MASS CUSTOMIZATION OR MASS CONFUSION?
- Giving the customer the car they want

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Agenda

1. Mass Production, Mass Customization and Open pipeline systems
2. Basic simulation models of open pipeline systems
3. Analytical models of open pipeline systems
4. Simulation models of real automotive systems
5. Conclusions

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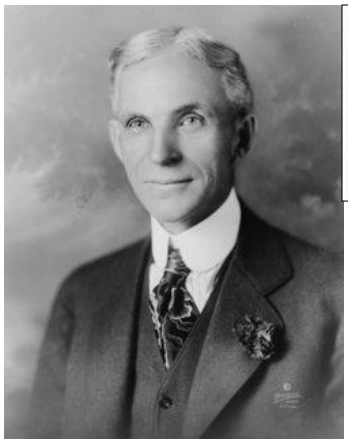
Henry Ford – a lesson in history



- Model T (1909 – 1927), originally **$850,** dropped to **$270** in 1923

"Any color the customer wants, as long as it's black." Henry Ford

By 1929 General Motors had overtaken Ford to become the leading American passenger-car manufacturer.

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Mass Customization (MC)

- **Davis (1987)**
- **Pine (1993)** - heralded as **a new paradigm!**
- Generated significant industrial and business interest but has proved **challenging!**
- The volume automotive sector became very interested

- **The production of customized products on a mass scale with mass production efficiencies**

MacCarthy et al. 2003

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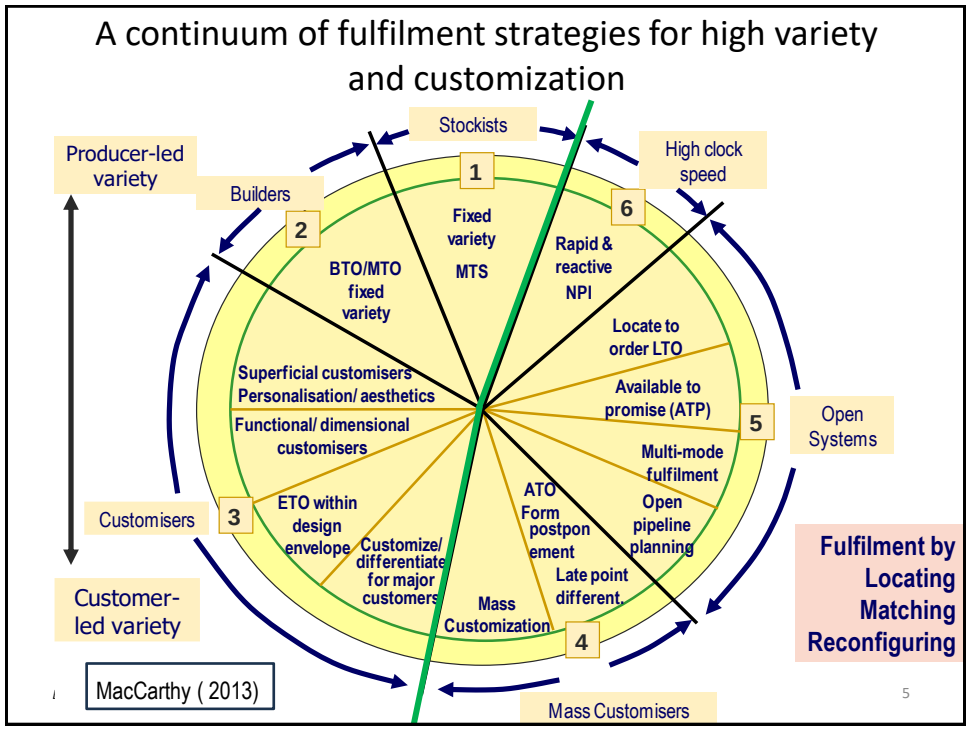

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Operational models

- Category 1 (*Stockists*)
- Category 2 (*Builders*)
- Category 3 *(Customisers)*

Traditional

- Category 4 (*Mass Customisers*)
- **Category 5 *(Open systems)**
- Category 6 *(High Clockspeed*)

Newer

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Automotive vehicle market

Body style Series Engine types Engine size Transmission

Exterior colour Interior Trim Wheel type options++++

High variety on offer - Brabazon & MacCarthy, 2012

Heterogeneous demand – different types of customer with different behaviors

Large scale systems – many modes of operation

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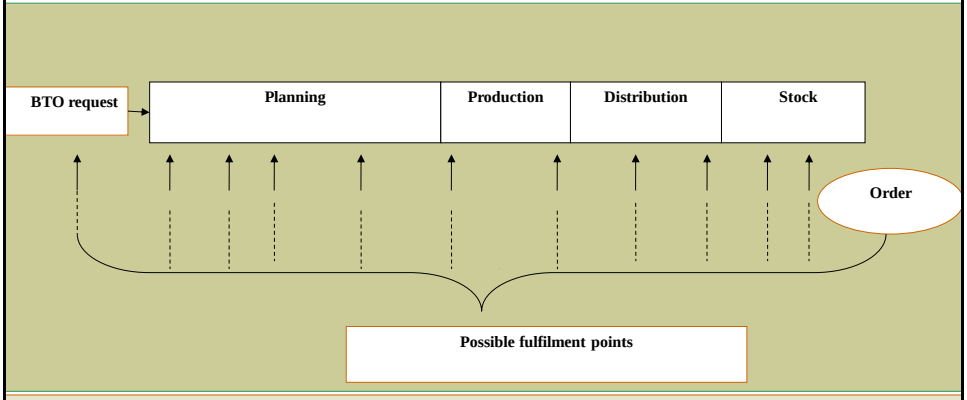
An open pipeline fulfilment system



- Generalisation of multi-mode fulfilment systems - **fulfil from anywhere in the system**
- Combines Build-to-Forecast with some or all of Stock, ATO, planning pipeline allocation & BTO- has a moving/floating decoupling point
- Introduce more flexibility – reconfigure product in the pipeline

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2. BASIC SIMULATIONS OF OPEN PIPELINE SYSTEMS

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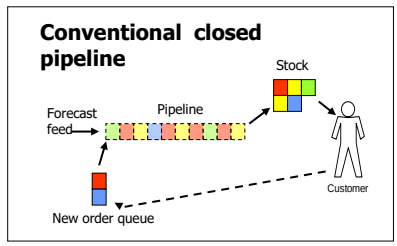
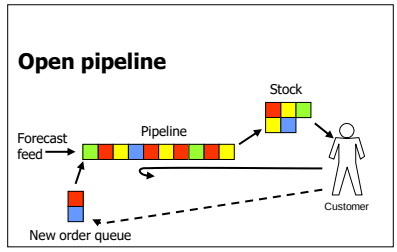
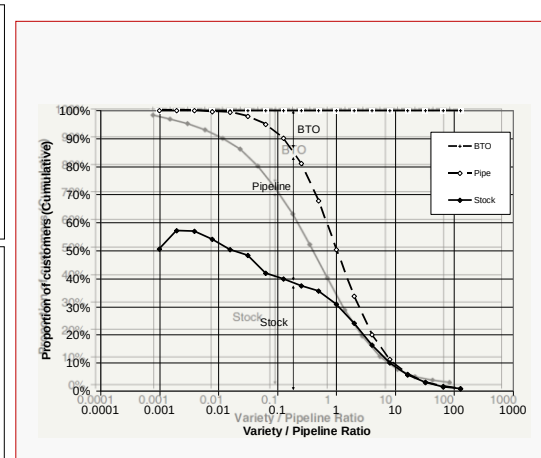
Conventional v Open system







Brabazon & MacCarthy (IJPE, 2006 – simulation)

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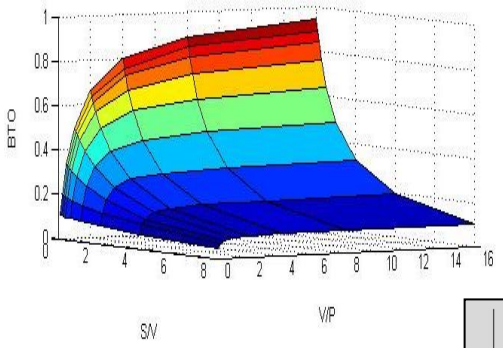
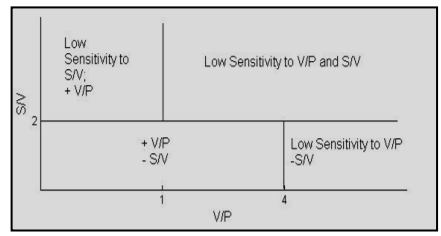


BTO % fulfilment for a range of parameter values

Summary plots showing behaviour for systems of different scale



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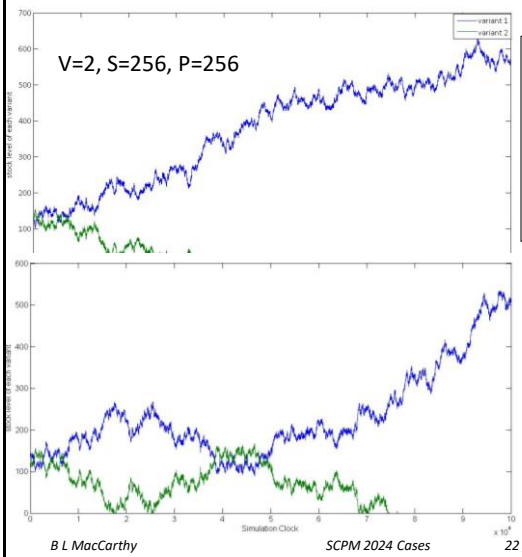
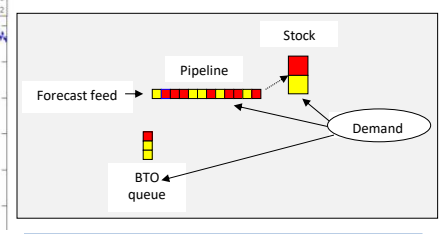
Low variety systems – counter-intuitive behaviour





- Variant out of stock
- Demand is fulfilled from pipe
- Stock not replenished- stock composition suffers
- Difficult to recover
- More likely for low variety systems

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3. ANALYTICAL MODELS OF OPEN PIPELINE SYSTEMS

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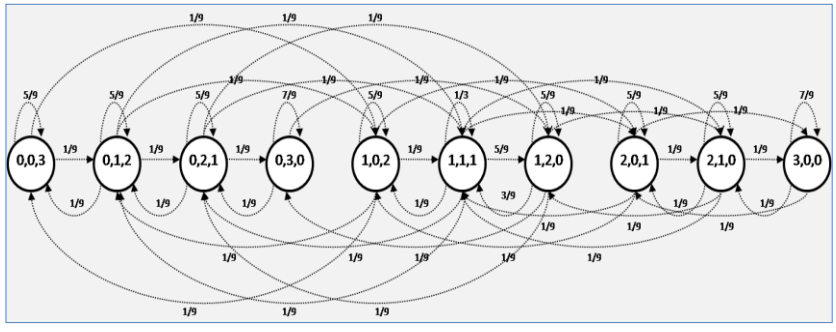
Analytical models for basic Open Pipeline systems

MacCarthy et al. (2013)

All states and transition probabilities for a system with S+P=3, V=3



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For an arbitrary system (P,V,S) under certain assumptions

V – variety level
P – pipeline length
S – initial stock level in the system

BTO % = (V-1) / (S+P+V-1) - **EXACT**

PIPE% , STOCK% , MLT, MSL - **APPROXIMATIONS**

P=2048	V/P										
S/P	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
0	2.8%	2.5%	1.8%	1.5%	0.9%	0.3%	0.0%	0.7%	0.7%	1.3%	1.2%
1/1024	2.9%	2.6%	1.4%	1.5%	0.9%	0.3%	0.1%	0.1%	0.9%	1.4%	1.2%
1/512	3.2%	2.5%	1.9%	1.5%	0.9%	0.3%	0.1%	0.6%	0.3%	1.1%	0.9%
1/256	3.0%	2.6%	1.6%	1.5%	0.9%	0.3%	0.4%	0.1%	0.7%	0.6%	1.2%
1/128	3.1%	3.2%	0.4%	1.6%	1.1%	0.6%	0.5%	0.8%	1.0%	1.1%	1.1%
1/64	2.5%	2.7%	0.8%	1.5%	0.9%	0.4%	0.4%	0.8%	0.8%	0.9%	1.0%
1/32	3.1%	3.2%	1.0%	1.7%	1.3%	0.6%	0.4%	0.4%	0.6%	1.1%	1.1%
1/16	3.1%	3.2%	2.7%	1.7%	1.5%	0.7%	0.2%	0.4%	0.7%	0.5%	1.1%
1/8	4.0%	2.9%	1.6%	1.6%	0.8%	0.5%	0.4%	0.3%	0.8%	0.1%	0.5%
1/4	3.1%	3.7%	0.7%	1.8%	2.2%	0.8%	0.7%	0.2%	0.2%	0.3%	0.4%
1/2	0.9%	2.6%	2.5%	1.9%	0.9%	1.0%	0.6%	0.9%	0.3%	0.0%	0.6%
1	1.3%	2.1%	1.9%	1.3%	2.3%	0.9%	1.2%	0.4%	0.5%	0.3%	0.9%
2	0.5%	1.4%	0.7%	0.1%	1.5%	0.2%	0.2%	1.5%	0.2%	0.6%	0.4%
4	1.7%	0.9%	1.9%	1.0%	0.7%	1.1%	0.6%	0.3%	0.7%	1.1%	0.7%

- MAPE% in pipe fulfilment - scheme works well for all **but low variety systems**

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4. SIMULATIONS OF REAL OPEN PIPELINE SYSTEMS

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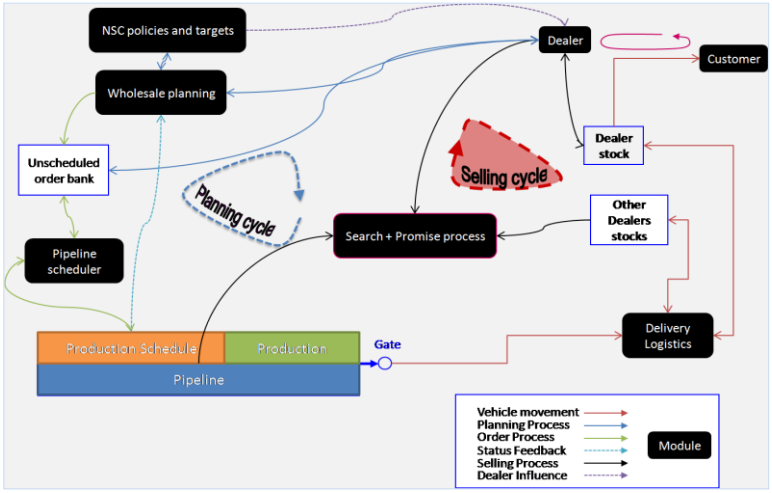
Overall view of the system being modelled



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Many studies


Omega
Investigating a long tail in retail vehicle sales


European Journal of Operational Research
The automotive Order-to-Delivery process: How should it be configured for different markets?


Int. J. Production Economics
Using a central Vehicle Holding Compound (VHC) in an open pipeline automotive order fulfilment system: A simulation study

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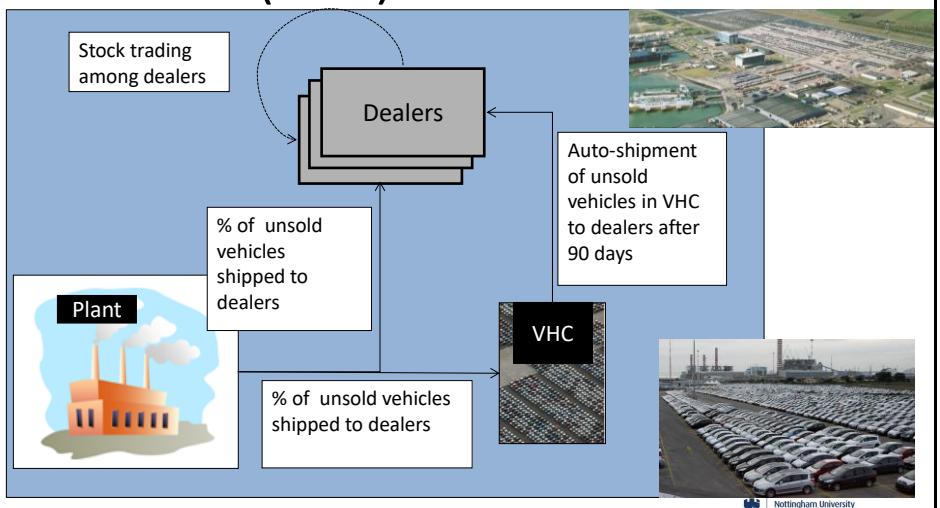
Introducing a Vehicle Holding Centre (VHC)



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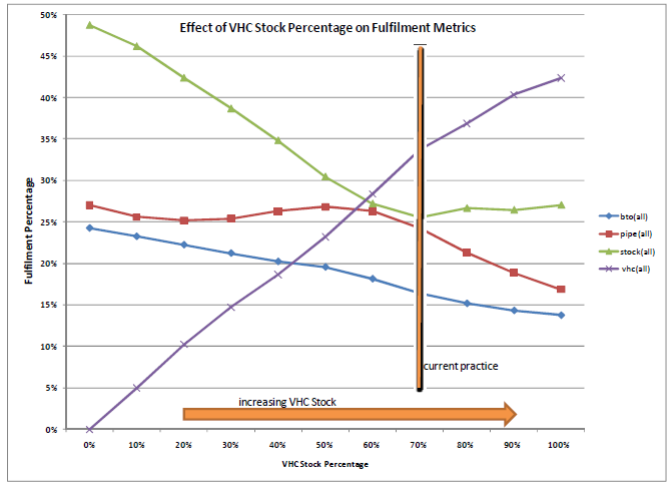
Effect of VHC/Local stock split on fulfilment modes



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Conclusions

- **Good models provide real insights** into large scale system behaviour – design, management and control
- **Simulation models are always approximations**
- **Simple models may show insights into 'global behaviour'** but can't answer specific important questions
- **Very challenging** to build, calibrate and validate a **realistic national model of this scale**
- What has happened since?

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Questions/discussion

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