Exam Revisit (I)

- Diagonal term vs. Off-diagonal term

- Matrix rearrangement

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} X & O & X & O \\ X & X & X & O \\ O & O & X & O \\ O & X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix}$$

Exam Revisit (II)

- Allowable tolerance / Probability of Success

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{Bmatrix} 2 \\ 1 \\ 3 \end{Bmatrix} = \begin{bmatrix} 1 & 2 & 0 & 2 & 2 & 0 \\ 0.5 & 1 & 0 & 0 & 1 & 0 \\ 0.1 & 0.2 & 0 & 0 & 3 & 0.5 \end{bmatrix} \begin{Bmatrix} DPa \\ DPb \\ DPc \\ DPd \\ DPe \\ DPf \end{Bmatrix}$$

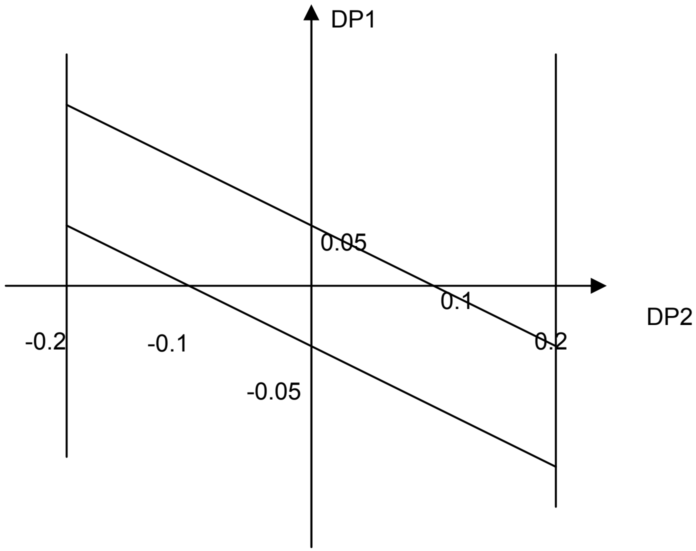
$$\begin{Bmatrix} FR2 \\ FR1 \\ FR3 \end{Bmatrix} = \begin{Bmatrix} 2 \\ 1 \\ 3 \end{Bmatrix} = \begin{bmatrix} 0.5 & 0 & 0 \\ 1 & 2 & 0 \\ 0.1 & 0 & 0.5 \end{bmatrix} \begin{Bmatrix} DPa \\ DPd \\ DPf \end{Bmatrix}$$

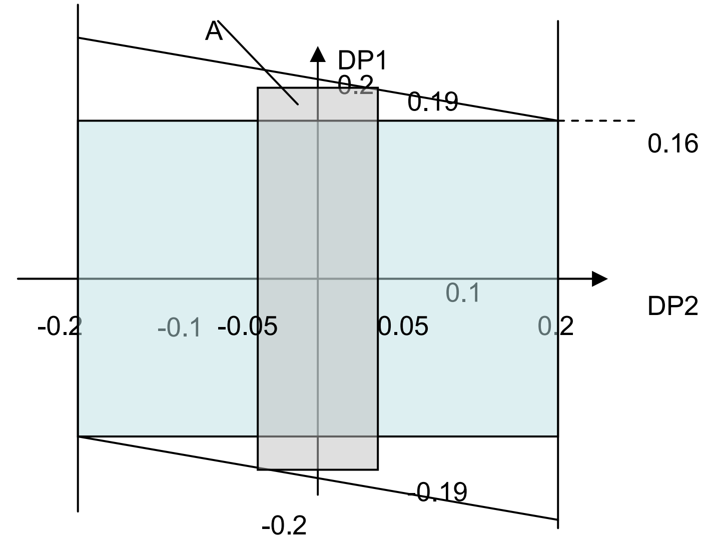
$$\Delta DP2^{+} = 2\Delta FR2^{+} = 0.2$$

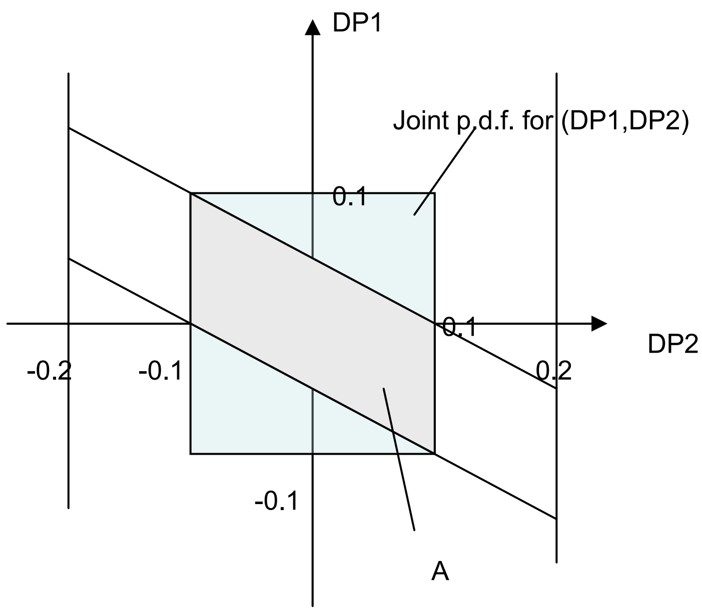
$$\Delta DP1^{+} = -0.5\Delta DP2^{+} + 0.5\Delta FR1^{+} = -0.05$$

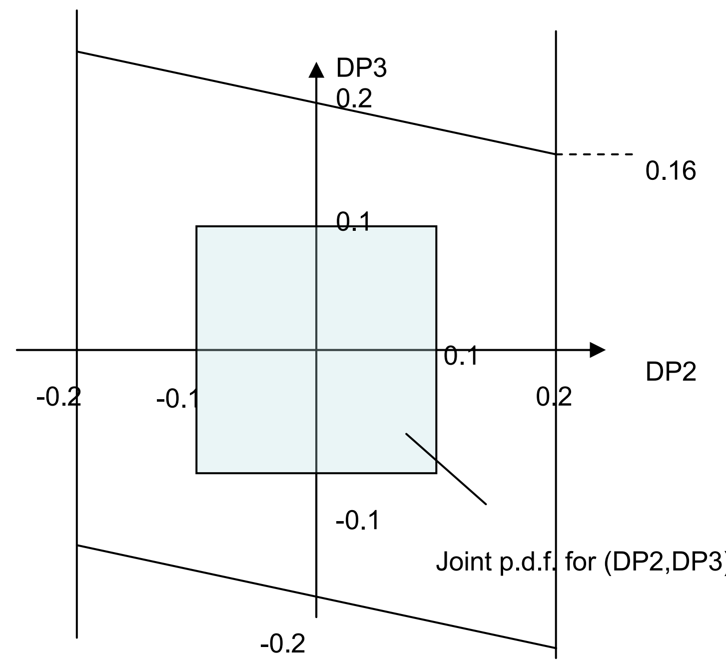
$$\Delta DP3 = -0.2\Delta DP2 + 2\Delta FR3 = 0.16$$

Exam Revisit (III)









Design of Manufacturing Systems

- What is a manufacturing system?

Photo removed for copyright reasons.

Photo removed for copyright reasons.

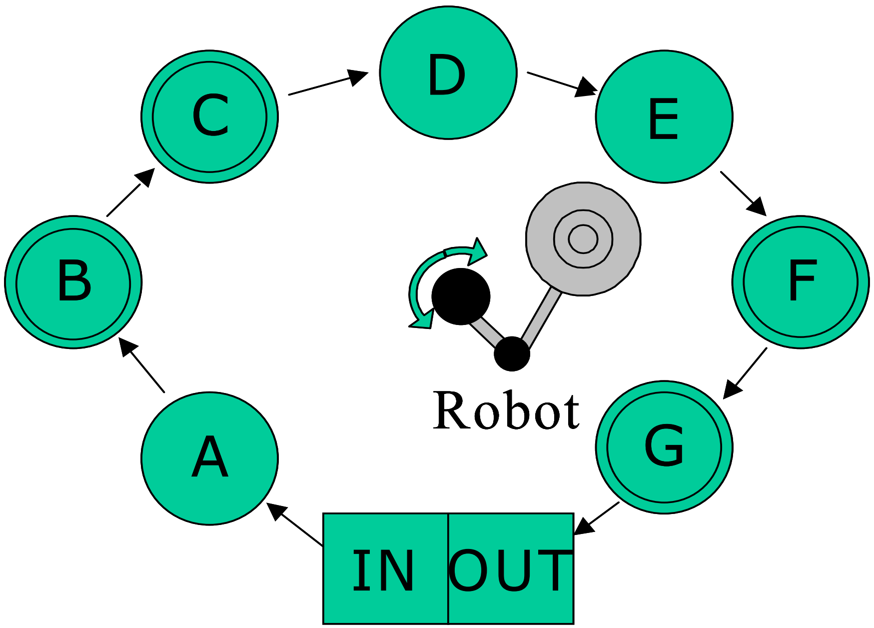
1910… Ford Motor Company

2010… Semiconductor Fab

Design of fixed manufacturing systems for discrete identical parts

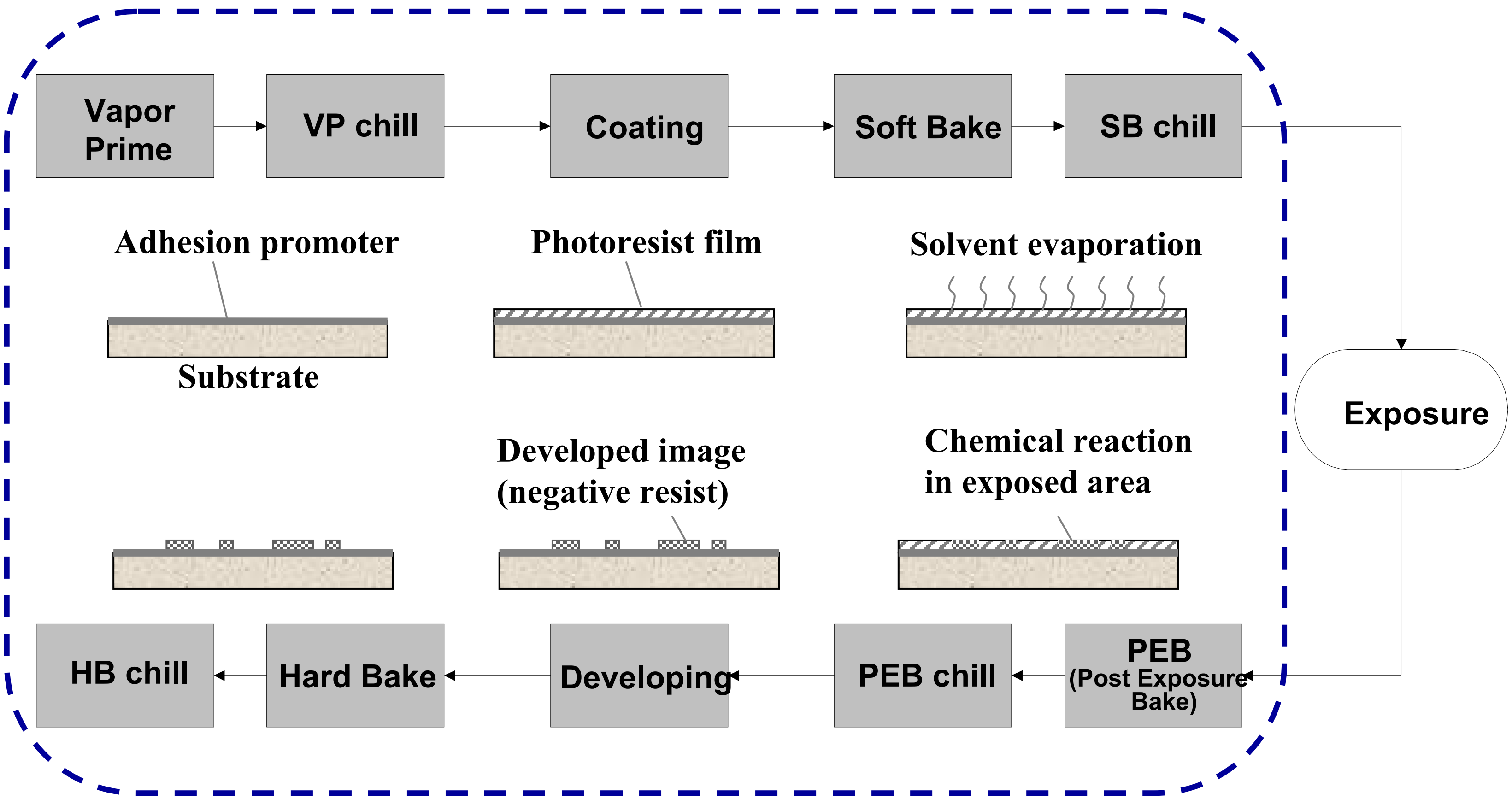
Small Scale Problems

I. Simple deterministic scheduling problem



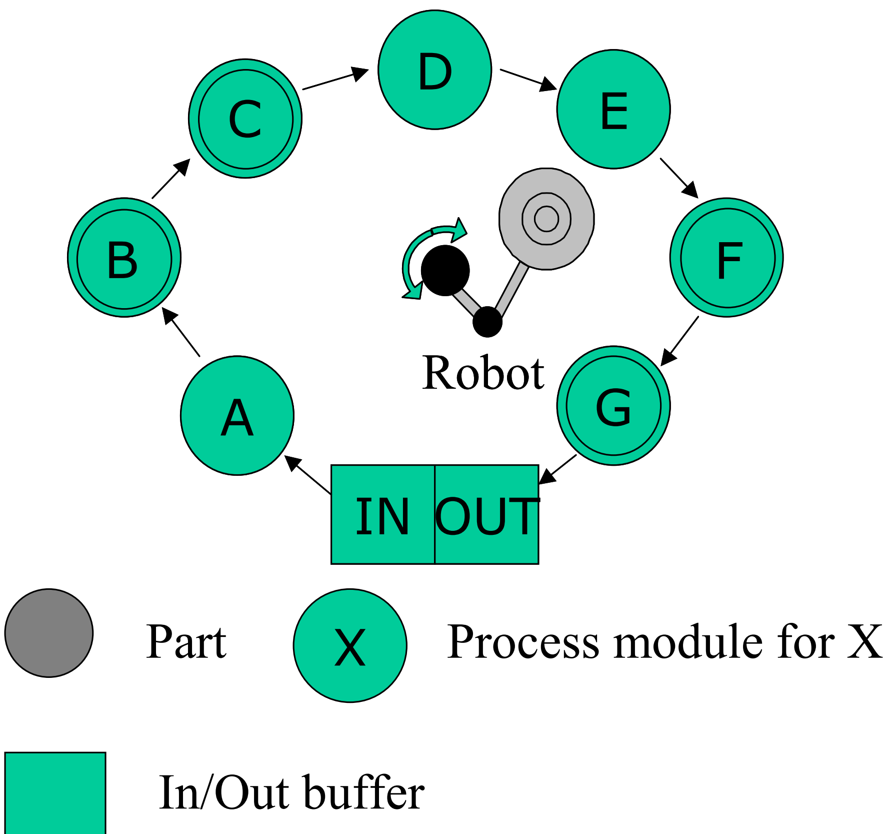
Design a manufacturing system to eliminate the root cause of a problem (symptom)

Photoresist processing



Deterministic scheduling problem

Machine diagram removed for copyright reasons.



Process	Time (sec)	# of modules
A	40	2
B	20	1
C	17	1
D	60	2
E	15	1
F	40	2
G	35	2

Level 1

	FRs	DPs
#.1	Perform process steps with desirable quality	Process modules
#.2	Satisfy process flow and throughput	System configuration

$$\begin{bmatrix} FR1 \\ FR2 \end{bmatrix} = \begin{bmatrix} X & \boldsymbol{X} \\ X & X \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \end{bmatrix}$$

Level 2

	FRs	DPs
#.1	Manage the recipe	Recipe handling module
#.2	Support the system physically	System layout
#.3	Move wafer when process is over	Transport system

$$\begin{bmatrix} FR2.1 \\ FR2.2 \\ FR2.3 \end{bmatrix} = \begin{bmatrix} X & O & O \\ O & X & \boldsymbol{X} \\ X & \boldsymbol{X} & X \end{bmatrix} \begin{bmatrix} DP2.1 \\ DP2.2 \\ DP2.3 \end{bmatrix}$$

Level 3 - Sub FRs/DPs of FR2.1

	FRs	DPs
#.1	Keep $TAKT_{process}$ below $TAKT_{system}$	Number of each process module
#.2	Maintain # of moves by main robot not to degrade target throughput	Number of IBTA
#.3	Locate process modules into 200-APS frame	Layout (module arrangement)

$$\begin{bmatrix} FR2.2.1 \\ FR2.2.2 \\ FR2.2.3 \end{bmatrix} = \begin{bmatrix} X & O & O \\ O & X & \boldsymbol{X} \\ X & \boldsymbol{X} & X \end{bmatrix} \begin{bmatrix} DP2.2.1 \\ DP2.2.2 \\ DP2.2.3 \end{bmatrix}$$

Level 3 - Sub FRs/DPs of FR2.2

	FRs	DPs)
#.1	Coordinate transport function	Command and control algorithm
#.2	Move wafer from CES to VP	CES handler
#.3	From VP to VPC	IBTA
#.4	From VPC to CT	Central handler
	⋮	⋮
#.	From HB to HBC	Central handler
#.	From HBC to CES	SI handler

* Design matrix depends on a process plan and selection of DPs.

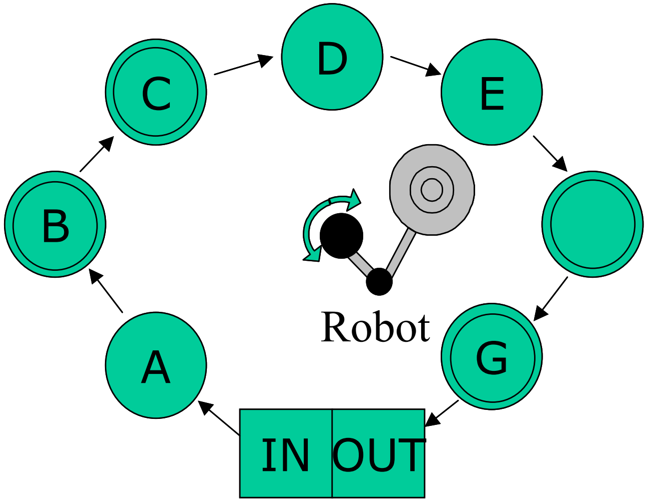
- FR1: move wafer from process 1 to 2
- FR2: move wafer from process 2 to 3
- :
- FR5: move wafer from process 5 to 6

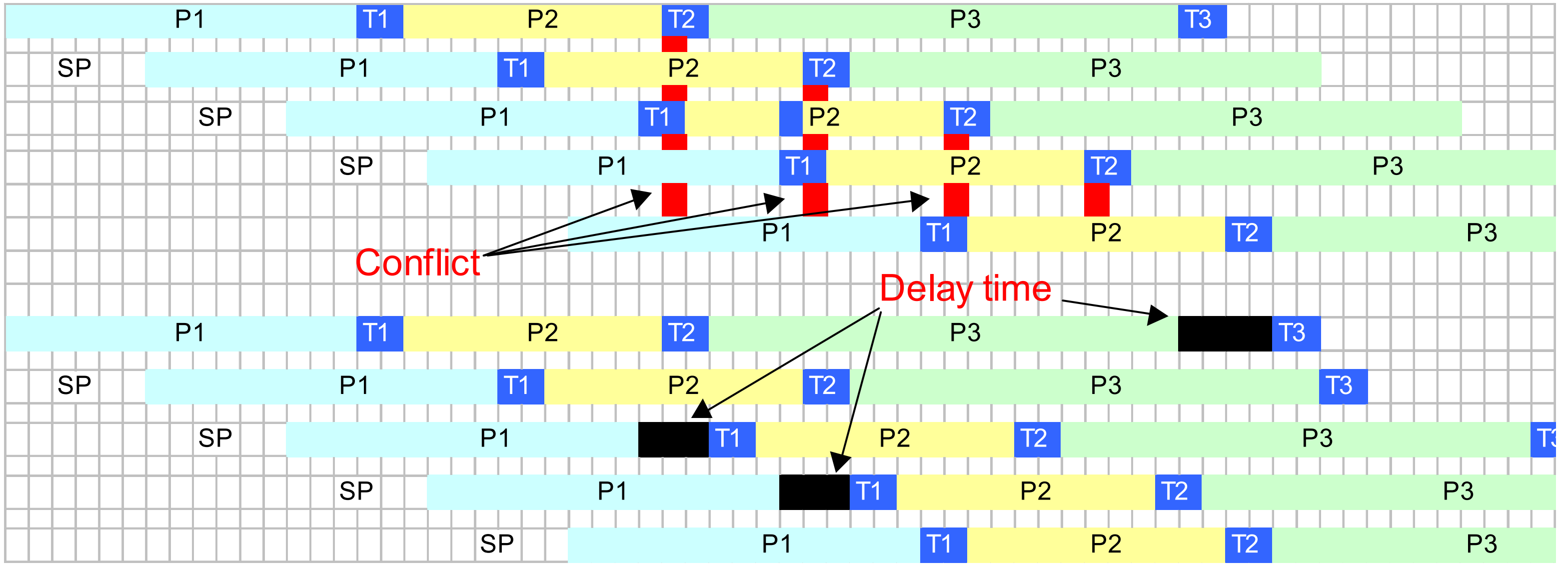
- DP1: robot 1
- DP2: robot 2

- t = 0 FR = {FR1} DP = {DP1}
- t = t1 FR = {FR4} DP = {DP2}
- ***t = t2 FR = {FR2, FR3, FR5} DP = {DP1, DP2}***

Coupling due to an insufficient number of DPs

- Problem definition
  - Conflict : more than one modules competing for a robot
  - The conflicts make the waiting time of wafers inconsistent, which degrades *on-wafer result variation*.





Example : Process timing diagram with a sending period(6 unit)

Deterministic scheduling problem

$$t_i = \sum_{j=1}^{i} P_j + \sum_{j=0}^{i-1} MvPk_j + \sum_{j=1}^{i} MvPl_j + n \cdot SP, \quad n = 0,1,2,\ldots$$

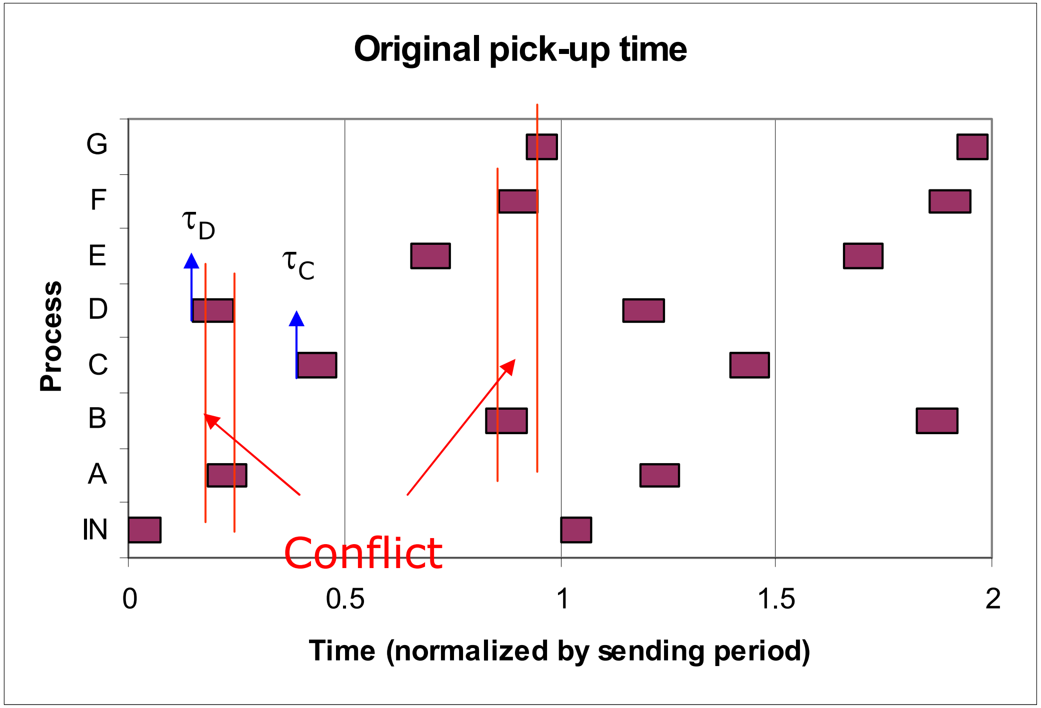
Dividing both sides by its SP yields

$$t_i' = \sum_{j=1}^{i} P_j' + \sum_{j=0}^{i-1} MvPk_j' + \sum_{j=1}^{i} MvPl_j' + n, \quad n = 0,1,2,\ldots$$

Taking only the decimal,

$$\tau_i = t_i' - \mathrm{int}(t_i')$$

τ_i indicates the (normalized) moment of i^{th} transport task within a period



Solution

- Basic concept
  - Break the conflicts among number of transport requests from process modules
  - Use predetermined “queue” as a decoupler between process and transport
  - Insert optimum queue at possible process steps

$$t_i^* = \sum_{j=1}^{i} P_j + \sum_{j=0}^{i-1} MvPk_j + \sum_{j=1}^{i} MvPl_j + n \cdot SP + \sum_{j=1}^{i} q_j, \quad n = 0,1,2,\ldots$$

Solution

Condition for no-conflict:

$$\tilde{t}_{\max} \le \left| \tau_i^{\,*} - \tau_j^{\,*} \right| \le 1 - \tilde{t}_{\max} \quad \text{for } i = 1,2,\cdots, N \,;\, j = 1,2,\ldots,(i-1)$$

Where

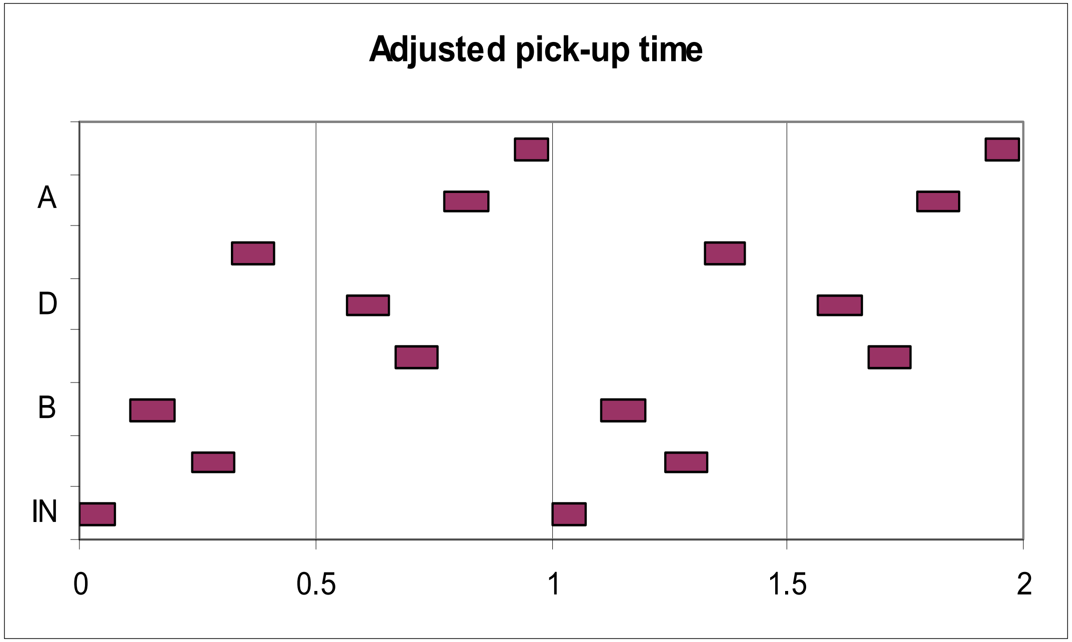
$$\tau_i^{\,*} - \tau_j^{\,*} = \tau_i - \tau_j + \sum_{k=1}^{i} q_k{}' - \sum_{k=1}^{j} q_k{}' = \tau_i - \tau_j + \sum_{k=1}^{N} (a_{ik} - a_{jk}) \cdot q_k^{'}$$

$\tilde{t}_{\max}$: longest transport time

Optimize values of q_k along with sending period, subject to no-conflict condition and process constraint ($q_{critical}$ = 0 sec)

$$\min \sum_{j=1}^{N} q_j^{'}$$

Solution



Process	Time (sec)	Delay (sec)
A	40	**2**
B	20	**8**
C	17	**0**
D	60	**5**
E	15	**9**
A’	40	**9**
F	35	**3**

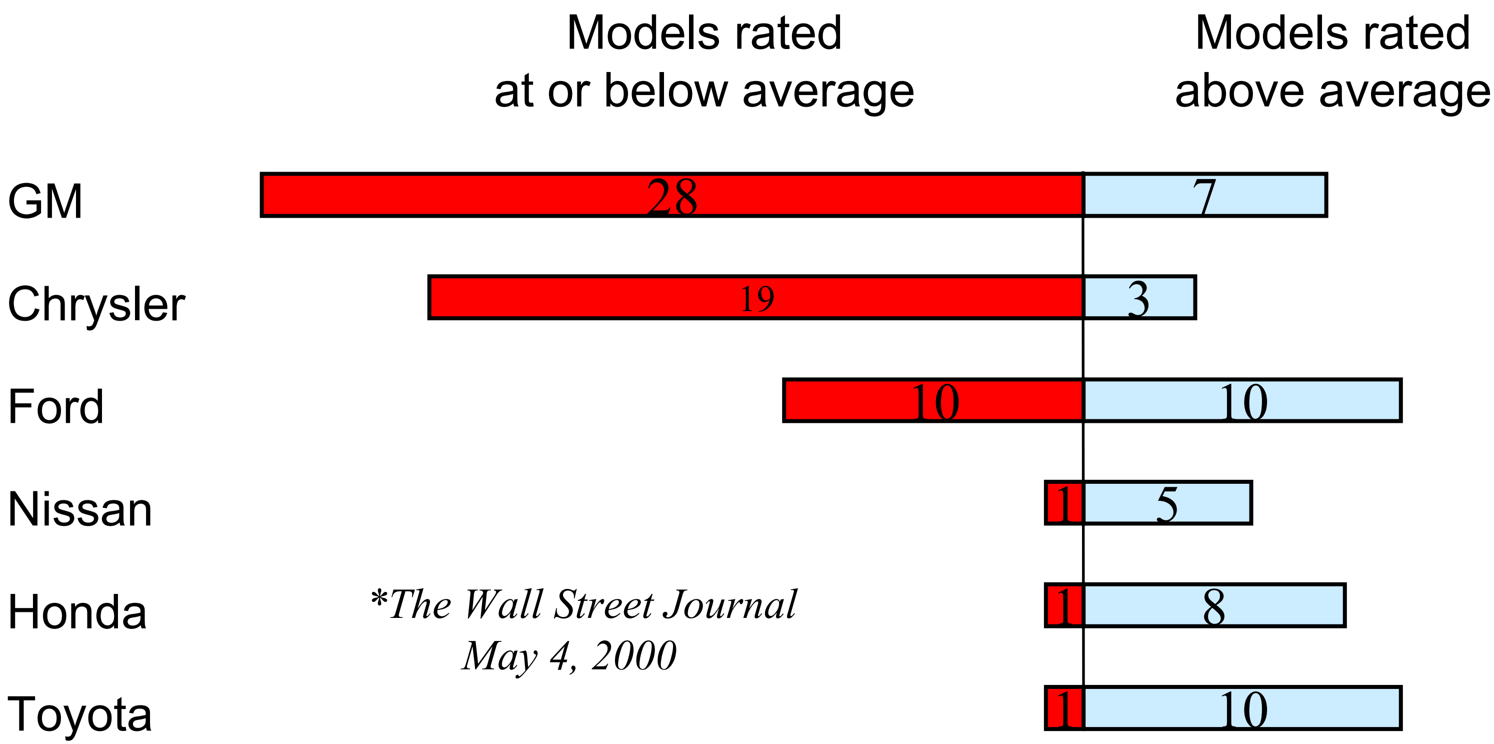
Transforming a potentially combinatorial complexity problem to a periodic problem

Solution is obtained for one (and repeating) period

Manufacturing Systems Design

Large Scale Problems

Customer's view on Toyota products



The Wall Street Journal May 4, 2000

- World's No.2 Automaker
- $12B profit (2003)
- No1. JD Power Initial Quality Prize
- Market capitalization of Toyota ($104B) > GM ($24B) + Ford ($23B) + DC ($37B) (2003.11.1)

TPS / Lean manufacturing system

Set of 19 slides removed for copyright reasons.
Source: Production System Design presentation by Dr. David Cochran

Conclusion

Cartoon removed for copyright reasons.