1]

- Process control based on profit/hour target KPI
- Advanced analytics of big process data
- Industry 4.0 infrastructure

1 Heldmann (2015)

Link to Agility Research

Fokus Buch[2]

Steigende Unsicherheit

Treiber

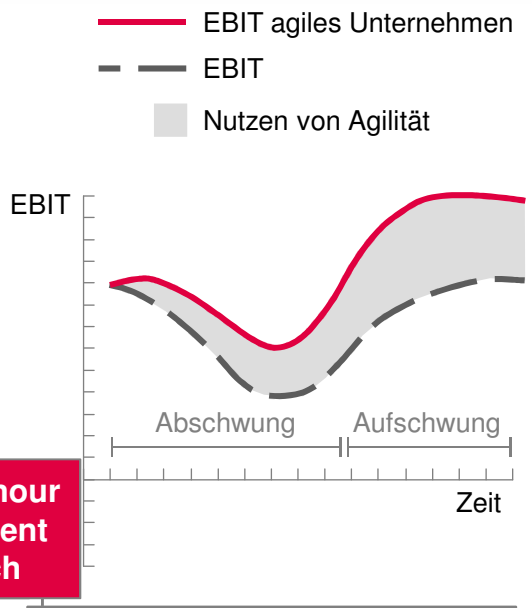
- Vernetztheit
- Digitalisierung
- Granularität
- Disruptionen

Auswirkungen

- Nachfrageschwankungen
- Produktionsstörungen
- Lieferkettenunterbrechung
- Volatilität der Faktorkosten

Agiles Unternehmenssystem

Unternehmensperformance



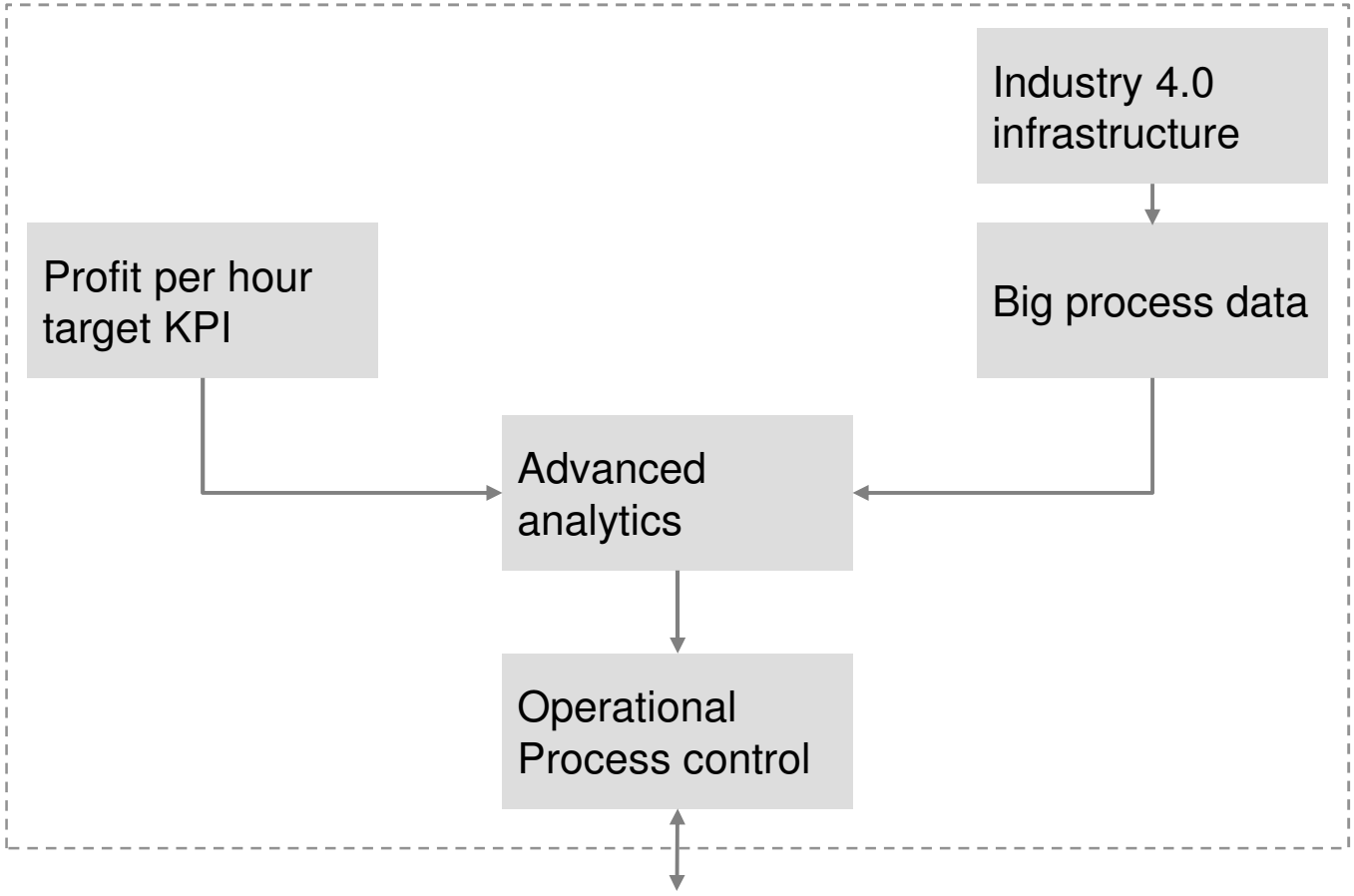
Operations-Stellhebel

- Arbeitsorganisation
- Produktionsanlagen
- Produktionsnetzwerk
- Beschaffung
- Logistik
- Produktgestaltung

1 Finanzen, HR und weitere indirekte Bereiche (G&A)
2 Ramsauer, Kayser, Schmitz (2016)

Research framework

Methodology to implement a profit/hour as operational target control parameter



Research gap, end products, and delimitation of research focus

Research gap	▪ Profit per hour as target process control parameter for resource productive manufacturing systems enabled by big data analytics and industry 4.0 infrastructure
End products	▪ Proof of profit per hour as operational target KPI ▪ Evidence of big data analytics as enabler ▪ Methodology for implementation ▪ *Optional: Tools (Cockpit, Checklist, …)*
Delimitation of research focus	▪ Production / Manufacturing Systems ▪ Process Industries ▪ Bottleneck processes ▪ Not inventing new algorithms, sensors, …

Research approach and inputs for the PhD thesis

Forschungsprozess[1]

Praxisbezug

- Erfassung und Typisierung **praxisrelevanter Probleme**
- Erfassung und Interpretation problem-relevanter **Theorien und Hypothesen** der empirischen Grundlagenwissenschaften
- Erfassung und Spezifizierung **problemrelevanter Verfahren** der Formalwissenschaften
- Erfassung und Untersuchen des relevanten **Anwendungszusammenhangs**
- Ableitung von **Beurteilungskriterien, Gestaltungsregeln und -modellen**
- **Prüfung** der Regeln und Modelle im Anwendungszusammenhang
- **Handlungsempfehlungen** für die Praxis

Structure of the PhD thesis

1. **Introduction**
   - Problem definition
   - Derivation of overall goals
2. **Basic theory and research needs**
   - Definition of terms & concepts
   - Delimitation of research focus
3. **Related work**
   - Definition of requirements
   - Derivation of research question
4. **Methodology conception**
   - Scope of work
   - Definition of approach & requirements
5. **Methodology design**
   - Classification and structure of model
   - Component definition
6. **Methodolgy validation**
   - Practical application
   - Evaluation of results and conclusion
7. **Conclusion**
   - Summary of the results of work
   - Outlook & further research needs

Practical Input

Preliminary studies and research results
- BSc thesis
- Industry pilots

Literature Research
- Internet of Things, Industry 4.0
- Big data analytics, Advanced Process Control, Measurement & Verification
- Performance Measurement & Control

Conference participation and external input

Exchange and discussion with company partner

Case study

Expert interviews

[1] Idealtypischer Forschungsprozess der anwendungsorientierten Betriebswirtschaftslehre nach ULRICH (1984)

Profit per hour as target process control parameter for resource productive manufacturing systems enabled by big data analytics and industry 4.0 infrastructure

Research focus	Hypotheses: PRELIMINARY
BASIC THEORY REVIEW: **Is a profit per hour** management approach **helping to take best available decisions** in process industries to achieve maximum EBITDA in volatile times?	▪ Profit per hour is a **suitable target KPI** for industrial operations management in manufacturing trading off conflicting targets (throughput, energy, yield, ….) ▪ **Cumulative benefits** of a profit per hour approach **are higher** than traditional methods (e.g. throughput maximization) ▪ **Limitations** to profit/hour (long vs. short term optimization, balance between economic and social benefits) exist
RESEARCH QUESTION 1: **Is big data** in manufacturing (i.e. both real time process data and advanced analytics) **a key enabler for a profit per hour** management approach?	▪ H1.1**: Big process data** is a key enabler to implement a profit per hour operational management approach ▪ H1.2: **Advanced algorithms** are required to solve for profit per hour as a target function ▪ H1.3: A live **decision cockpit** is a key tool for managers/operators **prior to full automated advanced process controls** (APC+)
RESEARCH QUESTION 2: **Can a profit per hour** operative management approach based on big process data **be implemented in a standardized way** (step-by-step methodology) in process industries?	▪ H2.1: A repeatable **standard process can be applied** to implement a profit per hour management approach in process industries ▪ H2.2: The steps taken follow **classical management frameworks** such as DMAIC and can include aspects of automation (e.g. APC) ▪ H2.3: **Measurement & Verification** is a crucial element to verify financial savings over time

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Management Accounting & Control has a long history with many issues related to performance measures

Analytical Modeling of Cost in Management Accounting Research

"The problem of control is defined as that of choosing **operating rules** for members of an organization and enforcement rules for the operating rules so to maximize the organization's **objective function**"[1]

"…**the process by which managers assure** that resources are obtained and used effectively and efficiently in **the accomplishment of the organization's objectives**"[2]

"The objective of the firm is to find the output-input combination that results in the **maximal profit."** […] "**A cost model** is viewed as a representation of the underlying economic structure of the firm. This **is a** rather **complex problem** and a **demand for simplification** is evident."[3]

Issues associated with individual measures of performance Issues associated with individual measures of performance include[1]:

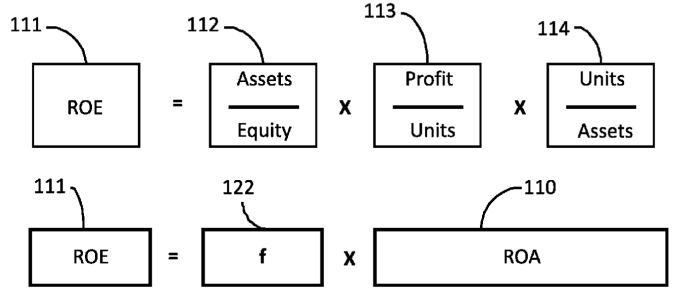
- Should measures **focus on processes**, the outputs of processes, or both?
- **Is time the fundamental** measure of manufacturing performance?
- How can the measurement of **total factor productivity** be simplified?
- How can performance measures be designed so that they **encourage inter-functional co-operation**?
- How can measures which do not encourage **short-termism** be designed?
- How can performance measures be designed so that they **encourage appropriate behaviour**?
- How should the data generated as a result of a particular measure **be displayed**?
- How can one ensure that the management **loop is closed** - that corrective action follows measurement?
- […]

- The final issue, and one which has not yet been touched, is that of **predictive performance measurement**. The assumption underpinning this review, and indeed much of the work on performance measurement to date, is that **managers use measures both to monitor past performance and stimulate future action**. […] A key item on the performance measurement research agenda must therefore be the identification, and/or development, of **"predictive performance measures".**

1 Arrow (1964); 2 Anthony (1965), 3 Christensen (2006), 4 Neely (1995)

Time-based Performance Management Systems and Computer-Aided System for Improving ROA exist

DuPont™ model for ROE from 1912[1,3]



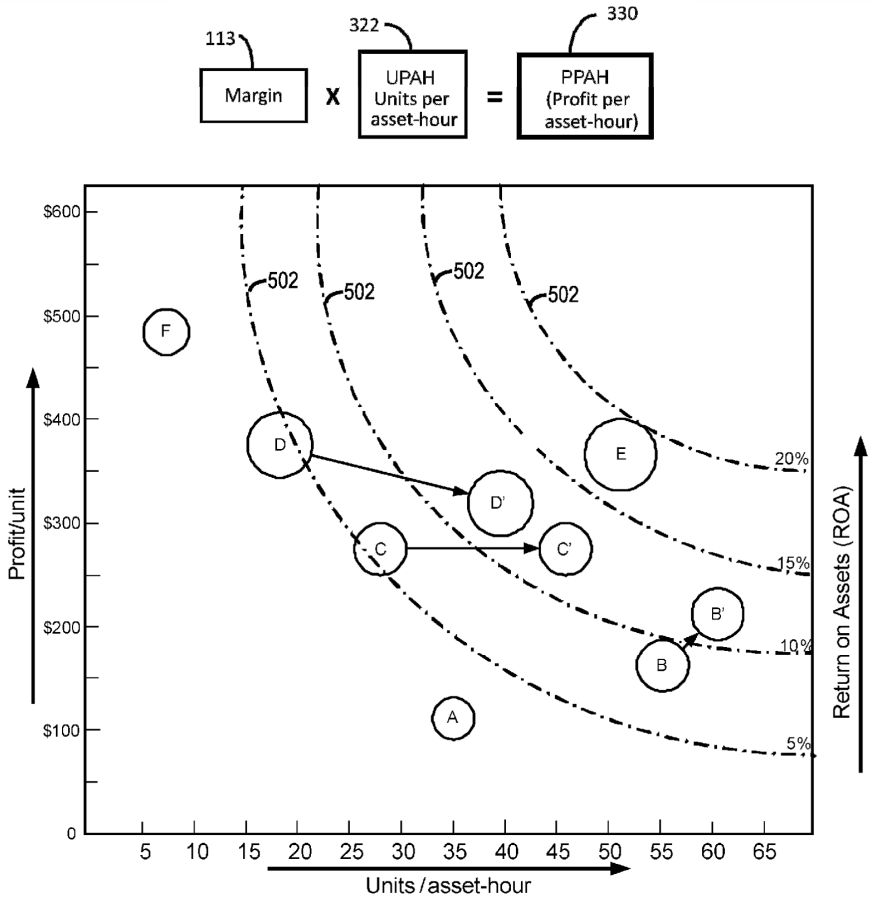
Time-based costing system known as throughput accounting[2]

[…] **the rate** at which **a product contributes** money **compared to** the rate at which **the factory spends** it that **determines** absolute **profitability**.

$$\text{Return per factory hour} = \frac{\text{Sale price} - \text{material cost}}{\text{Time on the key resource}}$$

$$\text{Cost per factory hour} = \frac{\text{Total factory cost}}{\text{Total time available on the key resource}}$$

Profit Velocity model linking profit per asset-hour to ROA[3]



1 Phillips (2015), 2 Galloway and Waldron (1988-89), 3 Pending patent US 2016/0092892 A1 (2015) "Computer-Aided System for Improving ROA", applied by Profit Velocity Solutions, LLC

Advanced analytics expands beyond the reach of APC systems and allows for production optimization at scale

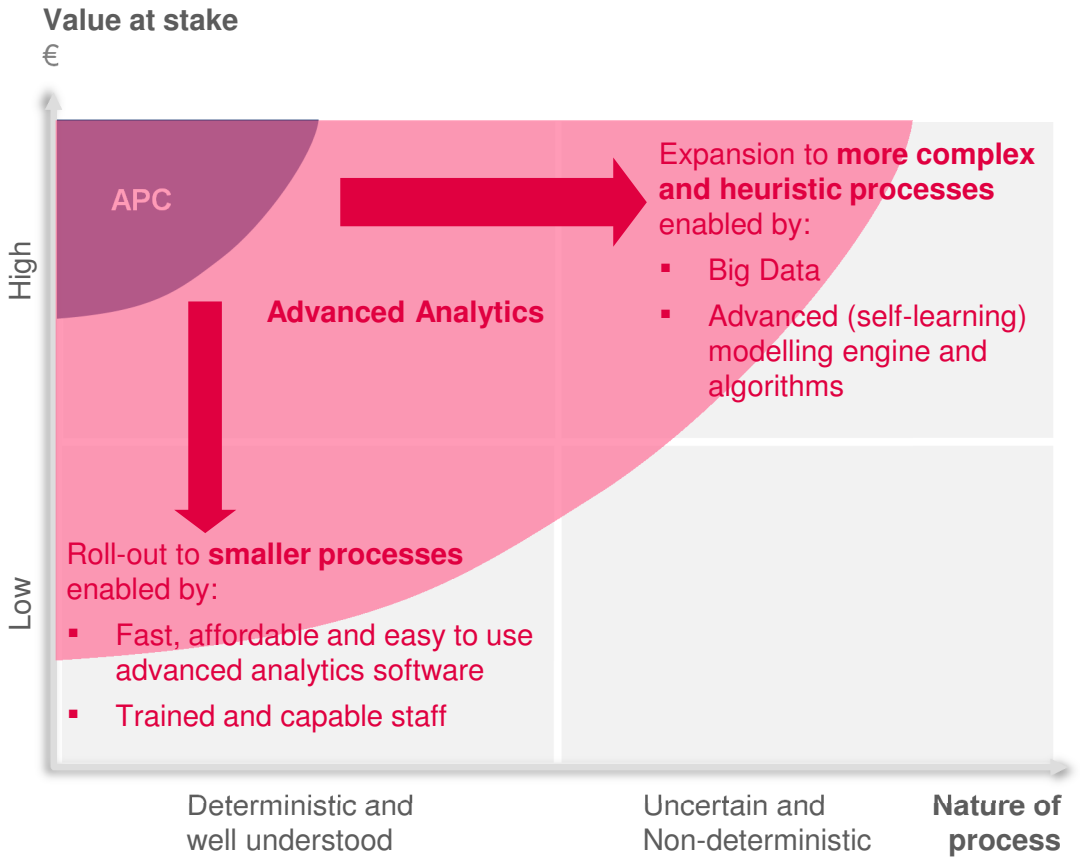
Evolution and revolution?

"[…] **the general activity of making sense** of data has evolved **from decision support, to executive support**, to online analytical processing, to business intelligence, to analytics and now to "big data"."[1]

"**Operational analytics** are embedded, automated decision making processes that prescribe and **cause actions to occur in decision time**.

- **Analytics 1.0** […] focused on **batch analysis** of internal structured data
- The **Analytics 2.0** era represents the rise of big data. It includes **new types of data, new analytical methods,** and the use of external data.
- The **Analytics 3.0** era **enables operational decisions** […] it evolves the best of Analytics 1.0 and 2.0 towards a unified analytics approach." 2

Advanced analytics expands beyond APC systems[3]



APC = Advanced Process Control 1 Davenport (2014), 2 Franks (2014), 3 McKinsey (2016)

Breaking down EBIT per time with analytics will help identify performance drivers and operational actions

Formula view

$$EBIT = \left[\sum_{all\ products} tons_{product} \times \frac{revenue}{ton} + \sum_{all\ energy\ types} energy\ generated_{units} \times \frac{revenue}{unit} \right]$$

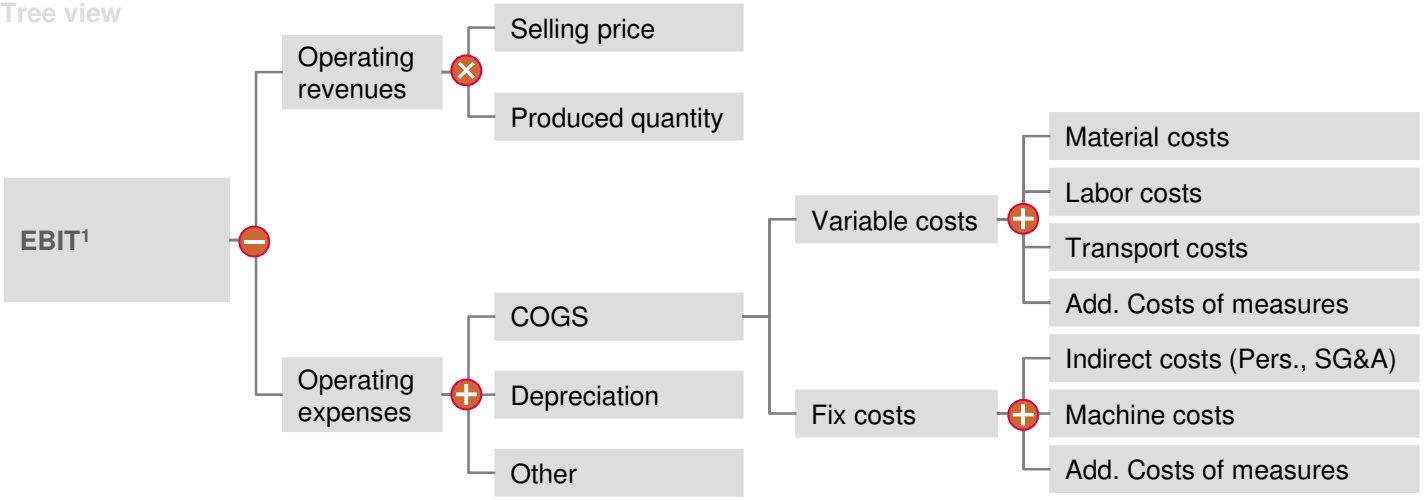
f (through-put, yield) | f (product mix, pricing) | f (through-put, yield) | f (energy pricing)

$$- \left[\sum_{all\ raw\ materials} tons_{raw\ material} \times \frac{cost}{ton} + \sum_{all\ energy\ types} energy\ consumed_{units} \times \frac{cost}{unit} + \sum_{all\ waste\ types} tons_{waste} \times \frac{cost}{ton} \right]$$

f (through-put) | f (raw materials pricing) | f (through-put, yield) | f (energy prices) | f (through-put, yield) | f (waste charges)

Incorporating tradeoffs like yield, throughput, energy and raw material consumption in one single, time-based profitability as decision basis

Tree view



1 Bernstein (1974)

The society of German Engineers drafted a “standard” big data workflow for production processes

“This status report describes the **best-practice workflows in industrial big data projects**.

The description explains each individual step **with reference to the DMAIC method from Six Sigma**[…]”[1]

1 VDI/VDE/GMA FA 7.24 (2016)

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Next steps and questions for input

Finalization of literature review and theory development | **Application in industrial case study** | **Validation of approach and conclusion**

Questions:

- What other initiatives are relevant for my work?
- Who else would you recommend me to talk to in academia and industry?
- What is your view on
  - industry 4.0 in process industries
  - data-driven decision making systems in manufacturing
  - time-based, financial performance metrics