An Implementation Roadmap for Lean Product Development

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Overview of This Presentation

• Part of on-going LAI research stream on implementing and managing Lean PD systems
• Research project from Oct 2008-April 2009
• Summary references (available at lean.mit.edu):
  • Benchmarking Report: “Efficient Introduction of Lean in Product Development: Results of the Survey”
• 3 article drafts under review (Lean PD framework; Lean PD Implementation Factors; Lean PD Roadmap Development)

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Our Motivation and Focus

• Motivation:
  • Lean PD thinking is relatively recent, emergent—empirical evidence is still somewhat limited
  • Many claims about what Lean PD comprises—what are the attributes of a lean PD system?
  • What is actually being done in organizations attempting lean PD?

• Research questions:
  • What are the components of a lean PD system?
  • How far have PD organizations progressed in implementing lean practices?
  • Can we identify processes or practices that facilitate the implementation of lean practices in PD?

Our Approach

• Review recent publications on Lean PD
  • Identify a core set of espoused Lean PD system components
  • Identify and collect data from a diverse sample of PD organizations
    • Design and implement a survey based on components identified in publications
    • Measure a variety of factors relating to the implementation of Lean PD components
  • Derive a framework and roadmap for implementing Lean in PD systems

We used a systematic, rigorous, data-based process to assess the state of Lean PD frameworks and practice
## Literature Review Identified Superset of Lean PD System Components

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## 11 Lean PD System Components Are the Basis for Gathering Data

1. Workload leveling
2. Strong project manager
3. Specialist career path
4. Responsibility-based planning and control
5. Cross-project knowledge transfer
6. Simultaneous engineering
7. Supplier integration
8. Product variety management
9. Rapid prototyping, simulation and testing
10. Process standardization
11. Set-based engineering
Two Online Surveys Developed

- The hypotheses were translated into two online-surveys (German and English) asking for:
  - General information on the introduction process
  - The company’s maturity level for each component
  - The perceived usefulness and difficulty of implementation for each component
  - The order of introduction the company has chosen
  - Particular problems experienced when introducing a component (open question)
- The survey announcement was distributed to about 900 product development managers, chief engineers and development engineers using German and US LinkedIn, MIT Alumni Database, contacts of LAI and IFU, ILP, industry associations, chambers of commerce as well as personal contacts
- 113 valid responses

An International Sample, Mostly Complex Assembled Products

- Participants according to country:
  - Germany: 65 (58%)
  - United States: 33 (29%)
  - Others: 15 (13%)
  - n = 113
- Participants according to industry sectors:
  - Automotive: 44 (39%)
  - Industrial Equipment: 16 (14%)
  - Aerospace Manufacturing: 11 (10%)
  - Electronics: 17 (15%)
  - Others: 25 (22%)
  - n = 113
We Measured Three Primary Constructs

- To what extent are they using a lean PD component (i.e., how widespread is the use)?
- What are the perceived benefits from each component and their ease of implementation?
- In what order did they implement the components? (rank order)
- Others
  - General information on the introduction process
  - Particular problems experienced when introducing a component (open question)
Average Implementation of Lean PD Components

Each Component is Measured by 4 Characteristics (44 In Total)

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n = 113
Average Perceived Benefits From Implementation of the Component

- Simultaneous Engineering: 5.14
- Process Standardization: 4.96
- Product Variety Management: 4.85
- Workload Leveling: 4.83
- Cross-project Knowledge Transfer: 4.79
- Supplier Integration: 4.78
- Strong Project Manager: 4.77
- Rapid Prototyping, Testing and Simulation: 4.62
- Set-based Engineering: 4.42
- Specialist Career Path: 4.38
- Responsibility-based Planning and Control: 4.34

n = 113

Average Rating Benefits of Implementation

Average Perceived Ease of Implementation

- Specialist Career Path: 3.48
- Simultaneous Engineering: 3.35
- Process Standardization: 3.29
- Rapid Prototyping, Testing and Simulation: 3.16
- Responsibility-based Planning and Control: 2.99
- Supplier Integration: 2.82
- Strong Project Manager: 2.68
- Workload Leveling: 2.68
- Set-based Engineering: 2.58
- Product Variety Management: 2.50
- Cross-project Knowledge Transfer: 2.39

n = 113

Average Rating Ease of Implementation
Is the Order of Implementation Driven by the Interdependencies Between the Components?

We Mapped the Component Interdependencies Based on Relationships Identified in the Literature

We Estimated the Strength of the Interdependencies

To what extent does the row component require the column component (on a scale from 0 to 5)?
A Bubble Chart Graphically Represents Dependencies Between Components

Requires other components (average rating)

Size of bubbles represents standard deviation from mean

Includes:
- Workload leveling
- Strong project manager
- Specialist career path
- Responsibility-based planning and control
- Cross-project knowledge transfer
- Common part architecture
- Rapid testing and prototyping
- Process standardization
- Supplier integration
- Set-based engineering
- Slow starts

Is required for other components (average rating)

Most effective order of implementation?

Logically, Implementation Should Proceed From Least to Most Dependent Practices

Requires other components (average rating)

Size of bubbles represents standard deviation from mean

Includes:
- Workload leveling
- Strong project manager
- Specialist career path
- Responsibility-based planning and control
- Cross-project knowledge transfer
- Common part architecture
- Rapid testing and prototyping
- Process standardization
- Supplier integration
- Set-based engineering
- Slow starts

Is required for other components (average rating)
Does Sequence of Implementation Matter?

Limited support for hypothesis that lower-level components enable implementation of higher-level components.

Does Existence of Lean PD Vision/Goals Affect Component Implementation Levels?

Weak but positive correlation between existence of Lean vision/goals and implementation levels.
How Do Dedicated Change Agents Affect Implementation?

Has your organization declared a person responsible for implementing Lean principles in product development?

- Yes: 46%
- No: 54%

Is your organization planning to use or already using external help (e.g., consultants, sensei, etc.) to implement Lean principles in product development?

- Yes: 37%
- No: 63%

Use of dedicated lean specialists not significantly correlated with greater implementation of components.

Is Value Stream Mapping a Widely-Used Tool in PD Settings?

- We have not conducted value stream mapping and we are not planning to use this method: 28 (24.8%)
- We have not conducted value stream mapping but we are planning to use it: 20 (17.7%)
- We have done value stream mapping for a small number of our processes: 41 (36.3%)
- We have done value stream mapping for the majority of our processes: 22 (18.5%)
- We have done value stream mapping for all of our processes: 2 (1.8%)

Use of VSM not significantly correlated with implementation levels—Generally not used or limited use in pockets of lean activity.
General Observations: Lean PD Components Form a Highly Interwoven System

- Significant positive correlations between nearly all Lean PD components for implementation/use
- Significant positive correlation between firm revenues and implementation/use of Lean PD components
- Strong Project Manager component not correlated with implementation of other components
  - Consistent high use across sample—a given for PD?
    - Spread in Strong PM characteristics scores suggest difference between traditional PM and Lean Strong PM
- Data don’t address impact of partial implementation of Lean PD components on overall system performance
  - Analysis highlights interdependencies in implementation of components, however

Developing an Implementation Roadmap

- Current state:
  - Build from what we know now: how firms are, on average, implementing Lean practices in PD
- Current state approximation:
  - We used the average use of each of the 44 characteristics to define the overall order of implementation

We assume that on average the overall level of implementation of a practice reflects its maturity or time in use, and therefore the order in which it was implemented
Lean PD components and characteristics

1. Standard milestones define a sequence in which the development tasks are conducted
2. Standardized tools are used for project planning and control
3. Standardized tools and procedures are used for design tasks
4. Standardized documents are used for capturing knowledge and lessons learned

5. Representatives from manufacturing, quality assurance and purchasing are integrated in the concept definition phase
6. There are frequent review meetings with development, manufacturing, quality assurance and purchasing
7. There is a formalized process for evaluating design proposals regarding manufacturing and assembly compatibility
8. Development and testing of production facilities is done in parallel to product development

9. Project manager leads the product development project from concept to market
10. Project manager defines the product concept and advocates the customer value
11. Project manager sets the project timeframe and controls the adherence to it
12. Project manager chooses the technology and makes major component choices

13. Project development resources are planned on a cross-project basis
14. Development activities are scheduled and prioritized
15. Actual and planned capacity utilization are compared frequently
16. Resources are flexibly adapted in case of occurring bottlenecks

Current State: Average Implementation of Lean PD Components

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<tr>
<th>Process Standardization</th>
<th>Simultaneous Engineering</th>
<th>Strong Project Manager</th>
<th>Workload Levelling</th>
<th>Specialist Career Path</th>
<th>Product Variety Management</th>
<th>Supplier Integration</th>
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<td>+30 +29 +31 +32 +33 +34</td>
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Use of Characteristic (reversed scale)
Developing an Implementation Roadmap, cont.

- **Future state prediction**: Adjust implementation timing for each characteristic reflecting insights from analysis of all components
- **Key Assumptions**:
  - If the use of one component positively affects the ease of use of other components (is beneficial), we would prefer to implement that component earlier
  - If a number of components are mutually dependent in use, we would prefer to implement those components concurrently

We couple the data analysis with these assumptions to adjust the timing of implementation of the Lean PD components in the future state implementation roadmap

### Future State: Adjusted Lean PD Component Implementation

<table>
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<tr>
<th>Component</th>
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Gaining Insights From the Future State Roadmap

- Roadmap divided into four major Implementation phases
  - Names induced from groupings of similar characteristics, from general themes in each group, and represent increasing levels of system lean maturity
- Lean PD components are implemented in concurrent and overlapping implementation streams
  - Of considerably differing lengths, with relatively large gaps between the implementation of single characteristics
  - Arrows showing the implementation streams for the Lean PD components have a clear beginning and end—implementation isn’t necessarily complete at the end of the arrow

Lean PD implementation stages

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<th>Integrated Organization</th>
<th>Responsible Organization</th>
<th>Learning Organization</th>
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Phase 1: Planning Organization

- Establish structure and discipline to enable more stable and predictable PD system operations
- Build the necessary capabilities for planning and scheduling product development projects. e.g.:
  - Standard milestones define the sequence of development tasks (no.1)
  - Development activities clearly scheduled and prioritized (no.14)
  - Standardized planning and control (no.2)
  - The project manager sets the project timeframe and controls adherence (no.11)
  - Performance of development engineers regularly evaluated and discussed in feedback meetings (no. 20 and 35)
- Initially the planning of PD projects may be done by designated planners, but this task should be delegated to the project managers by the end of phase one

Phase 2: Integrated Organization

- Establish tighter control over coordination of activities, and reduce variation and unpredictability in task execution, in part through rationalization of the product architecture
- Enhance internal design capabilities through tools and product optimization
  - Standardized tools and procedures for design tasks (no.3), computer-aided modeling and simulation (no.30) and quick physical modeling (no.29)
  - Clear goals for the use of off-the-shelf components within a product (no.21) and the reuse of product parts among different modules, products and product families (no.22)
- Important internal stakeholders (e.g., manufacturing and quality assurance) are integrated into the design process to ensure goals are well aligned
  - Integration of development, manufacturing, quality assurance and purchasing into the concept definition phase (no.5) and evaluating design proposals for manufacturing and assembly compatibility (no.7), with frequent review meetings (no.6)
- Phase 2 activities help prepare for phase 3, the responsible organization
  - Small number of high-capability, critical parts suppliers used (no.26)
  - A mentoring system for junior engineers (no.19)
  - Standardized documents capture best practices and lessons learned (no.4)
Phase 3: Responsible Organization

• Establish a sense of ownership among all participants
• Develop PD culture that rewards responsibility and personal commitment
  • Project manager directly involved in defining the product concept and advocating customer value (no.10), and choosing key technologies (no.12)
  • Developers check their own performance with formalized feedback process (no.34), set their own goals, negotiate deadlines for their tasks (no.33), and are given the opportunity to experiment with new approaches to improve efficiency (no.36)
  • Engineers’ promotions based on functional experience and knowledge (no.18), advancing in their functional areas without losing their technical focus (no.17)
  • Critical suppliers integrated early in the conceptual design process (no.27) and mentored/developed similar to internal employees (no.28)
• The resulting innovative potential enables the organization to explore a larger number of ideas and conserve the generated knowledge for reuse, e.g.,
  • Product solutions intensively tested using rapid prototyping technology (no.31), with decisions in favor of a particular solution delayed until objective data are available (no.39)
  • Implement methods to collect information on successful procedures, tools and designs across projects (no.41), with best practices and lessons learned reviewed and reused in subsequent projects (no.42)

Phase 4: Learning Organization

• Maximize organizational learning
  • Alternative solutions for a product module are designed and tested simultaneously (no.38), narrowed, and retained once a particular concept has been selected (no.40)
  • Quickly generate and test products using lean methods for prototype build and tool manufacturing (no.32)
  • The existing knowledge base is continuously updated (no.43)
  • Knowledge abstracted and simplified to yield generalizable conclusions on how to improve the company’s products and processes (no.44)
General Observations

• Lean PD implementation stages based on analysis are consistent with our general understanding of the attributes of these systems
  • Solid foundation: well-defined structure of disciplined practices and execution
  • Focus on the big picture: key stakeholders, tools, and products work together in harmony
  • Engage everybody’s full capabilities: develop distributed leadership and responsibility (“everybody everyday”) across the enterprise
  • Exploit the capabilities: continuous learning, rapid experimentation, widespread knowledge sharing and diffusion
    • Implication: increased capacity and quicker turns requires growth of the business to sustain

Study Summary

• Study contributes significant new benchmark data to Lean PD knowledge base
• Coherent set of Lean PD components defined based on broad review of competing ideas
• Relationships between components of a Lean PD system explored using empirical evidence
• Roadmap developed that identifies specific steps in the Lean PD journey, as well as high-level insights into the evolution of PD systems
• Caveat: analysis based on existing framing of Lean PD (no radical new concepts developed)
Questions?

Backup Slides
Workload Leveling

Resources and capacities are planned on a project and cross-project basis. In the course of the project, required resources are controlled frequently and flexibly adapted in the case of occurring bottlenecks.

Strong Project Manager

Product development projects are led by an experienced project leader, who is largely responsible for defining customer value and securing the success of the project from concept to market.
**Specialist Career Path**

1. Workload leveling
2. Strong project manager
3. Specialist career path
4. Responsibility-based planning and control
5. Cross-project knowledge transfer
6. Simultaneous engineering
7. Supplier integration
8. Product variety management
9. Rapid prototyping, simulation and testing
10. Process standardization
11. Set-based engineering

- Engineers are given the opportunity to advance in their technical domain, based on personal coaching and frequent feedback by their superiors.

**Responsibility-based Planning and Control**

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- Development engineers are locally responsible for planning, execution and control of detailed product development activities.
Cross-project Knowledge Transfer

Successful methods, designs and tools as well as areas for improvement are documented on a cross-project basis and actively used and refined in subsequent projects.

Simultaneous Engineering

Production, quality assurance and purchasing departments are integrated into development activities at an early stage. The design of production processes and facilities is conducted in parallel to the development of the product.
Supplier Integration

1. Workload leveling
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Suppliers of critical parts are identified early in the project, integrated into the development process and actively supported to improve their performance.

Product Variety Management

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There are targets for the use of off-the-shelf components and reuse of parts as well as standardized modules and product platforms.
**Rapid Prototyping, Simulation and Testing**

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For a fast and reliable evaluation of concepts and drafts, rapid prototyping technologies, computer aided simulation, methods for fast physical modeling and flexible manufacturing are used.

**Process Standardization**

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<tr>
<td>5</td>
<td>Cross-project knowledge transfer</td>
</tr>
<tr>
<td>6</td>
<td>Simultaneous engineering</td>
</tr>
<tr>
<td>7</td>
<td>Supplier integration</td>
</tr>
<tr>
<td>8</td>
<td>Product variety management</td>
</tr>
<tr>
<td>9</td>
<td>Rapid prototyping, simulation and testing</td>
</tr>
<tr>
<td>10</td>
<td>Process standardization</td>
</tr>
<tr>
<td>11</td>
<td>Set-based engineering</td>
</tr>
</tbody>
</table>

For planning, executing and documenting projects, standardized processes, tools and methods are used.
Set-based Engineering

When developing a product module, a large number of alternative solutions are considered early in the process. The set of solutions is subsequently narrowed based on simultaneous development and testing of the alternatives.

Using API to identify the future state

\[ POS_{\text{new},i} = POS_{\text{old},i} - x \cdot CF_i \]

- Task: adjust relative position \( POS_{\text{new},i} \) of characteristics along implementation timeline using empirical insights about interdependencies, challenges
- Use DSM assumption: minimize distance between highly interdependent characteristics
  - Measure interdependence by assessing degree to which use of one practice aids/hinders the implementation of another (using correction factor—\( CF_i \))
  - Interdependence is dimensionless—need to scale to units of measurement to make its impact meaningful (using correction coefficient—\( x \))
**CF₁: Correlation Between Use and Ease of Implementation**

<table>
<thead>
<tr>
<th>Component</th>
<th>Correlation Factor (CF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of Design/Project Manager</td>
<td>0.64</td>
</tr>
<tr>
<td>Use of Task/Engineering</td>
<td>0.62</td>
</tr>
<tr>
<td>Use of Process Standardization</td>
<td>0.63</td>
</tr>
<tr>
<td>Use of Simulization Engineering</td>
<td>0.64</td>
</tr>
<tr>
<td>Use of Workload</td>
<td>0.67</td>
</tr>
</tbody>
</table>

- **Assumption**: Components which have a positive impact on the perceived ease of implementing others should be introduced earlier; those which do not facilitate the introduction of other components should be implemented later.

- The role each of the component plays with regard to the implementation of others is reflected in the average correlation coefficient for each row in the table.

**Scaling the correction coefficient**

- **Use DSM assumption**: minimize distance in time between implementation of highly interdependent characteristics
  - Iterate to minima using empirical data and numeric methods
  - Use value of $x$ (1.3) to calculate new positions for characteristics along implementation timeline

\[
PO_{new,j} = PO_{old,j} - x \cdot CF_j
\]

Minimize the distance between correlated characteristics:

\[
\min \Delta = \sum_{i,j} \left| \frac{PO_{old,j} - PO_{new,j}}{COR_{ij}} \right|
\]

\[
\min \Delta = \sum_{i,j} \left| \frac{PO_{old,j} - PO_{old,i} - x \cdot (CF_i - CF_j)}{COR_{ij}} \right|
\]
Lean PD components and characteristics

<table>
<thead>
<tr>
<th>7. Specialist Career Path</th>
<th>17. There is a designated career path for technical specialists in their functional areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18. Promotion is based on functional experience and knowledge</td>
</tr>
<tr>
<td></td>
<td>19. More experienced employees are responsible for mentoring and supporting junior</td>
</tr>
<tr>
<td></td>
<td>engineers</td>
</tr>
<tr>
<td></td>
<td>20. Performance of individuals is regularly evaluated and discussed in feedback</td>
</tr>
<tr>
<td></td>
<td>meetings</td>
</tr>
<tr>
<td>6. Product Variety</td>
<td>21. There are clear goals for the use of off-the-shelf components within a product</td>
</tr>
<tr>
<td>Management</td>
<td>22. There are clear goals for the reuse of product parts among different modules,</td>
</tr>
<tr>
<td></td>
<td>products and product families</td>
</tr>
<tr>
<td></td>
<td>23. There are modular components with standardized interfaces</td>
</tr>
<tr>
<td></td>
<td>24. There are common product platforms encompassing several product lines</td>
</tr>
<tr>
<td>5. Supplier Integration</td>
<td>25. Parts are evaluated according to their criticality before making outsourcing</td>
</tr>
<tr>
<td></td>
<td>decisions</td>
</tr>
<tr>
<td></td>
<td>26. A small number of high-capability suppliers are used for critical parts</td>
</tr>
<tr>
<td></td>
<td>27. Critical suppliers are integrated in the concept definition phase</td>
</tr>
<tr>
<td></td>
<td>28. Suppliers are mentored to improve their performance</td>
</tr>
<tr>
<td>4. Rapid Prototyping,</td>
<td>29. Designs are quickly modeled and tested using physical models</td>
</tr>
<tr>
<td>Simulation and Testing</td>
<td>30. Computer-aided modeling and simulation are used</td>
</tr>
<tr>
<td></td>
<td>31. Rapid prototyping technology is used</td>
</tr>
<tr>
<td></td>
<td>32. Methods of Lean Production are used in prototype build and tool manufacturing</td>
</tr>
</tbody>
</table>

Lean PD components and characteristics

| 3. Responsibility-based Planning and Control | 33. Developers are given the opportunity to set their own goals and negotiate deadlines for their tasks |
|                                           | 34. Developers are given the opportunity to check their own performance based on a formalized feedback process |
|                                           | 35. Developers are evaluated based on their performance                               |
|                                           | 36. Developers are given the opportunity to experiment with new approaches to improve efficiency |
| 2. Set-based Engineering                  | 37. A large number of possible solutions for a product module are considered early in the process |
|                                           | 38. Alternative solutions for a product module are designed and tested simultaneously |
|                                           | 39. Decisions are delayed in favor of a particular solution until objective data are available |
|                                           | 40. A concept for a product module is not revised once it has been selected         |
| 1. Cross-project Knowledge Transfer       | 41. There are methods and devices to collect information on successful procedures, tools and designs across projects |
|                                           | 42. Best practices and lessons learned from previous projects are reviewed          |
|                                           | 43. Documented knowledge is continuously updated by the engineers                  |
|                                           | 44. The collected knowledge is frequently simplified and generalized               |


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