PPU 231- Integrated product and production *service systems* development

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Learning objectives

- Learning about challenges for integration in PSS
- Looking at different methodologies for integrated product and production service systems development
  - Concurrent Engineering (CE)
  - Set Based Concurrent Engineering (SBCE)
  - Value Creation Strategies
- How we will work with integrated product and production service systems development **in the course**

Recap: product service systems

From ownership to accessibility

- Shift towards sale of ‘use’ instead of sale of ‘product’
- Responsibility transferred from user to provider

New Challenges for product developers

- **Lifecycle view**
- Changes in **user behavior** and in the **production system** are
- common, but difficult to foresee

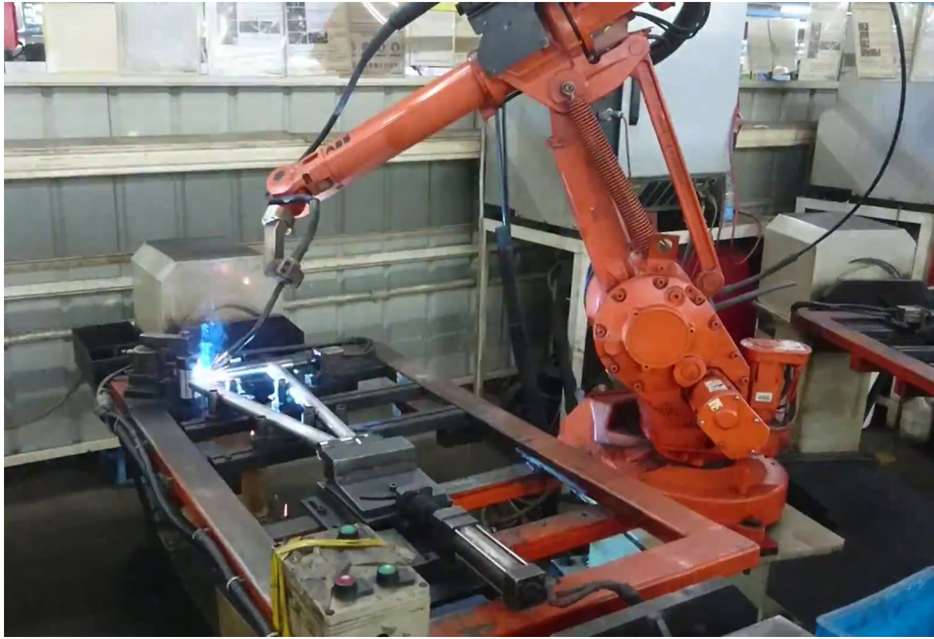
Recap: production service systems

From ownership to accessibility

- The same shift is observed in the production arena towards sale of ‘use’ instead of sale of ‘product’
- Selling ‘use’ (production throughput) rather than selling production equipment (e.g. robots)

New challenges for production system developers (e.g. smart maintenance system)

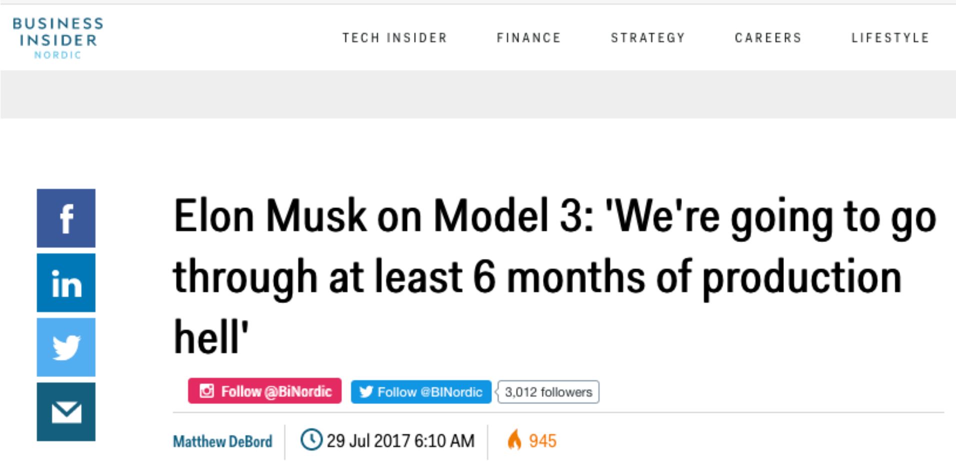
- **Lifecycle view**
- Changes in **product design** and **user behavior** is common, but difficult to foresee



Increasing dependencies between product and production

This happens already without PSS

- Tesla changing from aluminum to stainless steel in the body panels
- The change in materials would require processes new to Tesla.
- *"There's a big difference there. They haven't been doing a lot of spot welding on the first two vehicles because they're all aluminum,“*
- *"The learning curve is pretty steep."*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Elon Musk on Model 3: 'We're going to go through at least 6 months of production hell'

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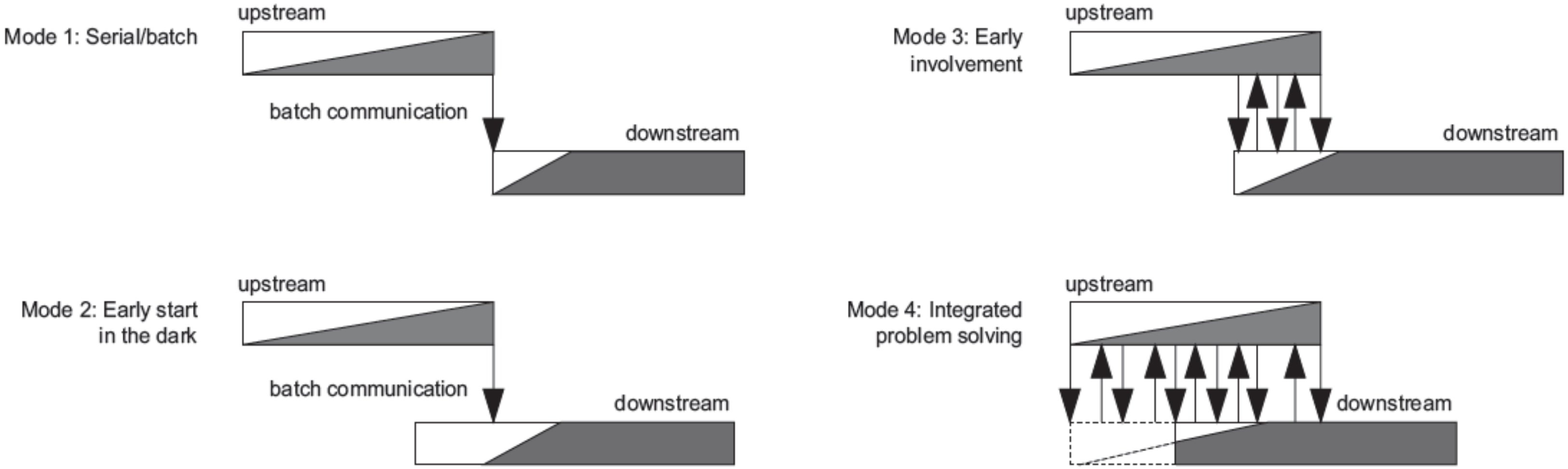
Tesla could be struggling to get the welding right with its Model 3 sedan. The vehicle's production ramp has been delayed. Tech investors are also struggling to understand the unique difficulties of building cars.

Integrated Product and Production development

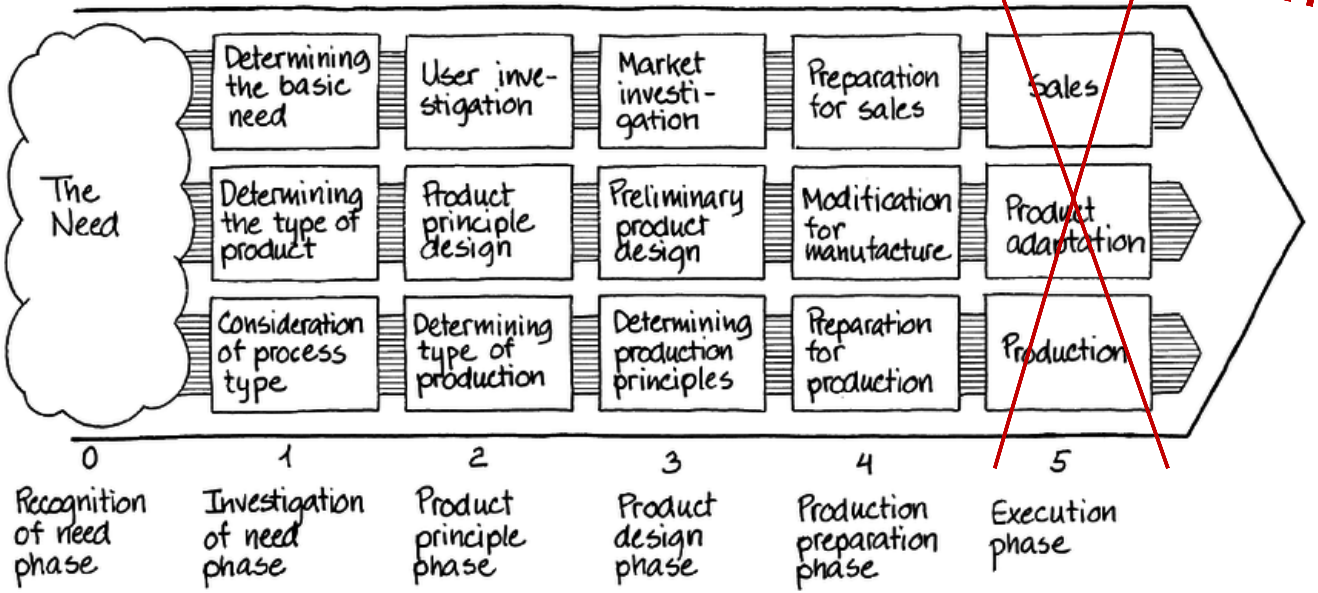
Four modes of interaction



Wheelwright, S. C., & Clark, K. B. (**1992**). Competing through development capability in a manufacturing-based organization. *Business Horizons*, *35*(4), 29-43.

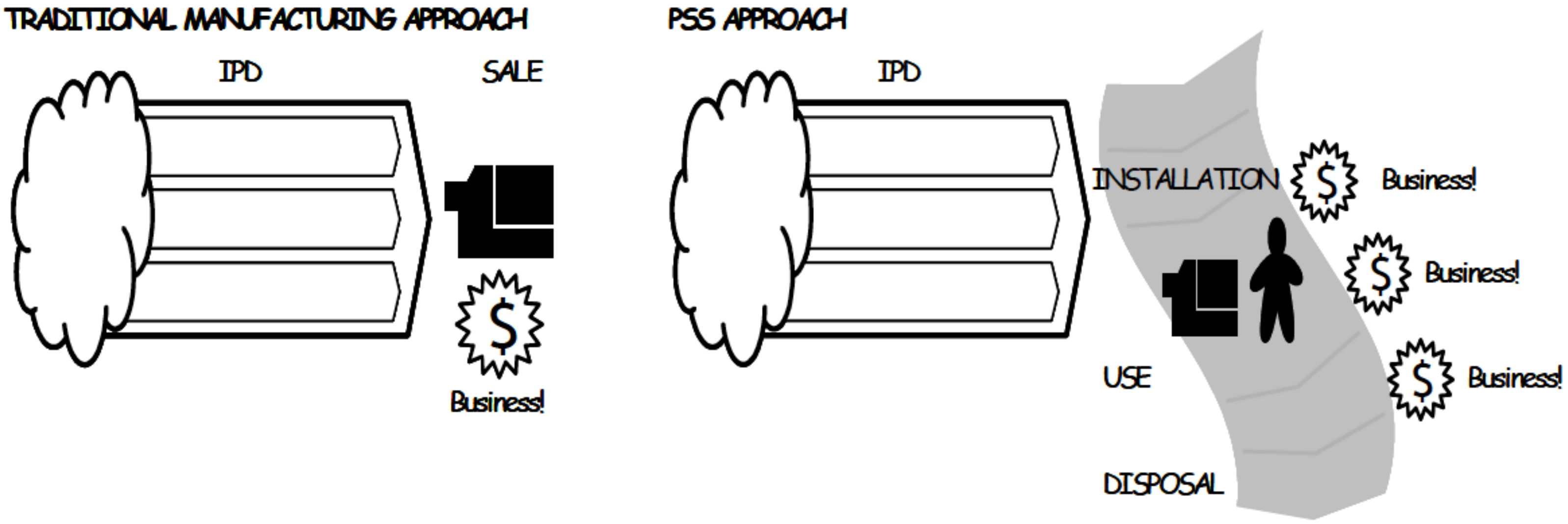
Integrated Product Development

CHANGES FOR A PSS



Andreasen, M. M., Hein, L., "Integrated Product Development", IFS (Publications) Ltd./Springer-Verlag, **1987**

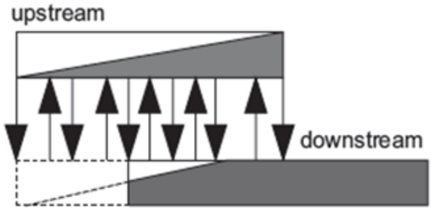
Integrated Product and Production *Service System* Development

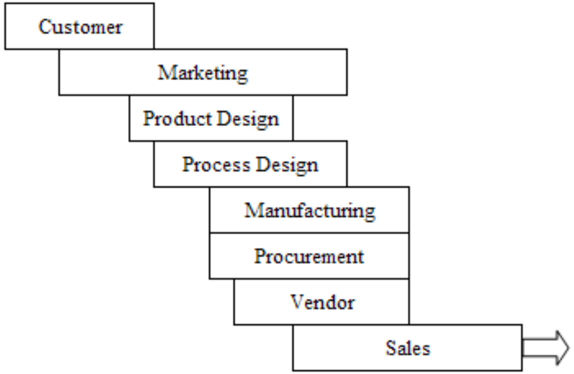


Tan, A. R., McAloone, T. C., & Andreasen, M. M. (**2006**). What happens to integrated product development models with produc/service-system approaches?. In IPD 2006: Proceedings of the 6th Workshop on Integrated Product Development, Magdeburg, Germany, 18.-20.09. 2006.

Enablers: Concurrent Engineering (CE)

A way to work with feedback and feed forward





1. **Concurrent engineering** (**CE**) is a work methodology emphasizing the parallelization of tasks (i.e. performing tasks concurrently),
2. sometimes called **simultaneous engineering** or **integrated product development** (**IPD**) using an integrated product team approach.
3. Built on core principles *such as Cross-functional teams, information sharing*

Prasad, B. (1996). Concurrent engineering fundamentals (Vol. 1). NJ: Prentice Hall PTR..

Enablers: Set Based Concurrent Engineering (SBCE)

A way to work with feedback and feed forward

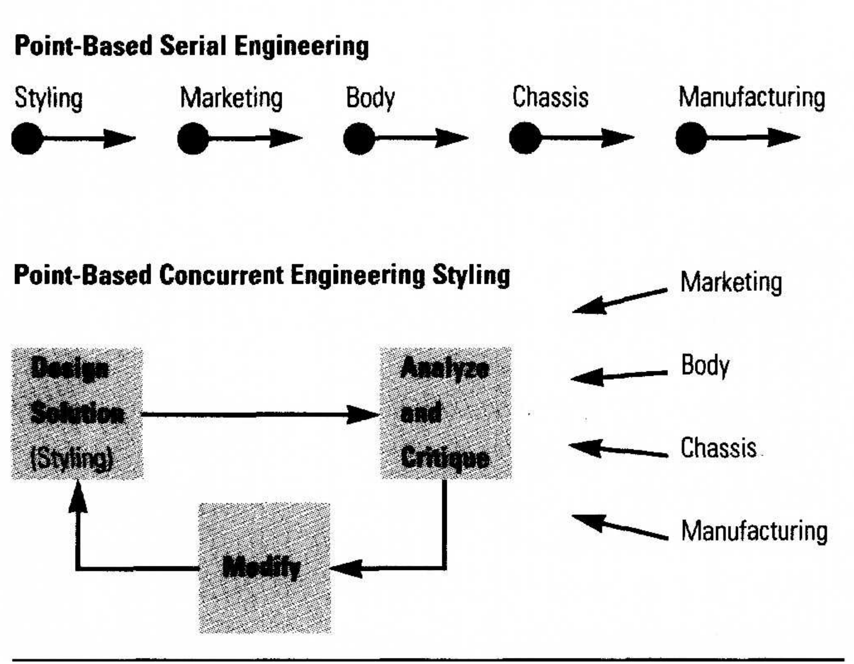
Formulated after observing the Toyota product development process

- **The Second Toyota paradox**
- *«Toyota considers a broader range of possible designs and **delays** certain decisions longer than other auotomotive companies do, yet has what it may be the **fastest** development cycle in industry.»*

Sobek II, D. K., Ward, A. C., & Liker, J. K. (1999). Toyota's principles of set-based concurrent engineering. MIT Sloan Management Review, 40(2), 67.

Enablers: Set Based Concurrent Engineering (SBCE)

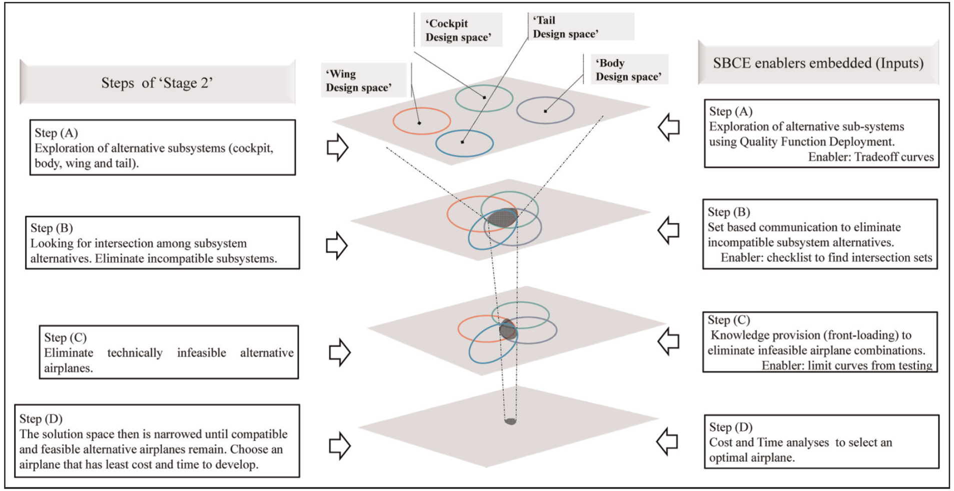
A way to work with feedback and feed forward



1. Traditional design practice, whether concurrent or not, tends to quickly converge to a solution, a point in the solution space, and to modify it until it meets design objectives.
2. This seems an efficient approach
3. **Unless one picks the wrong point in the design space**
4. SBCE, by contrast, focuses on considering sets of possible solutions, and to gradually narrowing the set to converge to a final solution.

Enablers: Set Based Concurrent Engineering (SBCE)

A way to work with feedback and feed forward

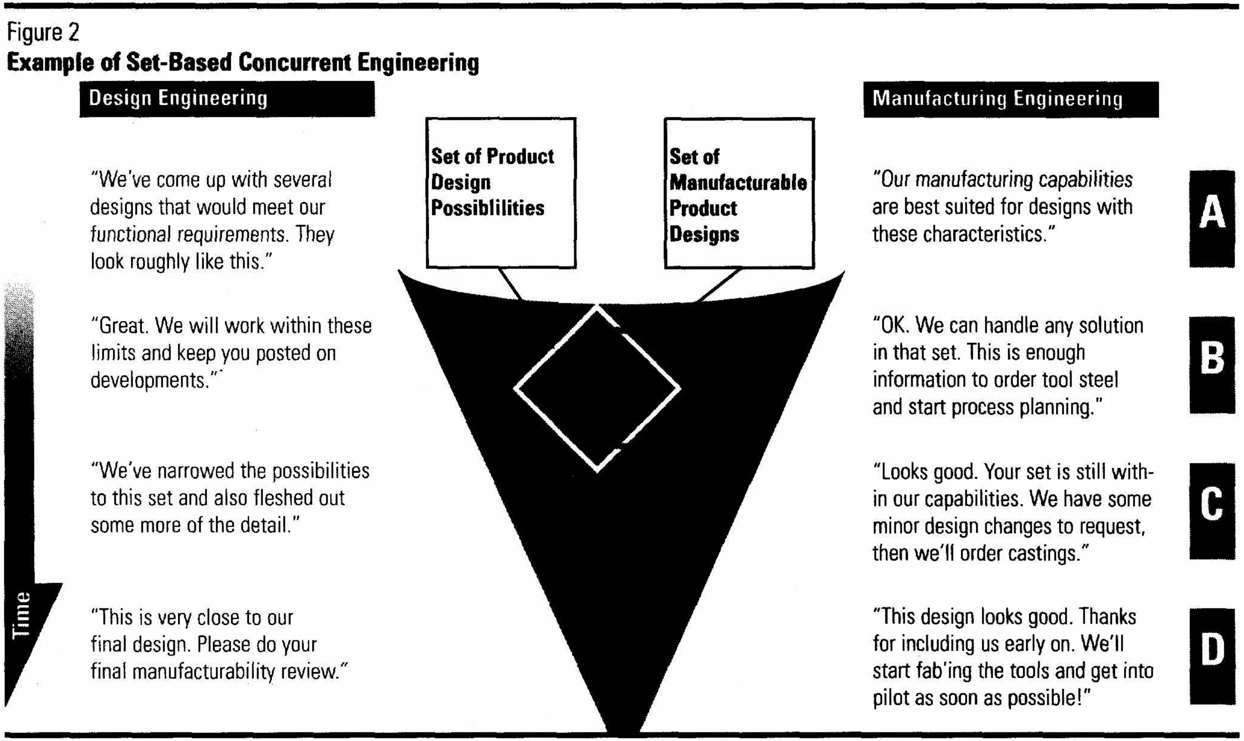


Three key principles:

1. **Map the Design Space:** thorough understanding of the sets of design possibilities for the subsystems
2. **'Integrate by intersection'**, or the principle of set-based communication
3. **'Establish feasibility before commitment'**, or the principle of convergence, that allows the aggressive elimination of inferior design solutions

Sobek II, D. K., Ward, A. C., & Liker, J. K. (1999). Toyota's principles of set-based concurrent engineering. MIT Sloan Management Review, 40(2), 67.

SBCE principles



Three key principles:

1. **Map the Design Space:**
2. **'Integrate by intersection',**
3. **'Establish feasibility before commitment**

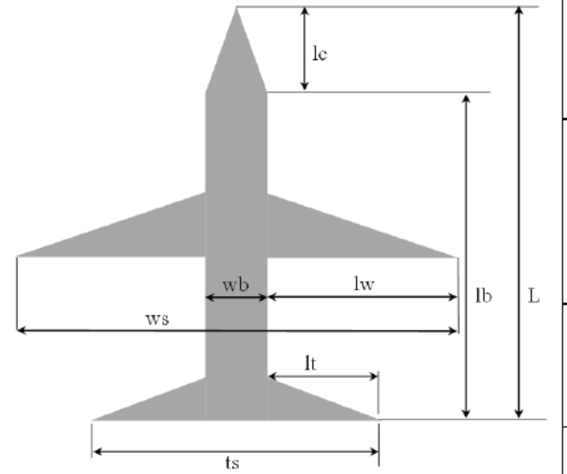
SBCE applied

SBCE game used for training

Participants divided into departments

First trying a PBCE approach, then a SBCE

Group 1		
Customer Requirements		
Ranges	Min	Max
Number of passengers	91	110
Length of airplane	10	22
Weight of airplane	9,500	14,500
Wingspan	7	20
Tail span	7	15



Key:

L – length of airplane
lc – length of cockpit
lw – length of wing
ws – wingspan
lb – length of body
lt – length of tail
wb – width of body
ts – tail span

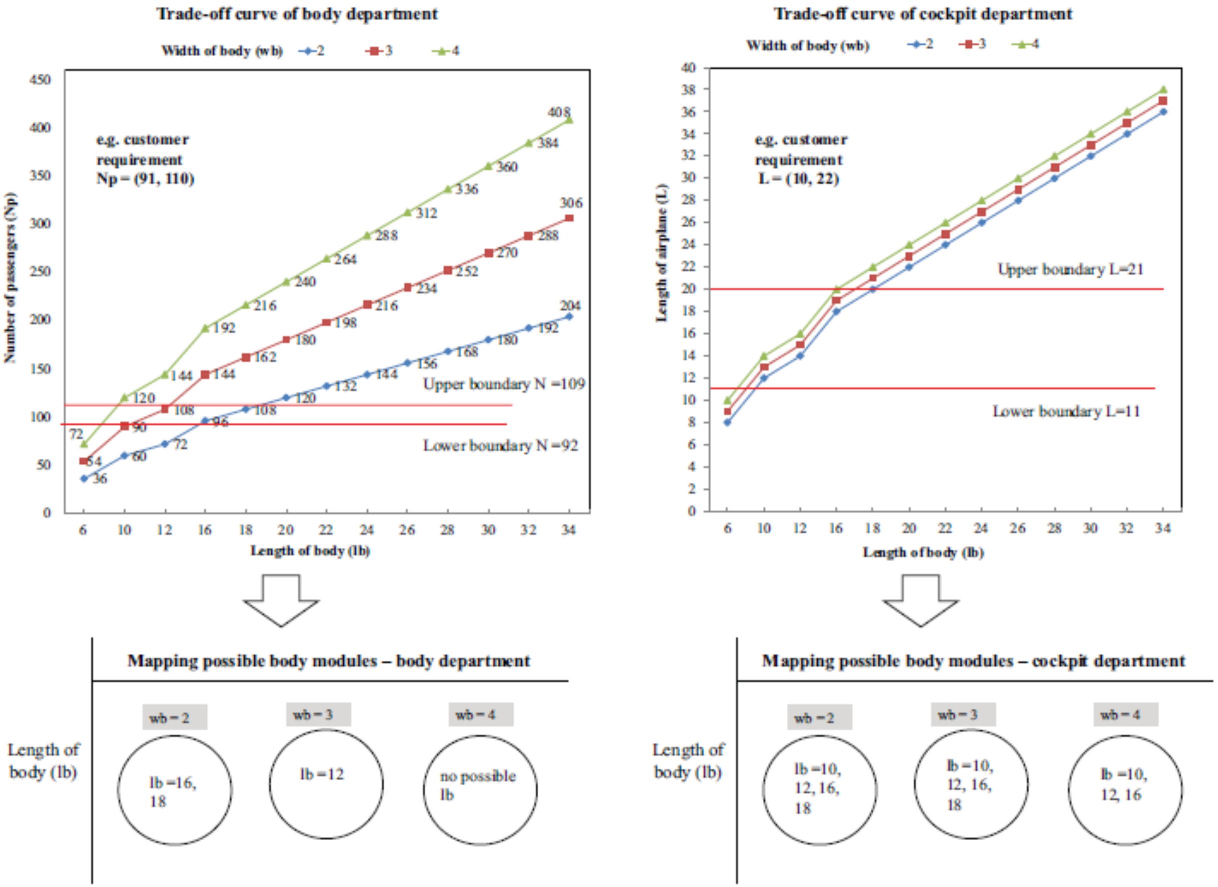
LEGO components	LEGO types	Number single points
Body		6
		10
Wing		3
		4
		6
Tail		3
		4
Cockpit		2
		3
		4

Kerga, E., Rossi, M., Taisch, M., & Terzi, S. (2014). A serious game for introducing set-based concurrent engineering in industrial practices. Concurrent Engineering, 22(4), 333-346.

SBCE methods and tools

Trade-off curves

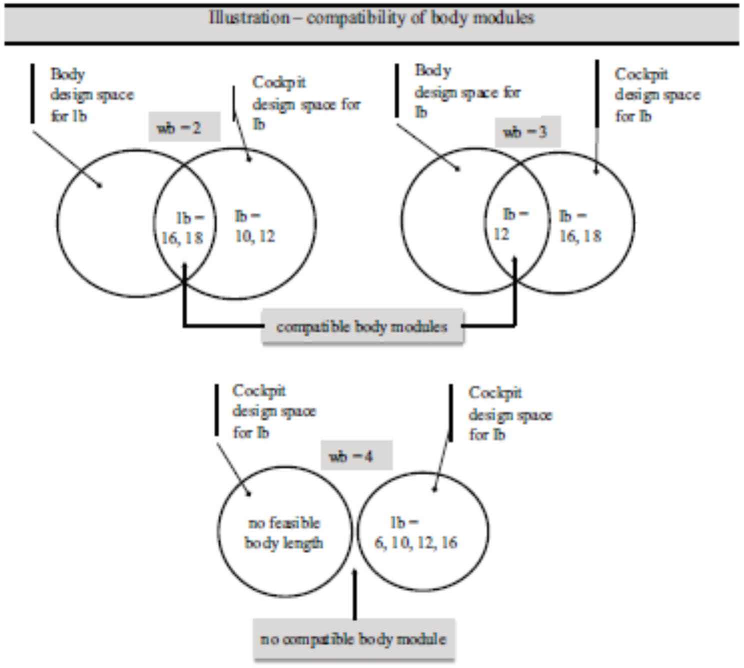
- In this case, the possible body modules (wb and lb) are (2, 10), (2, 12), (2, 16), (2, 18), (3, 10), (3, 12), (3, 16), (3, 18), (4, 10), (4, 12) and (4, 16). These body sizes are possible solutions to satisfy the customer requirement of L (10, 22).
- the trade-off curves provided for the subsystems departments, possible solutions are mapped out



SBCE methods and tools

Checklists for communication between departments

- In this example, the only body modules (wb and lb) that are workable for both the body and cockpit departments are (3, 12), (2, 16) and (2, 18).
- The rest of the solutions are eliminated from the solutions space.



	Alternative body modules		Customer requirements				
	lb	wb	Number of passengers Np = (91, 110)		Length of airplane L = (10, 22)		Compatibility
			value	ok/no?	value	ok/no?	
Explored by body department	2	16	96	ok	16	ok	compatible
	2	18	108	ok	20	ok	compatible
	3	12	108	ok	15	ok	compatible
Explored by cockpit department	2	10	60	no	12	ok	incompatible
	2	12	72	no	14	ok	incompatible
	2	16	96	ok	18	ok	compatible
	2	18	108	ok	20	ok	compatible
	3	10	90	no	13	ok	incompatible
	3	12	108	ok	15	ok	compatible
	3	16	144	no	17	ok	incompatible
	3	18	162	no	19	ok	incompatible
	4	10	120	no	14	ok	incompatible
	4	12	144	no	16	ok	incompatible
	4	16	192	no	20	ok	incompatible

Results

SBCE vs. PBCE

	Stage 1			Stage 2			Percentage improvement (Stage 2 vs Stage 1)	
Team number	Number of trials	Total development time	Total development cost	Number of trials	Total development time	Total development cost	Total development time	Total development cost
1	3	120	1200	1	58	580	> 50%	> 50%
2	1	45.6	380	1	45.6	380	0%	0%
3	2	52.5	518	1	45.6	380	14%	27%
4	2	110	900	1	52.8	440	> 50%	> 50%
5	3	102	1445	1	56	800	45%	45%
6	2	77.2	1192	1	61.6	880	20%	27%
7	2	108.3	1675.7	1	71.4	1020	34%	40%

Kerga, E., Rossi, M., Taisch, M., & Terzi, S. (2014). A serious game for introducing set-based concurrent engineering in industrial practices. Concurrent Engineering, 22(4), 333-346.

Value Creation Strategies

A way to work with SBCE before requirements are established

Current methods for SBCE imply that requirements are known and well defined

Often not the case in complex development projects

Group 1		
Customer Requirements		
Ranges	Min	Max
Number of passengers	91	110
Length of airplane	10	22
Weight of airplane	9,500	14,500
Wingspan	7	20
Tail span	7	15

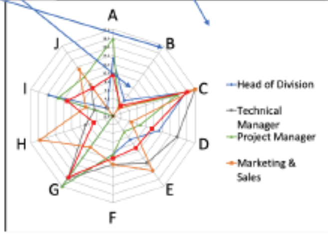
Depends on customer preferences, which depend on business scenarios subject to changes!

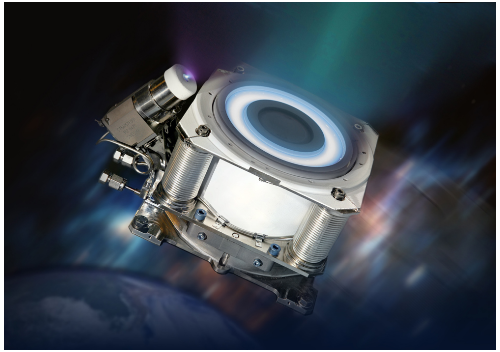
Isaksson, O., Kossmann, M., Bertoni, M., Eres, H., Monceaux, A., Bertoni, A., ... & Zhang, X. (2013, June). Value-driven design–a methodology to link expectations to technical requirements in the extended enterprise. In *INCOSE International Symposium* (Vol. 23, No. 1, pp. 803-819)..

Value Creation Strategies (VCSs)

A way to work with SBCE before requirements are established

	Stakeholder	Stakeholder Expectations	Stakeholder Needs
A	OPERATORS	Operators expect spacetugs with high timelines, defined as as the sum of Response Time (starting when mission order is received and ending when the target satellite is captured) and Transfer Time (from capture to satellite release at the desired destination).	Reduced transfer time
B	OPERATORS	Operators expect spacetugs with high mating capability, which is a matter of control and grappling mechanism sophistication and was described in discrete levels as low, medium, high, or extreme in terms of the mass of the grappling mechanism used.	Increased precision in operation
C	SUB-SYSTEM MANUFACTURER	Maintain current expectations on availability of use for satellite operators in order to ensure mission fulfillment without failure.	Maintain product reliability and robustness
D	SUB-SYSTEM MANUFACTURER	A product with higher cost will be proposed on the market at a higher price and may be less competitive; reduce non recurrent cost as low as possible.	Reduced product cost
E	SUB-SYSTEM MANUFACTURER	Exend the use of electric propulsion systems to a broader range of applications (e.g., towards both higher and lower power levels).	Increased product scalability
F	SUB-SYSTEM MANUFACTURER	Define an architecture that is compatible with the company's future technology roadmap.	Increased ability to integrate future technologies
G	SUB-SYSTEM MANUFACTURER	The qualification process should be reduced as much as possible implementing new procedures and developing new standards. Moreover, increasing the reliability of both stand-alone tests and scaled set-up could play an important role to reduce the time for the qualification of the product	Reduced Development lead time including Qualification
H	SUB-SYSTEM MANUFACTURER	Reduce "special" manufactoring processes; Supply chain evaluation (# of part/time); provide in/out-house components	Increased product manufacturability
I	SUB-SYSTEM MANUFACTURER	Develop reliable testing procedure for the characterization, qualification and acceptance testing phases; Increase chamber diagnostics (...); better understanding of facility interactions (background pressure, plasma-chamber wall interactions); Improve lab equipment capabilities; Improved space condition simulation;	Increased testing capability
J	SUB-SYSTEM MANUFACTURER	Operations with cheaper propellant, lowering the operational costs; possibility to design different e-PROP architecture could extend the market opportunities for different applications.	Increase product versatility



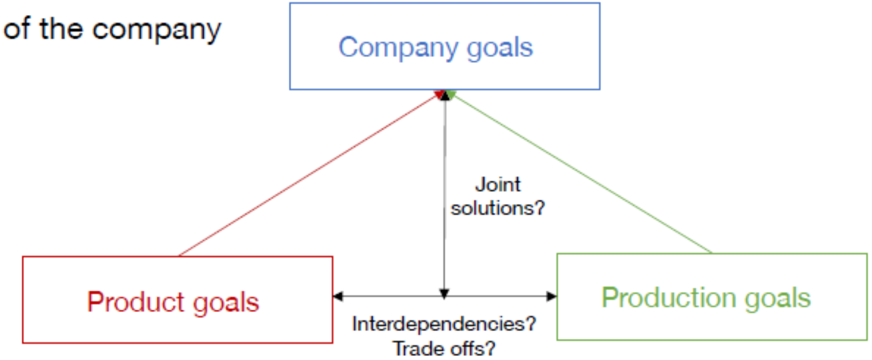


Panarotto, M., Isaksson, O., Habbassi, I., & Cornu, N. (2020). Value-Based Development Connecting Engineering and Business: A Case on Electric Space Propulsion. *IEEE Transactions on Engineering Management*.

Concurrent Engineering in PPU231

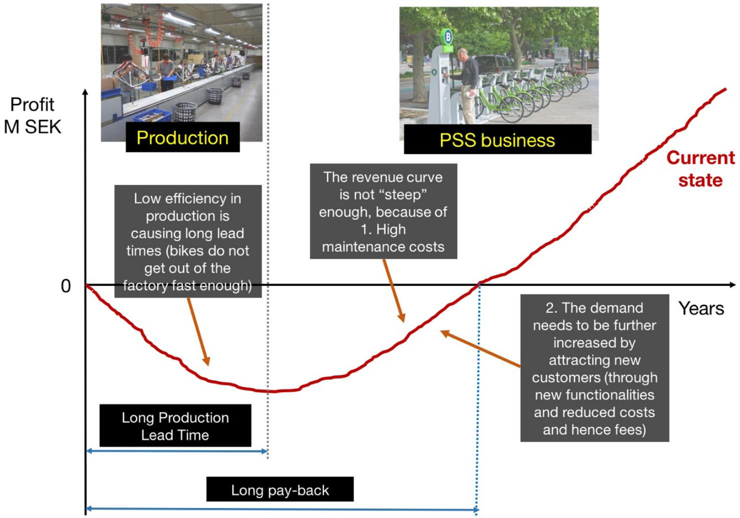
- Different **goals** for product and production
  - Product: fulfilling the needs of a broad customer base
  - Production: achieving high production efficiency
- **Interdependencies** between product and production
  - Decisions taken in product design affects production, and vice versa
- **Trade offs** between product and production performance
  - Improving frame design ***and*** ensuring production efficiency
- Joint **solutions** that benefit the overall goals of the company
  - Maximize profit of E-bike Inc.

Joint workshops
JW1: 11 Feb
J»2: 25 Feb
Task 5



Goals of Workshop 1

- Learn about **goals** from each other
- Understand **interdependencies** between each other
- Manage **trade offs** together
- Make joint decisions about **solutions** to convince the CEO



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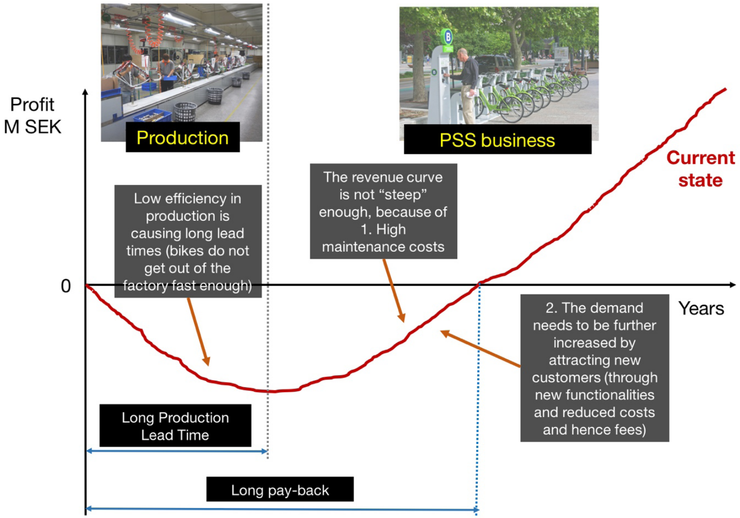
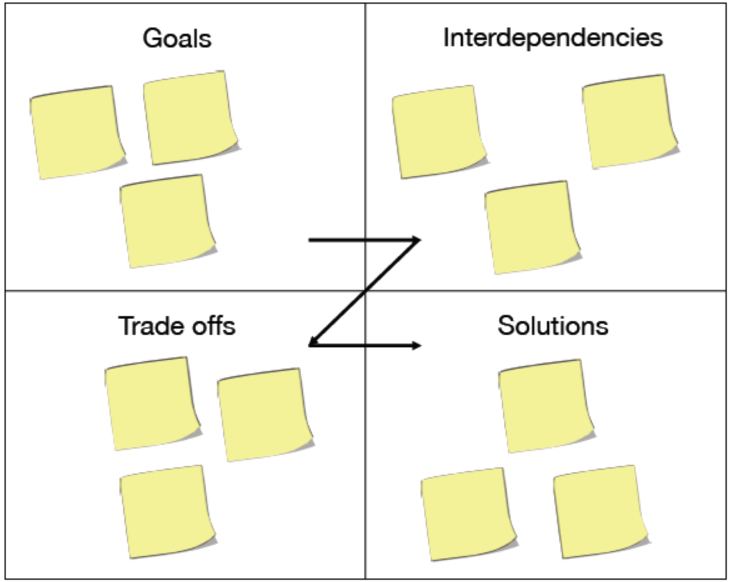


Goals of Workshop 1

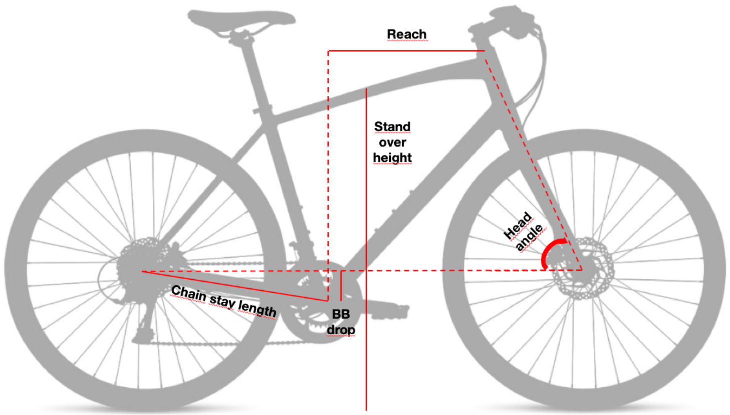
- Digital tool
- Goals & interdependencies (30min)
- Trade offs & solutions (30min)
- Presentation and final decision (15min)
- Relate **goals**, **interdependencies**, **trade offs,** and **solutions** to the goals of the company!
- **Everyone** needs to be involved!
- Work **together**!
- Convince the **CEO**!
  - Basis for grading task 5
  - • Include learnings in report!



CHALMERS

How can you prepare?

Product Projects



1. Start analysing the stakeholders needs
2. Strart with making a functional breakdown, and understand how the components of the bike impact the stakeholders needs
3. Propose alternatives!
4. Be prepared to describe the trade-offs invovlved in your decisions

Decision	Design change	Cutting	Welding	Heat treatment 1	Heat treatment 2
	7005 T6 material				
	7075 T6 material				
	Head angle				
	Chainstay length				
	Stand over height				
	Reach				
	Bottom bracket height				
	Bottom bracket type				

How can you prepare?

Production Projects

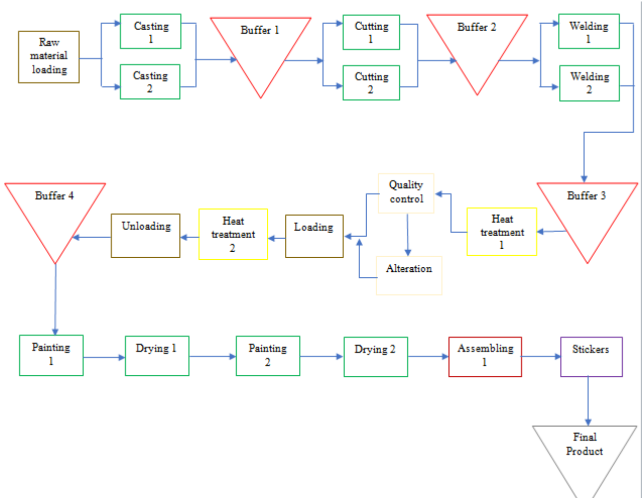


Figure 16 Sitting E-scooter production layout

1. Start analysing the Production System
2. Propose alternative production systems
3. Be prepared to describe the trade-offs invovlved in your decisions

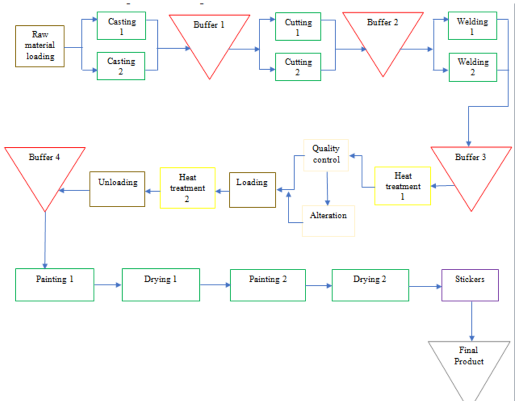


Figure 17 Standing E-scooter production layout

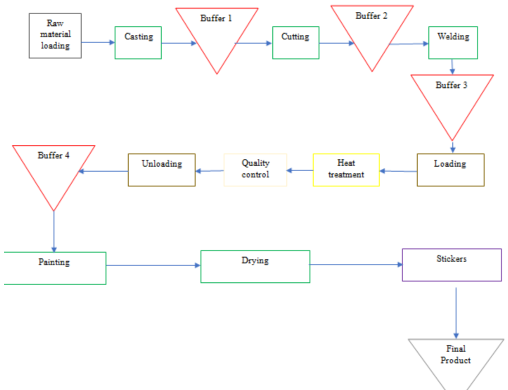
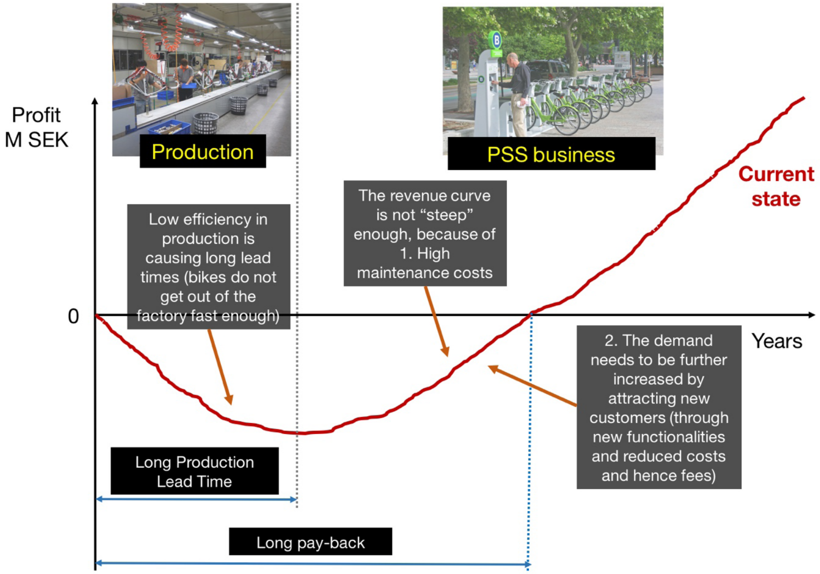


Figure 18 Skate E-scooter production layout

Summary

- New challenges
  - **Lifecycle view**
  - **Changes** is common, but difficult to foresee (e.g., variability in requirements)
- Further challenging integration capabilities
- New dependencies
- Need to ways and enablers for crossfunctional communication
  - E.g. set based concurrent engineering (Trade-off curves)
  - Net Present Value curves



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