Beyond Kanban: Creating and analyzing lean shop floor control policies

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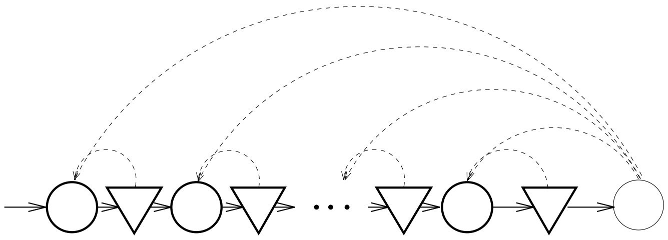
Outline

- A unified view of shop floor control policies
- Description of common policies wrt information flow
- New policies created by combining old ones
- Results from simulation comparing these policies
- New analytic tools for performance evaluation

Unified view of control policies

(Simple demand structure)

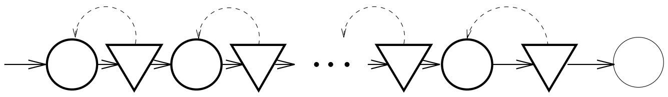


Information flow   Material flow

Two kinds of information flow:

- Local, between a buffer and an adjacent machine
- Global, from demand process to every machine

Kanban control



Information flow   Material flow

Local information flow only.
Often referred to as a "pull" policy.
Several different versions of kanban exist.
Corresponds to a reorder point system in a supply chain.

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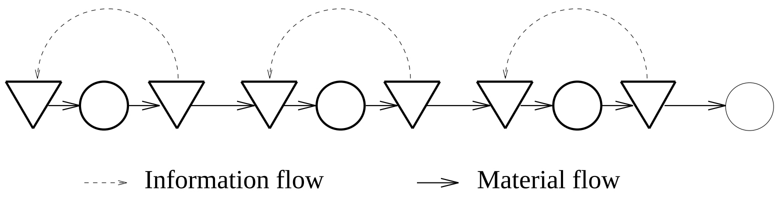
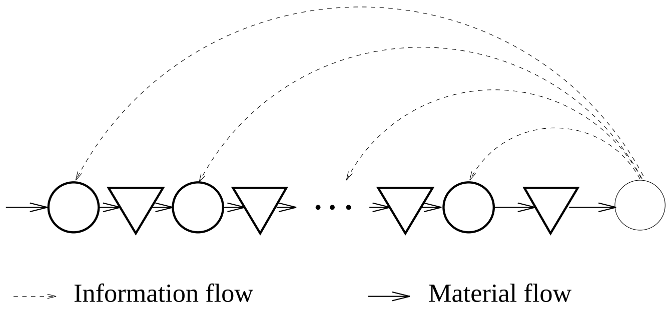
Minimal blocking control



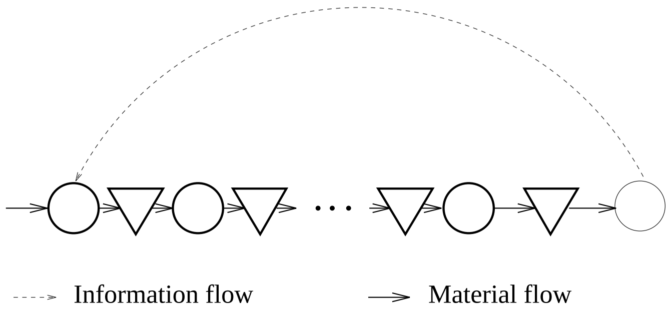
A variation of kanban, much studied in the literature.
Local information flow.
Cards (kanban) can bypass working or failed machines.
Higher throughput than traditional kanban for equal buffer sizes.
Introduced by So and Pinault (1988).

Basestock control



Global information flow only.
Work orders sent every time a demand arrives.
Will try to preserve initial buffer inventories.

CONWIP control



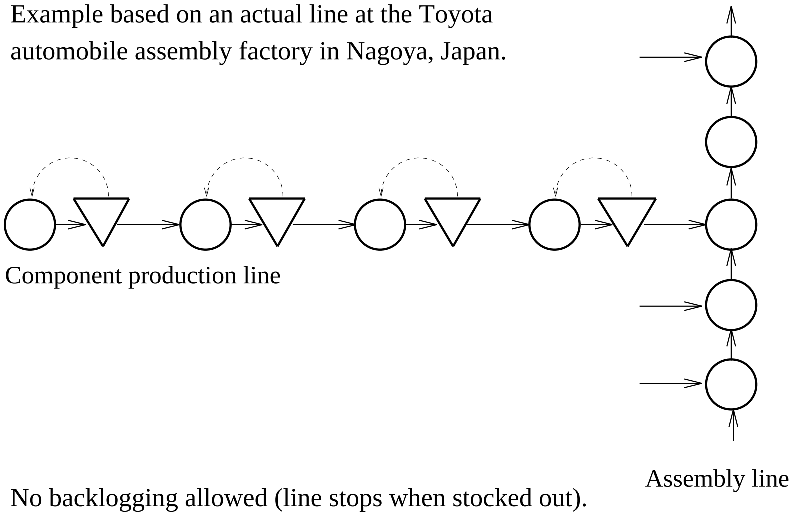
A release permission is sent every time a demand is satisfied.

Will try to maintain a constant number of jobs in progress.

Similar to a single kanban cell containing the entire line.

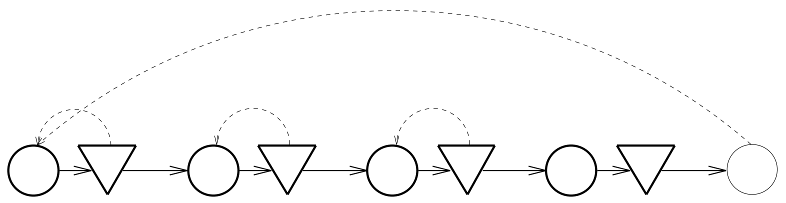
A component production line feeding final assembly

Example based on an actual line at the Toyota automobile assembly factory in Nagoya, Japan.



No backlogging allowed (line stops when stocked out).

Recommended CONWIP - kanban hybrid



Only structural change:
Pass kanban from assembly line
to the *first* machine instead of the last.

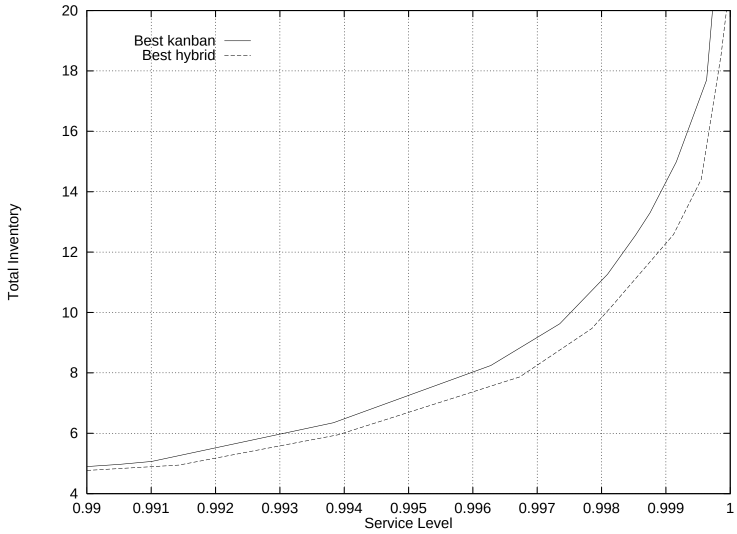
Hybrid policies do the job with the least WIP

Objective: 99.9% service with minimal WIP

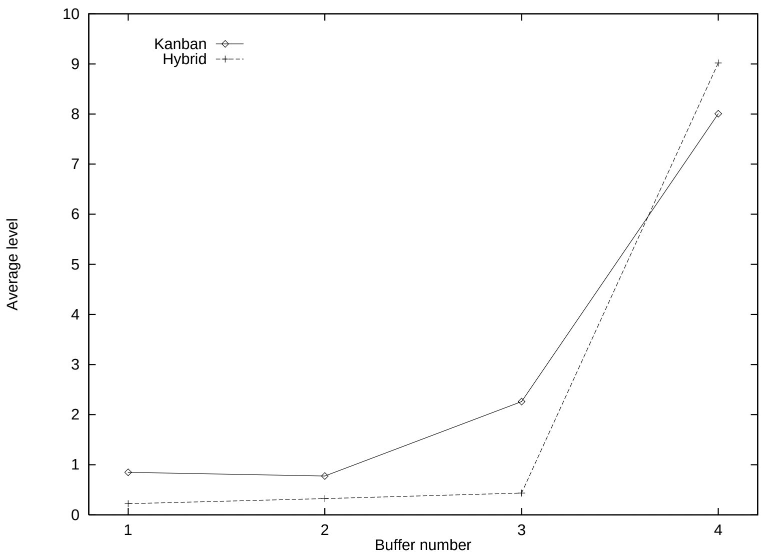
Best policy among:	WIP:
Kanban	15.82
Minimal blocking	15.62
Basestock	14.60
CONWIP	14.59
Hybrid	13.93

This is a 12% reduction in WIP with identical throughput and service.

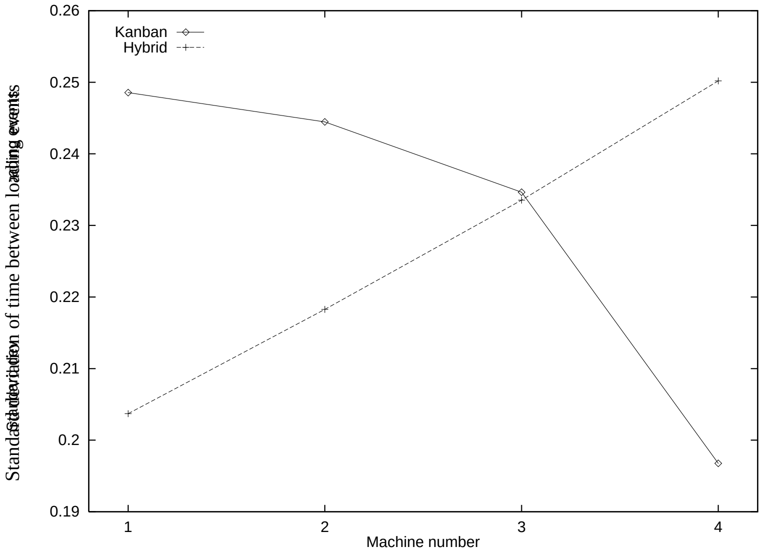
Advantage grows with required service level



Hybrid puts inventory closer to the customer



Hybrid attenuates upstream production variability



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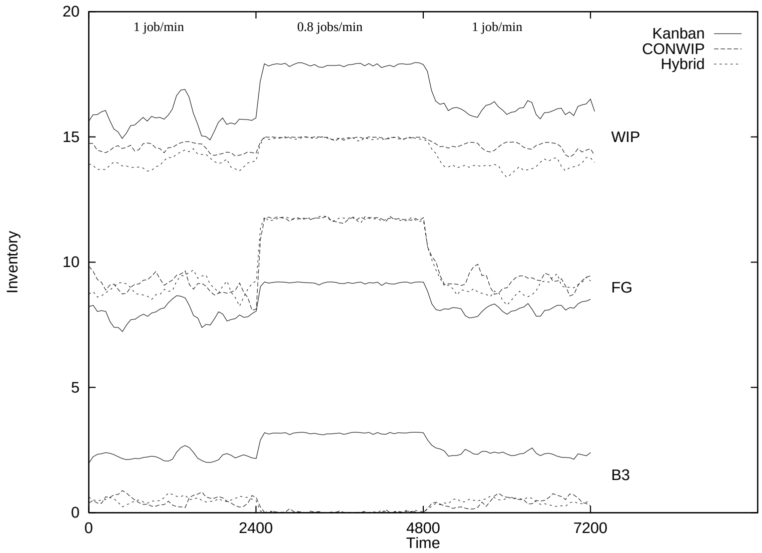
Hybrid flushes inventory when demand falls



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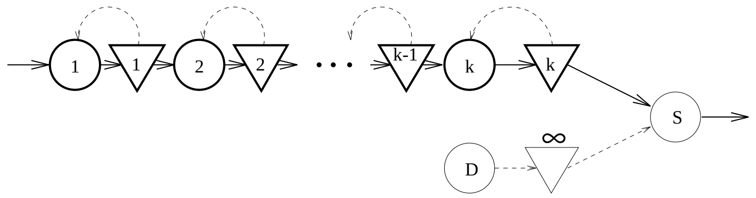
Finite buffer kanban model

(More general demand structure)



Demand structure modeled as an unreliable machine.

Allow demand to be backlogged if not satisfied from stock.

Fast and reliable synchronization ‘machine.’

The ranking is the same in different settings

10 machine line, unlimited backlogging, erratic demand process, more machine failures than in Toyota. Service req. 75% stock.

Policy	WIP
Kanban	26.4
Minimal blocking	23.8
Basestock	19.6
CONWIP	19.4
Hybrid	19.3

This is a 27% reduction in WIP with the same throughput and service.

Hybrid has less average backlog than kanban

10 machine line, unlimited backlogging, erratic demand process, more machine failures than in Toyota. Service req. 75% stock.

Policy	Avg. backlog
Kanban	4.9
Minimal blocking	3.7
Basestock	2.2
CONWIP	2.6
Hybrid	2.8

This is a 43% reduction in average backlog.

Why decomposition?

Simulations are time consuming to write and run.

Traditional queuing theoretic methods get exact solutions to very simplified systems.

We want to stay closer to important features of the system, but are willing to settle for approximate results.
(Features: Finite buffer space, machine failures and repairs.)

Time savings over simulation:

Takes seconds rather than days to run.

Makes optimization possible.

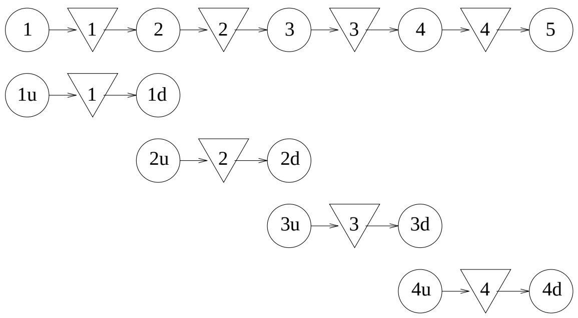
Comparison to Suri & Diehl

Same philosophy: Fast, approximate solution to realistic system.

Suri & Diehl use node decomposition, where a discrete flow of material is represented in terms of arrival and service processes in a system of multi-server queues.

We use a continuous flow of material that is interrupted by machine failures and flows through finite buffers.

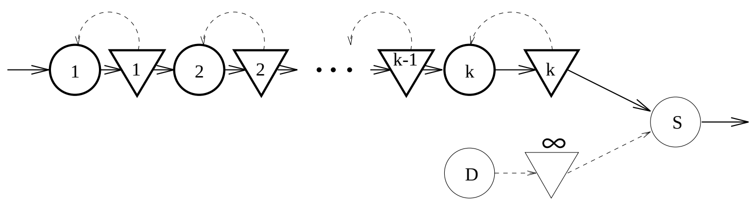
Decomposition principles



Entire line intractable for analysis.
Can analyze two-machine lines.
Focus on observed buffer behavior.
Describe line up- and downstream of a buffer by a single machine.
The parameters of these ‘virtual machines’ are unknown.
There is an efficient algorithm for finding these unknowns.

Finite buffer kanban model

(More general demand structure)



Demand structure modeled as an unreliable machine.

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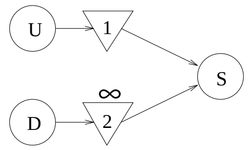
Fast and reliable synchronization ‘machine.’

Solving the synchronization stage

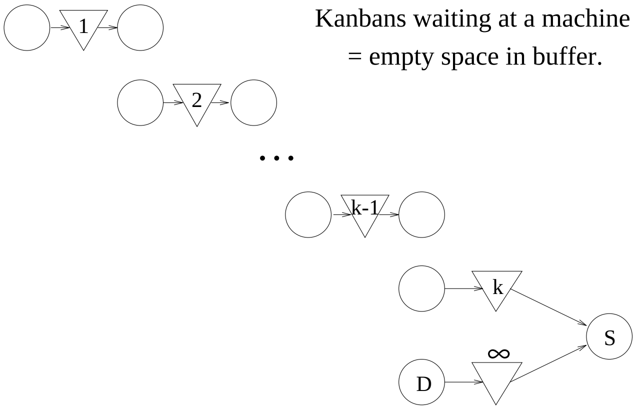


Machine U unreliable, can be up or down.
Synchronization ‘machine’ S reliable.
Demand ‘machine’ D unreliable.
Machines U and D are never starved.
Machine S is never blocked.

A continuous time, mixed state Markov process.
4 discrete states: Repair state of the two machines.
1 continuous state variable:
The level of buffer 1 - the level of buffer 2.
(buffer levels cannot be positive simultaneously)

The mathematics are the same as for a tandem 2-machine line!!!
(but we need to calculate a few extra integrals when it is solved.)

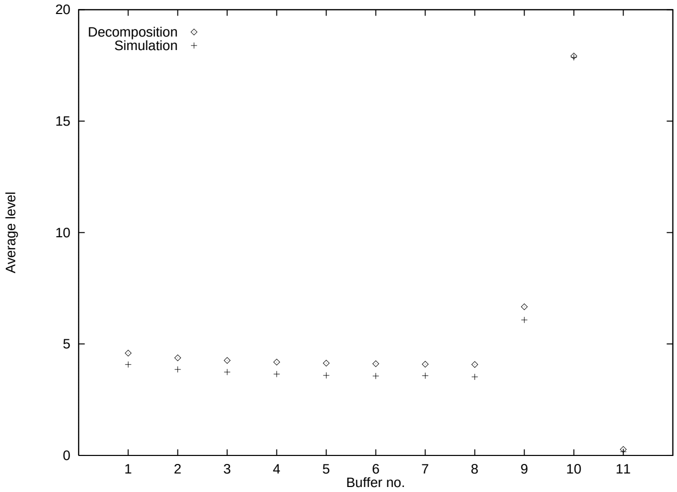
Finite buffer kanban model decomposed



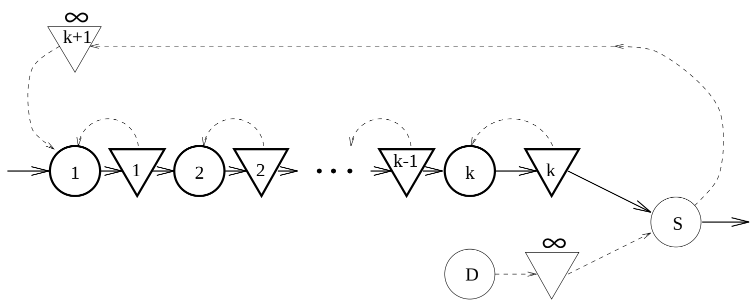
Kanbans waiting at a machine
= empty space in buffer.

Can be solved by the same algorithm as a tandem line, just using a single building block that is different.

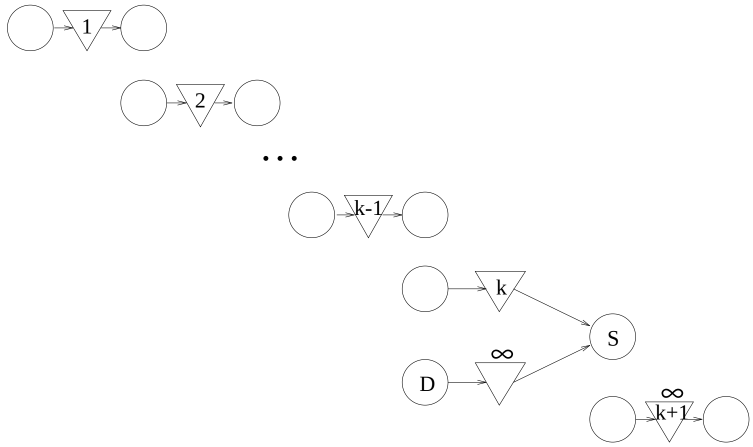
Buffer level estimates are accurate



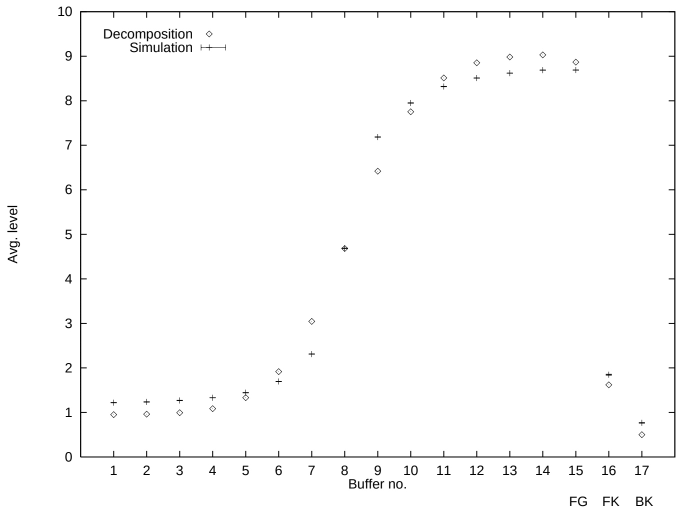
CONWIP/finite buffer hybrid



CONWIP/finite buffer hybrid system decomposed



Buffer level estimates are accurate for long lines



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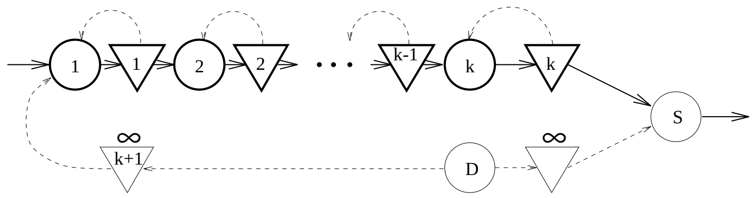
Basestock/finite buffer hybrid



First machine is notified when demand arrives.

Restriction: All base stock levels zero, except for finished goods.

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Conclusions

We have found a useful framework for describing and comparing shop floor control policies.

Within this framework, we have found hybrid policies that clearly outperform state-of-the-art kanban control.

We are in the process of constructing fast algorithms for estimating key performance measures of these policies.

This will eventually allow factory designers to optimize the equipment selection and the operating policies of the plant simultaneously.