Flyteffektivitet i engineer-to-order produksjon med FORRIDGE prinsipper

Erlend Alfnes

Norwegian University of Science and Technology, Trondheim, Norway

ACT, Mo i Rana, 15.11.2024

Erlend Alfnes

Hvem jeg er:

- Professor i Produksjonsledelse ved NTNU
- Leder av Advanced Production Management Systems sin interessegruppe "Operations Management in Engineer-to-Order Manufacturing"
- Leder av GEMINI senteret "Kundetilpasset produksjon"
- Leder av masterprogrammet "Global Manufacturing Management"
- Tidligere seniorforsker i Logistikk ved SINTEF
- Doktor Ingeniør (Ph.D) med tittel: "Enterprise Reengineering – A Strategic Framework and Methodology"

Mitt fag:

Mitt arbeid bidrar til at bedrifter oppnår konkurranseevne gjennom bedre produksjonsledelse og digitalisering. Målet er å utvikle nye **metoder, modeller** og **teknikker** som gjør det mulig for produksjonsledere å **modellere, analysere** og ta **beslutninger** som forbedrer produksjons- og logistikkprosesser. Mine nåværende forsknings- og utviklingsaktiviteter er innenfor tre områder:
1) produksjons- og logistikkstrategi, 2) planlegging og styring, og **3) lean og quick response produksjon** (nylig har fokus også vært sirkulære verdikjeder)

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Noen samarbeidspartnere:
Brunvoll, Siemens, Pipelife, Ulstein, Ekornes, Quarts Corp, Kongsberg Maritime, Cardiff University

Masteremner:
ERP og PLM systemer, Produksjonsstrategi, Produksjonslogistikk
Veiledning:
50+ Masterstudenter, 8 PhD studenter

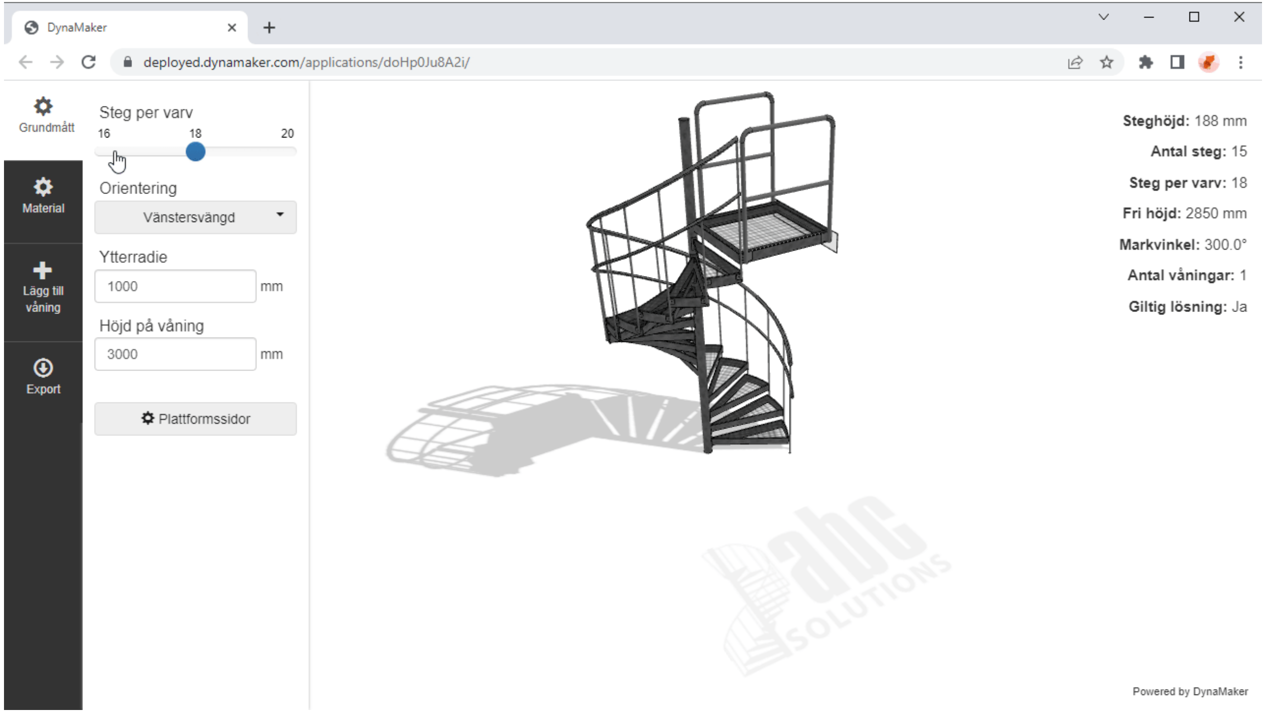
Engineer-to-order manufacturing

“Traditional”, MTS manufacturing

ETO manufacturing

Manufacturing operations where the technical specification and design is part of the order fulfillment process

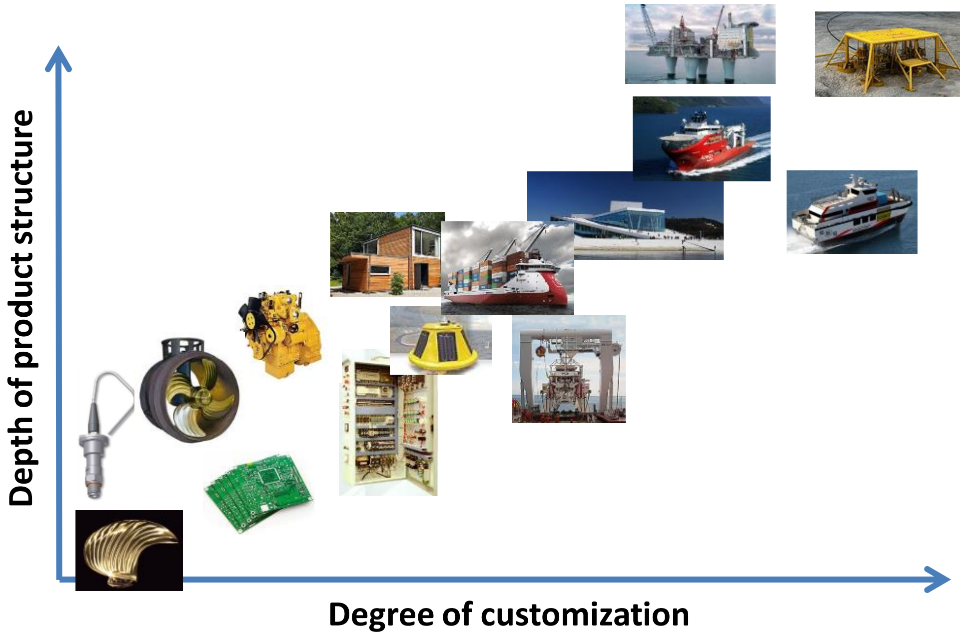
ETO - Sales and specification process



From engineer-to-order to mass customization?

Using parametric configurator

Depth of product structure vs. customization



Int. J. Production Economics 240 (2021) 108211

Contents lists available at ScienceDirect

International Journal of Production Economics

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ELSEVIER

Exploring systemic factors creating uncertainty in complex engineer-to-order supply chains: Case studies from Norwegian shipbuilding first tier suppliers

Erlend Alfnes[a,*], Jonathan Gosling[b], Mohamed Naim[b], Heidi C. Dreyer[a]

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[b] Cardiff Business School, Cardiff University, Cardiff, UK

ARTICLE INFO

Keywords:
Innovate
Uncertainty
Complexity
Redesign
Soft systems

ABSTRACT

times with poor capacity availability. A change programme is suggested to reduce uncertainty requiring primary consideration of process and control aspects before addressing demand-side and then supply-side changes. The findings are evaluated by independent interviews indicating that the method and tools adopted have validity, and that the findings are commensurate with wider industry expectations.

«2D-CODP» +«The uncertainty circle»

A method to classify product groups and identify contributing factors to uncertainty that inhibit efficient and effective flow for a product group

Int. J. Production Economics 262 (2023) 108903

Contents lists available at ScienceDirect

International Journal of Production Economics

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ELSEVIER

Rearticulating supply chain design and operation principles to mitigate uncertainty in the Norwegian engineer-to-order shipbuilding sector

Erlend Alfnes[a,*], Jonathan Gosling[b], Mohamed Naim[b], Heidi C. Dreyer[a]

[a] Norwegian University of Science and Technology, Trondheim, Norway
[b] Cardiff Business School, Cardiff University, Cardiff, UK

ARTICLE INFO

Keywords:
Uncertainty reduction
Innovate to order
Redesign to order
Replication research
Supply chain

ABSTRACT

showing the application of a conceptual replication research design in an operations management context. Further research is required to test the principles in other ETO-intensive sectors.

«FORRIDGE principles and tactics»

a set of principles and tactics to mitigate uncertainty and enable efficient and effective flow

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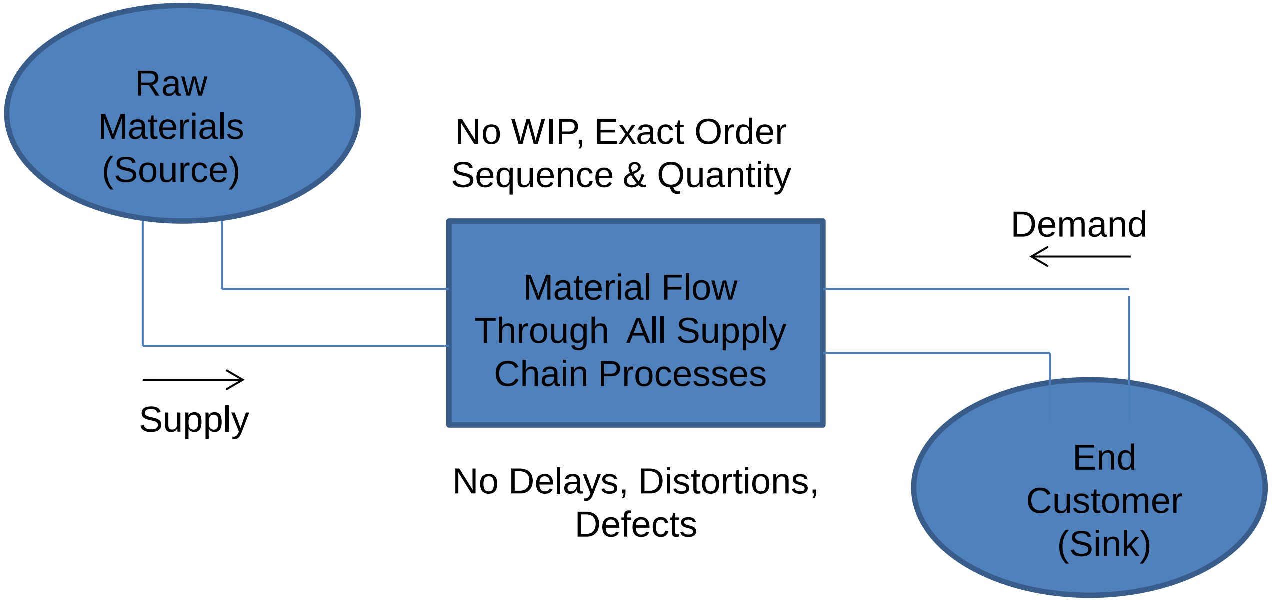
Outline

- Flow theory - FORRIDGE principles and tactics
- Toolkit
  - 2D framework for product classification
  - Uncertainty Circle
  - Risk matrix
  - Methodology to identify uncertainty sources, and to map principles and tactics against the uncertainty sources
- Our studies in engineer-to-order equipment suppliers
- Conclusions

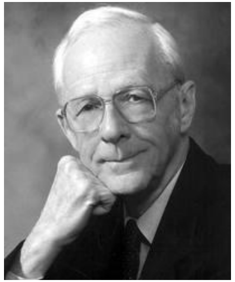
The Vision of Smooth and Seamless Flow



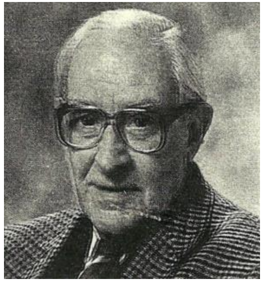
All players think and act as one, so the supply chain is seamless with both information and material flows fully integrated, based on the concept of smooth material flow
(Childerhouse and Towill 2003)

FORRIDGE

Principles for the design and operation of supply chains



Jay Forrester



Jack Burbidge

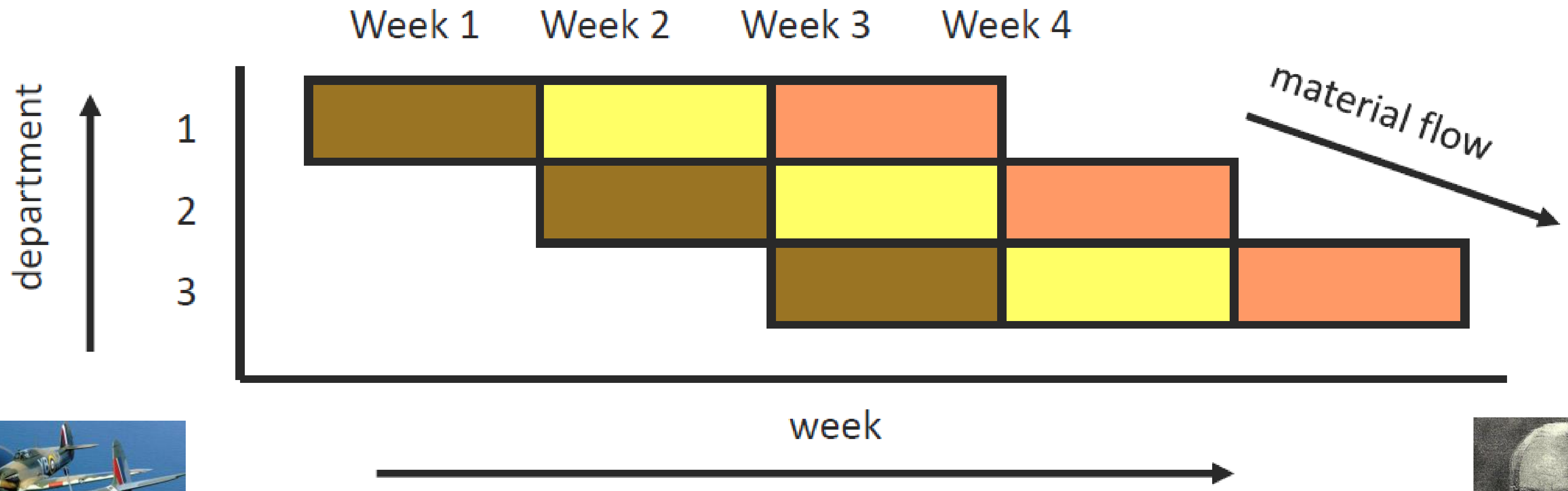
Denis Towill

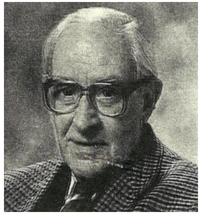
LEAN? "Apparently **Japanese** led, the associated roots of present good practice on material flow can be traced back in the USA to Jay **Forrester** and in the UK to John **Burbidge**". (Dennis Towill, 1994)

Cardiff Business School
Cardiff University

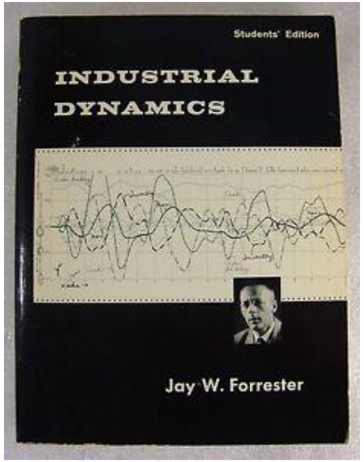
Ysgol Fusnes Caerdydd
Prifysgol Caerdydd

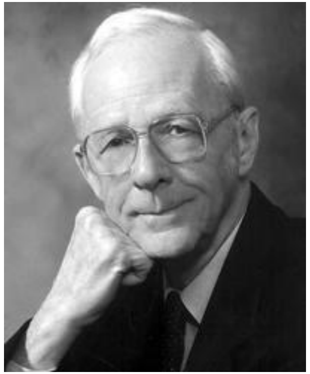
Periodic Batch Control





“1961 and all that: The influence of Jay Forrester and John Burbidge on the design of Modern Manufacturing Systems” (Dennis Towill, 1994)





THE “NEW APPROACH” TO PRODUCTION

by JOHN L. BURBIDGE,
A.M.I.Mech.E., M.I.Prod.E., M.B.I.M.

Mr. Burbidge is well known as a writer on Production Control and for his outspoken criticism of Batch Quantity Analysis.

Educated at Wellington School, Somerset, and Cambridge University, he entered industry as a student apprentice with The Bristol Aeroplane Company. Since then he has had 25 years of practical experience in management, in posts as varied as Shop Manager, Chief Inspector, Chief Planner, Sales Manager, General Manager, Works Director and Managing Director. He has an equally wide experience of different products, including aero-engines, marine - engines, agricultural machinery, printing machines, cars, wire, tractors, steel house frames, and plastics.

Mr. Burbidge, who is now a consultant in Industrial Engineering and Management, is the author of a book, "Standard Batch Control", and has also written a text book of Production Control which will be published shortly.

TO production historians of the future, the 20th century will be known as the "Age of Waste". An age when much of the wealth invested in production was stored away unused in the form of stock; an age when a large part of the labour force was wasted on the unproductive processing of administrative paper work; and an age in which most of the production capacity was left unused for long periods, due to our failure to control the demand cycle.

Production has reached a stage where normal evolution along traditional lines, only increases this waste. It has reached a point where substantial progress is only possible if we can find a new approach.

This Paper describes a possible approach. It advocates the use of high batch frequency line flow, for all types of product and for all levels of output. Such systems are already in use in mass production. It is here submitted that they have a universal value, irrespective of the volume, or type of product.

The Paper attempts to show that the New Approach is both theoretically sound and possible in practice. It is divided into four parts. Part I describes the material flow system, which is "production". Part II shows how material flow is related to the economies of production. Part III shows how our present philosophy of management tends to perpetuate the *status quo* and, finally, Part IV develops the philosophy of the "new approach", and describes how it can be, and has been applied in practice.

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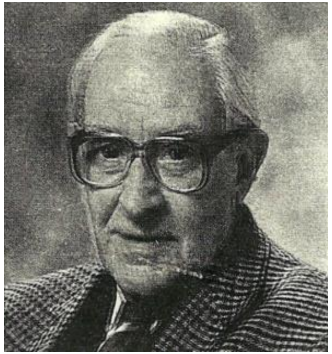
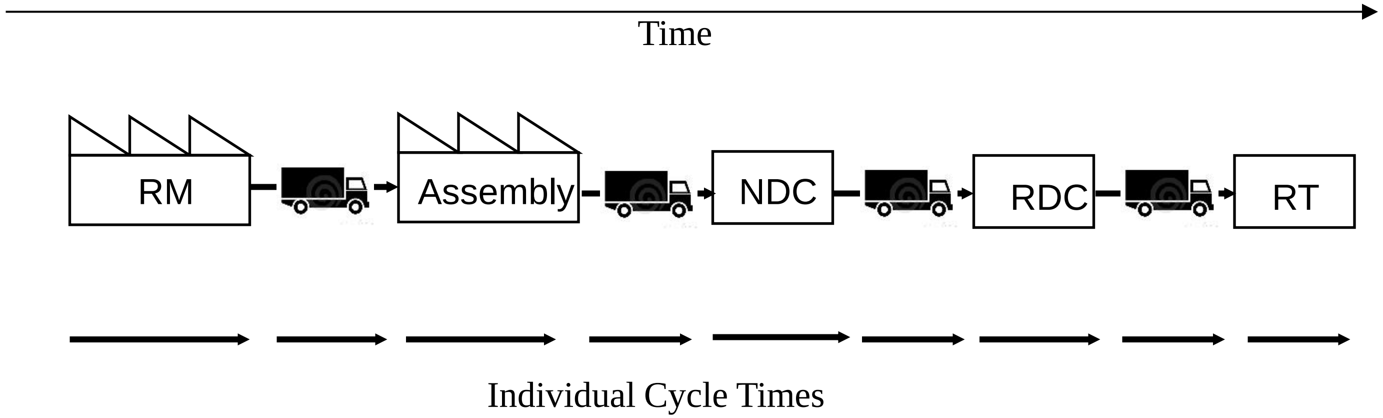


As reviewed in the paper the ground rules for effective manufacturing system design were co-incidentally established in 1961. Jay Forrester showed that medium period demand amplification was a system dynamics phenomenon which could be tackled by reducing and eliminating delays and the proper design of feedback loops. In parallel, via his "rules to avoid bankruptcy" and "laws of manufacturing systems", John Burbidge showed that short period demand amplification was due to multi-phased, multi-period ordering policies.

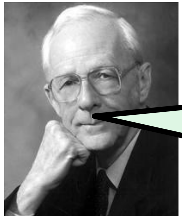
Adapted from Gosling et al 2014



Time Compression Principle

Design for time compression across chain activities

Every activity in the chain should be undertaken in the minimum time needed to achieve task goals



Faster order handling to improve stability and reduction of system time delays

Minimize the material throughput time

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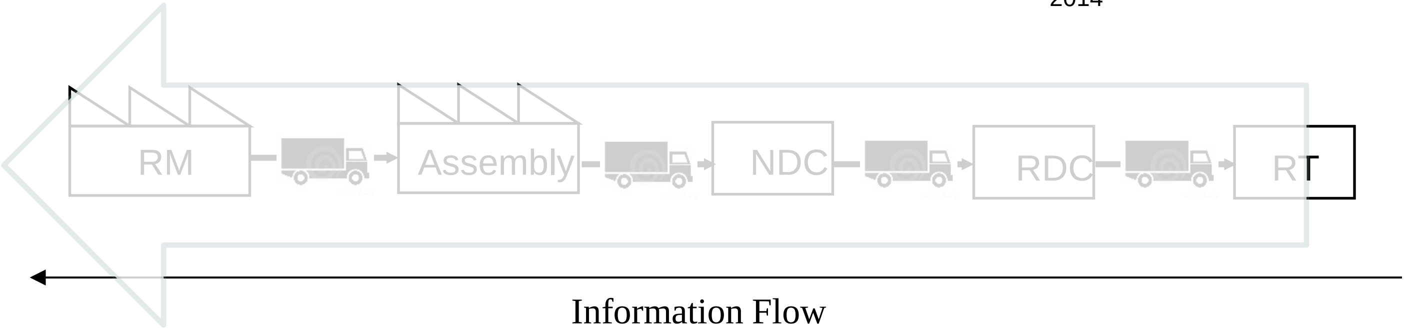
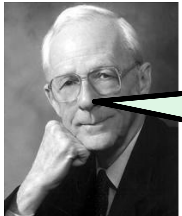
Adapted from Gosling et al 2014



Information Transparency Principle

Design to enable real time information transparency across chain activities. Up-to-the minute data free of 'noise' and bias should be accessed by all members in the system



Ensure appropriate design of information-feedback systems and loops for transparency

Don't rely on long term forecasts and promote 'connectance'

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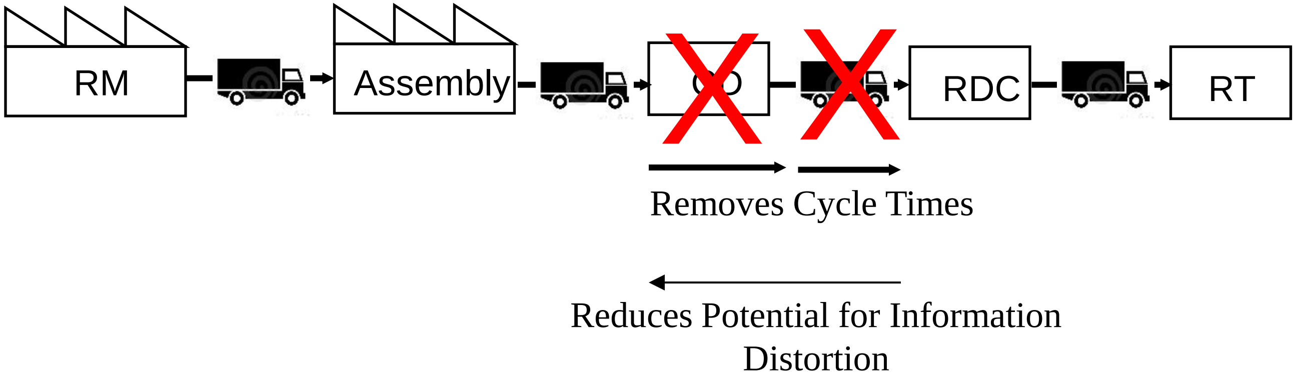
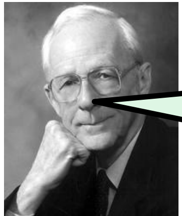


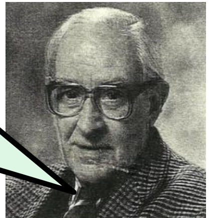
Echelon Elimination

Design the minimum number of echelons appropriate to the goals of the supply chain. Reduce complexity of material flow where possible



Eliminate distributor level to reduce demand amplification

Efficiency is inversely proportional to the complexity of its material flow system



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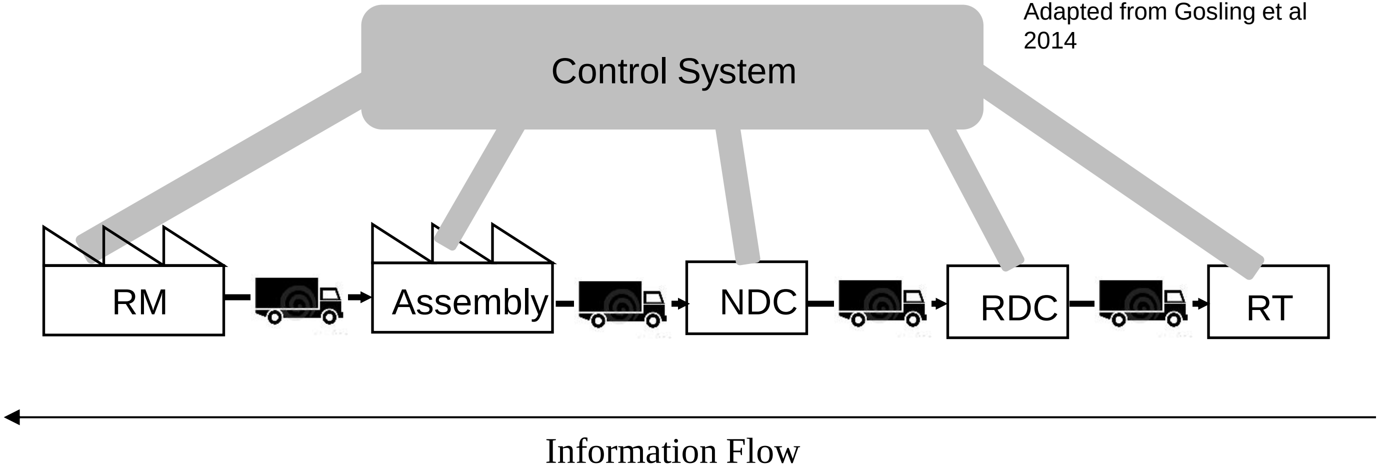
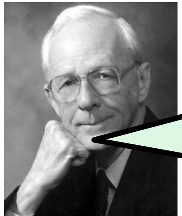


Adapted from Gosling et al 2014

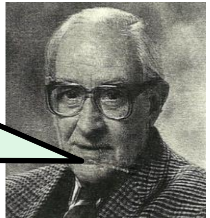
Control System Principle

Design a Decision Support System for Integrated Control. There is a need to select the most appropriate control system best suited to achieving user targets and taking unnecessary guesswork out of the system.



Change inventory policy to adjust the level of inventories and in-process orders

Only make in one period those components you need for assembly in the next period



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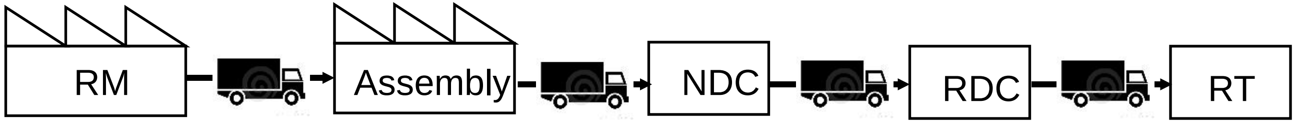
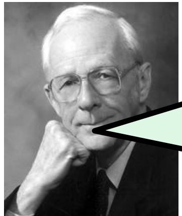
Adapted from Gosling et al 2014



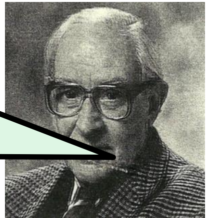
Synchronization Principle

Decisions, information and orders are co-ordinated and related to discrete points in time . There is continuous ordering synchronised throughout the chain.

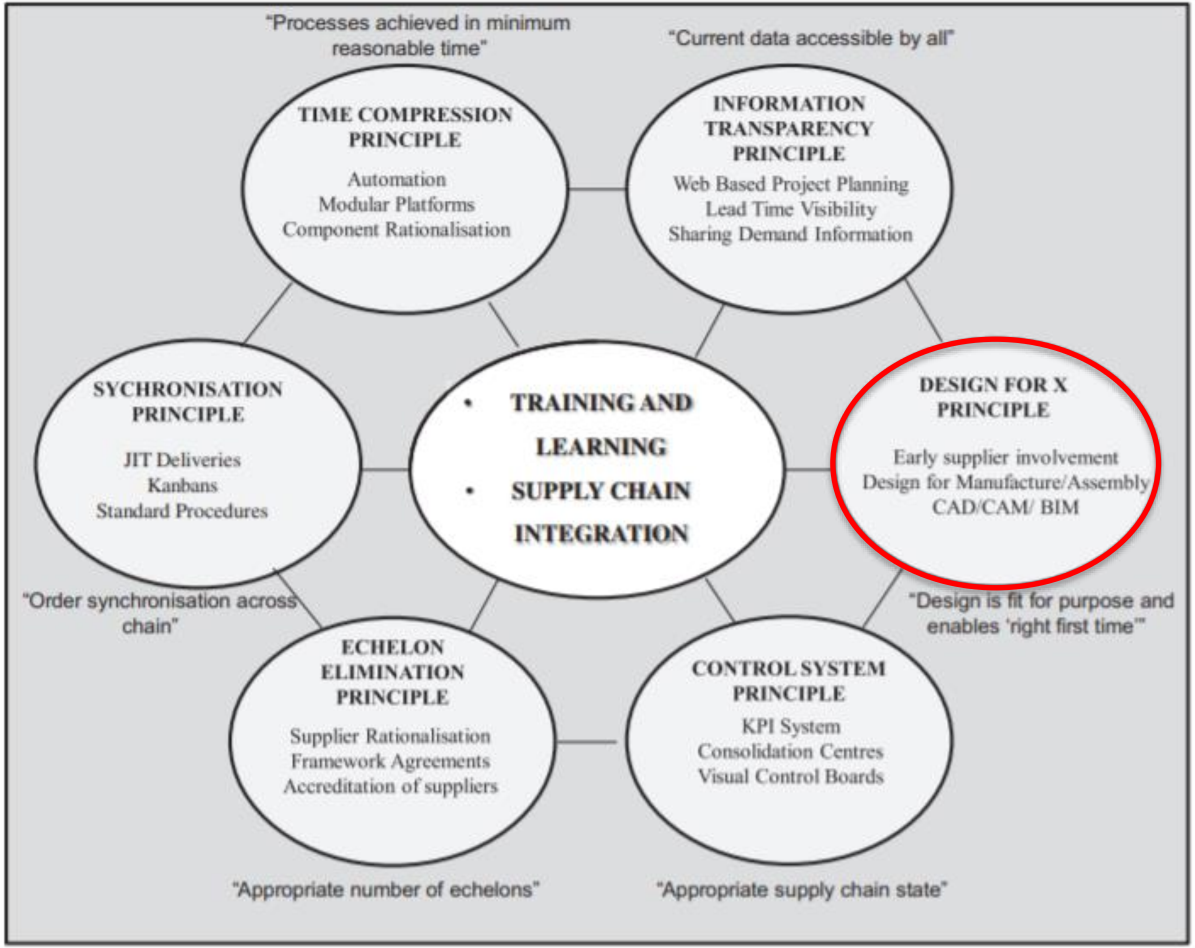


Events should be synchronized, so that orders and deliveries are visible at discrete points in time.

Use the shortest planning period and only take deliveries from suppliers in small batches as and when needed



FORRIDGE principles and tactics for construction supply chains (Gosling et. al, 2015)



Equipment Suppliers to Yards

Engineer-to-order manufacturing

MECHANICAL EQUIPMENT

Cranes | Winches | Propellers | Engines | etc

ELECTRICAL AND ELECTRONIC EQUIPMENT

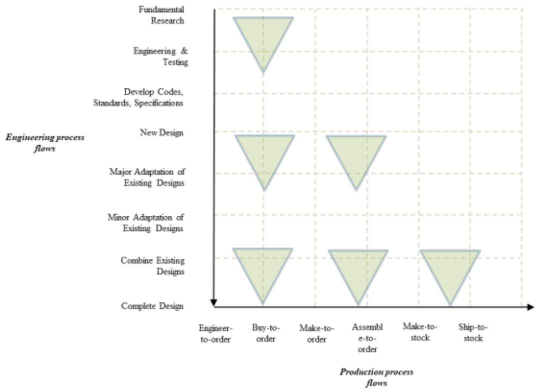
DP | Software | Specialised hardware | Bridge equipment | Sensors | etc

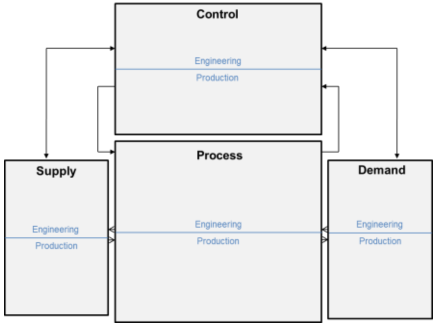
Engineer-to-order manufacturing and uncertainty

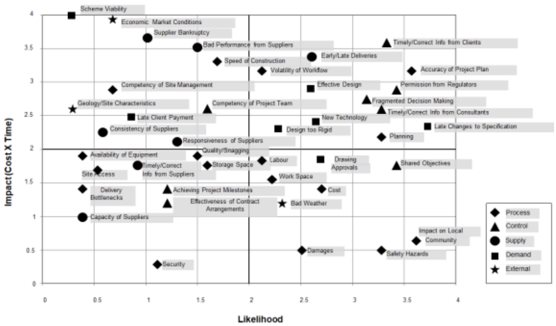
Highly customized manufacturing such as ETO is characterized by a high level of uncertainty in specification, design, planning, purchasing, and production

Supply chain uncertainty can be defined as "**situations in the supply chain in which the decision maker does not know definitely what to decide** as he is indistinct about the objectives; lacks information about or understanding of the supply chain system or its environment; lacks information processing capabilities; is unable to accurately predict the impact of possible control actions on supply chain behavior; or, lacks effective control actions" (van der Vorst and Beulens 2002).

Mapping and analysis tools







Principles	ITO tactics	Uncertainty type				
		Specification	Supply chain relation management	Engineering lead time	Supplier lead times	Product structures
P1 Time compression	Predesign analysis					
	Agile methods					
P2 Control system	Centralised cross-disciplinary project team					
P3 Synchronisation	Risk-sharing contracts					
P4 Information transparency	Design integration events					
	Knowledge transfer between projects					
P5 Echelon elimination	Cross-disciplinary innovation events					
P6 Design for X	Early customer and supplier involvement					
	Prototyping					
	Computer-aided modelling and simulation					

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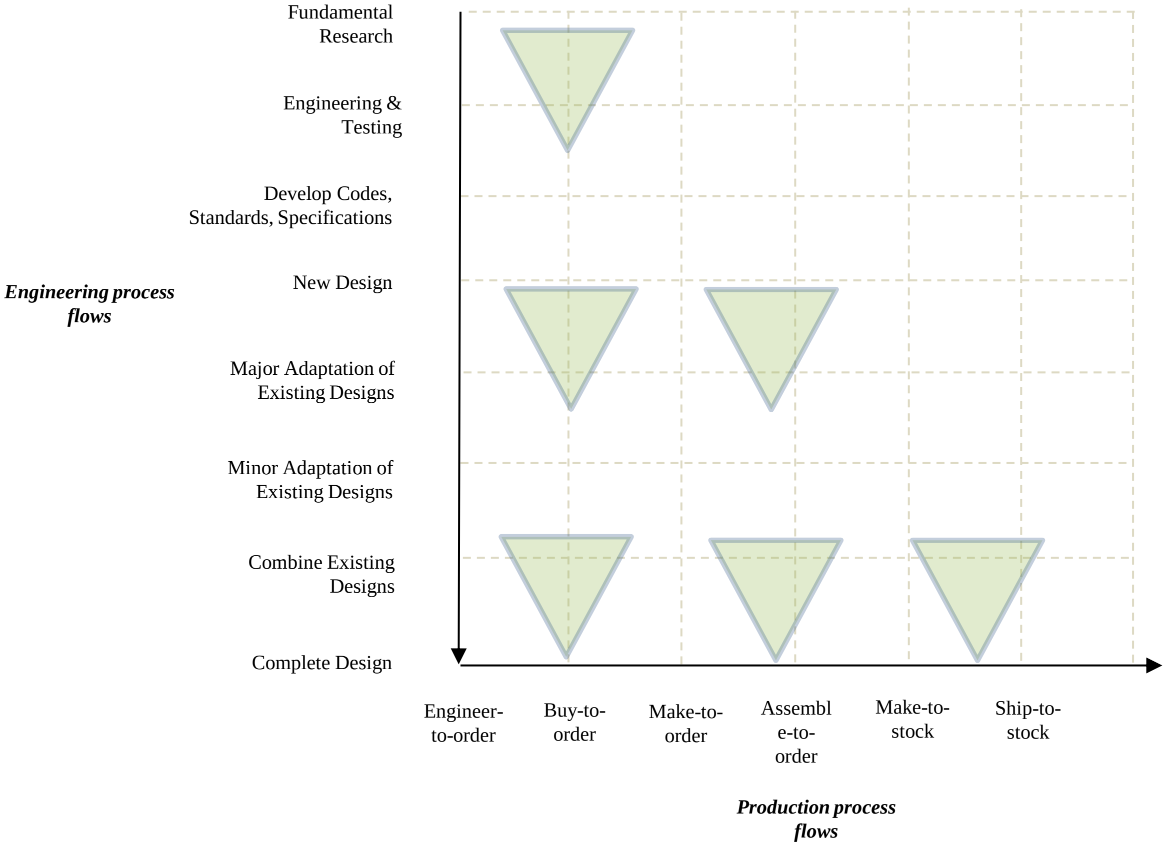
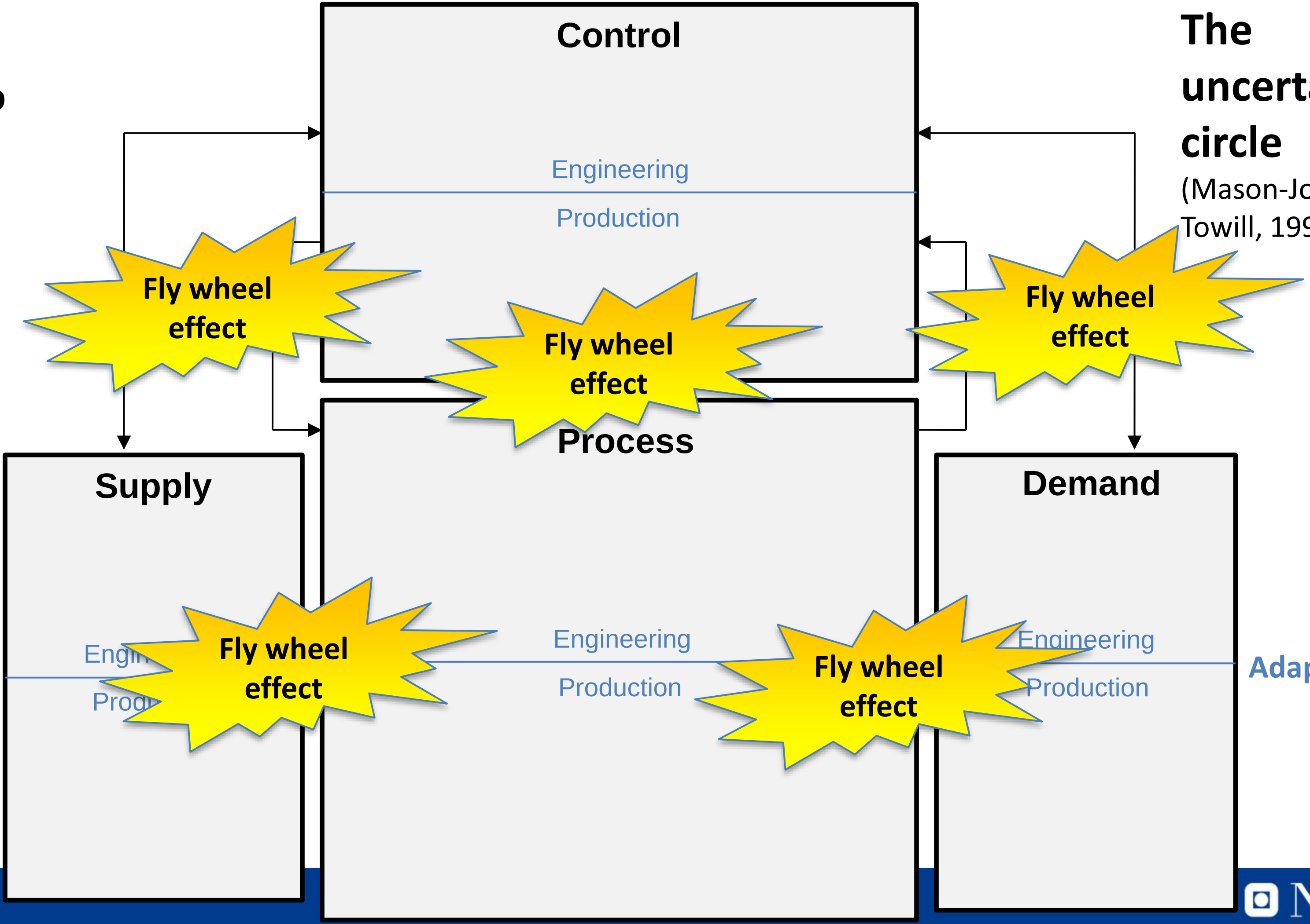
A 2-dimensional approach to classify decoupling positions across both engineering and production dimensions

(Canvas et. al. 2019)

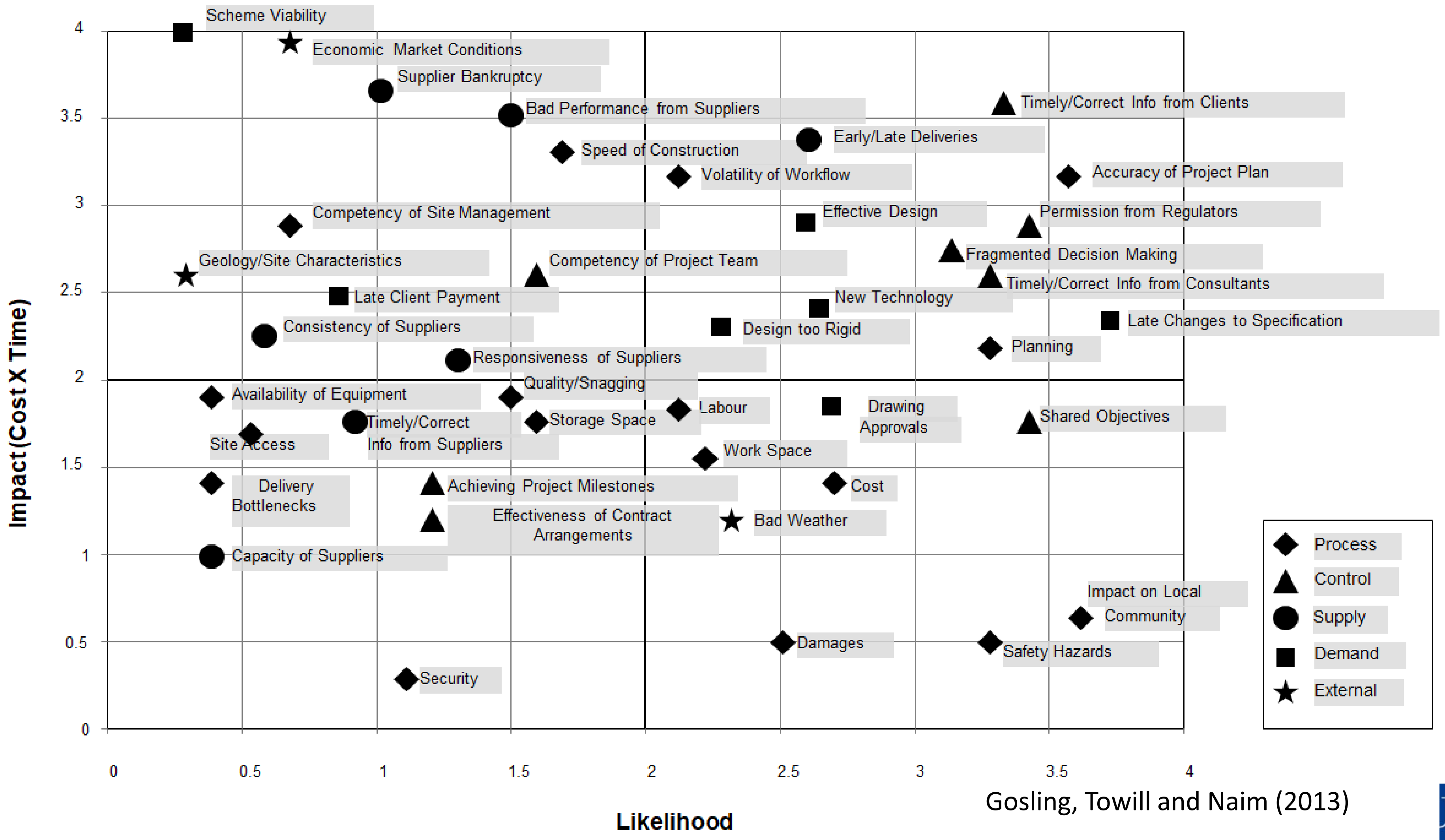


A stepwise approach to achieve integration:
1) Process
2) Supply
3) Demand and Control jointly
(Mason-Jones and Towill, 1998):

The uncertainty circle
(Mason-Jones and Towill, 1998)



Adapted to ETO

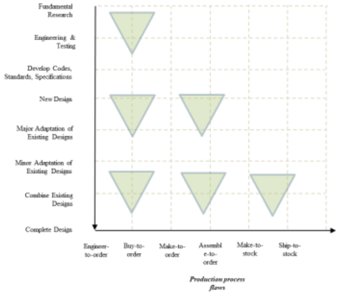


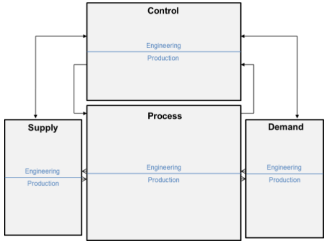
Gosling, Towill and Naim (2013)

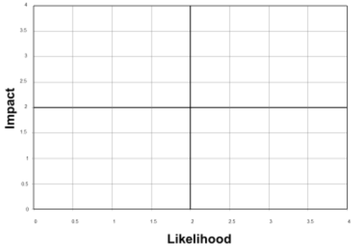
Methodology - how we identified uncertainty sources, and mapped principles and tactics against the uncertainty sources

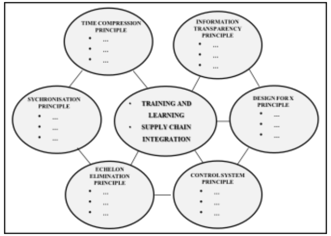
Structured workshops with suppliers in the ship building industry

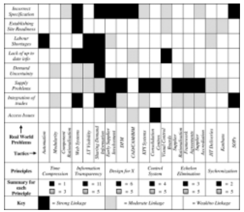
1. Determine product families
2. Ascertain and evaluate sources of uncertainty
3. Evaluate uncertainty scores
4. Identify and categorize tactics
5. Rank tactics
6. Applicability of principles and tactics to the uncertainties











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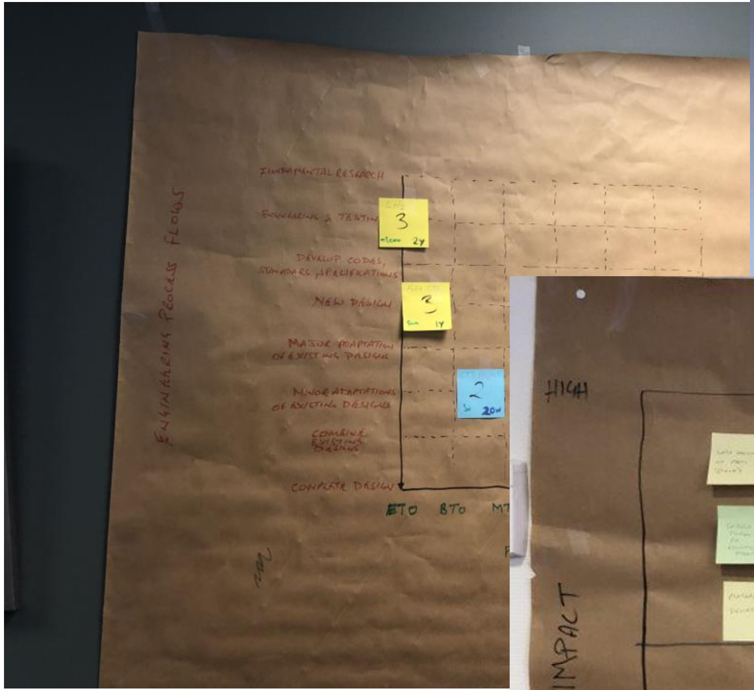
First study Alfnes et al (2021)

Energy capture and storage

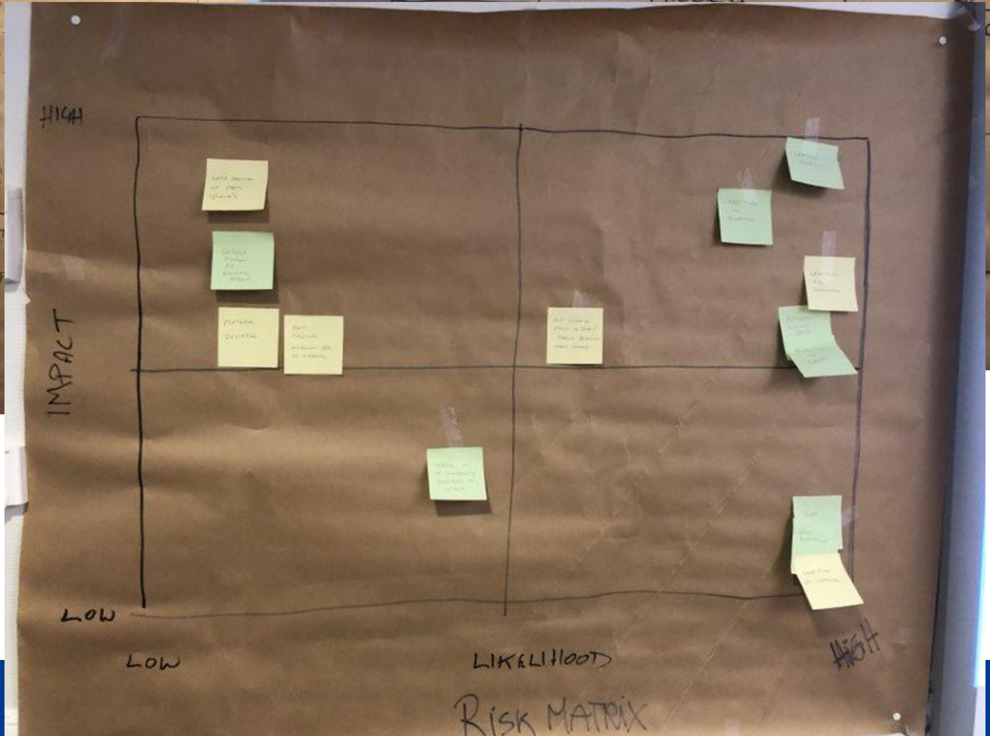
Monitoring and Transfer Systems

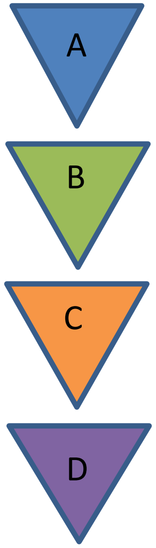
Cylinder and accumulators

Autonomous unmanned vehicles

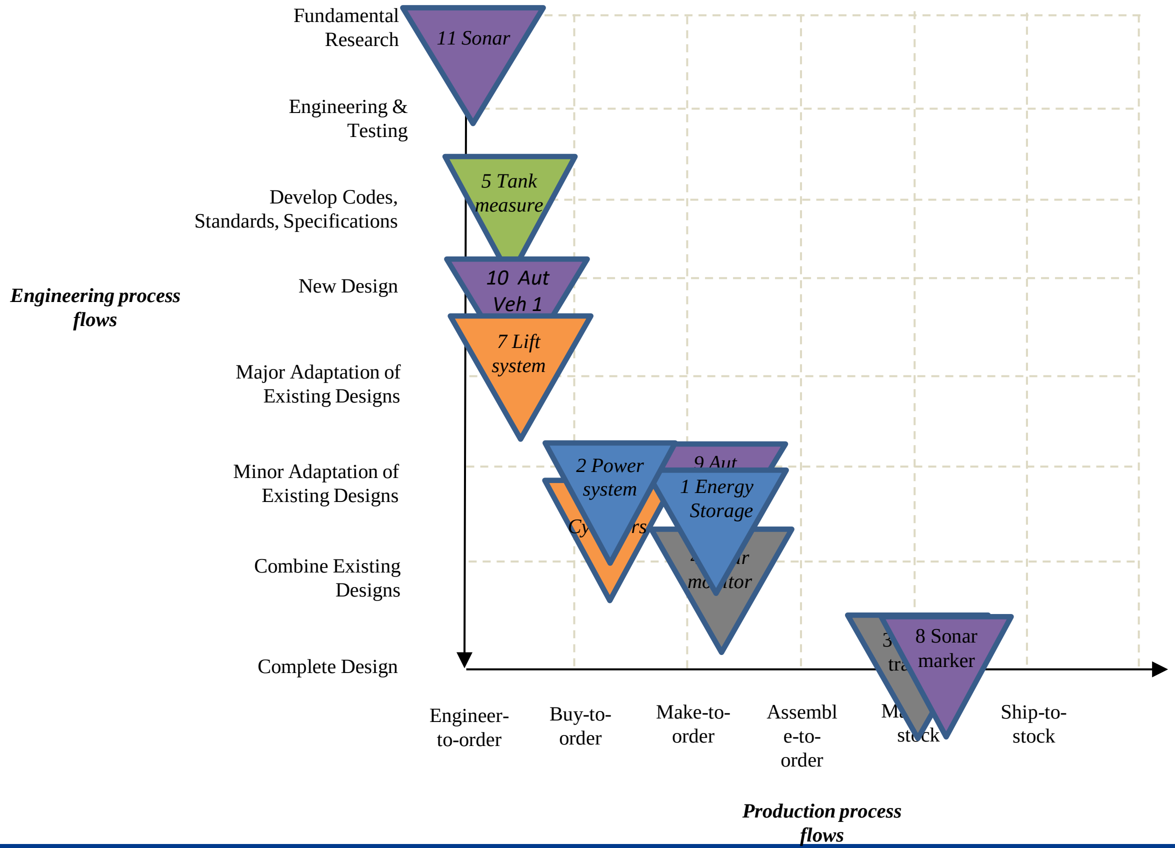

ENGINEERING PROCESS FLOWS
FUNDAMENTAL RESEARCH
ENGINEERING & TESTING
NEW DESIGN
ETO
BTO


EXTERNAL
CONTROL
EXTERNAL
ENG
PROD
PROCESS


HIGH
IMPACT
LOW
LOW
LIKELIHOOD
HIGH
RISK MATRIX



Italics signify those used for follow up activities



Alfnes et. al 2021:

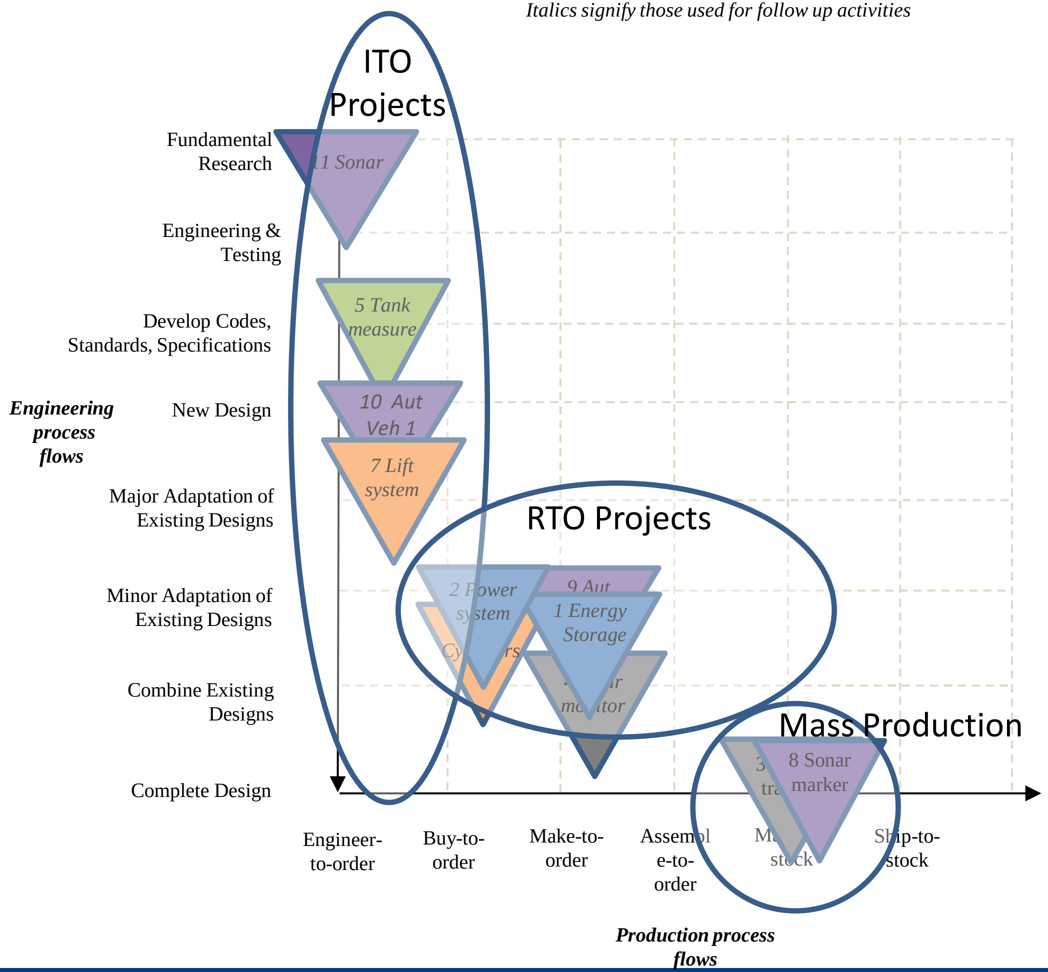
ITO projects

- Thousands of engineering hours
- performed in close collaboration with R&D personnel and technical specialists.
- to develop unique and premium-priced solutions for the customer.

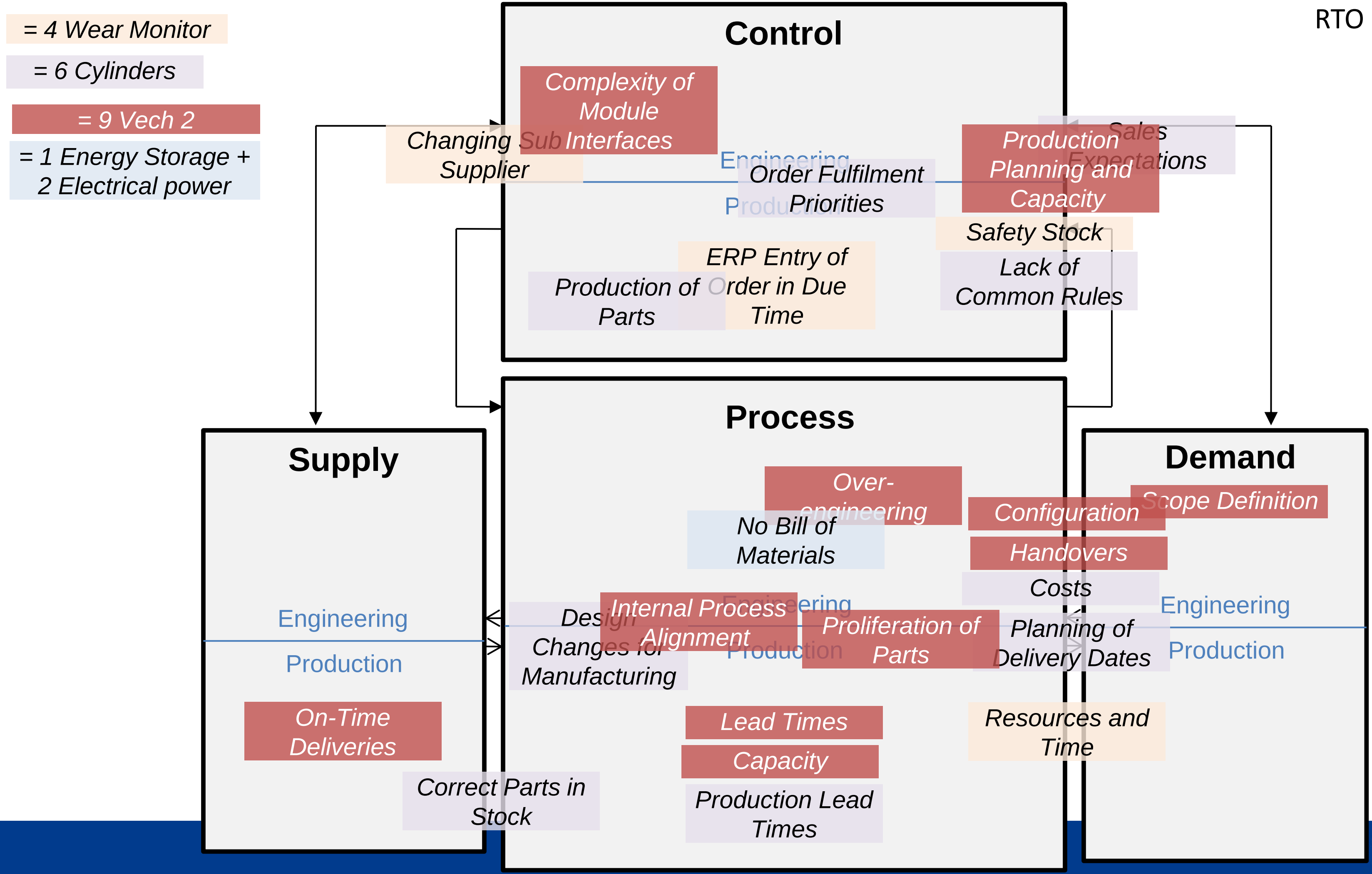
RTO projects

- minimum number of engineering hours
- are competing in a price-sensitive market by offering slightly customized designs

Italics signify those used for follow up activities

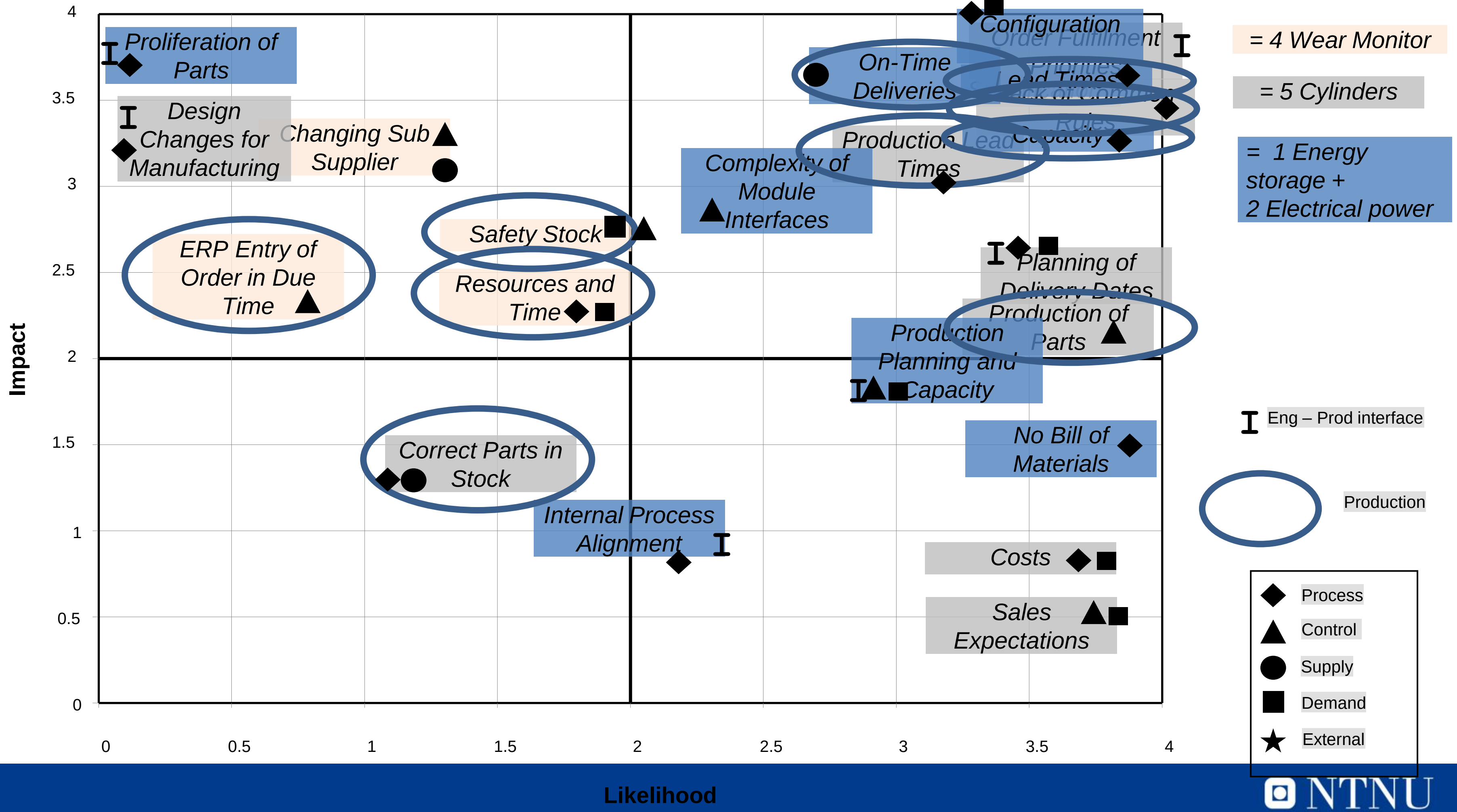


RTO systems



= 4 Wear Monitor
= 6 Cylinders
= 9 Vech 2
= 1 Energy Storage + 2 Electrical power
Control
Complexity of Module Interfaces
Changing Sub Supplier
Engineering
Production
Order Fulfilment Priorities
Production Planning and Capacity
Sales Expectations
Safety Stock
Lack of Common Rules
ERP Entry of Order in Due Time
Production of Parts
Process
Over-engineering
No Bill of Materials
Engineering
Production
Design Changes for Manufacturing
Internal Process Alignment
Proliferation of Parts
Lead Times
Capacity
Production Lead Times
Supply
Engineering
Production
On-Time Deliveries
Correct Parts in Stock
Demand
Scope Definition
Configuration
Handovers
Costs
Planning of Delivery Dates
Engineering
Production
Resources and Time

Reengineer to order Systems



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Second study Alfnes et al (2023)

- A Ship cranes
- B Power technology
- C Propulsion systems
- D Ship interior
- E Lightning systems
- F Sensor systems
- G Engine systems
- H Hydraulic systems
- I Winch systems
- J Sewage treatment systems

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TOP 5 uncertainties

RTO Uncertainties	Cases									
	A	B	C	D	E	F	G	H	I	J
Specification	***	*	**	***	**	***	***	***	***	*
Supplier lead times	**	***	*	*	**	**	***	***	**	***
Cross-functional coordination	***	*	***	**	***	**	**	**	**	*
Production capacity	–	***	**	–	***	–	–	*	*	***
Configuration	**	–	–	–	**	–	*	*	*	*

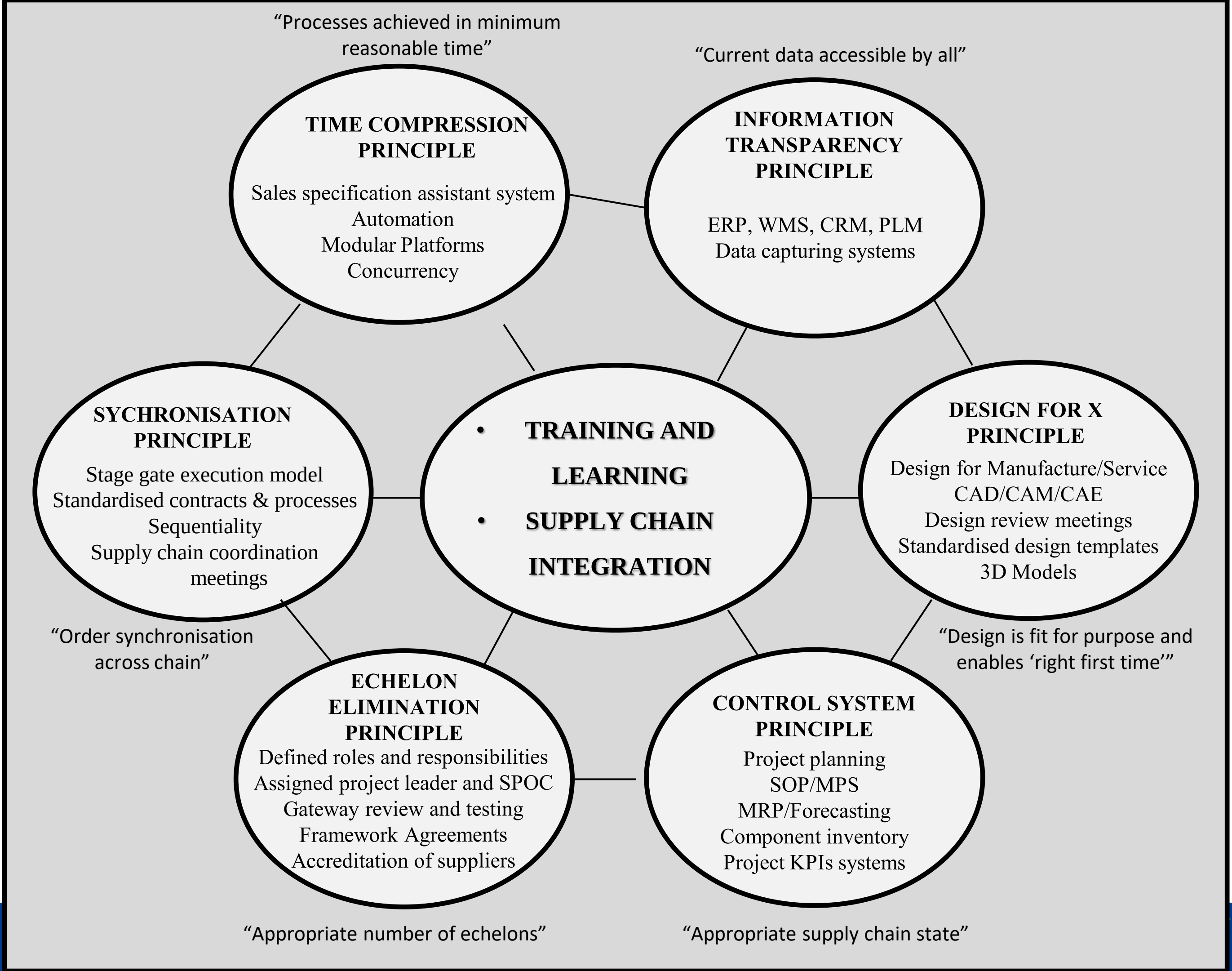
***Highly important ** Important * Less important – Not important.

ITO uncertainty sources	Cases									
	A	B	C	D	E	F	G	H	I	J
Specification	***	***	*	***	***	***	***	***	***	
Relationship management	***	**	***	***	**	**	**	**	***	
Engineering lead times	*	***	***	**	*	*	***	***	***	
Supplier lead times	**	*	*	**	*	*	*	*	**	
Product structure	**	*	**	–	*	–	*	*	*	

***Highly important ** Important * Less important – Not important.

Specification is the most important uncertainty source:
RTO: A major concern being that unclear customer requirements and technical complexity make it challenging to decide the right price on the design adjustments requested by the customer for these mature products
ITO: The high level of innovation, customisation and complexity makes it difficult to capture customer requirements and understand technological challenges at an early stage

FORRIDGE principles and the identified tactics for ship building RTO supply chains



Map principles and tactics against uncertainty sources

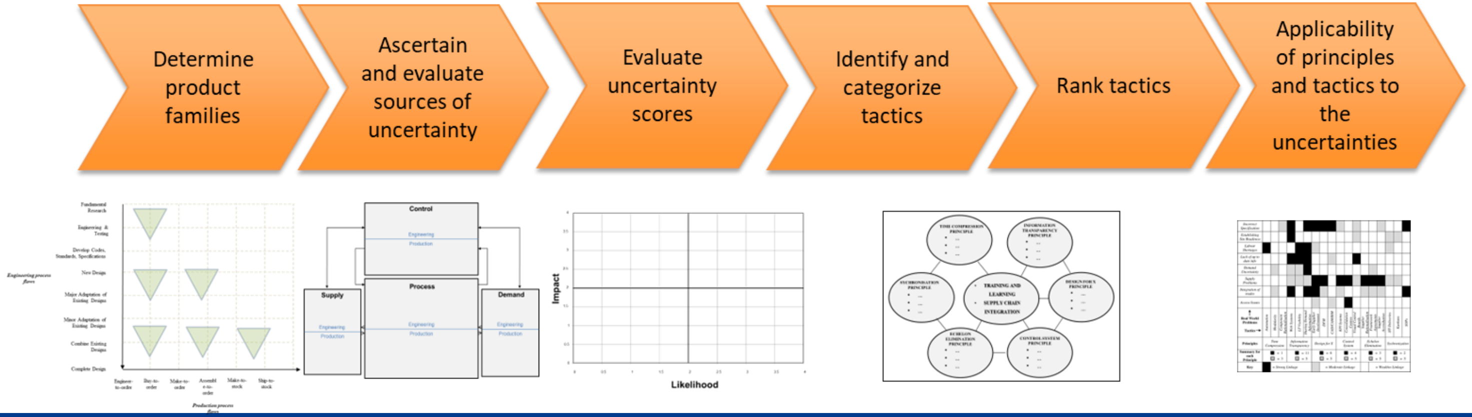
Principles	RTO tactics	Uncertainty type				
		Specification	Cross func. Coordination	Supplier lead times	Production capacity	Configuration
P1 Time compression	Product specification assistant system	■				■
	Automation				■	▒
	Modular platforms	■				■
	Component inventory			■	▒	
	Subcontracting				■	
P2 Control system	Sales & operations planning		■	▒	■	
	Material requirement planning		■	■		
	KPI systems		■			
P3 Synchronisation	Stage gate execution model		■			
	Standard contracts and procedures	■	■	▒		
	Supply chain coordination meetings		■	■	▒	
P4 Information transparency	Enterprise resource planning systems		■	▒	▒	■
	Product lifecycle management systems	■	■			■
	Forecasting		■	■	▒	
	Project planning system		■	■	▒	
P5 Echelon elimination	Defined roles and responsibilities in projects		■			
	Handover review and testing	▒	■			
	Framework agreements			■		
	Accreditation of suppliers			■		
P6 Design for X	Design for manufacturing/service	■		▒	▒	
	CAD/CAM	■				
	Product templates	■				▒

Principles	ITO tactics	Uncertainty type				
		Specification	Supply chain relation management	Engineering lead time	Supplier lead times	Product structures
P1 Time compression	Predesign analysis	■	▒	■		▒
	Agile methods			■		
P2 Control system	Centralised cross-disciplinary project team		■	■	▒	
P3 Synchronisation	Risk-sharing contracts	▒	■		■	
P4 Information transparency	Design integration events	■		■		
	Knowledge transfer between projects	▒	■	▒		
P5 Echelon elimination	Cross-disciplinary innovation events	■	■	■	▒	
P6 Design for X	Early customer and supplier involvement	■	■			▒
	Prototyping	■		■		■
	Computer-aided modelling and simulation	■		■		■

FORRIDGE	Construction Suppliers Tactics (Gosling et. al. 2015)	Ship building Suppliers – RTO Tactics	Ship building Suppliers – additional tactics for ITO
P1 Time compression	Automation Modular Platforms Component Rationalisation	Automation Modular Platforms Product specification assistant system Component inventory Subcontracting	Predesign analysis Agile methods
P2 Control system	KPI system Consolidation Centre Visual Control Boards	KPIs systems Sales & Operations Planning Material Requirement Planning	Centralised interdisciplinary project team
P3 Synchronisation	JIT deliveries Kanbans Standard procedures	Stage gate execution model Supply chain coordination meetings Standardised contracts and processes	Risk sharing contracts
P4 Information transparency	Web based project planning Lead time visibility Sharing demand Information	Project planning system ERP systems Product Lifecycle Management systems Forecasting	Design integration events Knowledge transfer between projects
P5 Echelon elimination	Supplier Rationalization Framework Agreements Accreditation of suppliers	Defined project roles and responsibilities Handover review and testing Framework Agreements Accreditation of suppliers	Cross disciplinary innovation events
P6 Design for X	Early supplier involvement Design for Manufacture/Assembly CAD/CAM/BIM	Design for Manufacturing/Service CAD/CAM Product templates	Early customer and supplier involvement Prototyping Computer-aided engineering modelling and simulation

Conclusions

- The FORRIDGE principles provide a “system based” and slightly alternative perspective to flow efficiency (did not come from Toyota, and include no Japanese words…..)
- The principles remains the same, but the tactics vary between industry sectors
- The methodology provide the means to arrange a set of structured workshops to:
  - identify product families,
  - map uncertainty sources for each family,
  - and to define the principles and tactics to improve the flow for each family



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