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**INTRODUCTION**

**IMPACT FACTORS FOR PRODUCTION SYSTEMS**

- Shorter Product Lifecycle
- New (European and National) Legislation
- Increasing Costs and Market Competition
- Increasing Labor Costs
- Fluctuating Production Volumes and Revenues
- Rapidly Changing Technologies
- Basic Requirement: Continuously Adaptation

Production System improvement is driven by **dynamic impact factors**
Increasing demand for **efficient and flexible production systems**
Current approach of European production companies: **Toyota Production System**
THE TOYOTA PRODUCTION SYSTEM

- General framework and philosophy to design and organize the manufacturing system
- Objective: Provide best quality, lowest cost, shortest lead time through the elimination of waste
- As the main goal of the TPS is to eliminate waste, TPS is generally known as lean production
- Toyota was capable of significantly reducing cost and inventory using the TPS, enabling it become one of the ten largest companies in the world
- TPS is continuously improved through iterations of standardized work and kaizen

LEAN PRODUCTION SYSTEM
IMPLEMENTATION IN EUROPE

- Due to the success of the TPS and faced with the rapidly developing changes in global markets the TPS framework and various of its inherent methods have been adapted by many European production enterprises (large-scale but also small and medium sized companies)
- As these 'TPS adaptations' show significant accordance, they can be summarized as Lean Production Systems (LPS)
- Only few European companies have achieved "lean" results, e.g. in terms of productivity and continuous improvement processes, like Toyota

Figure 1: TPS House, adapted from Ohno 1998, Liker 2004
INTRODUCTION

PRODUCTION SYSTEM REQUIREMENTS CHANGE OVER THE PRODUCT LIFE CYCLE

> The Production System Design has to cope with different Products (P), strategic Objectives (SO), and Change Drivers (CD) over time.

> Different requirements over the Production System Life Cycle lead to changing Production System Capabilities (e.g. volume flexibility, dependability).

> Production System capabilities result from fulfilling certain Functional Requirements (FR) within the Production System.
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> Production System capabilities result from fulfilling certain Functional Requirements (FR) within the Production System

> Design Parameters (DP) that allow to fulfill Functional Requirements have their own temporality and need efforts and time to take effect on the FR fulfillment

> The number of different Design Parameters and dynamic changing requirements impede the identification of appropriate Design Parameters

PRODUCTION SYSTEM IMPROVEMENT DYNAMICS

> Improvement Activities for Production System Design generally cause dynamic interactions

> Unknown dynamics often impede Production System Improvement processes
## Importance and Realization of Production System Design Parameter (Own Survey, German SME, n=1955)

### Current Situation of Production System Improvement

- The establishment of a continuous improvement process and the strategic alignment of improvement activities represent some of the main problems today in German production SME.

### Survey on the Importance and Degree of Realization of Production System Design Parameters (Methods, Tools, etc.)

<table>
<thead>
<tr>
<th>Design Parameter (Principle, Method, Tool, etc.)</th>
<th>Importance (Mean)</th>
<th>Realization (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Continuous Improvement Process, Kaizen</td>
<td>58.25</td>
<td>2.20</td>
</tr>
<tr>
<td>2. Development of company strategy</td>
<td>54.26</td>
<td>2.10</td>
</tr>
<tr>
<td>3. Strategic planning and controlling</td>
<td>54.15</td>
<td>2.15</td>
</tr>
<tr>
<td>4. Data protection</td>
<td>54.00</td>
<td>2.10</td>
</tr>
<tr>
<td>5. Expansion of product portfolio</td>
<td>55.28</td>
<td>2.34</td>
</tr>
<tr>
<td>6. Employee development and training</td>
<td>58.50</td>
<td>2.42</td>
</tr>
<tr>
<td>7. Integration and information of employees</td>
<td>56.00</td>
<td>2.37</td>
</tr>
<tr>
<td>8. Business Process Integration (BPI)</td>
<td>10.70</td>
<td>0.60</td>
</tr>
<tr>
<td>9. Application of Six Sigma projects</td>
<td>15.00</td>
<td>1.00</td>
</tr>
<tr>
<td>10. Application of POM software</td>
<td>23.26</td>
<td>1.31</td>
</tr>
<tr>
<td>11. Application of SCM software</td>
<td>24.00</td>
<td>1.25</td>
</tr>
<tr>
<td>12. Implementation of KANBAN</td>
<td>26.00</td>
<td>1.23</td>
</tr>
<tr>
<td>13. Total Productive Maintenance (TPM)</td>
<td>30.00</td>
<td>1.48</td>
</tr>
<tr>
<td>14. Cooperation with university partner</td>
<td>31.25</td>
<td>1.33</td>
</tr>
<tr>
<td>15. Application of ERP software</td>
<td>41.26</td>
<td>1.76</td>
</tr>
<tr>
<td>16. Just in time production</td>
<td>46.09</td>
<td>1.56</td>
</tr>
<tr>
<td>17. Team work</td>
<td>49.00</td>
<td>1.63</td>
</tr>
<tr>
<td>18. Development of company network</td>
<td>49.26</td>
<td>1.50</td>
</tr>
<tr>
<td>19. Employee self-organization</td>
<td>53.75</td>
<td>2.01</td>
</tr>
<tr>
<td>20. Application of PPS software</td>
<td>57.25</td>
<td>2.00</td>
</tr>
<tr>
<td>21. Total Quality Management (TQM)</td>
<td>58.50</td>
<td>2.20</td>
</tr>
</tbody>
</table>

### Research Objectives

- To support strategic and life cycle oriented Production System Design, it is necessary to support the following functions:

  - The integration of strategic and product life cycle requirements into a structured planning process for production system design.

  - The derivation of adequate Design Parameters (e.g. Methods, Tools, Principles, etc.) based on best-practice knowledge to support improvement efforts as decision support.

  - The consideration of complex interdependencies to prevent unforeseen interactions and negative interrelations.
Introduction

Challenges and current Situation of Production System Design

Research Objectives

Framework Approach for Production System Design

Linking Systems Thinking and Life Cycle Thinking for Production System Design

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THE SYSTEMIC PLANNING PROCESS

The general systemic planning process provides a starting point for production system design.

The five steps of the planning process guide the planning team and support the team to gain comprehensive understanding of the current situation and possible design solutions:

1. Identification of Chances, Risks and Capability Requirements
2. Understanding of dynamics, interrelations and conflicts of current and future situation, processes, methods, tools, etc.
3. Development of means and controls for viable production system design
4. Assessment of effects of possible design solutions and required optimization efforts
5. Realization and anchoring design solutions
SYSTEMIC PLANNING PROCESS FOR PRODUCTION SYSTEM DESIGN

> The planning and realization process has to consider manifold input information, such as corporate strategy, legal requirements, change driver, new technologies, and capability gaps.

LINKING LIFE CYCLE THINKING AND SYSTEMS THINKING

LINKING THE SYSTEMIC PLANNING PROCESS WITH THE PRODUCT LIFE CYCLE

> The planning and realization process has to consider manifold input information, such as corporate strategy, legal requirements, change driver, new technologies, and capability gaps.

> The Product Life Cycle oriented Production System Design requires the proactively collection of requirements and other dependencies from all product life cycle phases.
LINKING THE SYSTEMIC PLANNING PROCESS WITH THE PRODUCT LIFE CYCLE

> The planning and realization process has to consider manifold input information, such as corporate strategy, legal requirements, change driver, new technologies, and capability gaps.

> The Product Life Cycle oriented Production System Design requires the proactively collection of requirements and other dependencies from all product life cycle phases.

> Feedback information of current Production System Design of all life cycle phases is a prerequisite for long-term production system design optimization.

AXIOMATIC DESIGN BASED DECOMPOSITION OF FUNCTIONAL REQUIREMENTS OF THE PRODUCTION SYSTEM

> To comprehensively describe and support the planning process, common understanding of complex production systems is necessary.

> The Manufacturing System Design Decomposition (MSDD) Approach by Cochran et al. (MIT, 1990) allows to separate objectives from the means of achievement of production system design.
AXIOMATIC DESIGN BASED DECOMPOSITION OF FUNCTIONAL REQUIREMENTS OF THE PRODUCTION SYSTEM

> To comprehensively describe and support the planning process, common understanding of complex production systems is necessary.

> The Manufacturing System Design Decomposition (MSDD) Approach by Cochran et al. (MIT, 1990) allows to separate objectives from the means of achievement of production system design.

> The central idea of axiomatic design is to distinguishing between what (objectives) is to be achieved and how (means) it will be achieved.

> In axiomatic design terminology, the objectives of the design are expressed as Functional Requirements (FRs) and the solutions are expressed as Design Parameters (DPs).

### Production System Functional Design Description

<table>
<thead>
<tr>
<th>FR</th>
<th>DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Cont. Improve</td>
<td>Service equipment regularly</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Regular preventive maintenance program (TPM)</td>
</tr>
<tr>
<td>Predictable Output</td>
<td></td>
</tr>
<tr>
<td>Delay Reduction</td>
<td></td>
</tr>
<tr>
<td>Costs &amp; Investment</td>
<td></td>
</tr>
</tbody>
</table>

ADDING INFORMATION TO FUNCTIONAL REQUIREMENTS AND DESIGN PARAMETERS

> To support the systemic planning process, the defined Functional Requirements and Design Parameters allow to add information for planning and evaluation purpose.
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FR-related information can be used to describe the current state and to describe interrelations that affect or are affected by FR achievement.

DP-related information can be used to describe detailed information on DP application as well as the expected efforts and benefits of over time.
EXAMPLE FOR FUNCTIONAL STRUCTURE OF THE FRAMEWORK

> **FR-DP-related Information** can be used for **assessment**, **evaluation**, and **analysis** purpose.

**Production System Assessment and Definition of Strategic Objectives**

**Comparing FR Level, Strategic Relevance of FR, and estimated FR efforts**

**Visualization for Decision Support**

**Software Implementation of the Framework Approach**

**Conceptual Structure and Information Flow of the Framework**

**Overview of current State of Development**

**Conclusion**
STEP 1

> **Assessment** of the current state of the production system based on the fulfillment of functional requirements.

> Verbal descriptions are used to depict five different levels of FR achievement.
**STEP 2**

> **Definition** and **weighting** of the pursued **production strategy** in terms of strategic capability dimensions (e.g. costs, quality, dependability, volume flexibility, etc.).

> By **weighting** selected **strategic dimensions**, the **strategic relevance** of specific **FRs** can be determined.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Definition of Strategy Set</th>
<th>Diagnosis</th>
<th>Evaluation</th>
<th>Consulting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Production System Type &amp; Performance</td>
<td>Definition of strategic objectives, change dr.</td>
<td>Identification of (strategic) Improvement potentials</td>
<td>Evaluation of different possible design parameter</td>
<td>Providing Prod. System Design Information</td>
</tr>
</tbody>
</table>

**STEP 3**

> **Derivation** of **critical Functional Requirements** based on a Prioritization Matrix for improvement potentials.

> Critical FRs can be selected and their position within the **Decomposition Tree** can be analyzed.
STEP 4 & 5

> Derivation of appropriate Design Parameters (e.g. methods) for production systems improvement.

> Provision of information on expected efforts (time, costs, qualification, etc.) for implementation of design parameters.

> Appropriate Design Parameters can be added to the preliminary project collection list.

Assessment of preliminary FRs

List of FR-associated Design Parameters

Selected critical Functional Requirement

Detailed Method Information Template

Collection of preliminary FRs
CONCLUSION

> The integration of Strategic and Life Cycle oriented requirements into the Production System planning process are a key to successful Lean Production System Design.

> The presented Framework approach supports a systemic and life cycle oriented improvement process of Lean Production Systems.

> The Software prototype supports companies to derive adequate Design Parameters with respect to their current situation, strategy and company-internal interdependencies.

> In the next steps, the software prototype will be evaluated and tested in production companies.
Framework For Life Cycle Oriented Production System Design

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