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"
  - Thesis: "The Lean Innovation Roadmap – A Systematic Approach to Introducing Lean in Product Development Processes and Establishing a Learning Organization", June 2009
- 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

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Literature Review Identified Superset of Lean PD System Components

Lean PD Component	Clark et al. 1987	Womack et al. 1991	Karlsson 1996	Ward 2001	Kennedy 2003	Morgan, Liker 2006	Brown 2007	Schuh 2008
Workload leveling			x			x	x	x
Strong project manager	x	x	x	x	x	x		x
Specialist career path				x	x	x		
Responsibil.-based plann. and contr.				x	x	x	x	x
Cross-project knowledge transfer						x	x	
Simultaneous engineering	x	x	x			x	x	
Supplier integration	x		x			x		
Product variety management						x		x
Rapid prototyp., simul. and testing						x	x	
Process standardization						x	x	x
Set-based engineering				x	x	x	x	x

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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

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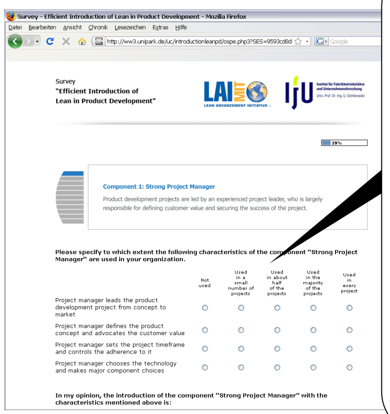
Two Online Surveys Developed



- 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

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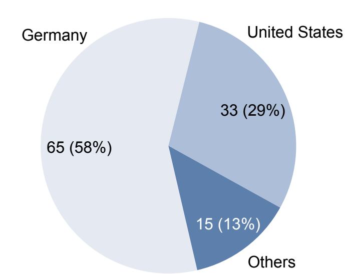
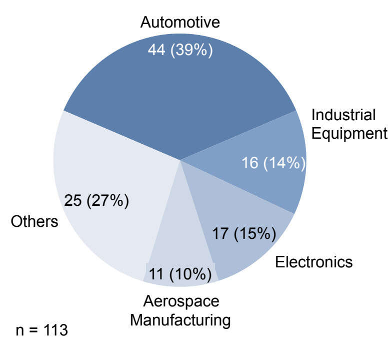
An International Sample, Mostly Complex Assembled Products



n = 113

Participants according to country



n = 113

Participants according to industry sectors

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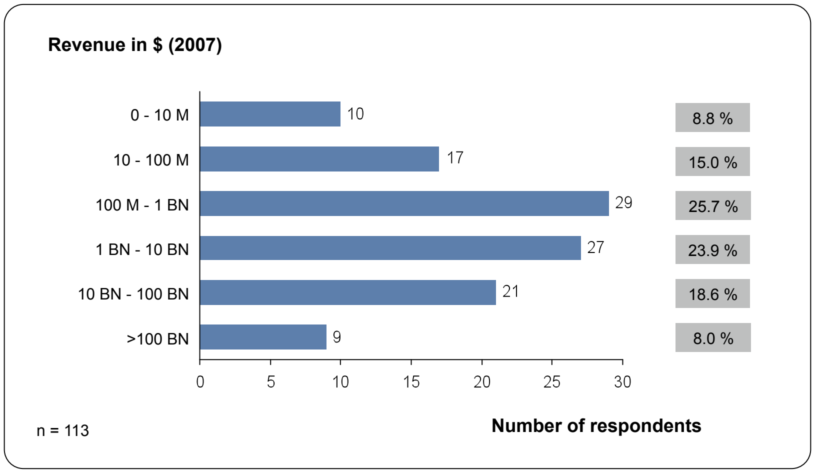
Respondents' Median Revenues ~ $1B



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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)

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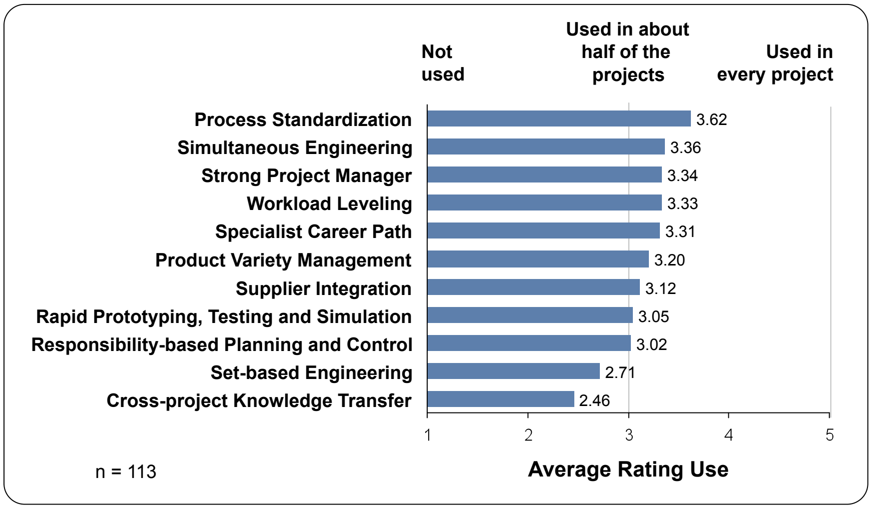
Average Implementation of Lean PD Components



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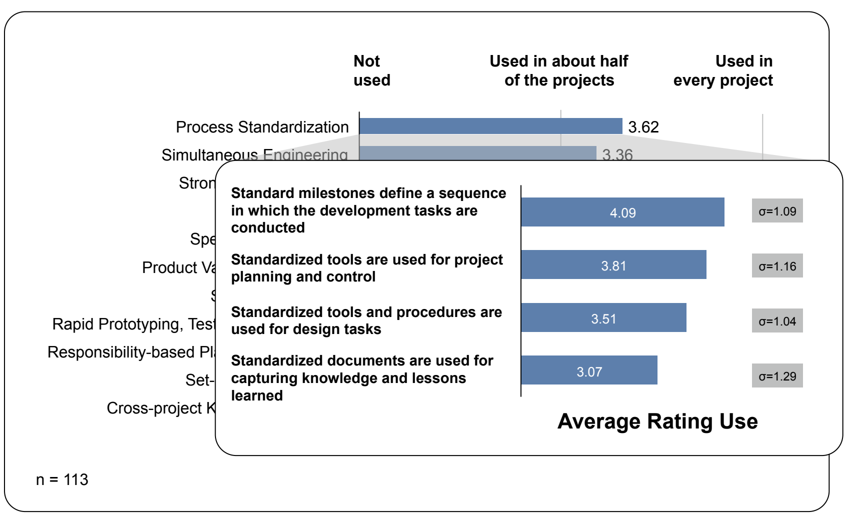
Each Component is Measured by 4 Characteristics (44 In Total)



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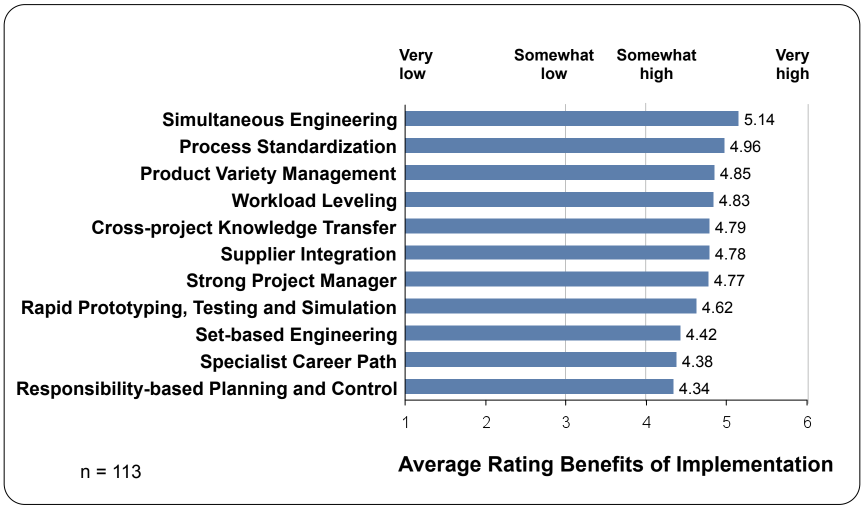
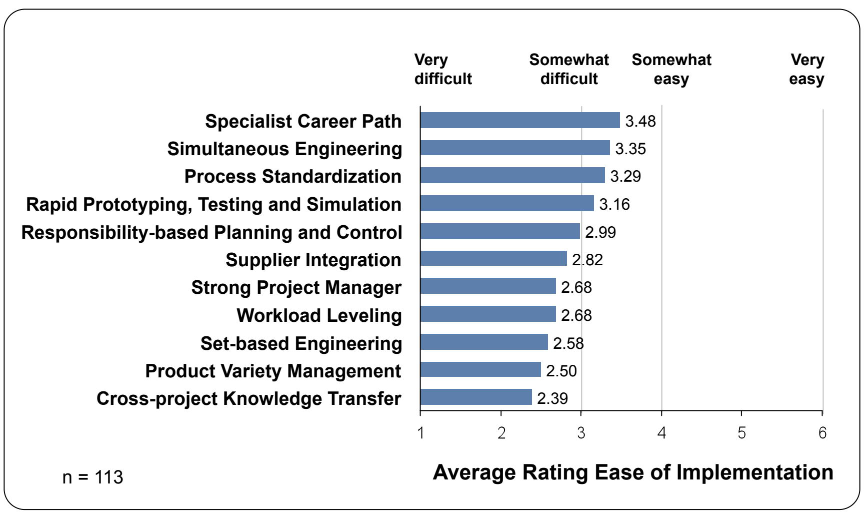
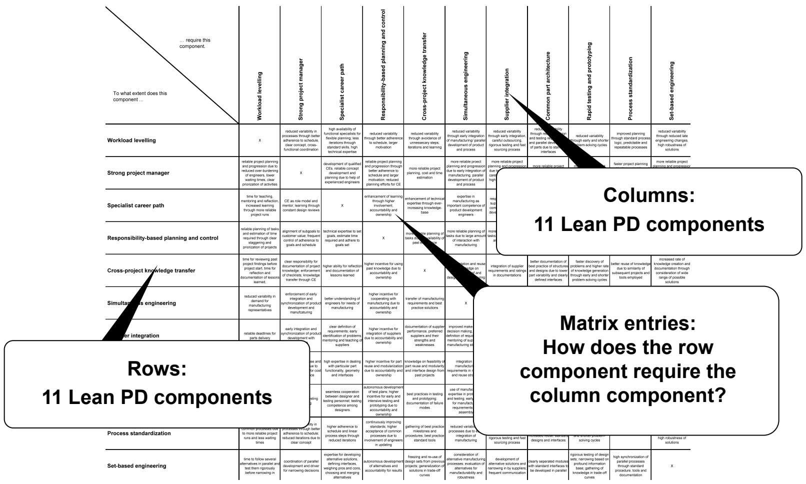
Average Perceived Benefits From Implementation of the Component



Average Perceived Ease of Implementation

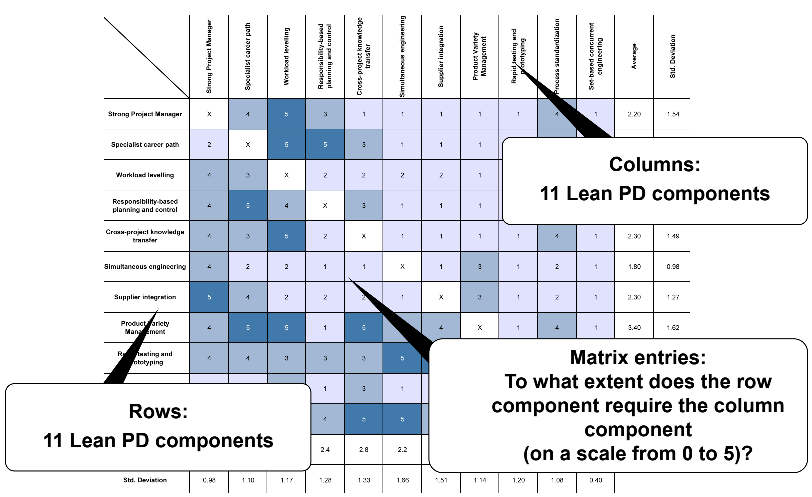


Is the Order of Implementation Driven by the Interdependencies Between the Components?



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

We Estimated the Strength of the Interdependencies



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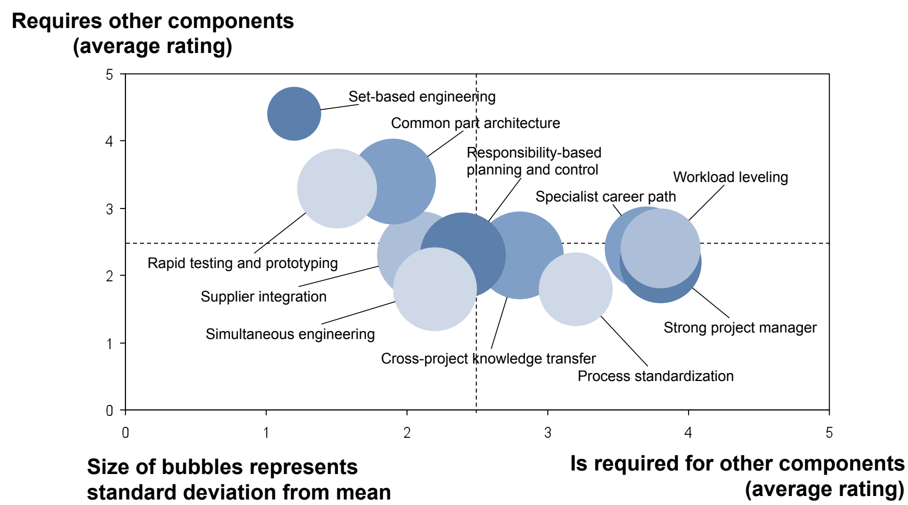
A Bubble Chart Graphically Represents Dependencies Between Components



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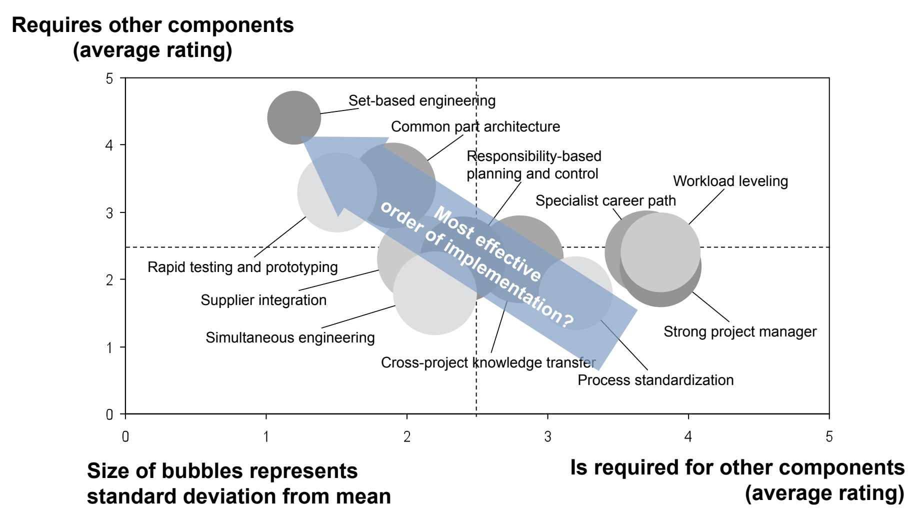
Logically, Implementation Should Proceed From Least to Most Dependent Practices



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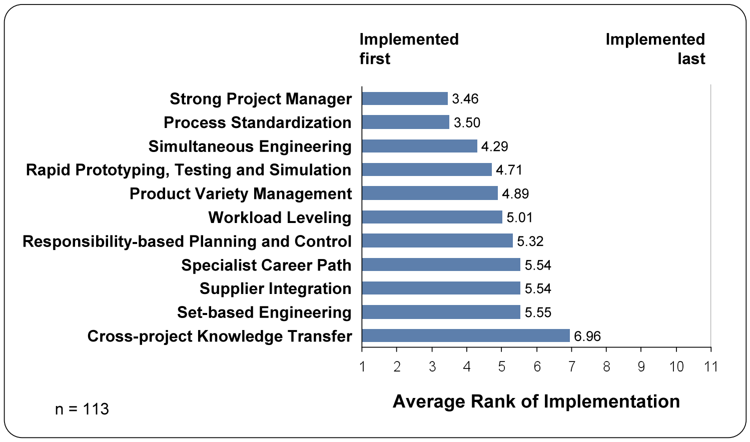
Does Sequence of Implementation Matter?



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

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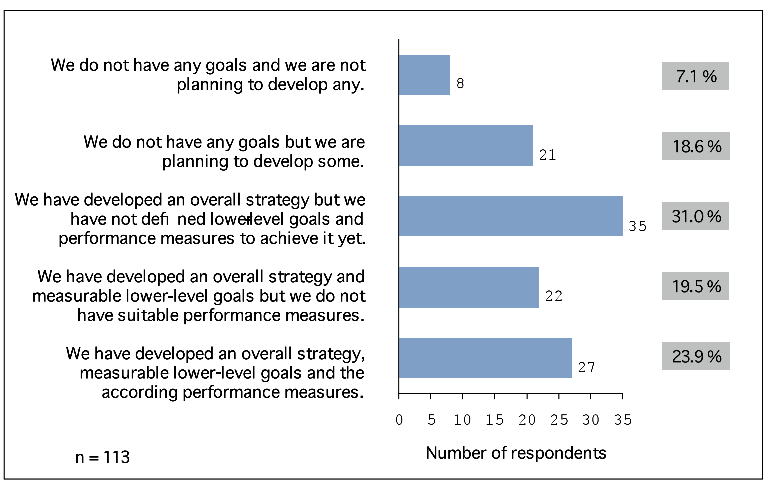
Does Existence of Lean PD Vision/Goals Affect Component Implementation Levels?



Weak but positive correlation between existence of Lean vision/goals and implementation levels

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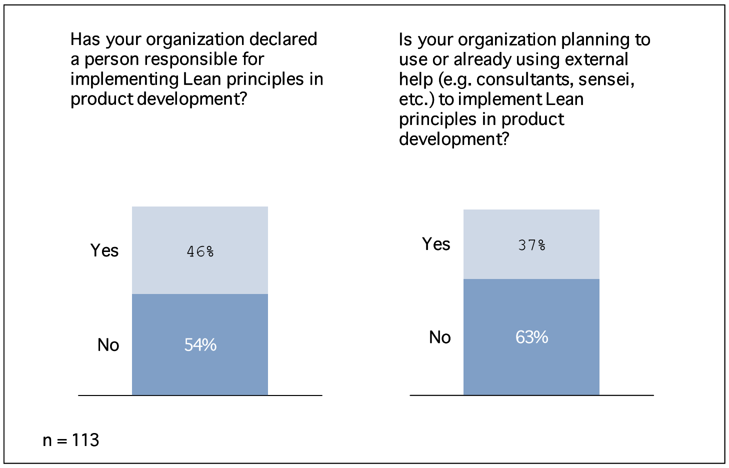
How Do Dedicated Change Agents Affect Implementation?



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

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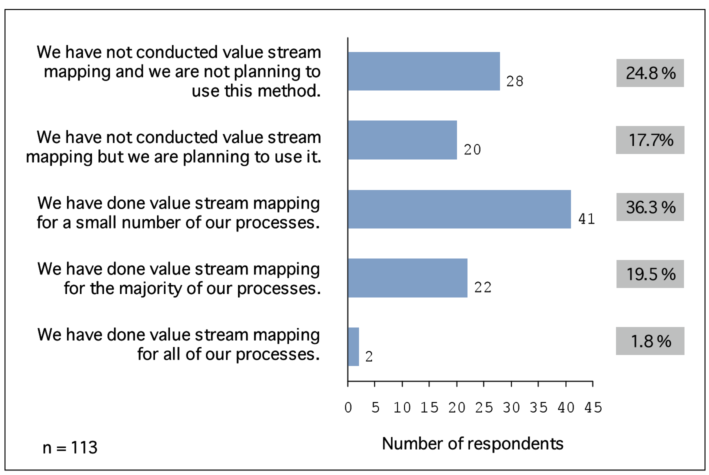
Is Value Stream Mapping a Widely-Used Tool in PD Settings?



Use of VSM not significantly correlated with implementation levels— Generally not used or limited use in pockets of lean activity

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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

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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

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Lean PD components and characteristics

11.	Process Standardization	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
10.	Simultaneous Engineering	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.	Strong Project Manager	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
8.	Workload Leveling	13.	Product 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

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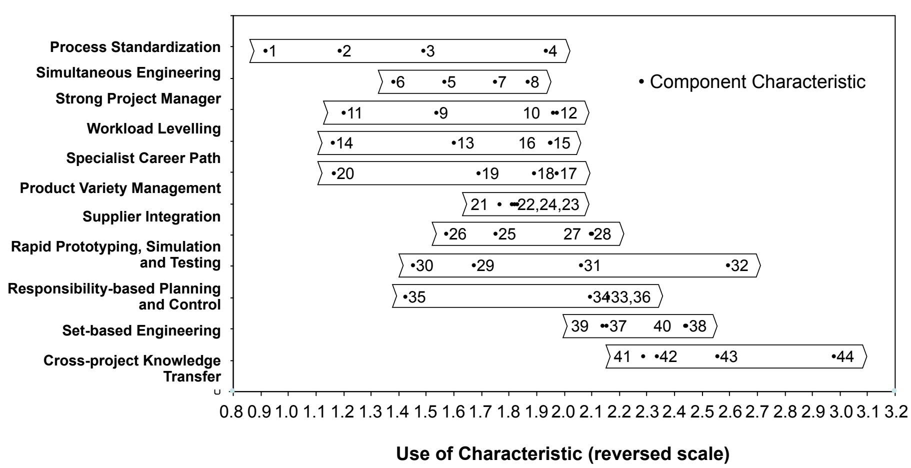
Current State: Average Implementation of Lean PD Components

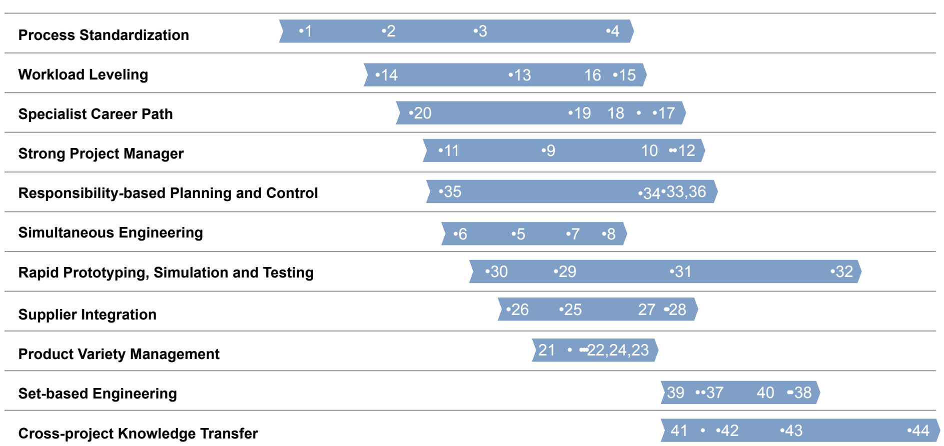


Developing an Implementation Roadmap, cont.

- 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

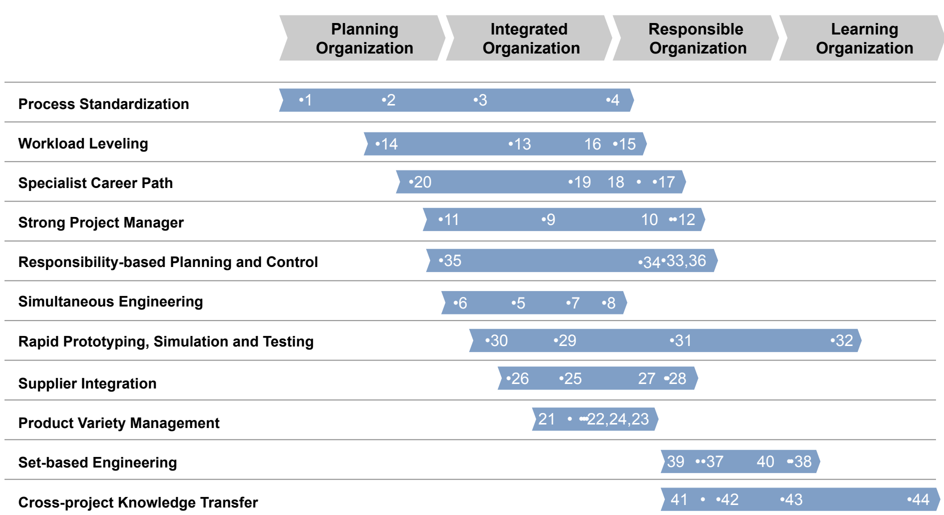
Future State: Adjusted Lean PD Component Implementation



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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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**

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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)

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Questions?

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Backup Slides

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Workload Leveling

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

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.

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Strong Project Manager

1. Workload leveling
2. Strong project manager
3. Specialist career path
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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.


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

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
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11. Set-based engineering

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.

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Simultaneous Engineering

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
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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.

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Supplier Integration

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
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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.

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Product Variety Management

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
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11. Set-based engineering

There are targets for the use of off-the-shelf components and reuse of parts as well as standardized modules and product platforms.

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Rapid Prototyping, Simulation and Testing

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
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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.

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Process Standardization

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
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For planning, executing and documenting projects, standardized processes, tools and methods are used.

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Set-based Engineering

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
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11	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.

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Using API to identify the future state

$$POS_{new,i} = POS_{old,i} - x \cdot CF_i$$

- Task: adjust relative position ($POS_{new,i}$) 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)

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CF_i: Correlation Between Use and Ease of Implementation

	Ease of Implementation Strong Project Manager	Ease of Implementation Set-based Engineering	Ease of Implementation Process Standardization	Ease of Implementation Specialist Career Path	Ease of Implementation Product Variety Management	Ease of Implementation Workload Leveling	Ease of Implementation Supplier Integration	Ease of Implementation Responsibility-based Planning and Control	Ease of Implementation Cross-project Knowledge Transfer	Ease of Implementation Rapid Prototyping, Simulation and Testing	Ease of Implementation Simultaneous Engineering
Use of Strong Project Manager	.312**	-.244**	-.034	-.095	-.191*	-.080	-.140	-.080	-.258**	-.077	-.097
Use of Set-based Engineering	.091	.391**	-.021	.205*	-.144	-.114	-.008	.144	-.086	.022	-.039
Use of Process Standardization	.187*	.155								.007	.080
Use of Specialist Career Path	-.025	.178								-.070	-.103
Use of Product Variety Management	-.046	.184								.064	-.068
Use of Workload Leveling	.120	.220*								.117	-.052
										.133	.024
										.052	.046
										-.018	.039
										.353**	-.045
										.024	.235*

Component		Correction Factor (CF)
11.	Process Standardization	0.053
10.	Simultaneous Engineering	0.018
9.	Strong Project Manager	-0.086
	ng	0.051
	Path	-0.034
	Management	0.027
	ion	0.035
	g, Simulation and Testing	-0.009
	sed Planning and Control	0.088
	eering	-0.017
	owledge Transfer	0.088

- 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

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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**

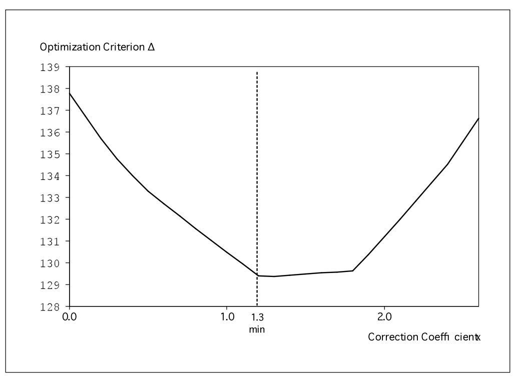
$$POS_{new\,i} = POS_{old\,i} - x \cdot CF_i$$

Minimize the distance between correlated characteristics:

$$\frac{\left|POS_{new\,i} - POS_{new\,j}\right|}{COR_{i,j}}$$

$$\min\ \Delta = \sum_{i=1}^{11}\sum_{j=1}^{11}\frac{\left|POS_{new\,i} - POS_{new\,j}\right|}{COR_{i,j}}$$

$$\min\ \Delta = \sum_{i=1}^{11}\sum_{j=1}^{11}\frac{\left|POS_{old\,i} - POS_{old\,j} - x\cdot\left(CF_i - CF_j\right)\right|}{COR_{i,j}}$$



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Lean PD components and characteristics

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

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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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