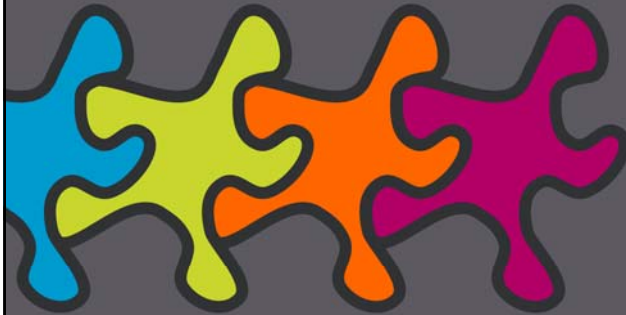


Lean Design OR An optimal design process for an adequate product?



John Clarkson

An optimal design process for an adequate product?

Introduction

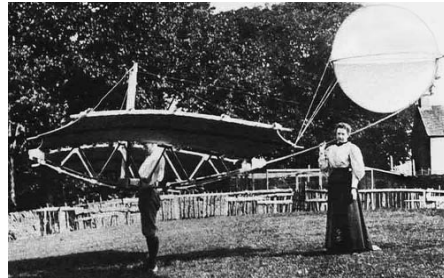
- Percy Pilcher's interest in flight began in 1895
- He built his first glider, the 'Bat', in the same year



An optimal design process for an adequate product?

Introduction

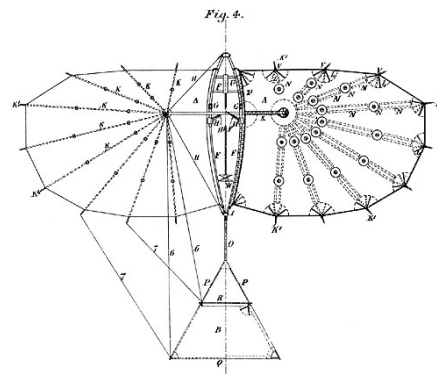
- Percy experimented with gliders to inform the development of designs for powered flight



An optimal design process for an adequate product?

Introduction

- Percy planned to add an internal combustion engine to his 'Hawk' glider
- The heavy engine required an increase in wing area
- The larger wing added to the weight
- The result - a triplane



An optimal design process for an adequate product?

Introduction

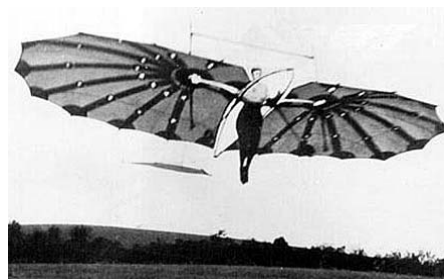
- Had Percy not died following a glider crash on October 2nd 1899, he might have been the first man to fly a powered aeroplane
- What can we say about Percy's design process?



An optimal design process for an adequate product?

Introduction

- Percy designed the product alone
- He developed his design on paper
- He tested using physical prototypes
- His design was not reliable



An optimal design process for an adequate product?

Introduction

- Boeing used nearly 17 000 designers for the 777
- They made extensive use of CAD/CAM
- They tested using virtual prototypes
- Their design is reliable

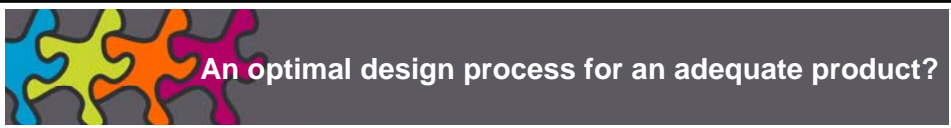


An optimal design process for an adequate product?

Introduction

- The knowledge required to complete the design can no longer be retained by one person alone
- There is now a need for active process and knowledge management





Introduction

- Process management
- Change management
- Lean design



Process management

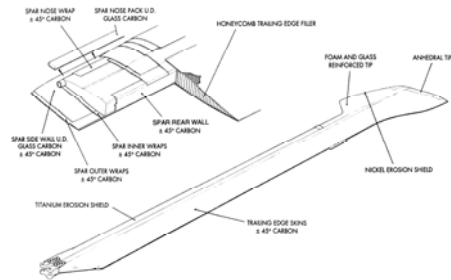
- Westland helicopters
- World leaders in rotor-blade design
- Wished to capture their design process



An optimal design process for an adequate product?

Process management

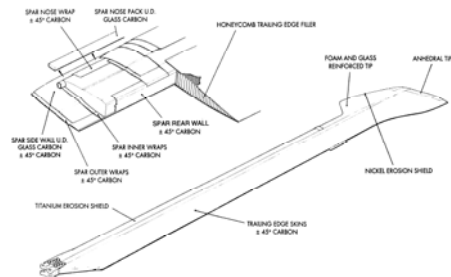
- No one person had the complete picture
- Designers knew what they did
- Many alternative tasks



An optimal design process for an adequate product?

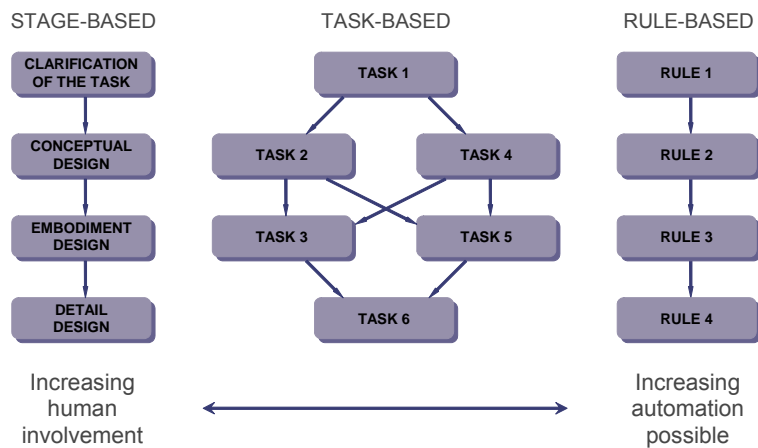
Process management

- Designers need appropriate knowledge and information to do appropriate tasks at appropriate times
- However, design is dynamic and the appropriate task may change



An optimal design process for an adequate product?

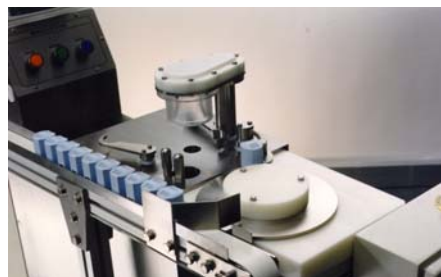
Process management



An optimal design process for an adequate product?

Stage-based design

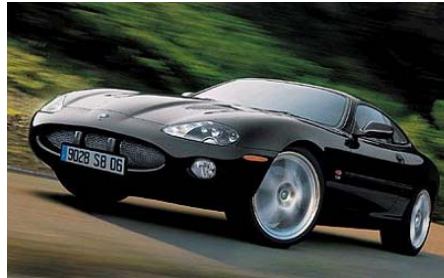
- Well suited to original design
- Design tasks are not defined
- Stages generally overlap considerably
- Design as taught to students
 - Pahl and Beitz



An optimal design process for an adequate product?

Rule-based design

- Well suited to variant design
- Design tasks and their order are well defined
- Design automation is possible
- Many example applications
 - Jaguar cars
 - Boeing



An optimal design process for an adequate product?

Task-based design

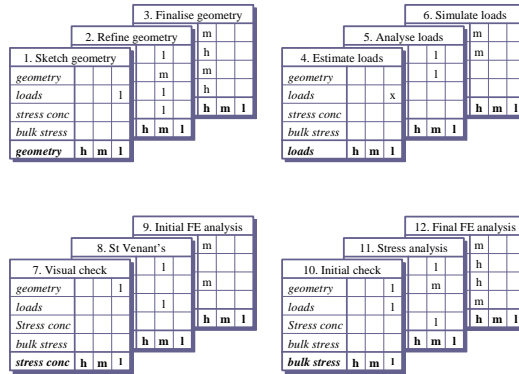
- Well suited to adaptive design
- Design as often practised
- Design support is possible
- Few example applications
 - Rolls-Royce
 - Construction sector



An optimal design process for an adequate product?

Identifying possible tasks

- No one person had the complete picture
- Designers knew what they did
- Many alternative tasks



An optimal design process for an adequate product?

Identifying possible tasks

- They are described in terms of required inputs and possible outputs

if stress analysis *satisfactory*
and at least *low* confidence in geometry
and at least *medium* confidence in loads

and at least *low* confidence in bulk stress
then at most *medium* confidence in bulk stress

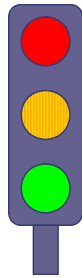


11. Stress analysis			
geometry		1	
loads		m	
stress conc.			
bulk stress		l	
bulk stress	h	m	l

An optimal design process for an adequate product?

Identifying possible tasks

- The availability of information drives the process
- Information must be at an appropriate level of maturity

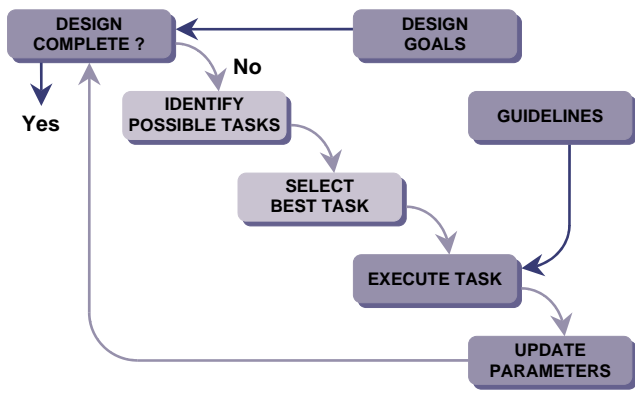


- Red - task inappropriate
- Amber - task possible but not helpful
- Green - task possible with potential to improve design

An optimal design process for an adequate product?

Identifying possible tasks

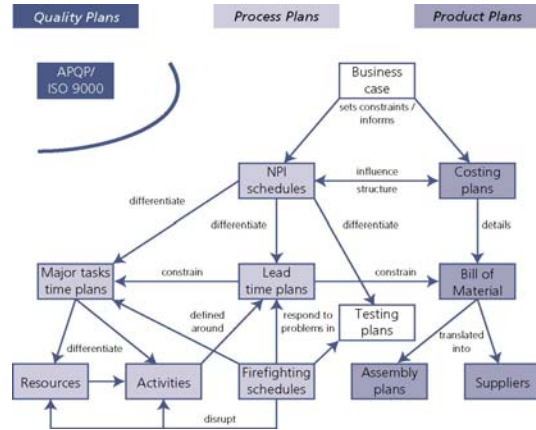
- An iterative process



An optimal design process for an adequate product?

Identifying possible tasks

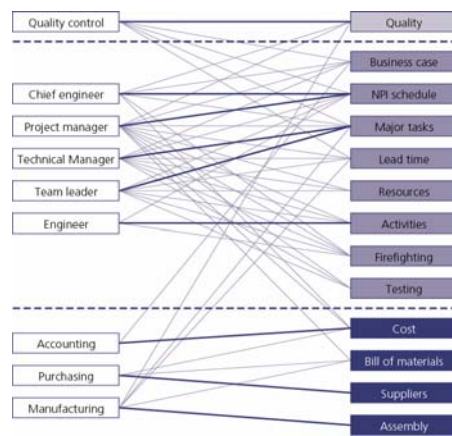
- Designers know their activities/tasks
- Managers have their schedules



An optimal design process for an adequate product?

Identifying possible tasks

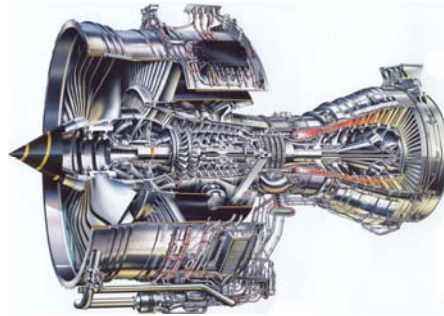
- Who owns the process?



An optimal design process for an adequate product?

Identifying possible tasks

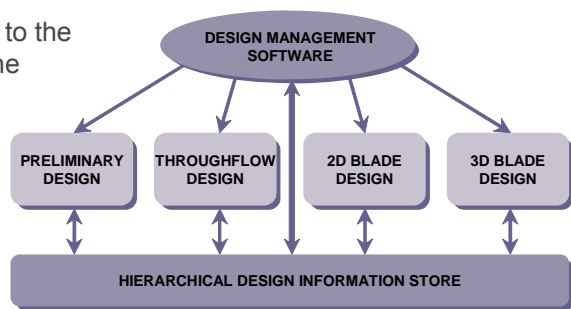
- Signposting applied to the design of a jet-engine compressor



An optimal design process for an adequate product?

Identifying possible tasks

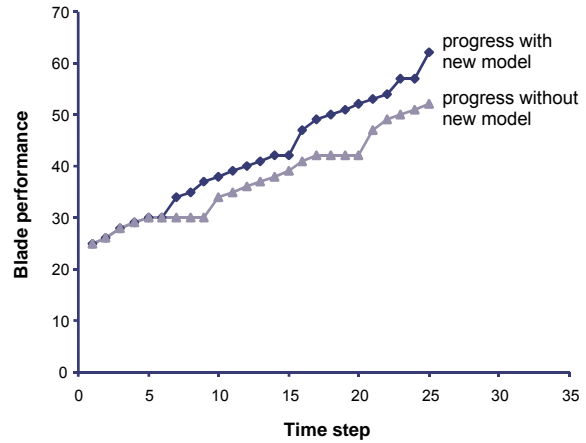
- Signposting applied to the design of a jet-engine compressor



An optimal design process for an adequate product?

Identifying possible tasks

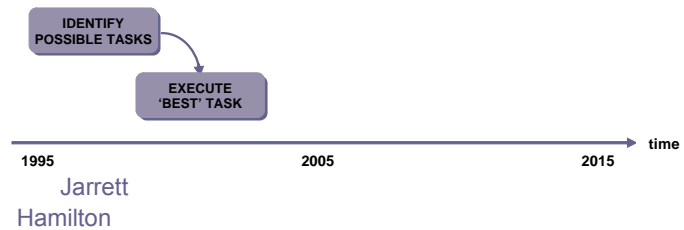
- Sensitivity analyses identify 'best' tasks



An optimal design process for an adequate product?

Identifying possible tasks

- Identify possible tasks
- Execute 'best' task?



An optimal design process for an adequate product?

Identifying the 'best' policy

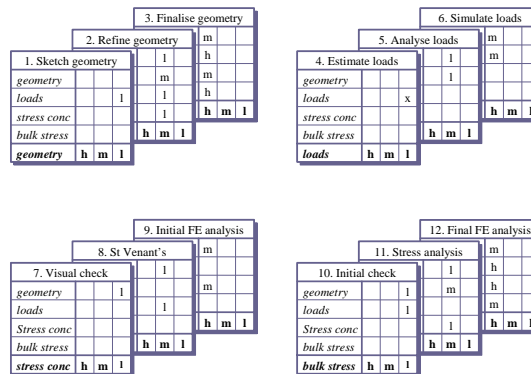
- Multiple options?
- How long?



An optimal design process for an adequate product?

Identifying the 'best' policy

- Identify dependencies



An optimal design process for an adequate product?

Identifying the 'best' policy

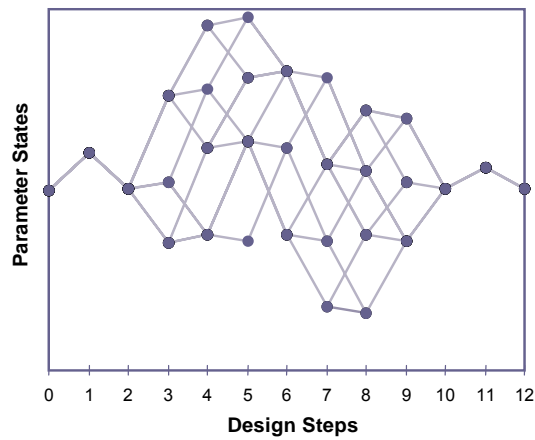
- Identify dependencies

Task id	4	1	5	7	10	8	2	6	9	11	12	3
7. Visual check		✓										
10. Initial check	✓	✓										
8. St Venant's		✓	✓									
2. Refine geometry		✓	✓	✓	✓							
6. Simulate loads			✓					✓				
9. Initial FE analysis						✓	✓					

An optimal design process for an adequate product?

Identifying the 'best' policy

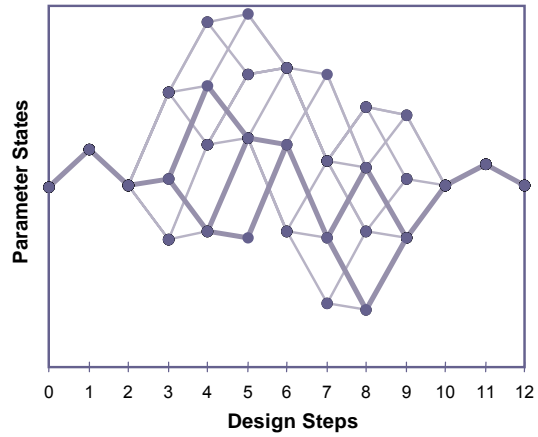
- Identify dependencies



An optimal design process for an adequate product?

Identifying the 'best' policy

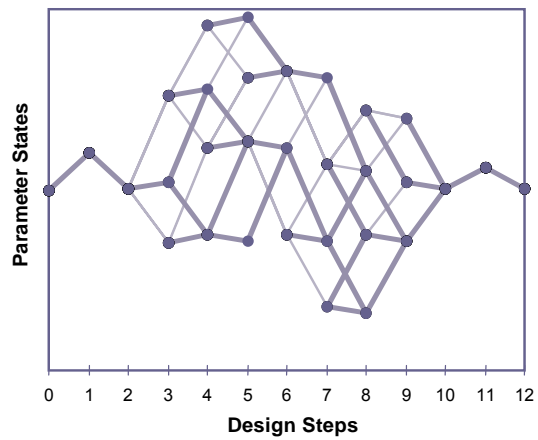
- Identify dependencies
- Identify 'best' route



An optimal design process for an adequate product?

Identifying the 'best' policy

- Identify dependencies
- Identify 'best' route
- Identify 'best' policy



An optimal design process for an adequate product?

Identifying the 'best' policy

- Identify dependencies
- Identify 'best' route
- Identify 'best' policy

Task id	4	1	5	7	10	8	2	6	9	11	12	3
4. Estimate loads												
1. Sketch geometry	✓											
5. Analyse loads	✓	✓										
7. Visual check		✓	✓									
10. Initial check	✓	✓										
8. St Venant's		✓		✓								
2. Refine geometry		✓	✓	✓	✓	✓						
6. Simulate loads			✓				✓					
9. Initial FE analysis						✓	✓					
11. Stress analysis		✓	✓		✓					✓		
12. Final FE analysis							✓	✓	✓	✓		
3. Finalise geometry						✓	✓	✓			✓	

An optimal design process for an adequate product?

Identifying the 'best' policy

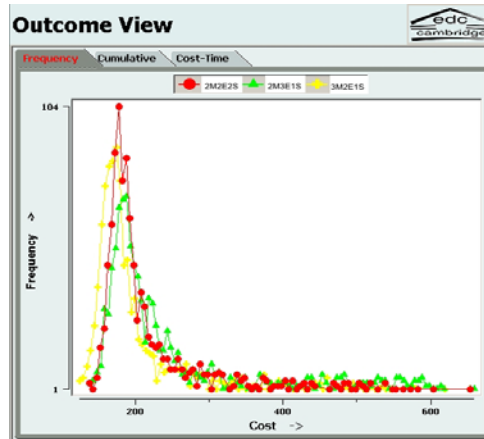
- Simulating alternative processes



An optimal design process for an adequate product?

Identifying the 'best' policy

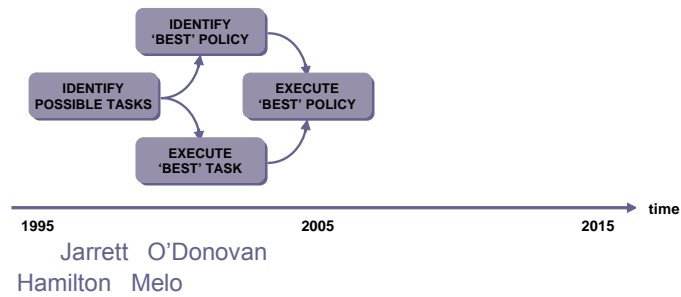
- Simulating alternative processes
- Identify 'best' policy



An optimal design process for an adequate product?

Identifying the 'best' policy

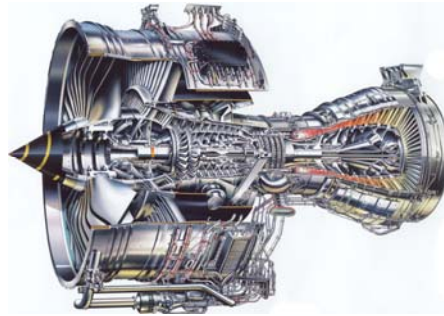
- Identify 'best' policy
- Execute 'best' policy?



An optimal design process for an adequate product?

Identifying the 'best' plan

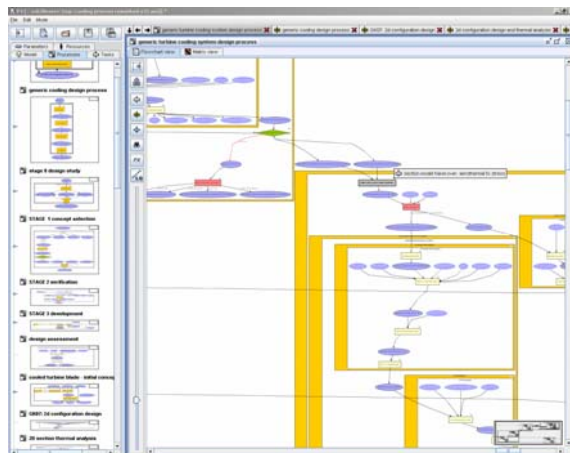
- Back to reality?
- Where is the plan?



An optimal design process for an adequate product?

Identifying the 'best' plan

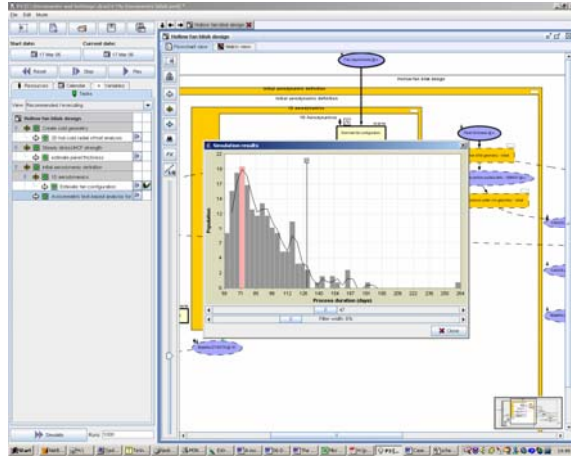
- Building processes from processes elements
- Constructing simple networks of tasks and parameters



An optimal design process for an adequate product?

Identifying the 'best' plan

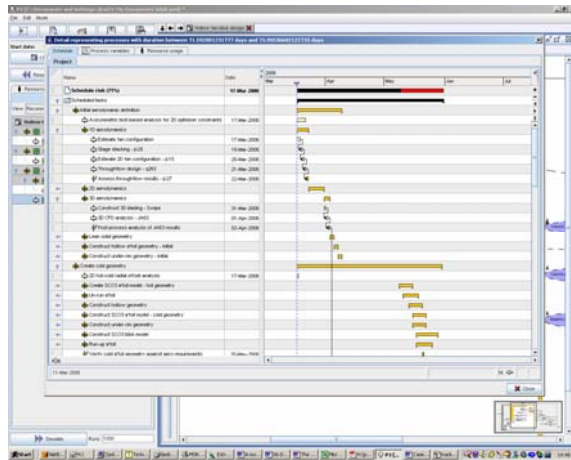
- Simulation yields frequency / time distributions
- Performance may be checked against targets



An optimal design process for an adequate product?

Identifying the 'best' plan

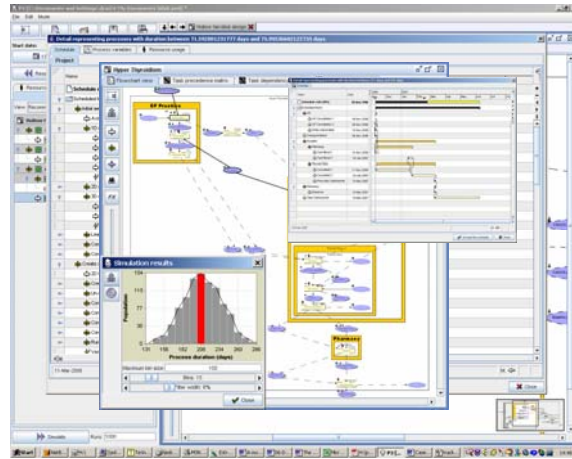
- Gantt charts can be generated
- Iteration can be identified



An optimal design process for an adequate product?

Identifying the 'best' plan

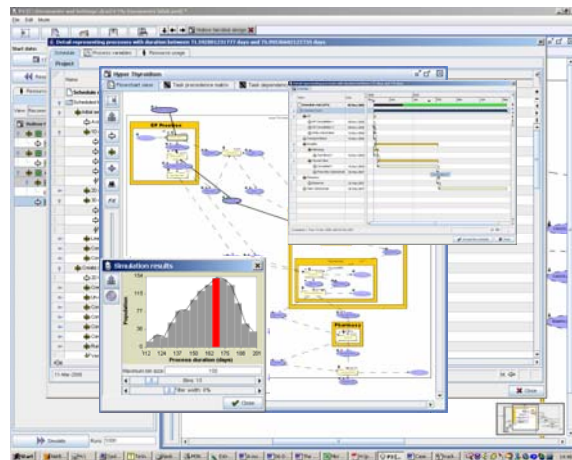
- 'As is' process for hyper thyroidism diagnosis
- Mean duration 214 days



An optimal design process for an adequate product?

Identifying the 'best' plan

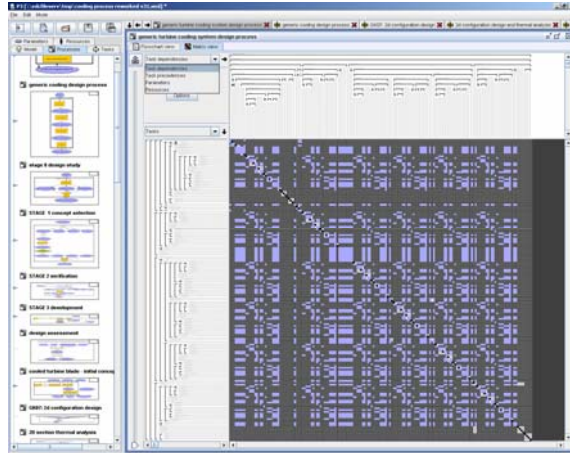
- 'To be' process for hyper thyroidism diagnosis
- Mean duration 175 days



An optimal design process for an adequate product?

Identifying the 'best' plan

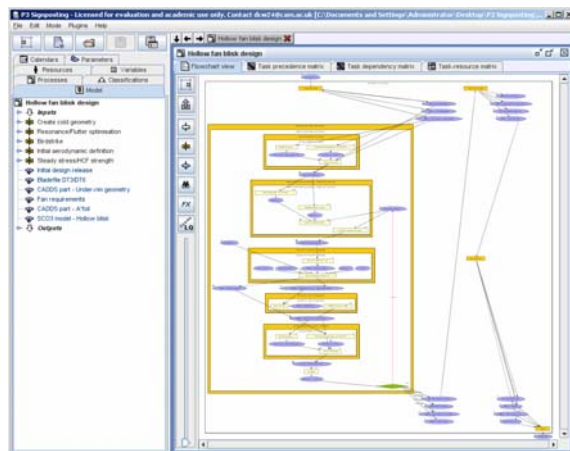
- A dependency matrix can be extracted for the process
- Hard dependencies arise from information flows
- Soft dependencies arise from process risks



An optimal design process for an adequate product?

Identifying the 'best' plan

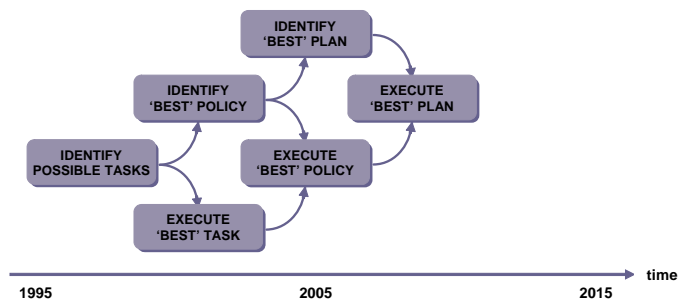
- Understand process behaviour
- Identify process metrics
- Identify patterns of design



An optimal design process for an adequate product?

Identifying the 'best' plan

- Identify 'best' plan
- Execute 'best' plan?



Jarrett O'Donovan Wynn
Hamilton Melo Flanagan

An optimal design process for an adequate product?

Identifying a 'robust' plan

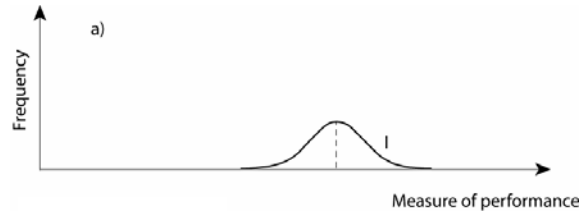
- What might go wrong?
- Is there a better plan?



An optimal design process for an adequate product?

Identifying a 'robust' plan

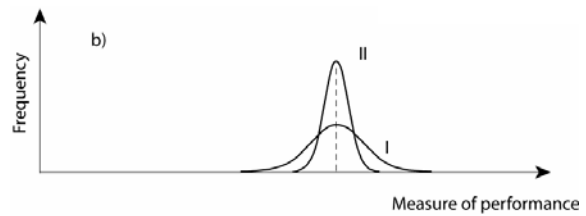
- Simulating performance



An optimal design process for an adequate product?

Identifying a 'robust' plan

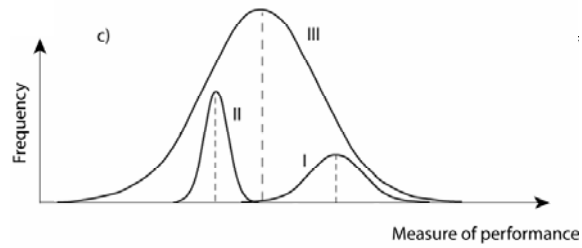
- Simulating performance
- Modifying performance



An optimal design process for an adequate product?

Identifying a 'robust' plan

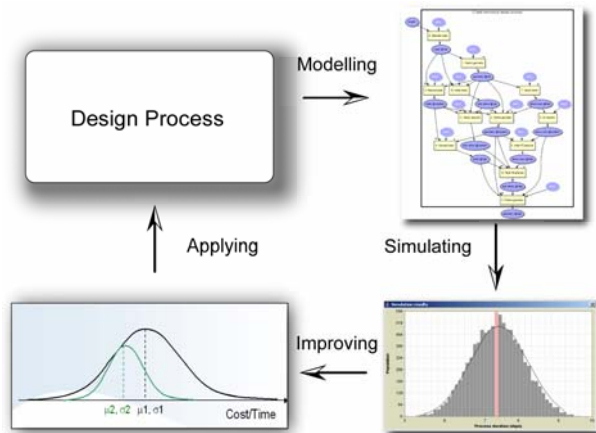
- Simulating performance
- Modifying performance
- Selecting performance



An optimal design process for an adequate product?

Identifying a 'robust' plan

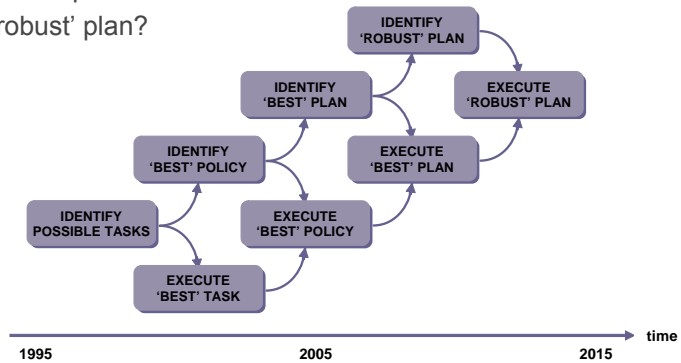
- Modelling the process
- Simulating the process
- Improving the process
- Applying the process



An optimal design process for an adequate product?

Identifying a 'robust' plan

- Identify 'robust' plan
- Execute 'robust' plan?



1995

2005

2015

time

Jarrett O'Donovan Wynn
Hamilton Melo Flanagan Chalupnik

An optimal design process for an adequate product?

Identifying an 'optimal' plan

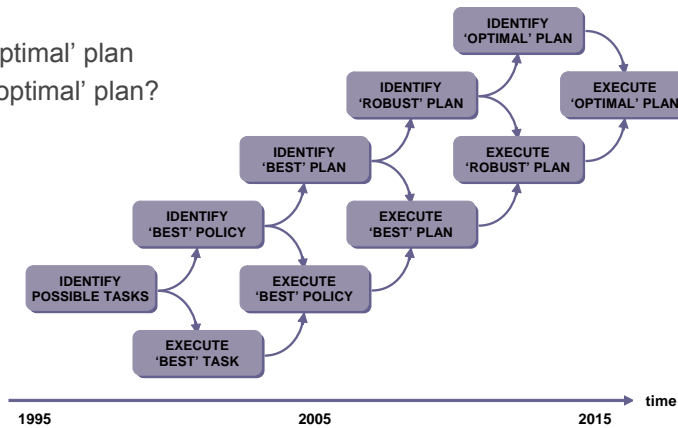
- Can we do better?
- Is there an optimal plan?
- What is the cost/benefit for such a plan?



An optimal design process for an adequate product?

Identifying an 'optimal' plan

- Identify 'optimal' plan
- Execute 'optimal' plan?

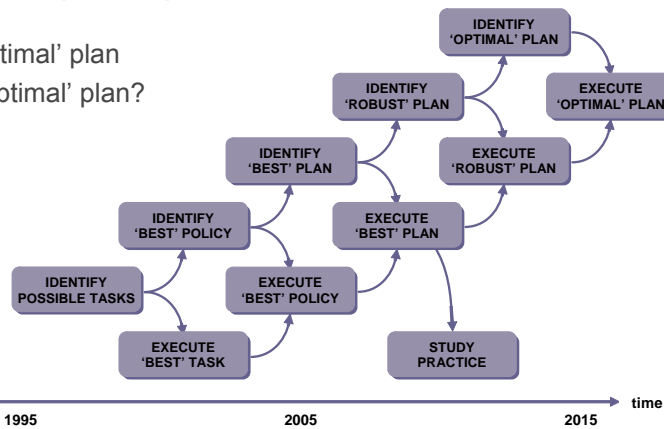


Jarrett O'Donovan Wynn
Hamilton Melo Flanagan Chalupnik Koh

An optimal design process for an adequate product?

Identifying an 'optimal' plan

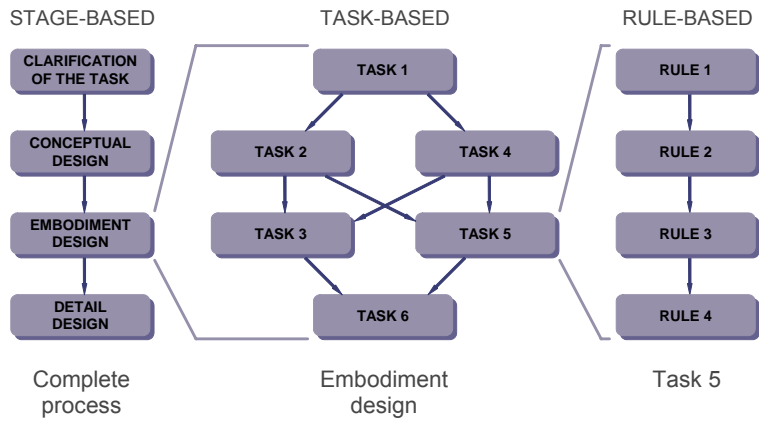
- Identify 'optimal' plan
- Execute 'optimal' plan?



Jarrett O'Donovan Wynn de Lessio
Hamilton Melo Flanagan Chalupnik Koh

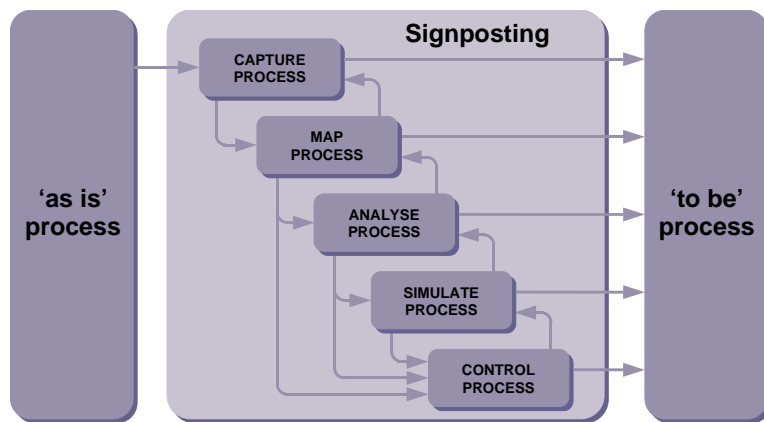
An optimal design process for an adequate product?

Process management



An optimal design process for an adequate product?

Process management



An optimal design process for an adequate product?

Introduction

- Process management
- Change management
- Lean design

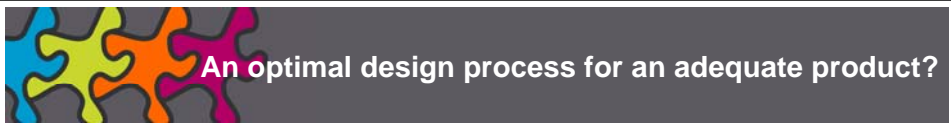


An optimal design process for an adequate product?

Change management

- Signposting provides a flexible approach to design process management
- Signposting is useful as a form of knowledge capture





Change management

- However, the design process may begin with an assessment of change
- What price do we put on this product?



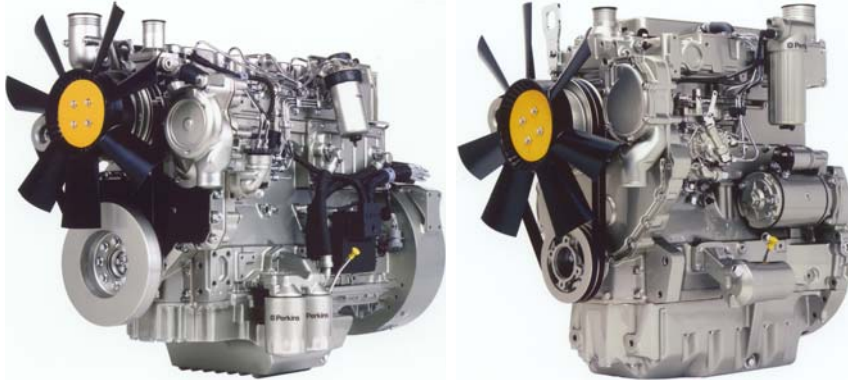
Change management

- Much product development is adaptive



An optimal design process for an adequate product?

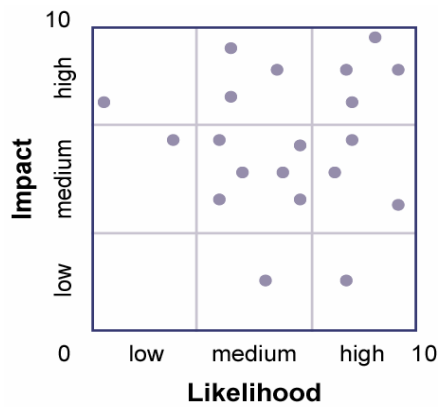
Change management



An optimal design process for an adequate product?

Change management

- Changes are necessary, but can propagate through the product
- Each subsequent change has a likelihood and an impact
- Risk = likelihood x impact



An optimal design process for an adequate product?

Change management

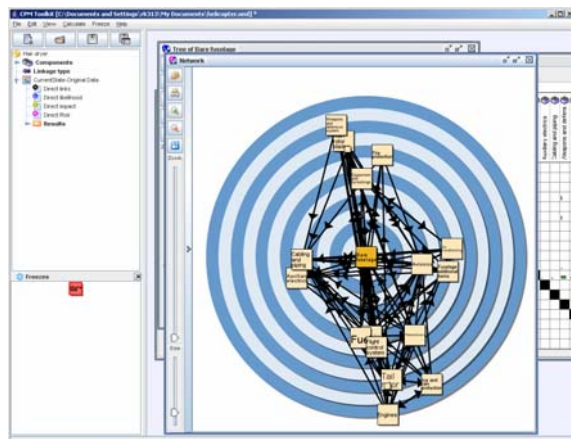
- The product can be divided into geographical areas and/or systems



An optimal design process for an adequate product?

Change management

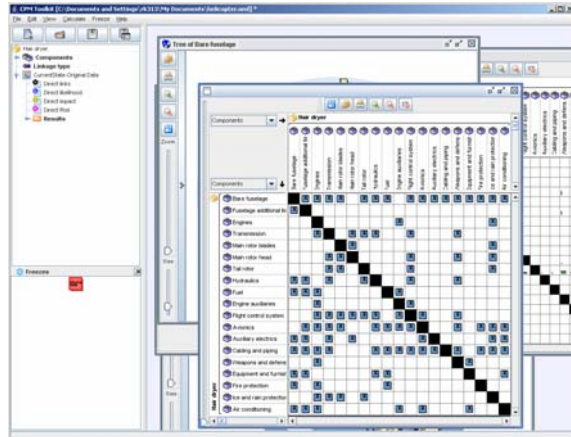
- Links can be made explicit and categorised



An optimal design process for an adequate product?

Change management

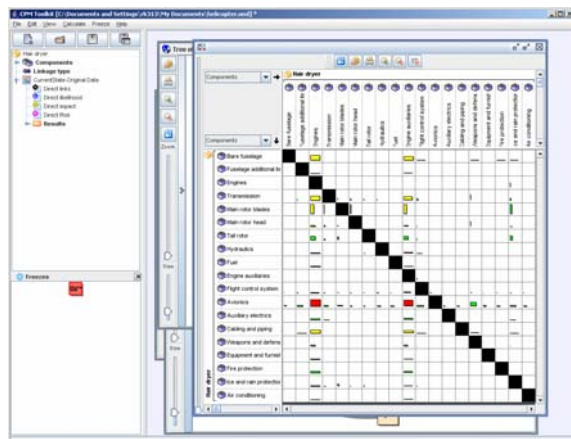
- Direct risk can be captured



An optimal design process for an adequate product?

Change management

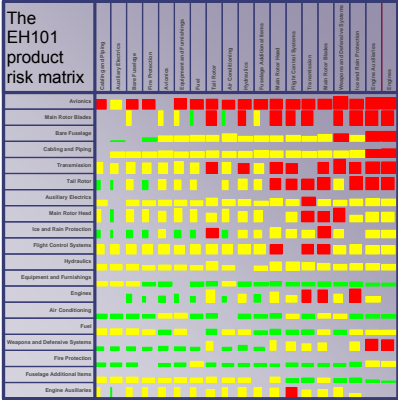
- Combined risk can be calculated
- Columns show the consequences of a change request
- Re-ordering accentuates change drivers



An optimal design process for an adequate product?

Change management

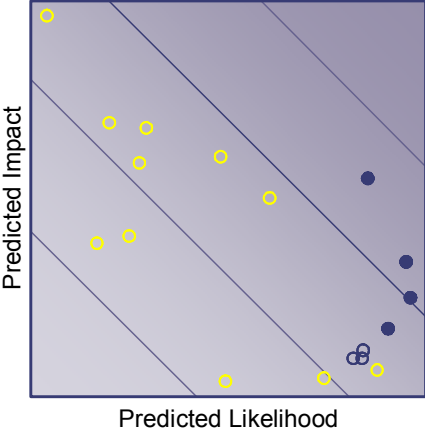
- Changes to the EH101 where predicted and observed for three change cases
- Interviews with 22 senior and chief engineers to build the model



An optimal design process for an adequate product?

Change management

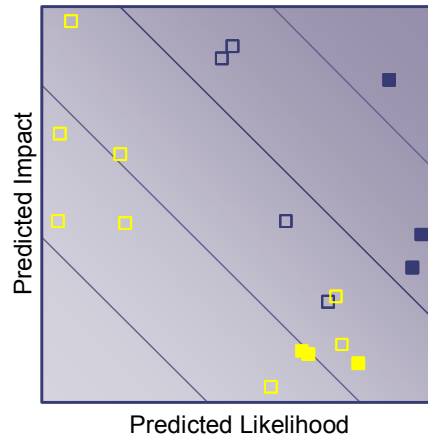
- Change to fuselage additional items
- 4 changes result
- 0 changes indirect



An optimal design process for an adequate product?

Change management

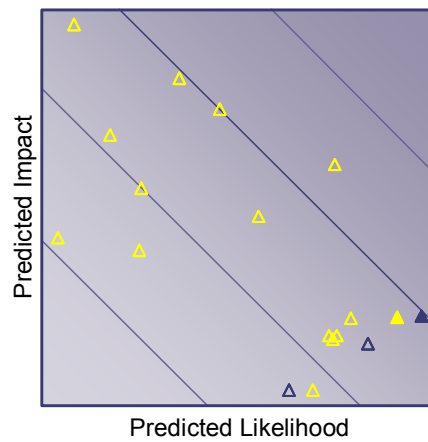
- Change to weapons and defensive measures
- 6 changes result
- 3 changes indirect



An optimal design process for an adequate product?

Change management

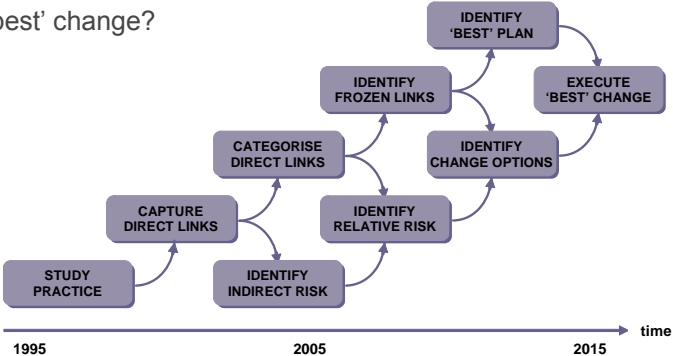
- Change to equipment and furnishings
- 2 changes result
- 1 change indirect



An optimal design process for an adequate product?

Change management

- Identify 'best' plan
- Execute 'best' change?



1995 2005 2015 time
 Eckert Jarratt Eger Kilpinen
 Simons Keller Ariyo Ahmad

An optimal design process for an adequate product?

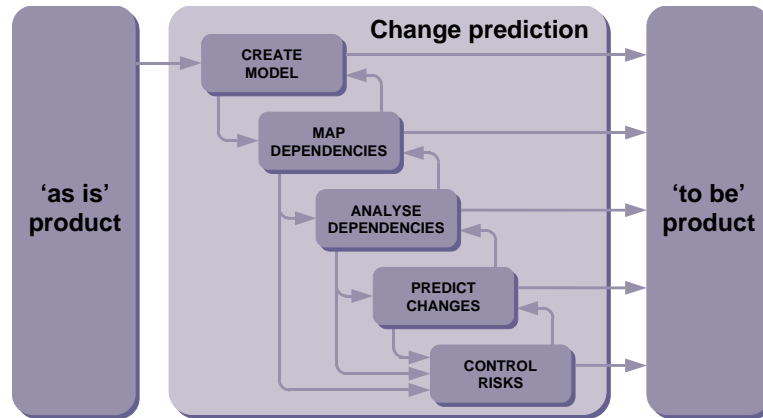
Change management

- Change prediction provides a platform for managing risk during product redesign



An optimal design process for an adequate product?

Change management



An optimal design process for an adequate product?

Introduction

- Process management
- Change management
- Lean design



An optimal design process for an adequate product?

Lean design

- The elimination of wasteful processes in the design of a product before it even reaches the factory



An optimal design process for an adequate product?

Lean design

- Eliminate waste
- Amplify learning
- Decide as late as possible
- Deliver as fast as possible
- Empower the team
- Build integrity in
- See the whole



An optimal design process for an adequate product?

Lean design

- Design is a 'wicked problem'
- Wicked problems have incomplete, contradictory and changing requirements
- Solutions to them are often difficult to recognise as such because of complex interdependencies



An optimal design process for an adequate product?

Lean design

- "What other tasks must be completed before I begin this one?"
- "What information do I need from other tasks before I can complete this one?"



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Lean design

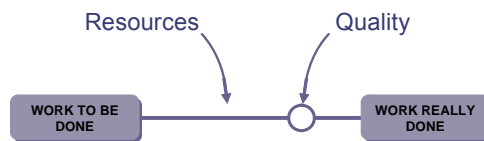
- Rearrange the sequence of tasks
- Reconsider the organization of tasks
- Reduce the number of information exchanges
- Manage unplannable work



An optimal design process for an adequate product?

Lean design

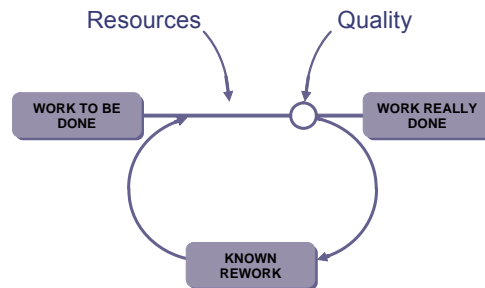
- The 'rework cycle'
- Work is done by design resources to a particular level of quality



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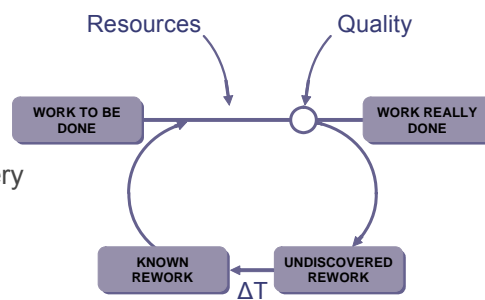
- The 'rework cycle'
- Errors give rise to rework causing development delays



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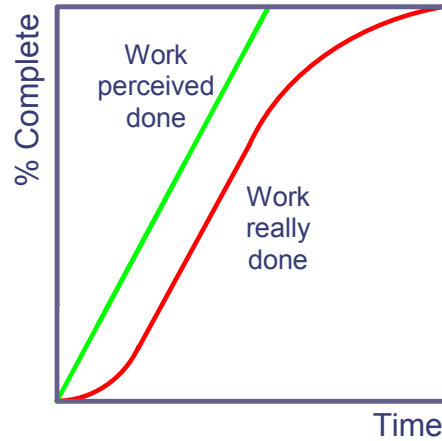
- The 'rework cycle'
- Undiscovered rework causes unforeseen development delays
- Timely rework discovery is critical



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Lean design

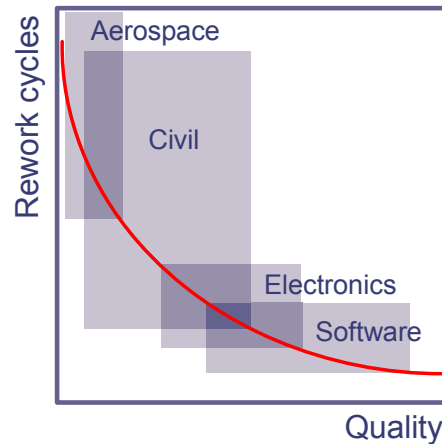
- The work perceived to be done may vary significantly from the work really done



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Lean design

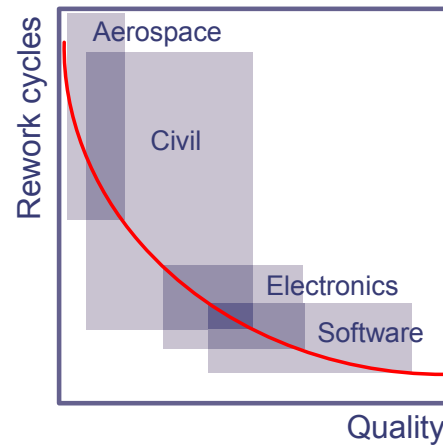
- 'Quality' is a measure of correctness rather than competence
- 'Quality' is dependent on complexity
- Rework is often inevitable



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Lean design

- Plans should explicitly accommodate rework
- Plans can adopt a fixed number of design cycles, a probability of success or 'do until' approach, or contingency



An optimal design process for an adequate product?

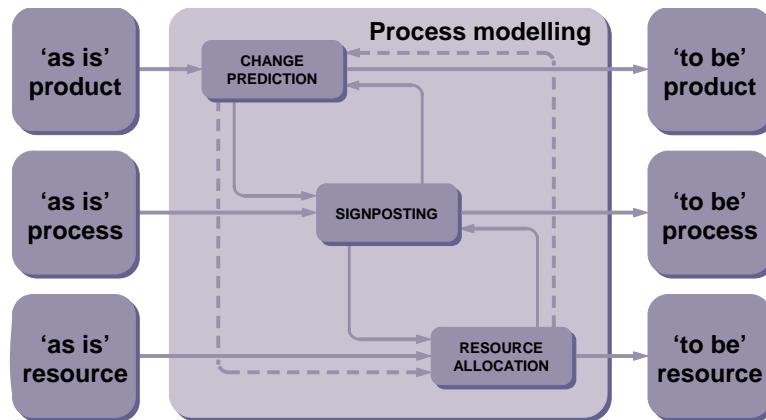
Lean design

- Ensure common purpose and visibility of process
- Ask the 'what if' questions
- Minimise undiscovered rework
- Know when to update the plan
- Minimise unexpected change propagation



An optimal design process for an adequate product?

Lean design



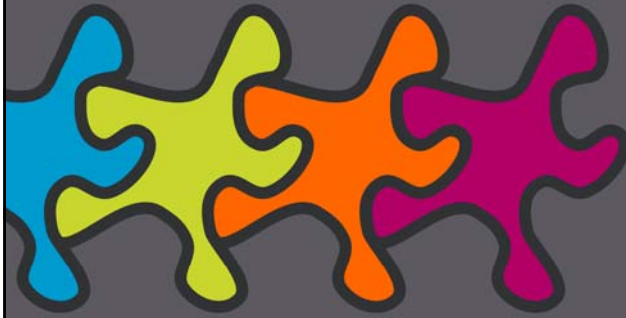
An optimal design process for an adequate product?

Lean design

- 'Wicked problems' can be solved
- But can we find an optimal design process for an adequate product?



**Lean Design OR An optimal design process
for an adequate product?**



John Clarkson