Developing a production engineering based theory of production

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Outline

1. Key challenges for production technology in high-wage countries
2. A production engineering based theory of production
3. The Value Added Model
4. The Cybernetics Model
5. Conclusion
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1  Key challenges for production technology in high-wage countries

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Fast, market-ready innovations are the key to success for high-wage countries

Factors of success for high-wage countries like Germany

1. Offering a wide range of product variants at competitive prices by taking advantage of the *economies of scale*.

2. Reducing the risk of imitations through *highly innovative products*.

3. Staying one step ahead of the competitors by *shortening the time-to-market*.

4. Enhancing *ressource efficiency* in the product life cycle

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The polylemma of production is resolved by simultaneously addressing the poles of the field of tension.

**Planning economy**
- **Value orientation**
  - Decentralized near-process decision making
  - Standardised methods and procedures
  - Elimination of “muda”
- **Planning orientation**
  - Centralized Knowledge Management
  - Integration of virtual models and real world applications
  - Intense use of resources

**Production economy**
- **Economies of scale**
  - Continuous throughput
  - Synchronised processes
  - Standardized products and processes
  - High frequency production cycle
- **Economies of scope**
  - One-Piece-Flow
  - Flexibility and versatility
  - Dynamic and complex production creation chains

How can a good synchronisation of objectives for all activities with simultaneously high system dynamic be achieved?

How can products be realised with minimum production costs, which are matching perfectly with customer demands?
The solution hypothesis for companies in high-wage countries is higher integrativity in production technology

Definition of Integrativity

- Holistic approach to simultaneously address economic, ecologic and social challenges for production technology in high-wage countries
- Interdisciplinary inter-divisional cooperation in research and industry
- Expansion of the solution space by combination of established technological and managerial approaches

Prerequisites for integrative production technology:

- Sound understanding of a production system’s mathematical and physical fundamentals
- Regulatory framework for interdisciplinary collaboration and knowledge management

Central hypothesis: Integrativity is the key to generate social added value by enabling competitive production technology in high-wage countries.
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Production theories deliver a theoretical approach to describe the cause-effect relationships of production systems.

- **Typ A** – Classical and neoclassical production theory
  - 1766-1950
  - Resources as carriers of the performance potential

- **Typ B** – Theory of Gutenberg
  - Limitationality
  - Theory of Leontief

- **Typ C** – Production theory by Heinen
  - Modularization by describing the process as a sequence of elementary combinations

- **Typ D** – Input/Output models by Kloock
  - Dependency of the production on machine intensity

- **Typ E** – Production theory by Küpper
  - Dated quantities, instead of assignment to sub-periods
  - Integration of the financial sector

- **Typ F** – Production theory by Matthes
  - Short-term dynamic production function
  - Link with production planning

Evaluation of existing production theories:

- Lack of engineering basics to describe interrelations of technologies and production.
- Insufficient description of interdisciplinary interdependencies in production systems.

Production theory in the service sector

Decision oriented Production theory

Development of a production theory by Wiendahl and Nyhuis

Other approaches

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Development of a production engineering based theory of production

Theory of Production (Virtual World)

Value Added Model

\[ f(x) = \ldots \]

Emergentism
Find phenomena and structures

Reductionism
Find particles and interaction laws

Cybernetics Model

Comprehension

Design

Materials (m) → Transformation

\[ P = f(m, n) \]

\[ F = f(m, n) \]

Means of Production (n) → Products (P)

Function (F)

Production System (Real World)
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Interdisciplinary interactions of production technology need to be described mathematically and physically

- The tool costs ($K_{WZ}$) depend on the coat thickness $b$ (about 5mm) and the price $K$ of the grinding wheel (about € 5.000) as well as on the dressing infeed.

  \[ K_{WZ} = \frac{a_{ed}}{n \cdot b} \cdot K \]

- Costs have two components
  - Machine and Labor Costs $K_{ML}$
  - Tool Costs $K_{WZ}$

  \[ K_F = K_{ML} + K_{WZ} \]

- Machine and Labor Costs

  \[ K_{ML} = \left( K_{MH} + K_{LH} \right) \cdot t_e \left( Q'_w \right) \]
The goal is to identify actuating variables and target values as well as their cross-dependencies.

Formula-based description of production technological interdependencies within a production system.

- To avoid intradisciplinary local optimization, the interactions between the dimensions of evaluation need to be examined.

- The interdisciplinary approach allows the derivation of the overall optimal operating point.

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Optimal operating point
single system
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Optimal operating point
total system
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- Variance

- Production
  - Volume

- Logistics

- Flexibility

- Quality
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The human being is the perfect archetype to design a complexity oriented structure for a cybernetic management system.


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The Cybernetic Production Management System fosters maximum autonomy, continuous learning and structural evolution.

Autonomous Process Management and Control

Normative Production Management
  - Normative specifications
  - Coordination routines, Corrective measures

Strategic Production Management
  - Targets and strategies

Tactical Production Management
  - Current process plans, corrective measures

Process Coordination Center
  - Sequences, priorities, measures

Operating points, priorities

Processes of order processing

Quelle: Brosze 2011, p.168
The multilevel structure enables a self-preserving system based on autonomous elements

- Definition of Identity
- Environment and Change Monitoring
  - Development of Production Strategy
  - Design of Production System
- Process Configuration
  - Process Guidance and Control (hierarchical)
  - Process Coordination (hierarchical)
  - Process Monitoring
- Process Synchronization (non-hierarchical)
  - Process Stabilization (cross-process)
- Process Control
  - Process Optimization
  - Process Monitoring
  - Process Stabilization
  - Project Monitoring

### Levels:

- **Normative Production Management**
  - Normative specifications
- **Strategic Production Management**
  - Targets and strategies
- **Tactical Production Management**
  - Coordination routines, corrective measures
- **Autonomous Process Management and Control**
  - Operating points, priorities
  - Current process plans, corrective measures
  - Sequences, priorities, measures

### Processes of order processing

Granularity and accuracy of reference values
Response-time behavior
Dynamic reference value corridors
To develop cybernetic control mechanism, new ways of experimental research will be performed in the Enterprise-Integration-Center.

**Enterprise-Integration-Center (EIce)**

**IT support**

**Data Management**

**Production planning and control**

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**Cybernetic Production Planning and Control**

- **Mastering dynamics** with almost real-time processing of reported informations
  
  ![Diagram of Rough Planning, Scheduling, Detailed Planning, and Process with Feedback](image)

- **Decentral** and **robust** control systems to separate automated and manual actions and reactions

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**Data management for High Resolution**

- **High Resolution** identification of materials, parts and process status

  ![QR Code](image)

- **Mastering dynamics** with the update of relevant data (Refurbishment times, prices, etc.)

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**Interoperable IT support**

- **Standardized** IT structures and systems to reach versatility (ERP-as-a-Service, Best-of-Breed etc.)

- **Barrier-free cross-company** communication in real-time using transmission standards
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A production engineering based theory of production is the key for success in high-wage countries

1. **Integrative production technology generates social value in high-wage countries.**

2. **The Value Added model delivers a formula-based description of production technological interdependencies within production systems.**

3. **The Viable System Model allows to integrate autonomous but interdependent subsystems in a production system, which is capable to self-preserve under dynamic conditions.**
Thank you for your attention!

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