Cellular Automaton Modeling of CFRP Component Production for Airframes

By Tetsuya Morimoto[1)]

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1)morimoto.tetsuya@jaxa.jp

Contents

1. Introduction:
   CFRP Airframe - Experimental / Mass Production
2. Cell Automaton:
   Lean Production - CFRP Components
3. Stagnation:
   Production Troubles in CFRP Components
4. Discussions
5. Concluding Remarks

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Carbon Fiber Reinforced Plastics (CFRPs)

Experimental: Good!





Vacuum Assisted Resin Transfer Molding (VaRTM) CFRP Models: Experimental

CFRP Components : Supply Chain

Supply Chain
(Upper Stream)

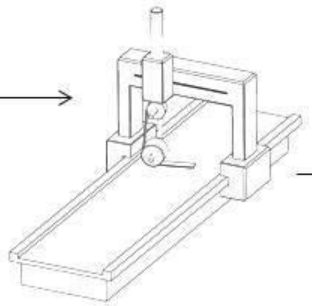






Prepreg Rolls: Cold Storage

Prepreg Rolls: Warm Up
(Tackness Recovery)

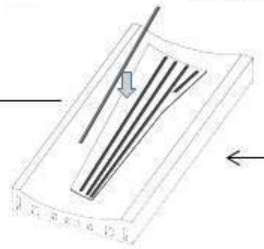


Layup Machine: Setup/Operation

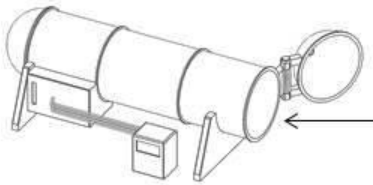


Green Body / Inventory

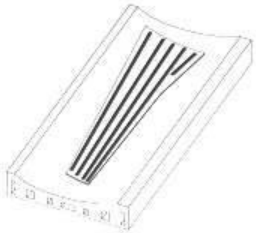
Setup: Vacuum Bag/Linkage



Co-Bond



Autoclave:Cure



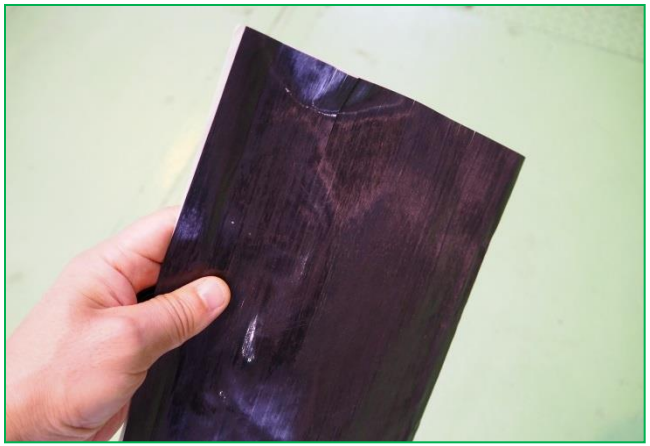
CFRP Component

Supply Chain
(Lower Stream)





CFRP Prepreg・・・



Carbon Fibers

+ Resin

Shelf Life

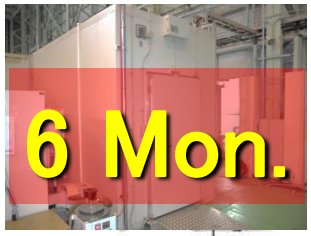
・－18℃：6 Months

・Room Temperature：2 Weeks

CFRP Components : Supply Chain

Supply Chain
(Upper Stream)



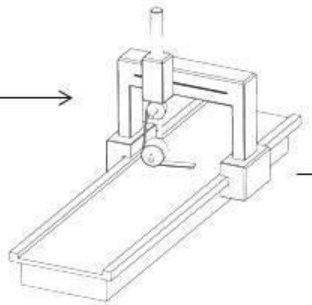




Prepreg Rolls: Col

Prepreg Rolls: W Up
(Tacknes

2 weeks

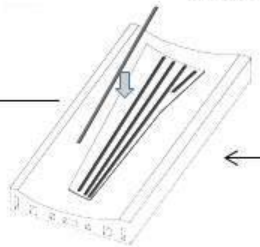


La Machine: Setup/Operation

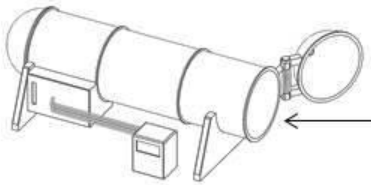


Green Body / Inventory

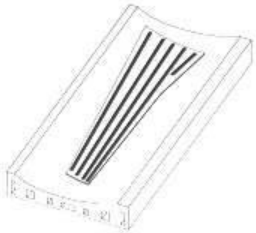
Se p: Vacuum Bag/Linkage



Co-Bond



Autoclave:Cure



CFRP Component

Supply Chain
(Lower Stream)





Carbon Fiber Reinforced Plastics (CFRPs)

Experimental: Good!

Mass Production ・・・?

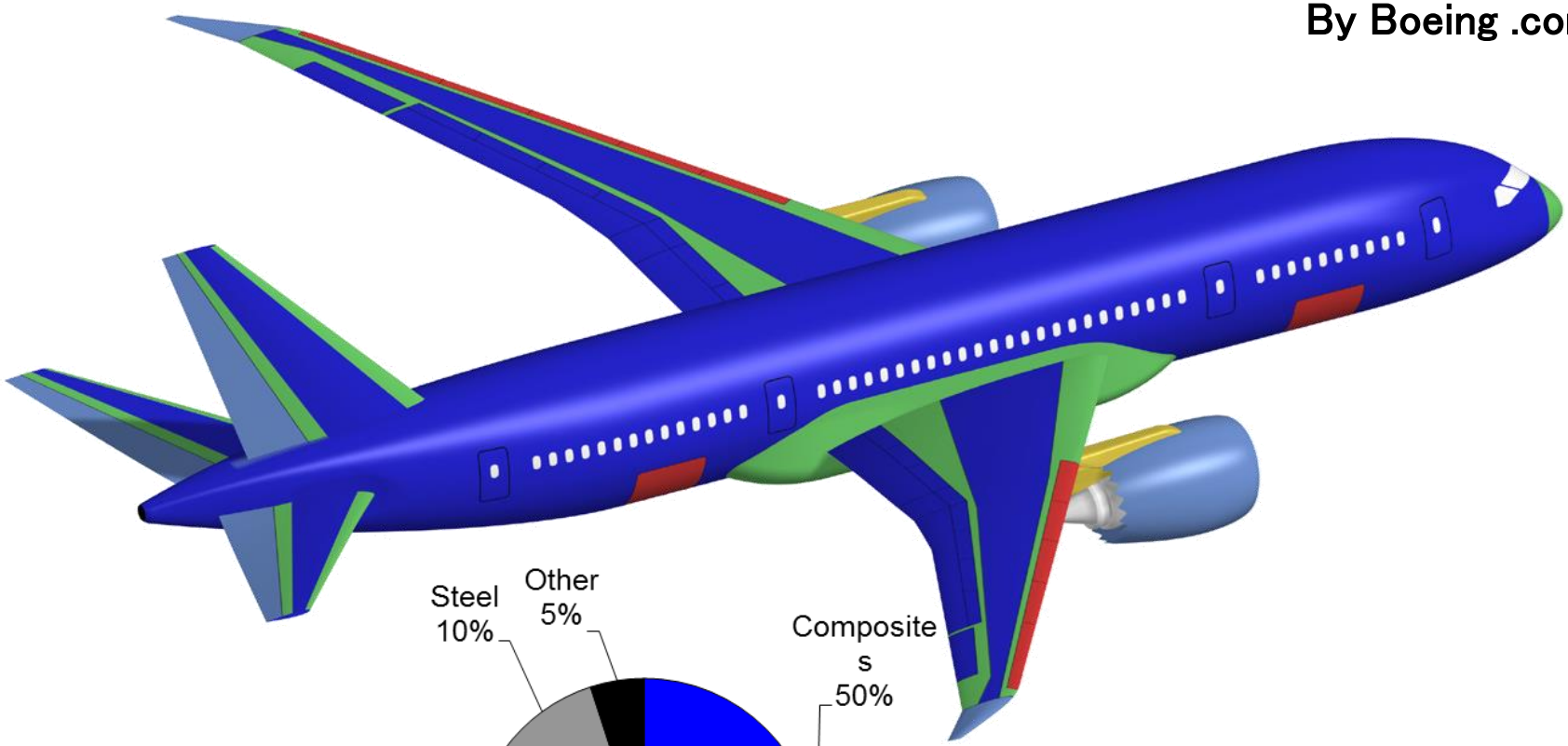


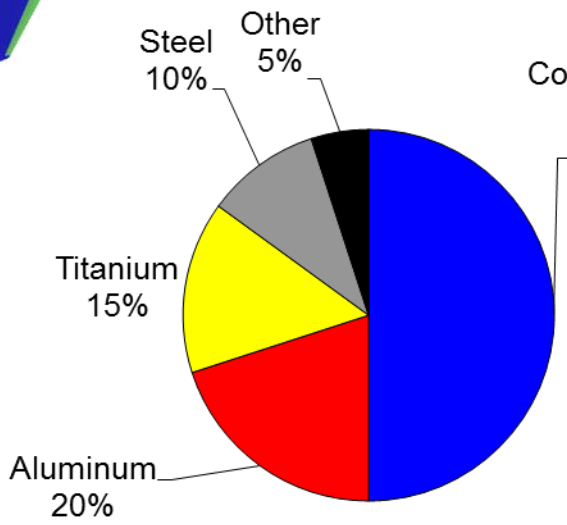


Vacuum Assisted Resin Transfer Molding (VaRTM) CFRP Models: Experimental

Boeing 787: Structural Materials

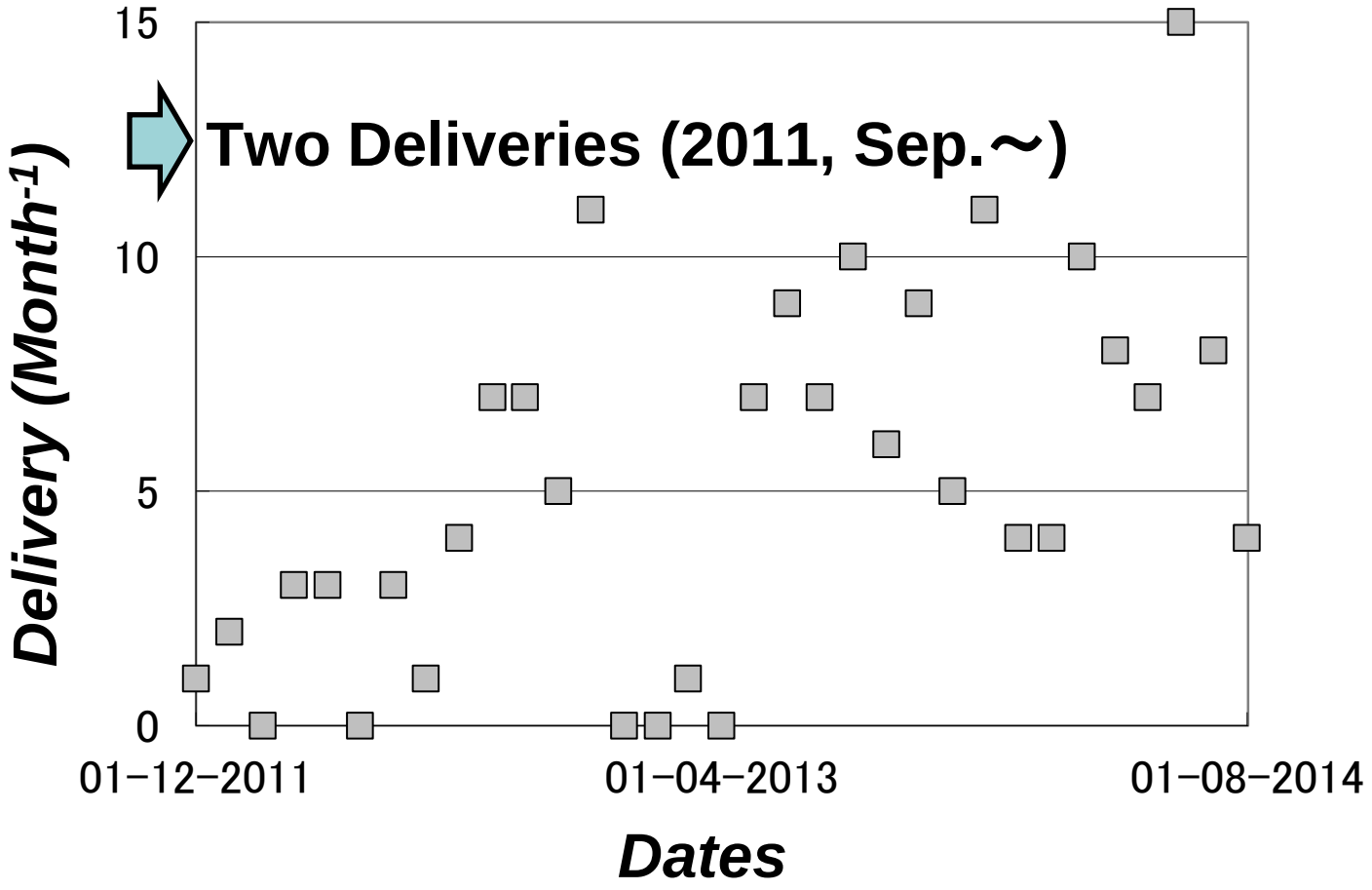
By Boeing .com





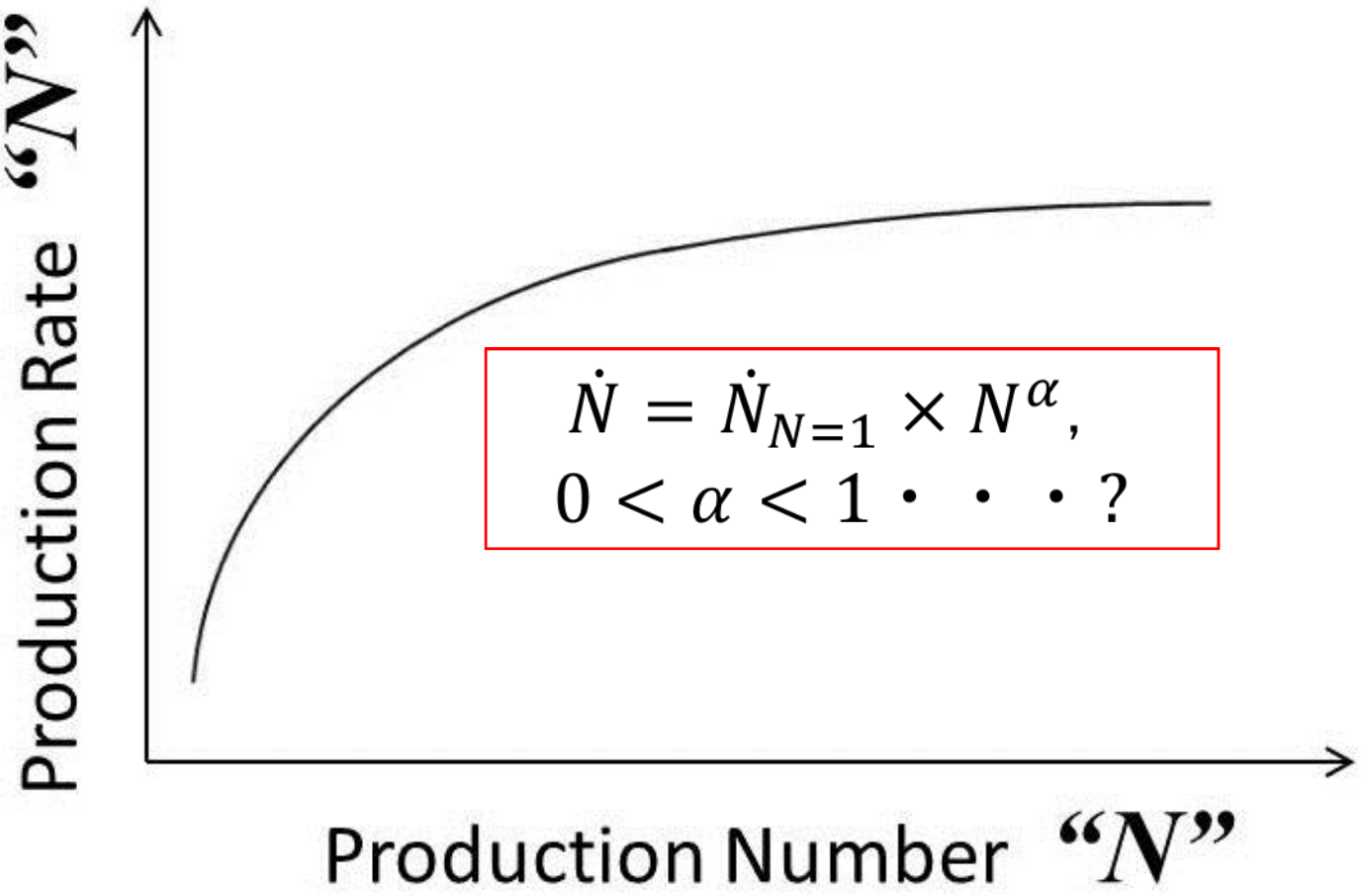
CFRPs: ～50%

2016:Target→14/Mon.

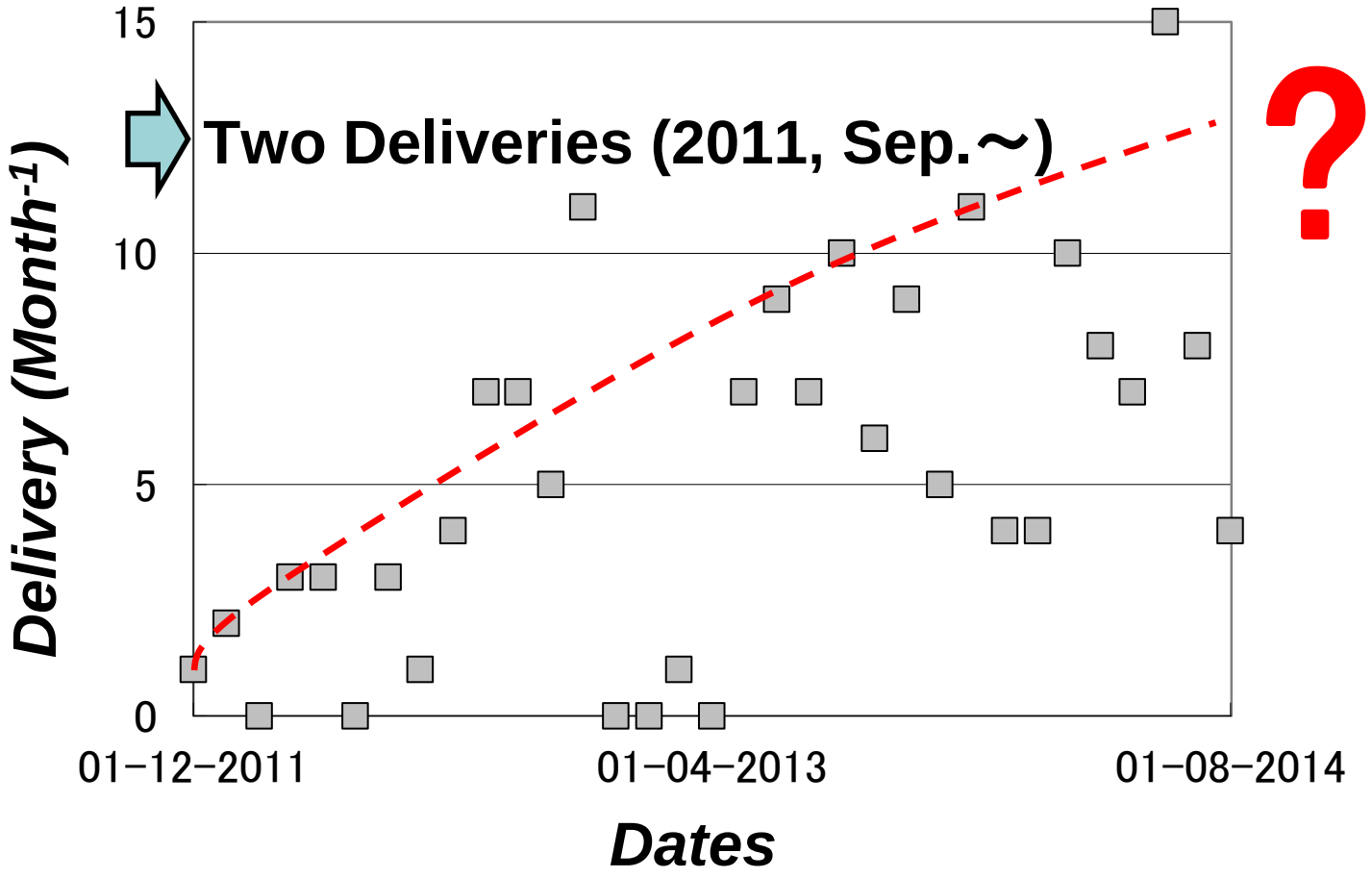


Monthly Delivery of Boeing 787

Learning Curve – ?

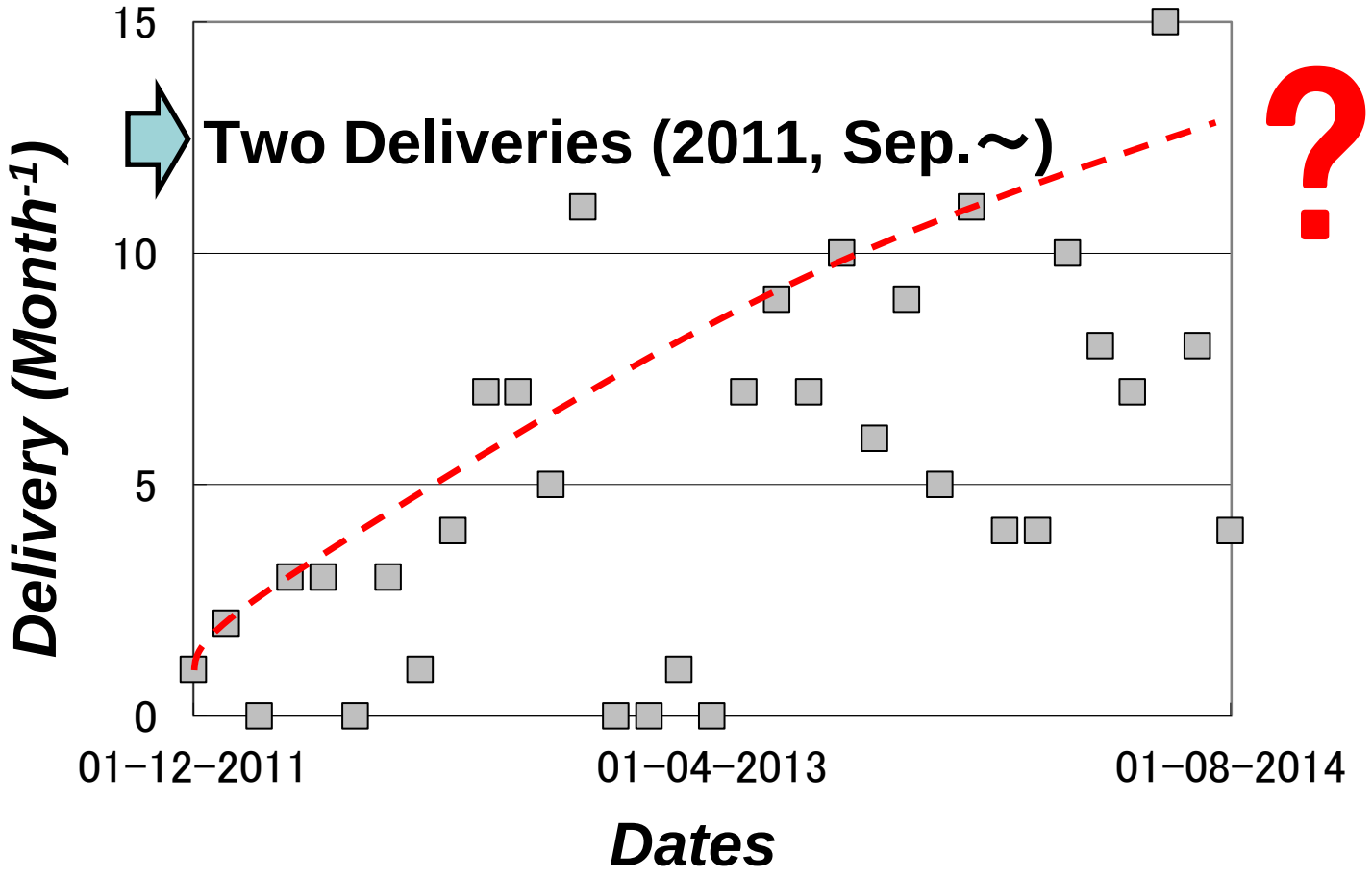


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Monthly Delivery of Boeing 787

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Supply Chain
(Upper Stream)

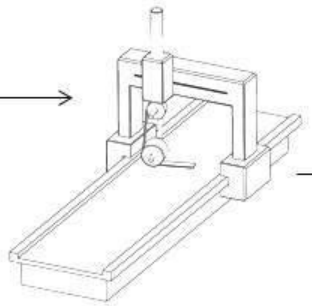






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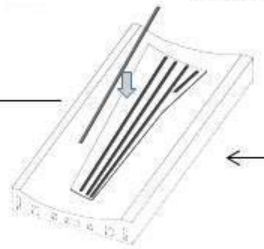


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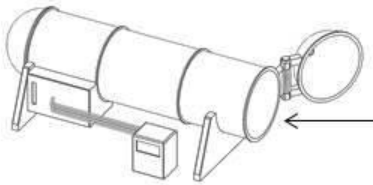


Green Body / Inventory

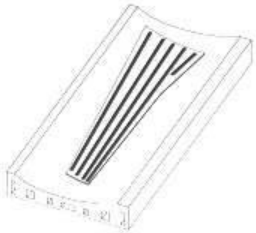
Setup: Vacuum Bag/Linkage



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Autoclave:Cure



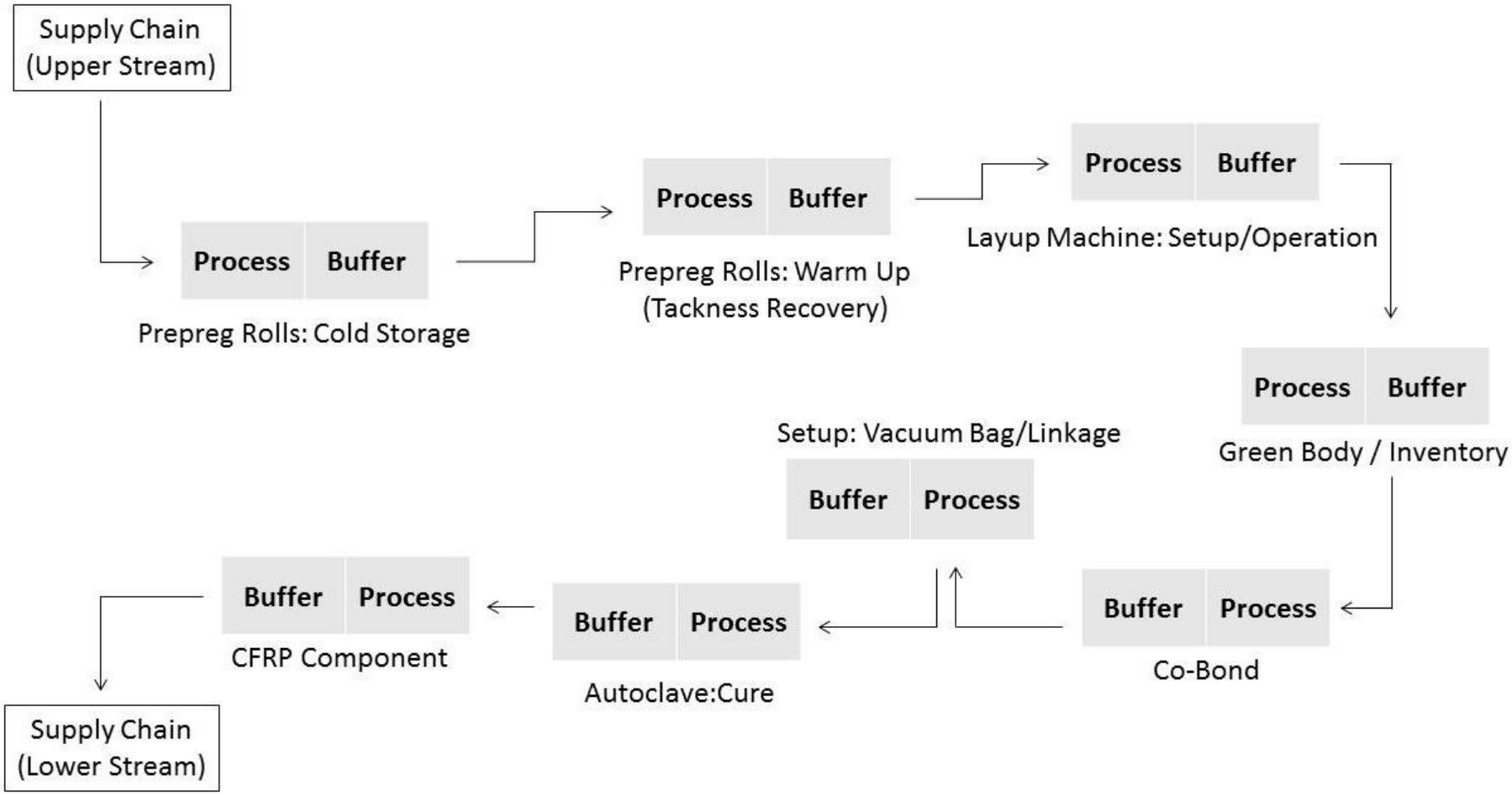
CFRP Component

Supply Chain
(Lower Stream)

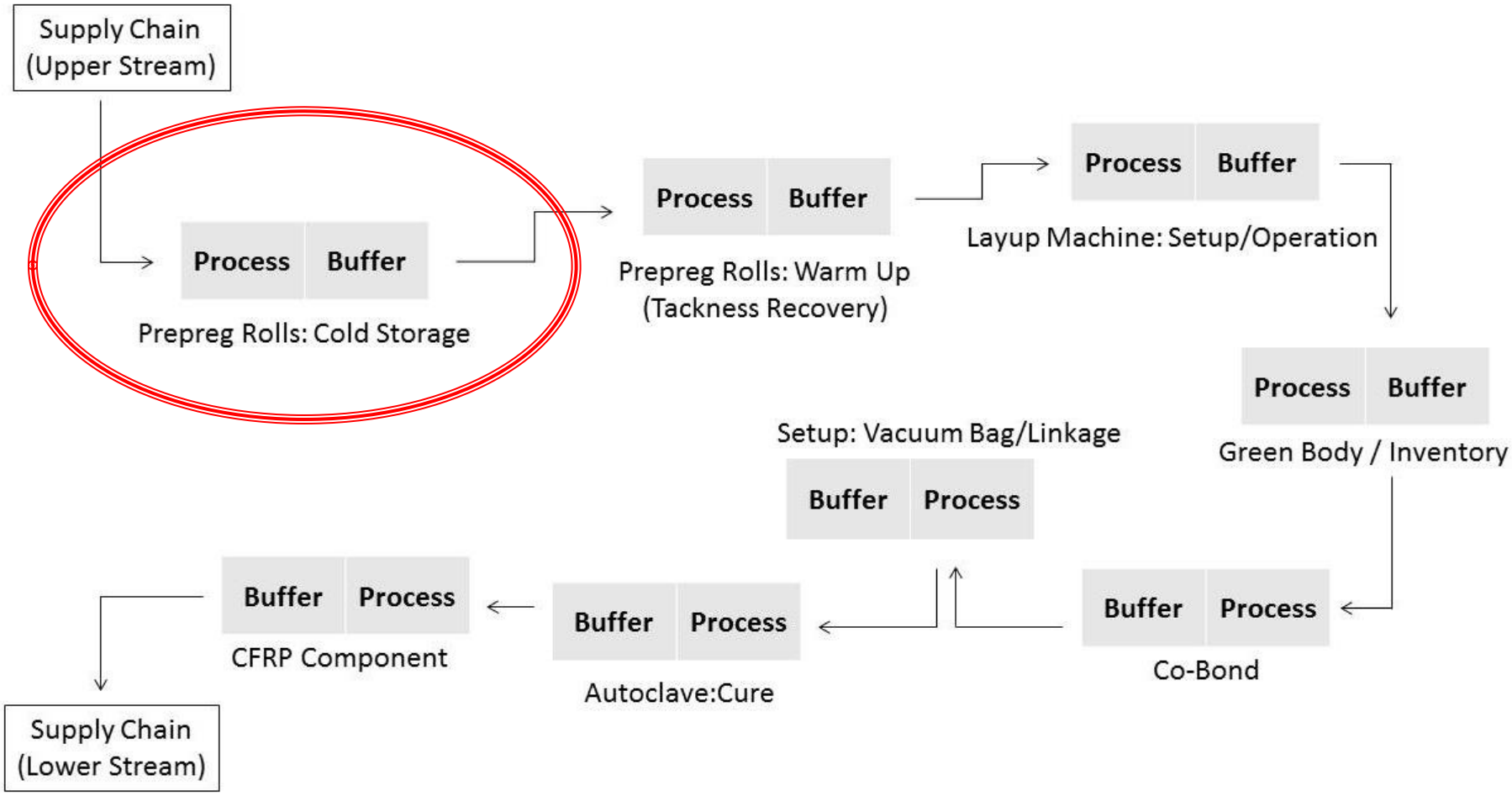




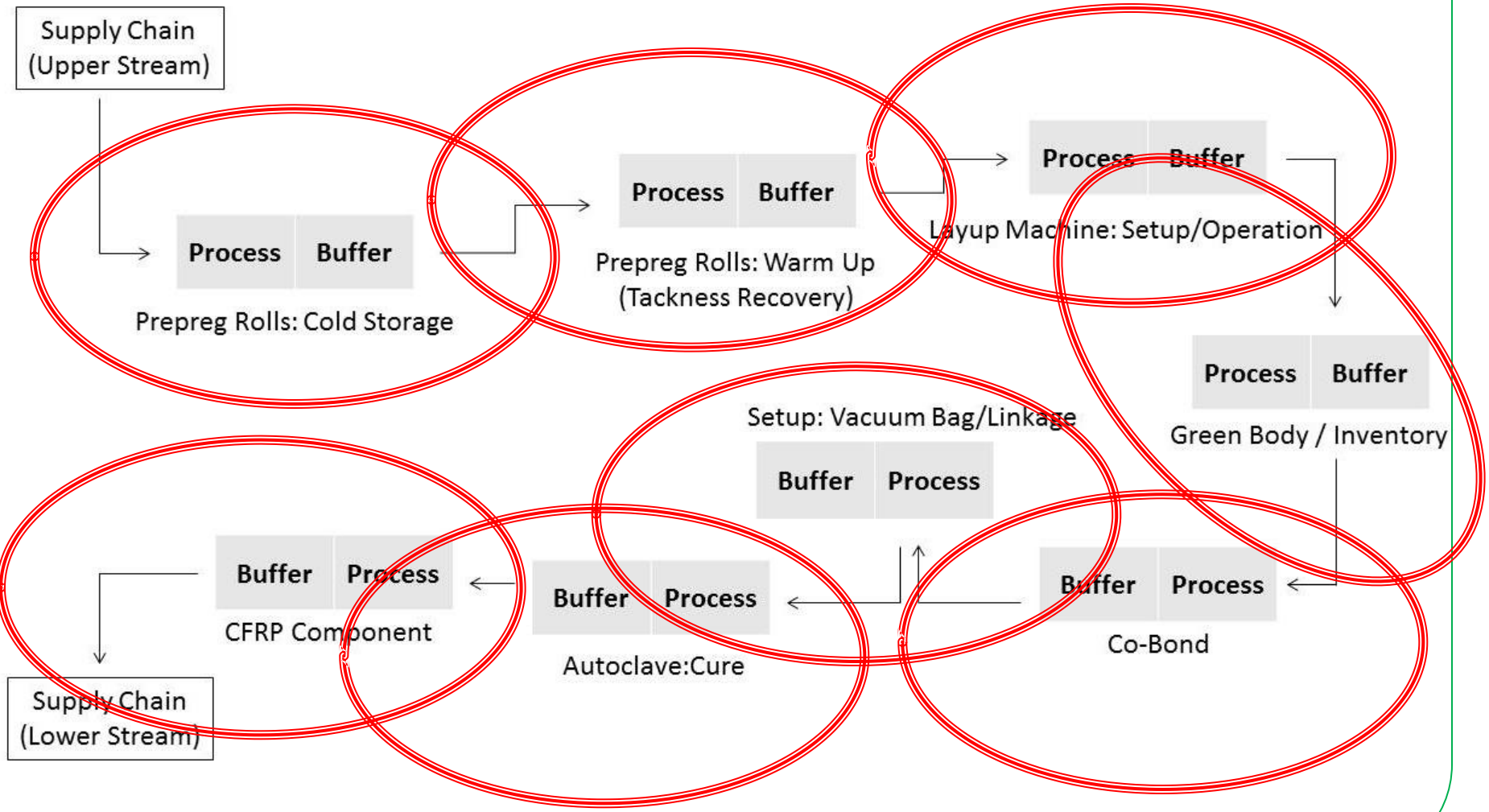
Supply Chain : Model



Supply Chain : Model



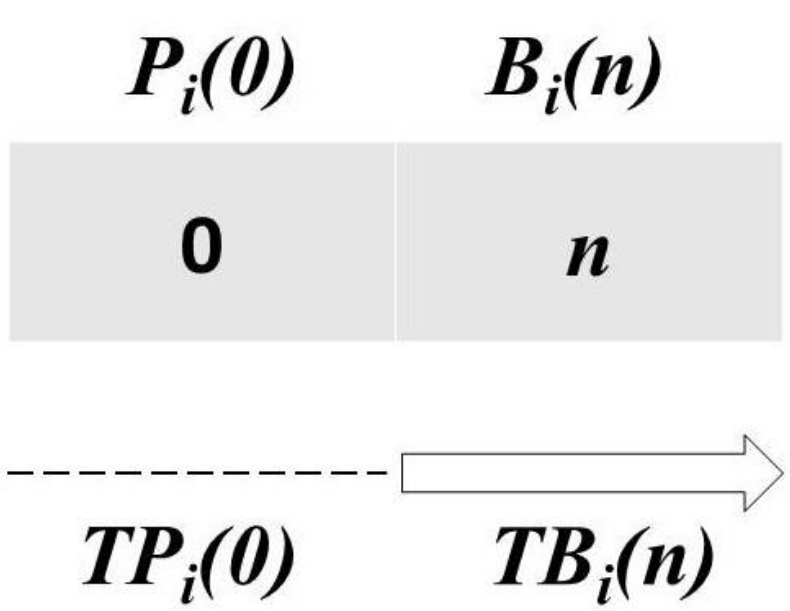
Supply Chain : Model

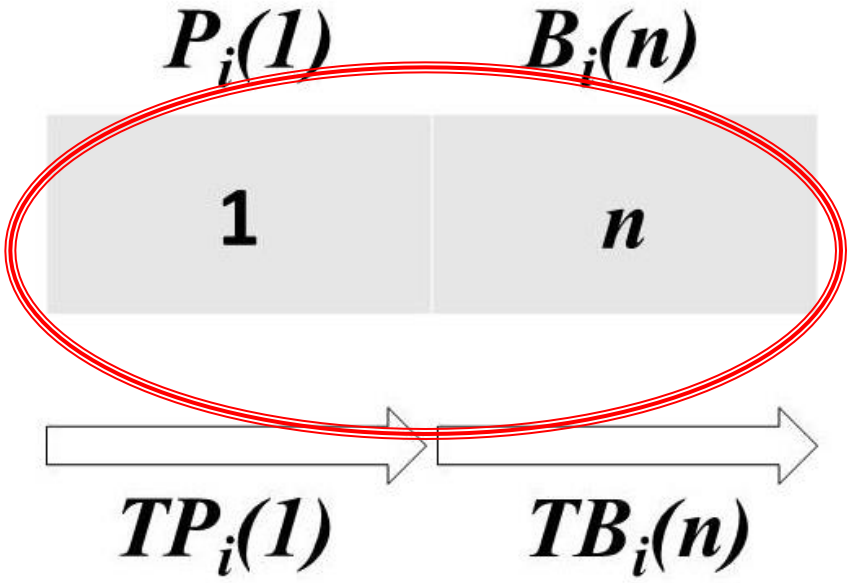


A Ring of Chain:

1,2,3・・n: ON

0 :OFF





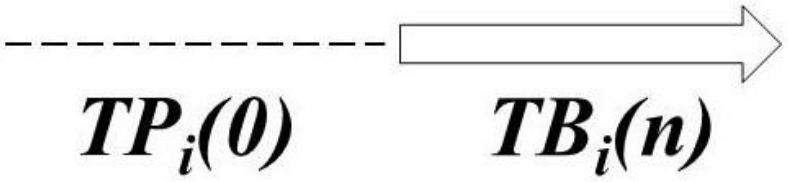
n inventories at buffer・・・**Time**

A Ring of Chain:

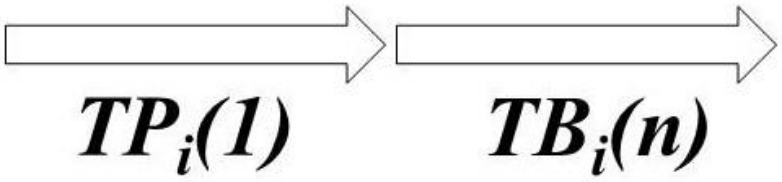
1,2,3・・n: ON

0 :OFF

$P_i(0)$	$B_i(n)$
0	n



$P_i(1)$	$B_i(n)$
1	n



n inventories at buffer・・・**Time**

A Ring of Chain:

1,2,3・・n: ON

0 :OFF

$P_i(0)$	$B_i(n)$
0	n

$TP_i(0)$ $TB_i(n)$

$P_i(1)$	$B_i(n)$
1	n

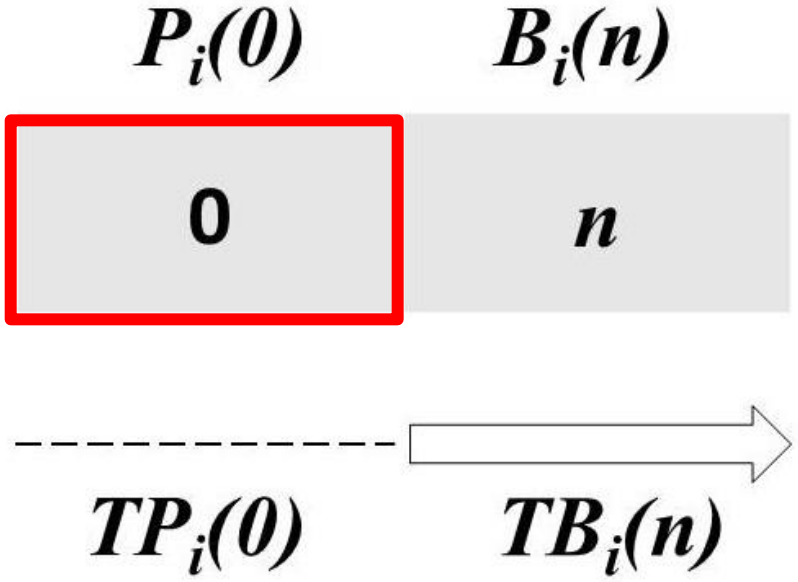
$TP_i(1)$ $TB_i(n)$

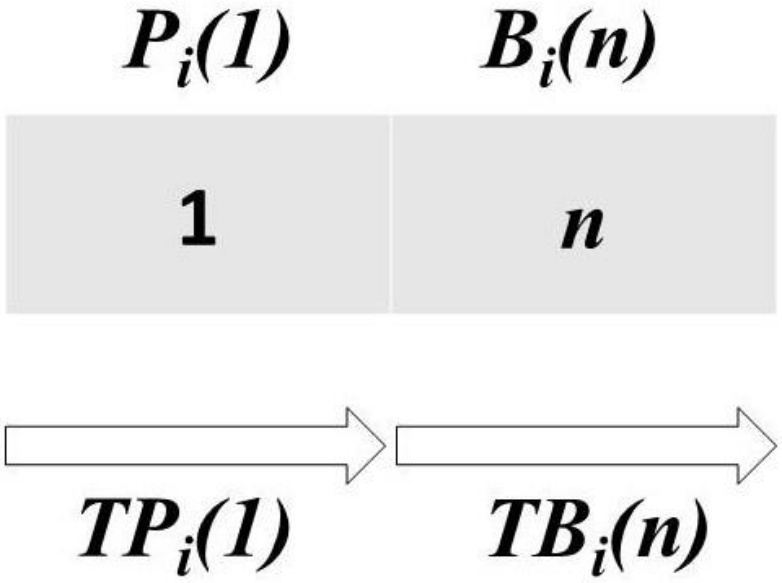
n inventories at buffer・・・**Time**

A Ring of Chain:

1,2,3・・***n***: ON

0 :OFF



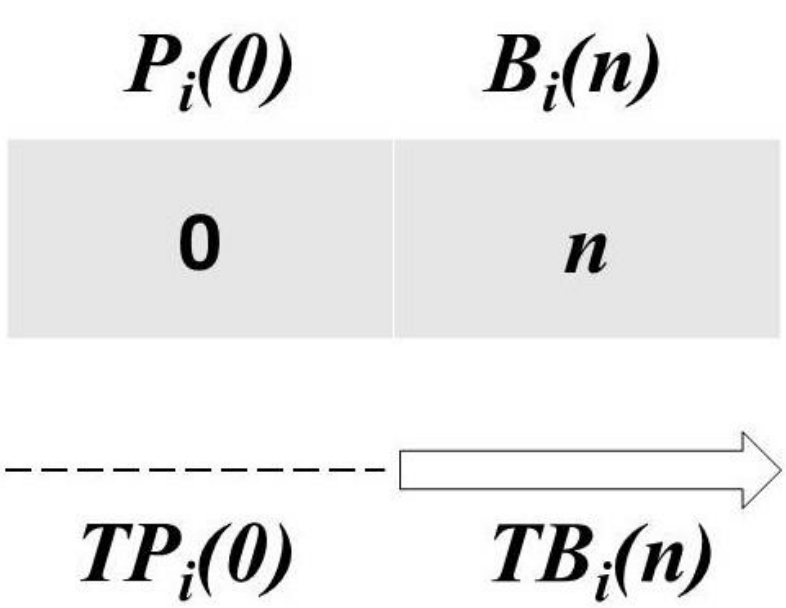


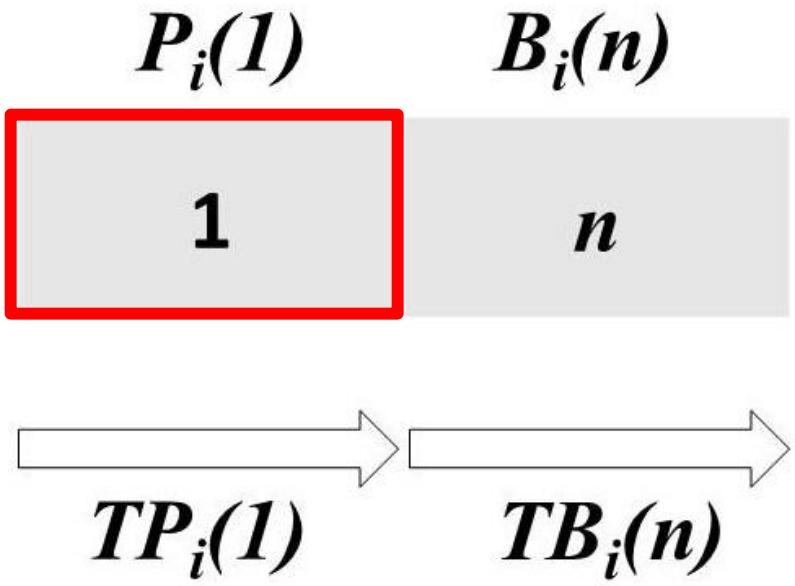
n inventories at buffer・・・**Time**

A Ring of Chain:

1,2,3・・***n***: ON

0 :OFF



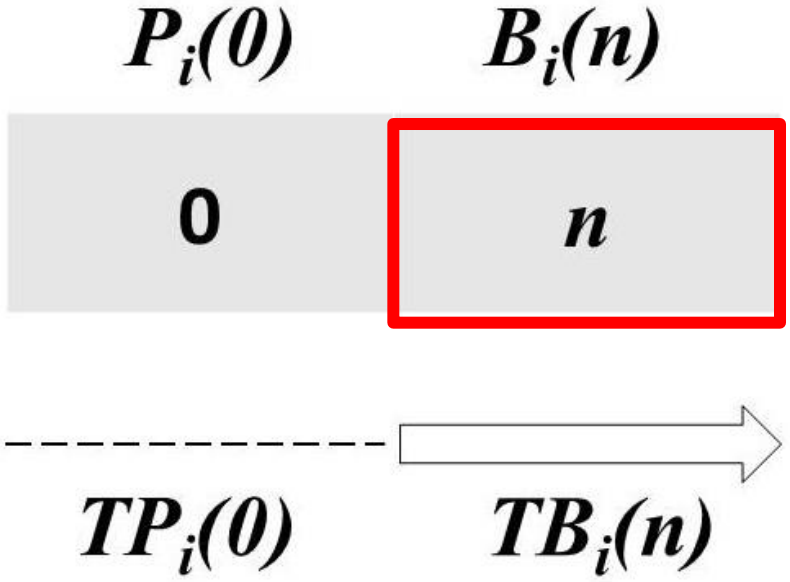


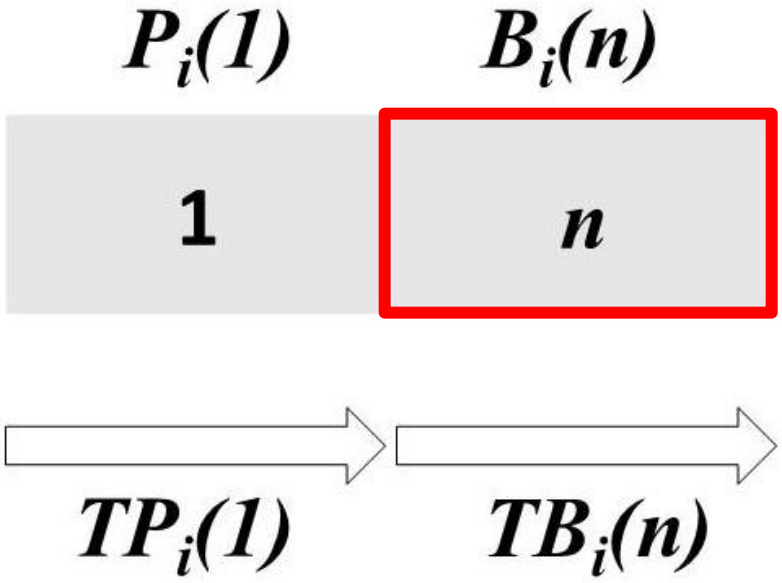
n inventories at buffer・・・**Time**

A Ring of Chain:

1,2,3・・***n***: ON

0 :OFF





n inventories at buffer・・・**Time**

A Ring of Chain:

1: ON

0: OFF

$P_i(0)$	$B_i(0)$
0	0

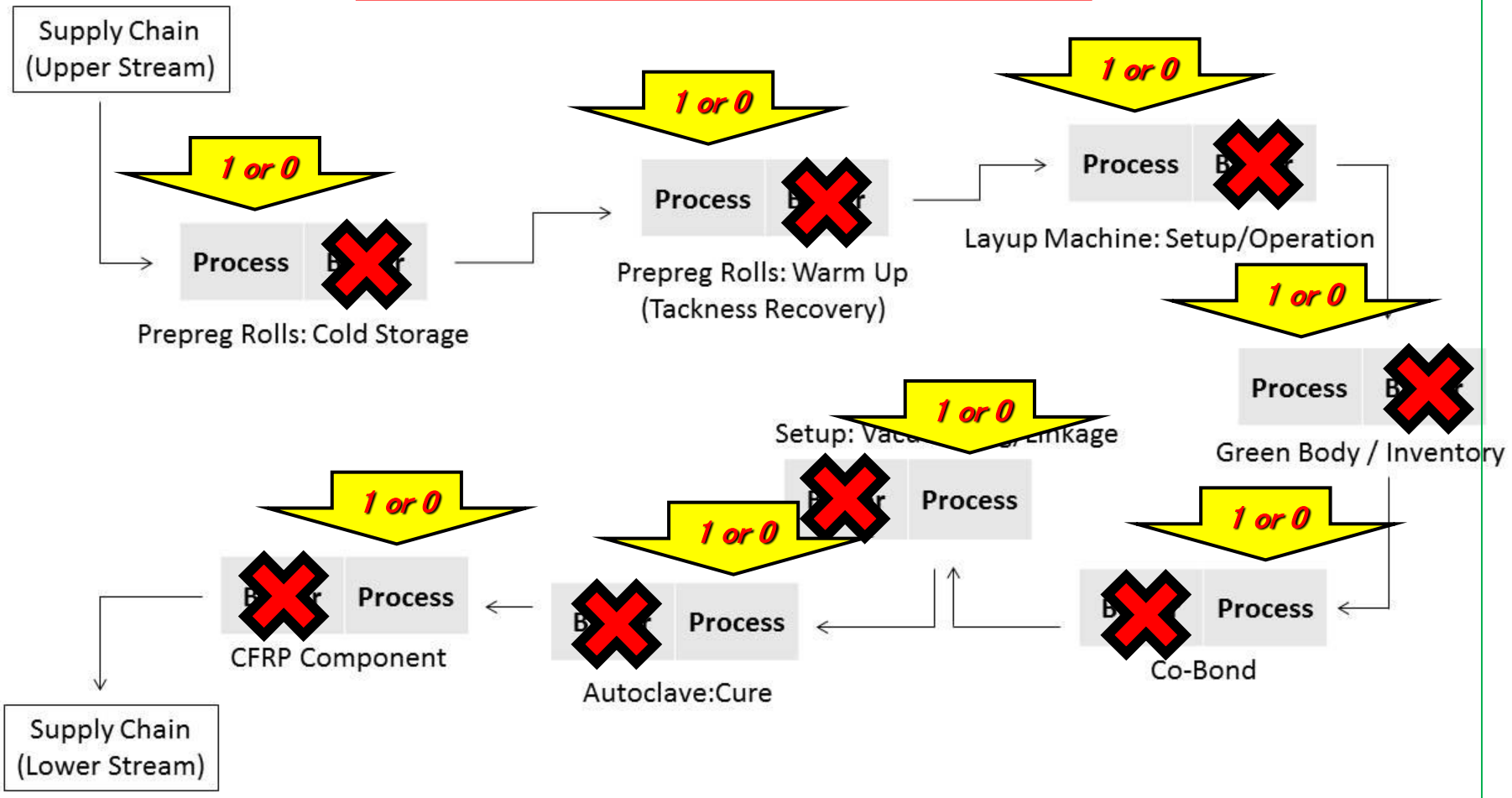
$TP_i(0)$ $TB_i(0)$

$P_i(1)$	$B_i(0)$
1	0

$TP_i(1)$ $TB_i(0)$

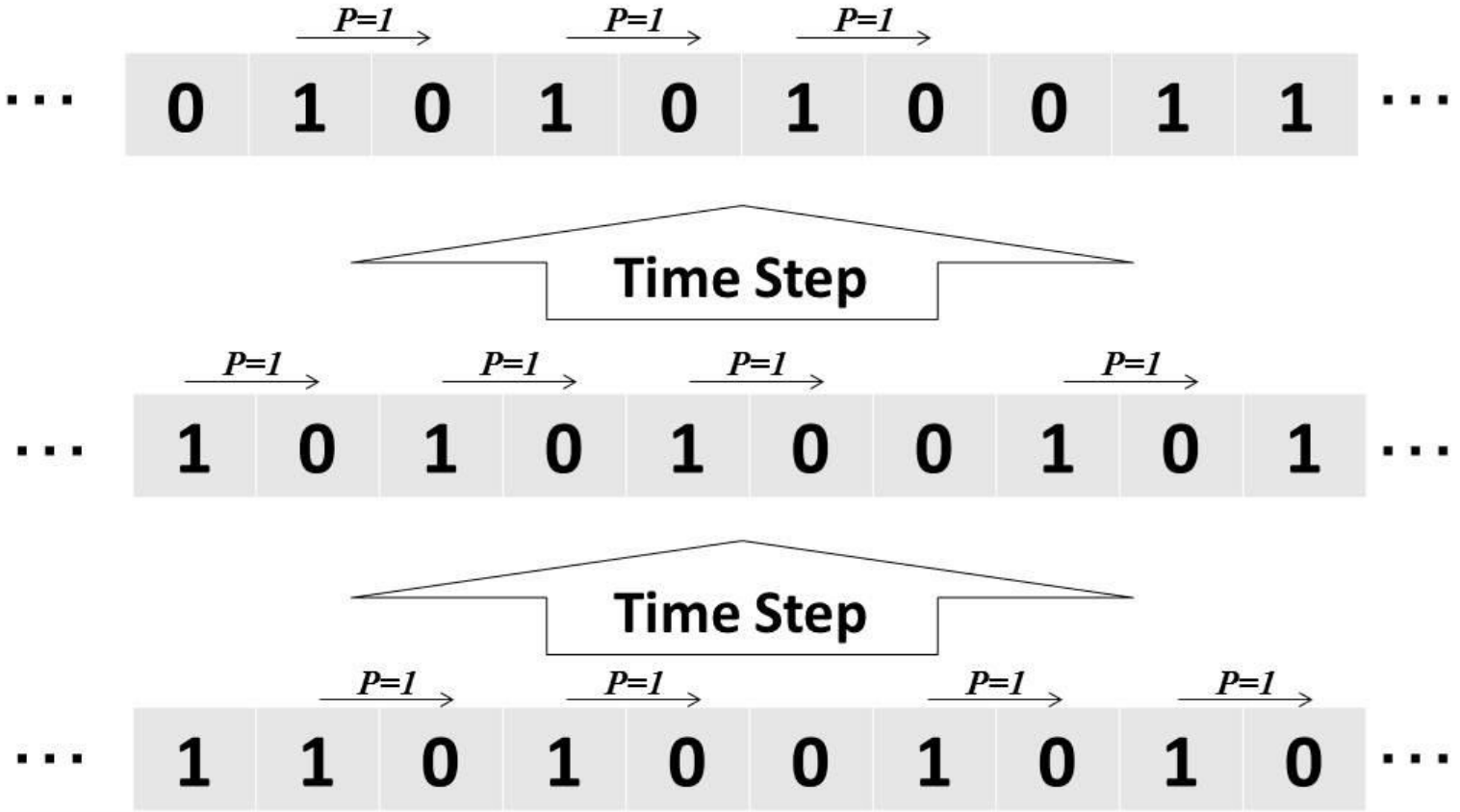
Buffer··· “*0*”

Lean Production



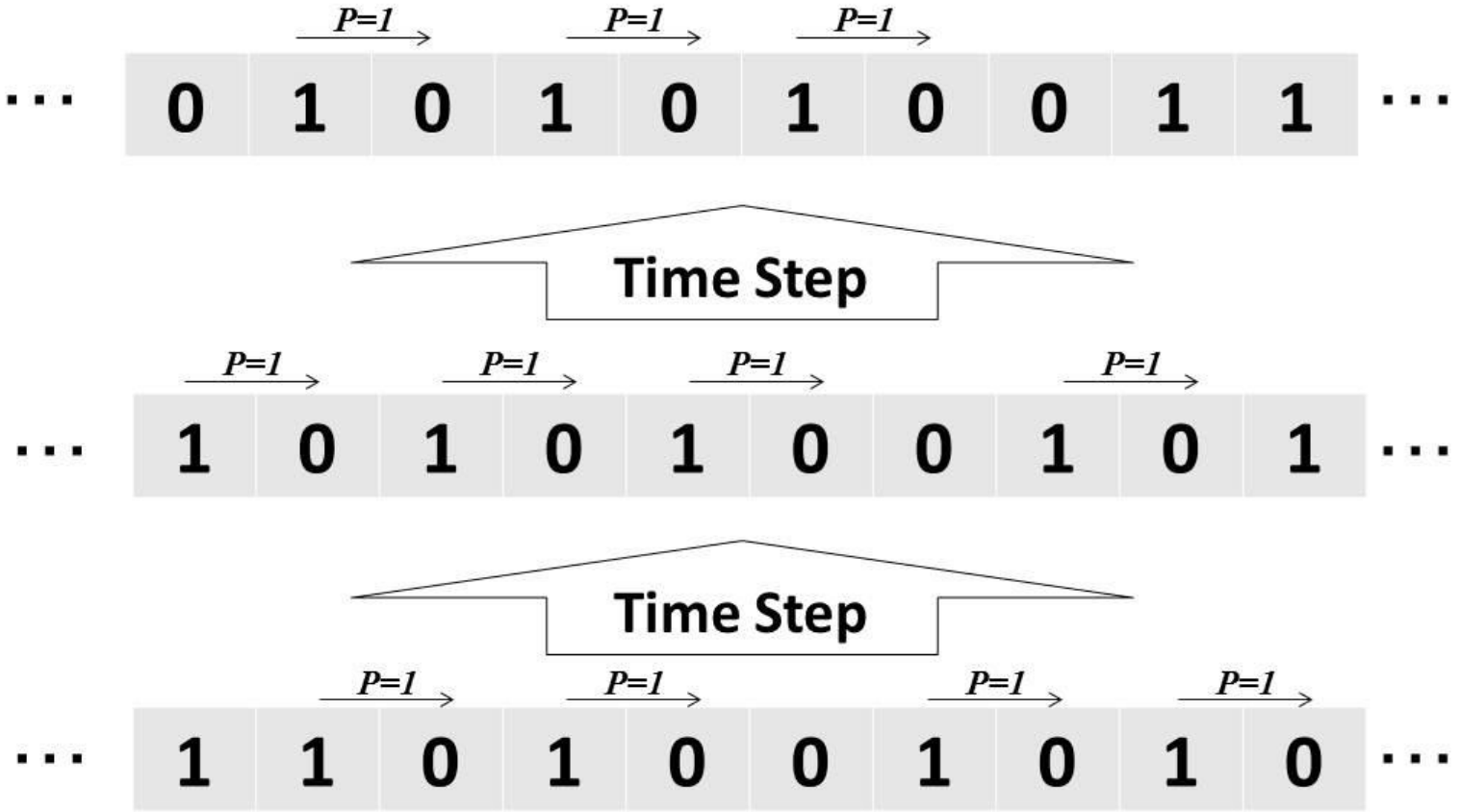
Lean Production

⇒Cell Automaton: Wolfram Rule 184



Lean Production

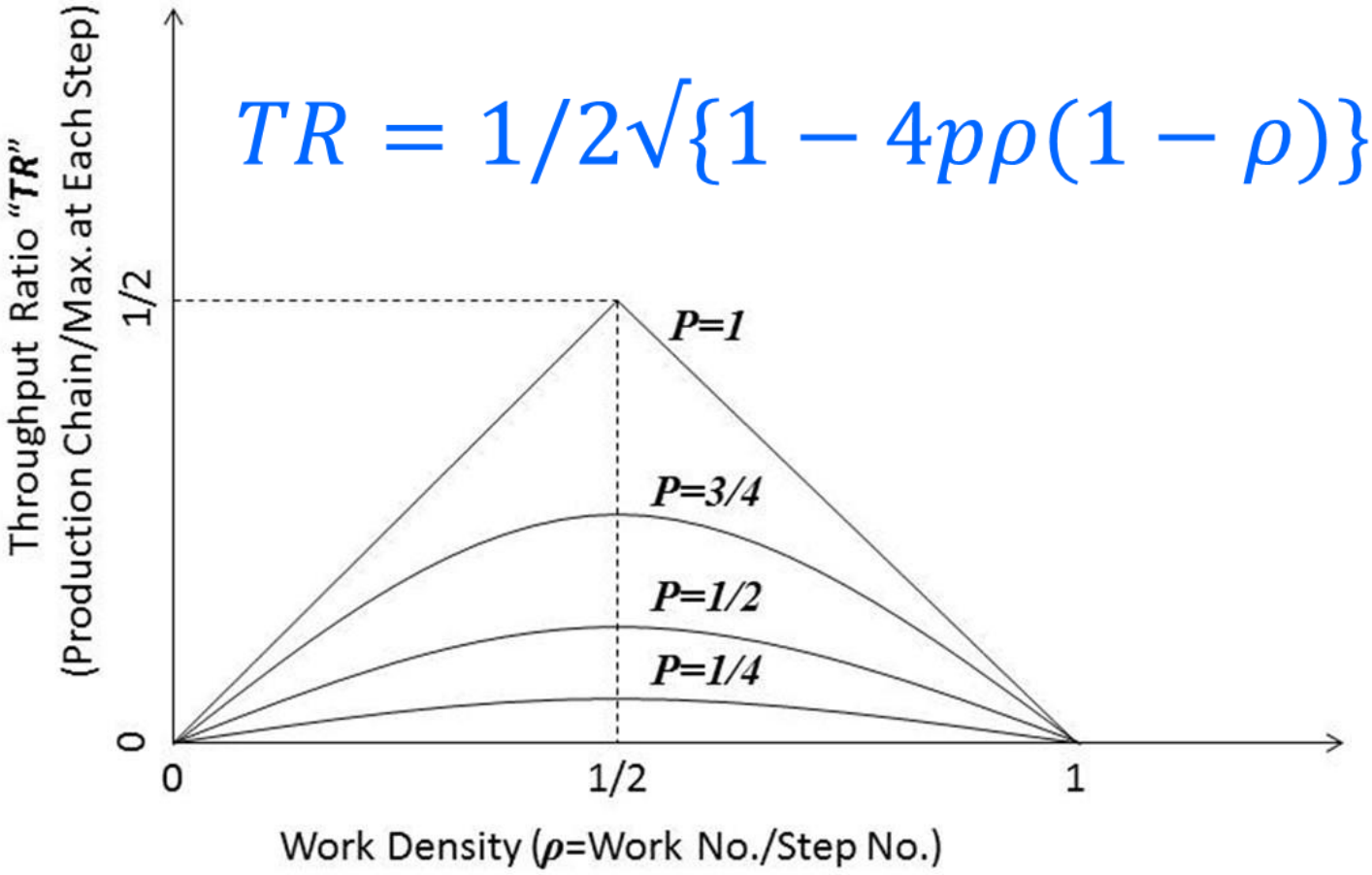
⇒Cell Automaton: ASEP Model



Max. Throughput

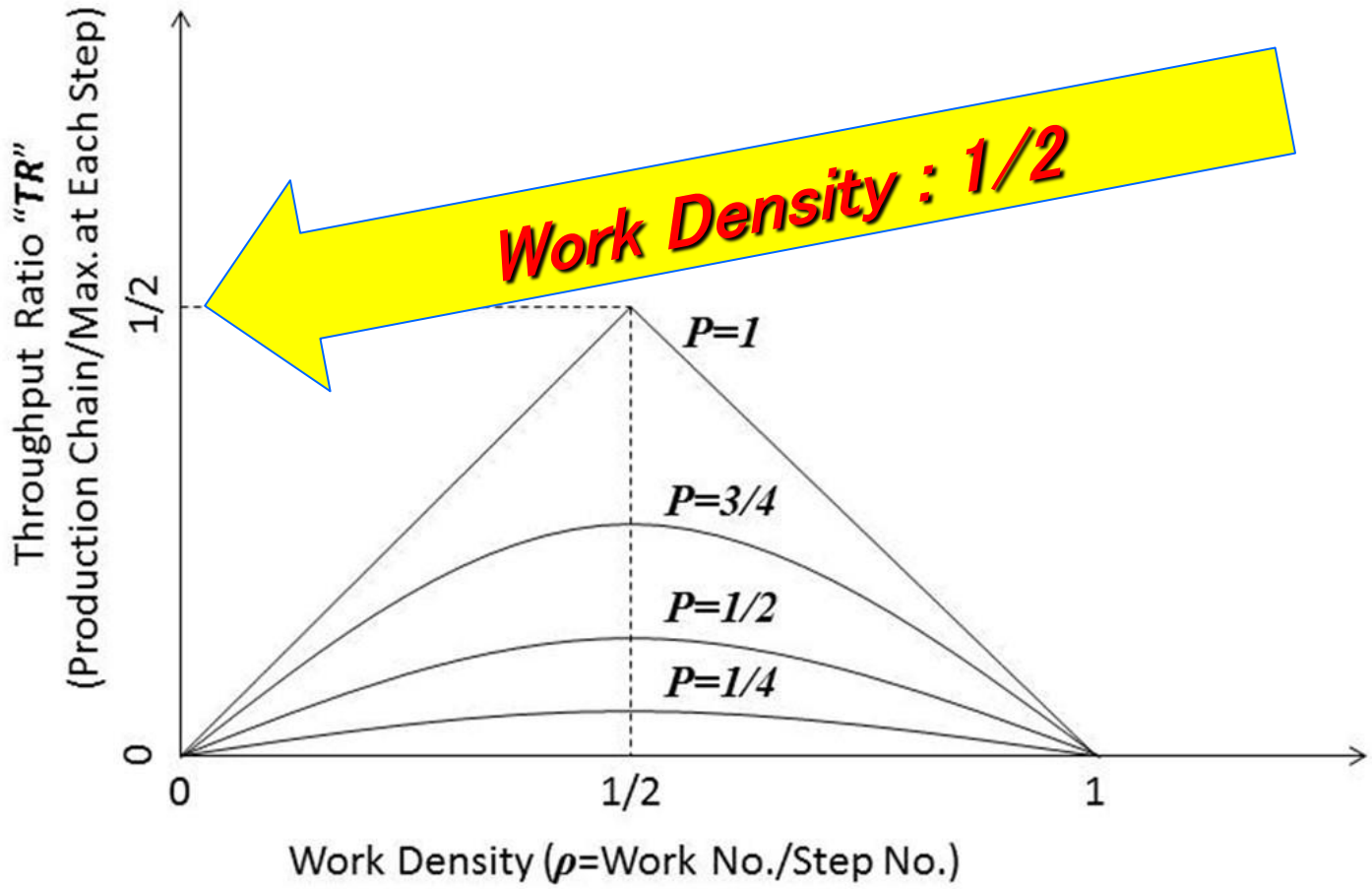
– Cell Automaton: Wolfram Rule 184 –

$$TR = 1/2\sqrt{\{1 - 4p\rho(1-\rho)\}}$$



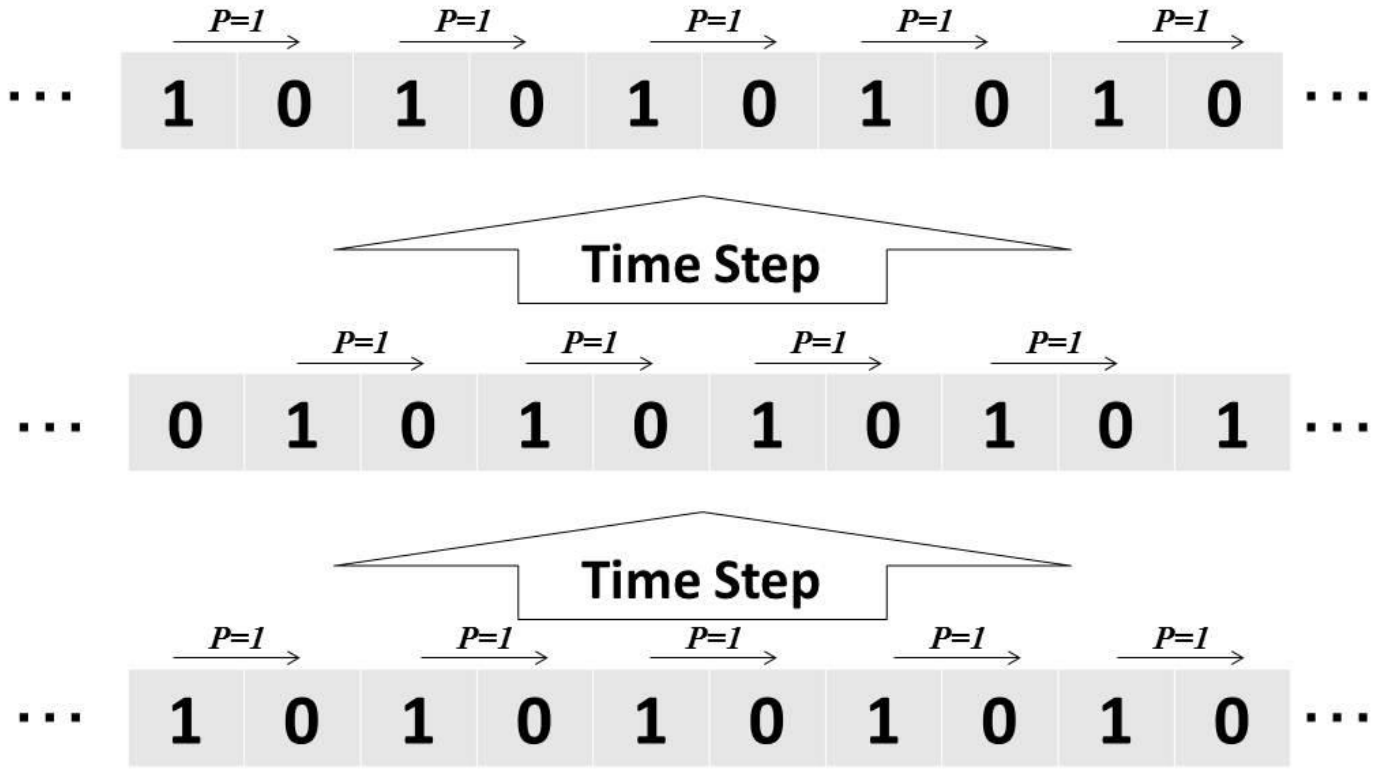
Max. Throughput

– Cell Automaton: Wolfram Rule 184 –



Max. Throughput

– Cell Automaton: Wolfram Rule 184 –

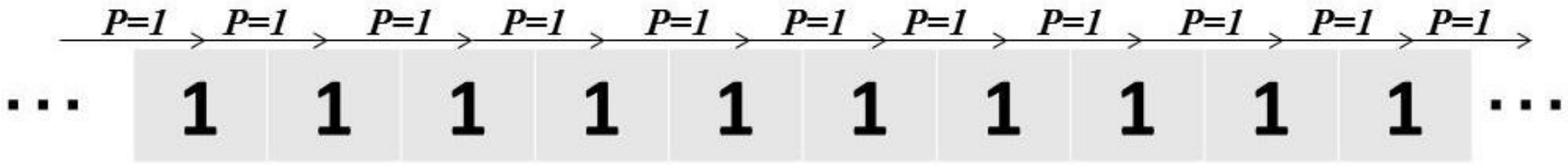


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“IF” Over the Max. Throughput・・・?

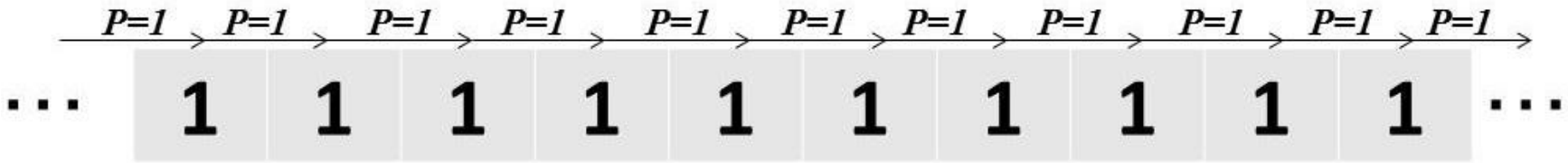
– Cell Automaton: ~~Wolfram Rule 184~~ –



“Metastable” Condition

Over the Max. Throughput・・・?

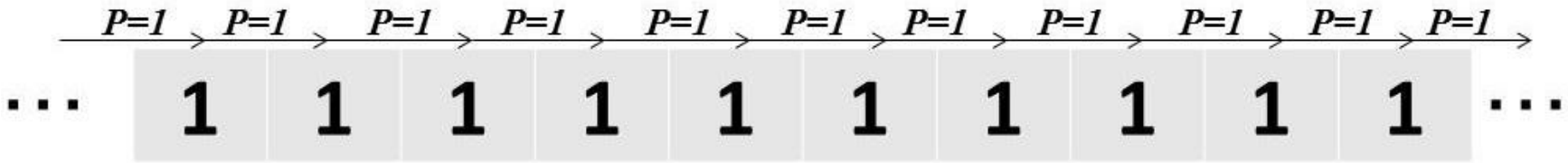
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“Metastable” Condition

Over the Max. Throughput・・・?

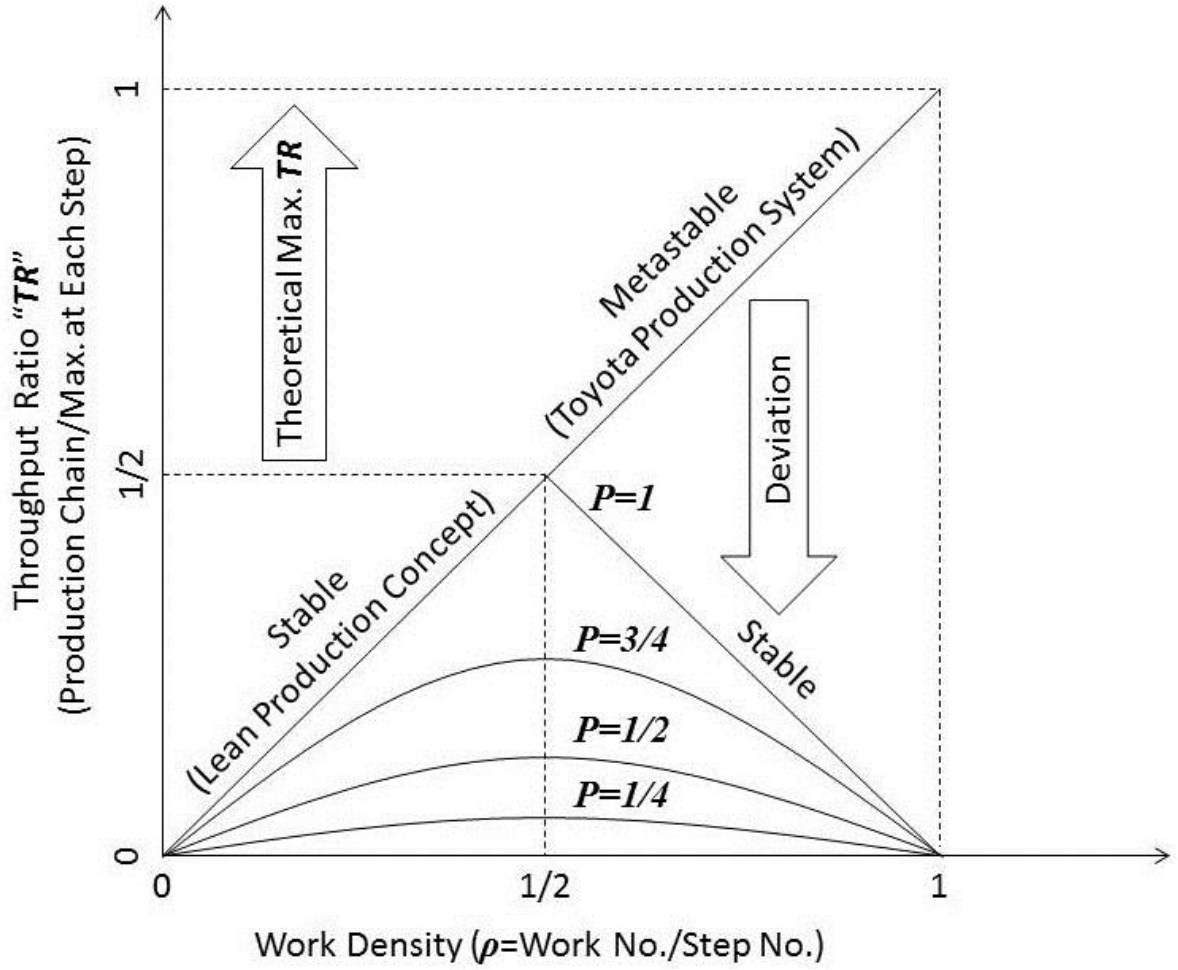
– Cell Automaton: ~~Wolfram Rule 184~~ –



“Metastable” Condition

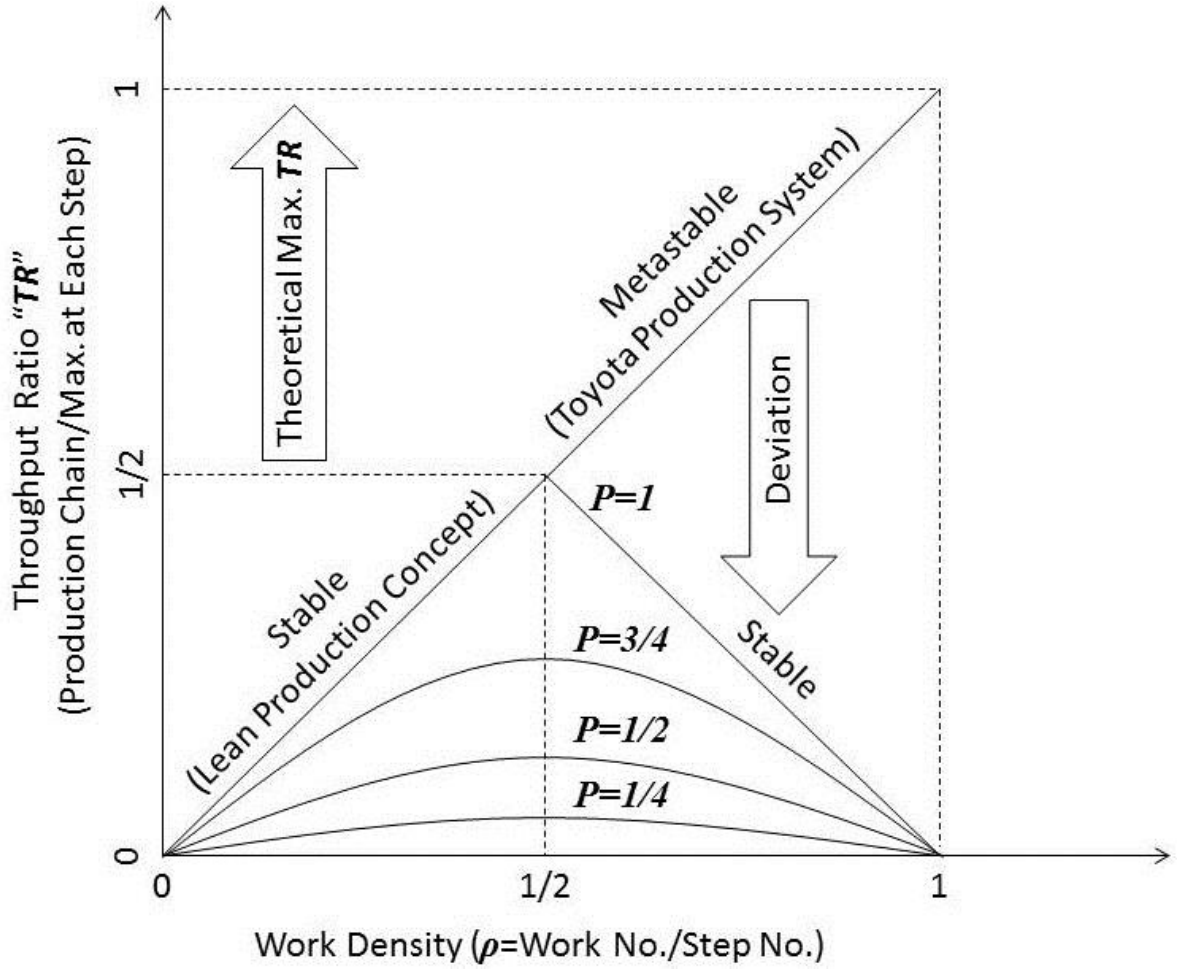
Over the Max. Throughput・・・?

– Cell Automaton: ~~Wolfram Rule 184~~ –



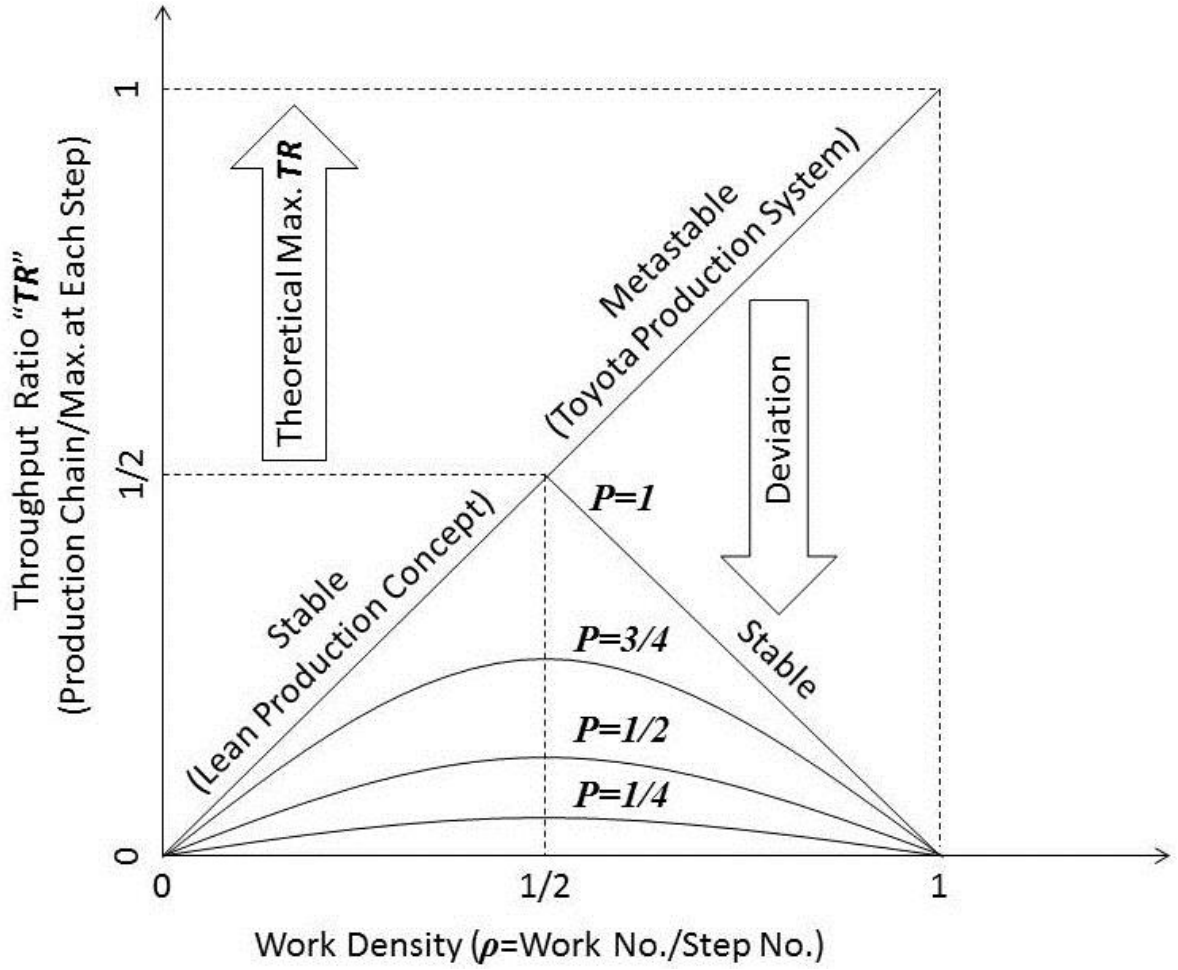
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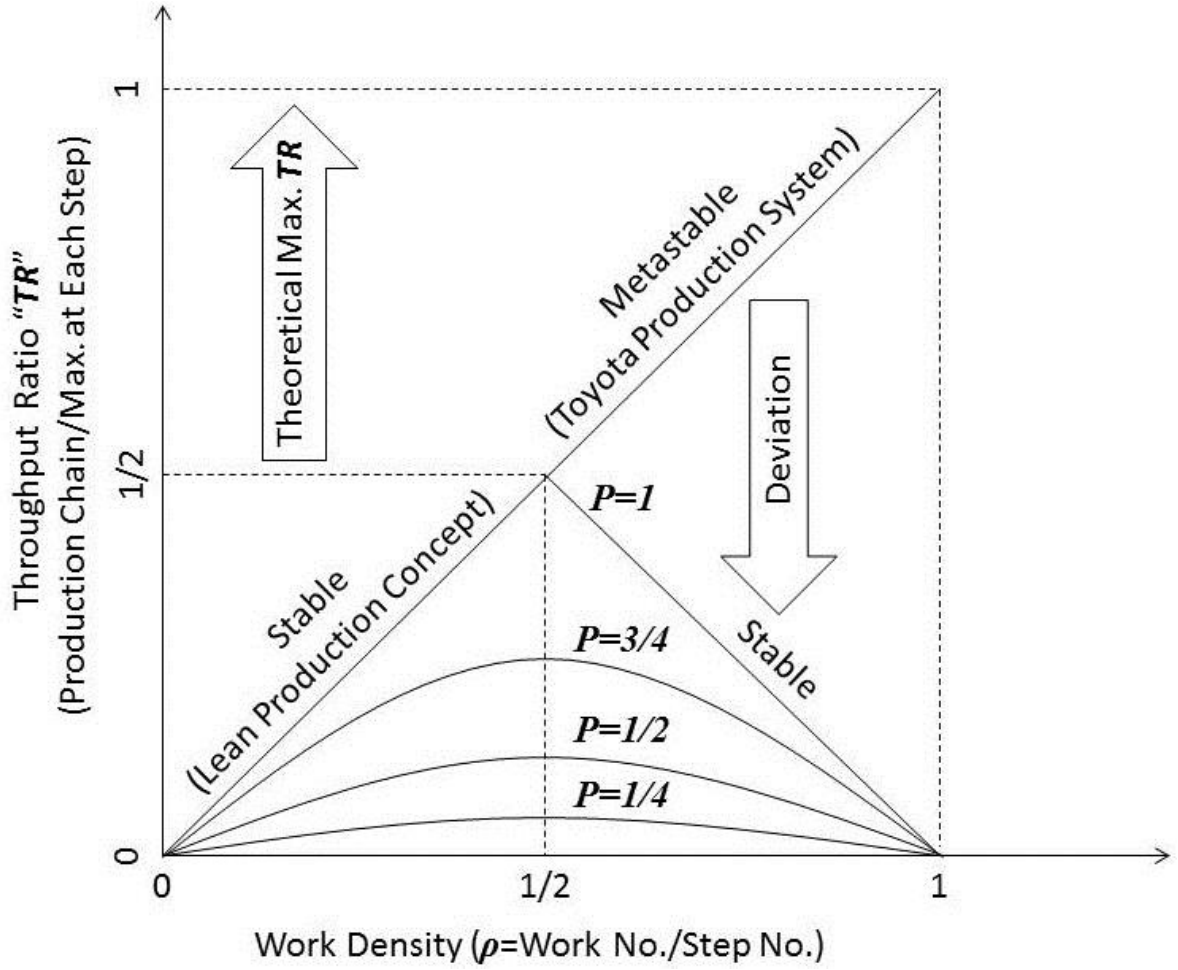
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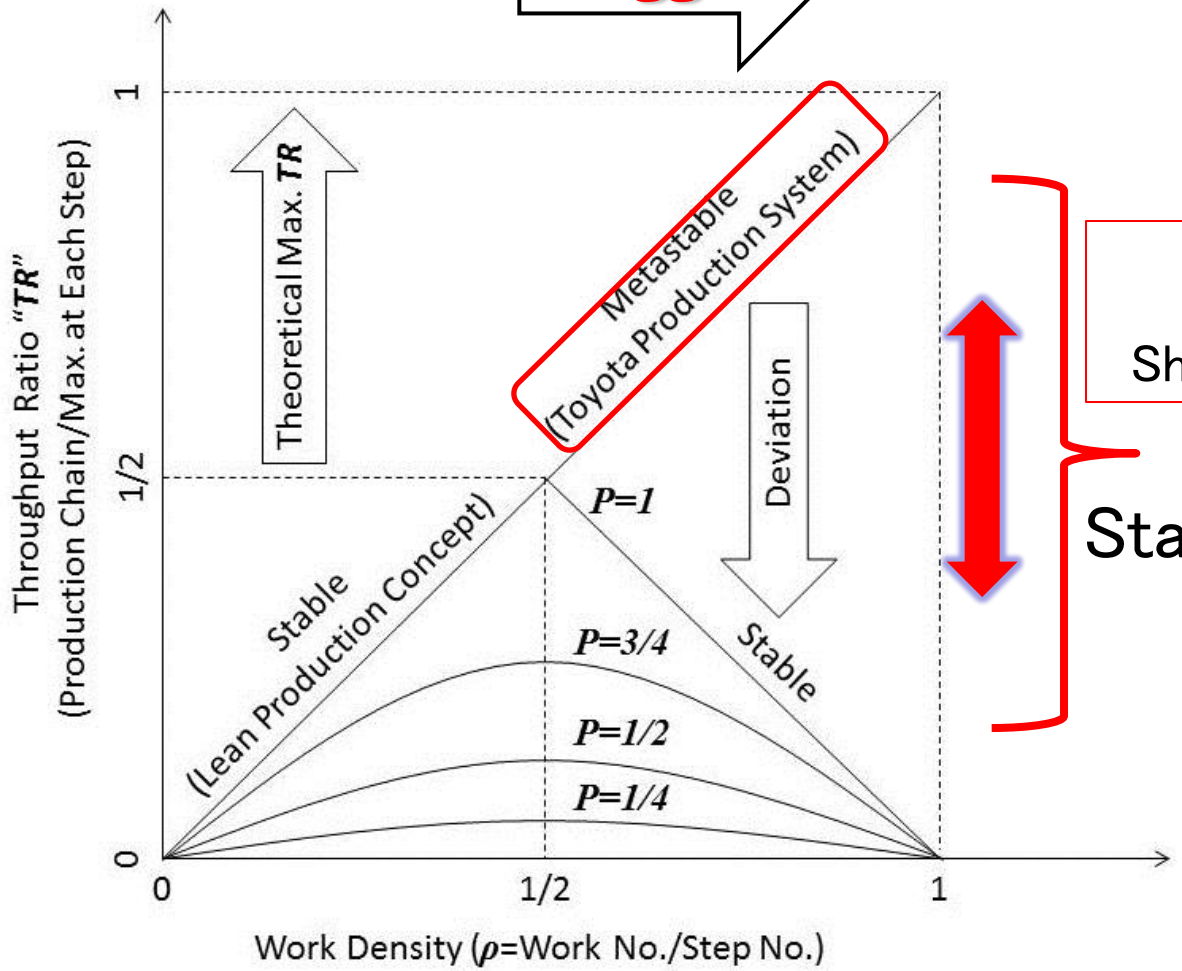
Over the Max. Throughput・・・?

– Cell Automaton: ~~Wolfram Rule 184~~ –



Over the Max. Throughput・・・?

“Slight Deviation **Trigger** Stagnation”

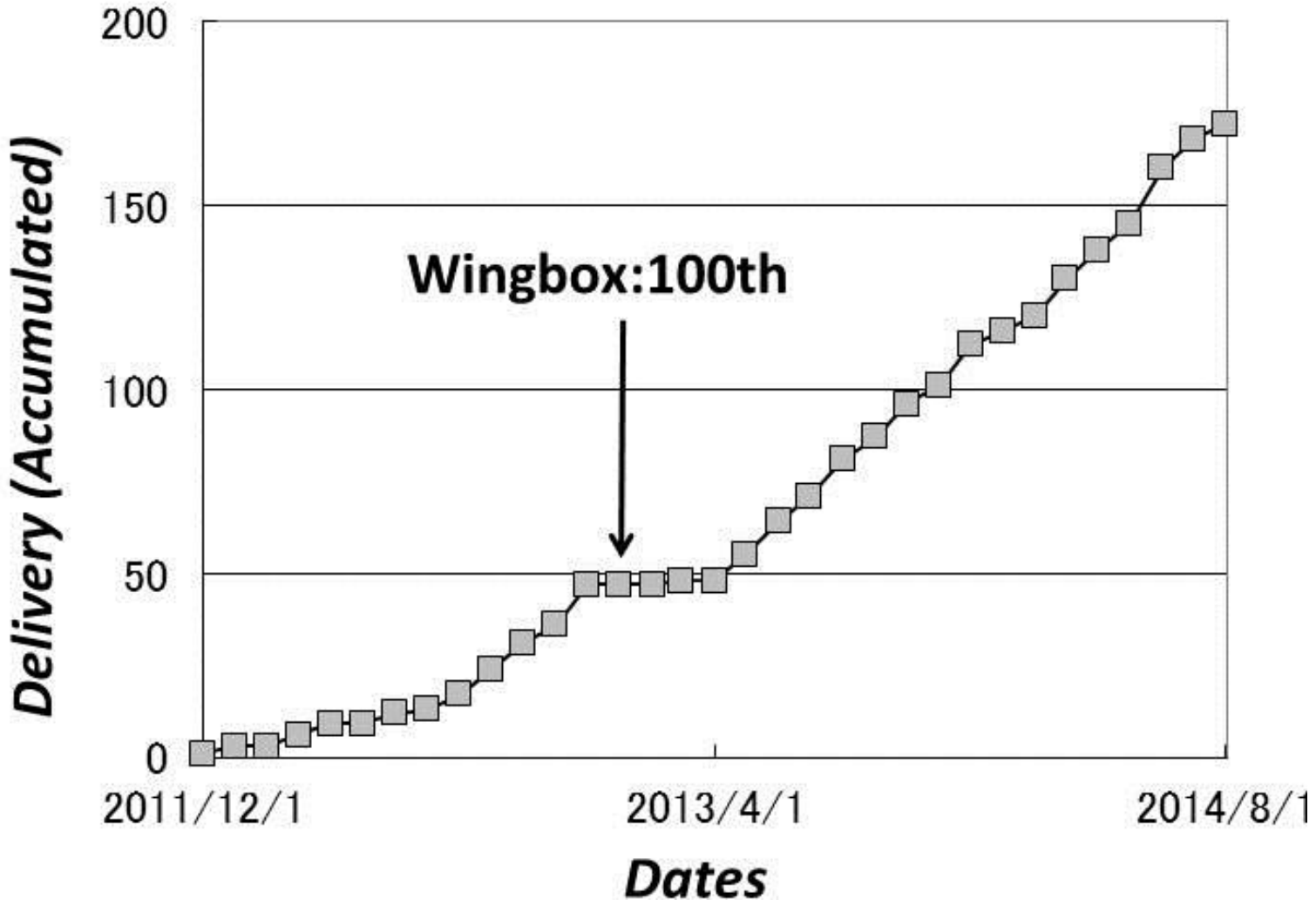


CFRP:

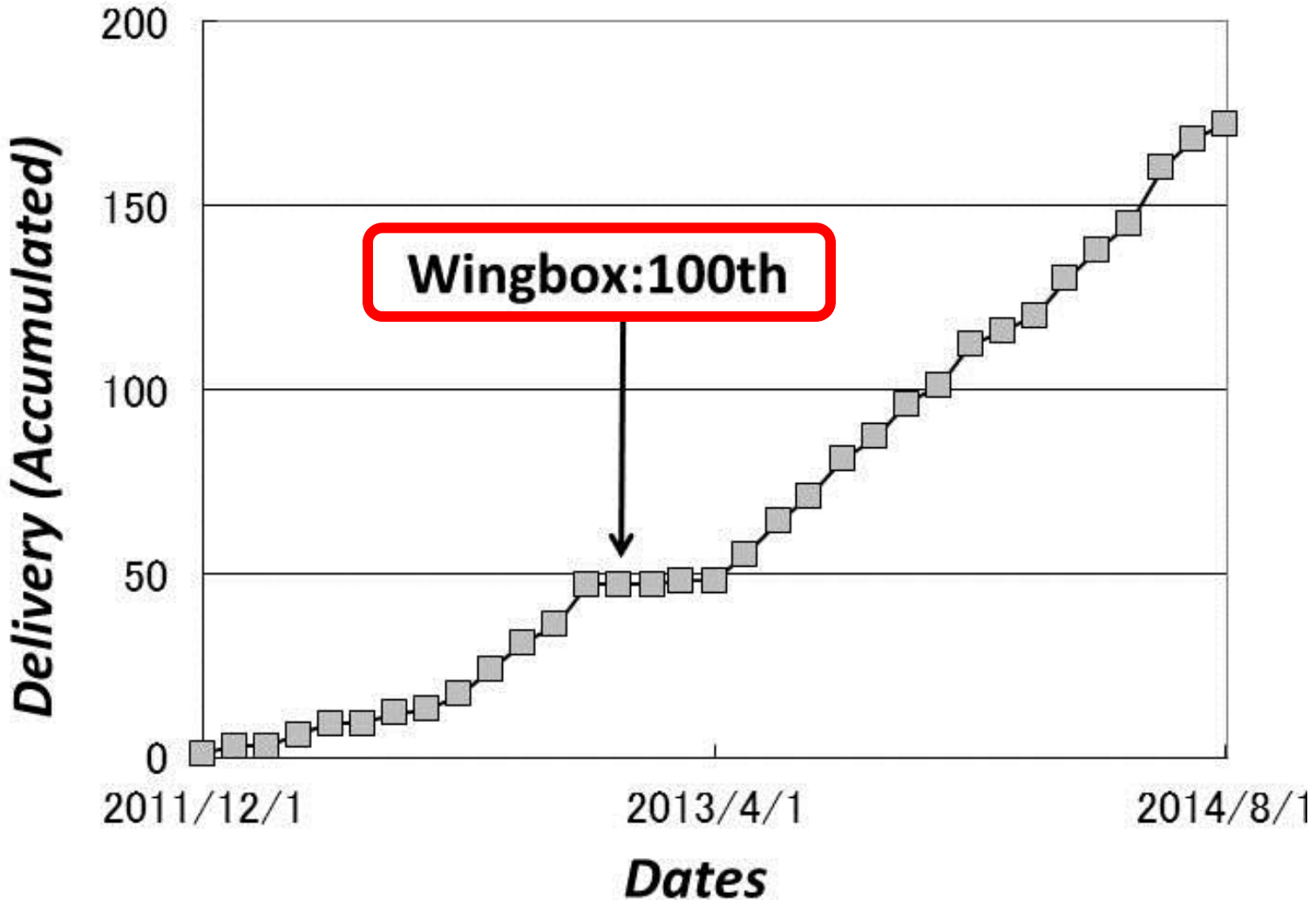
Shelf Life・・・

Line Stagnation

Accumulated Delivery of Boeing787

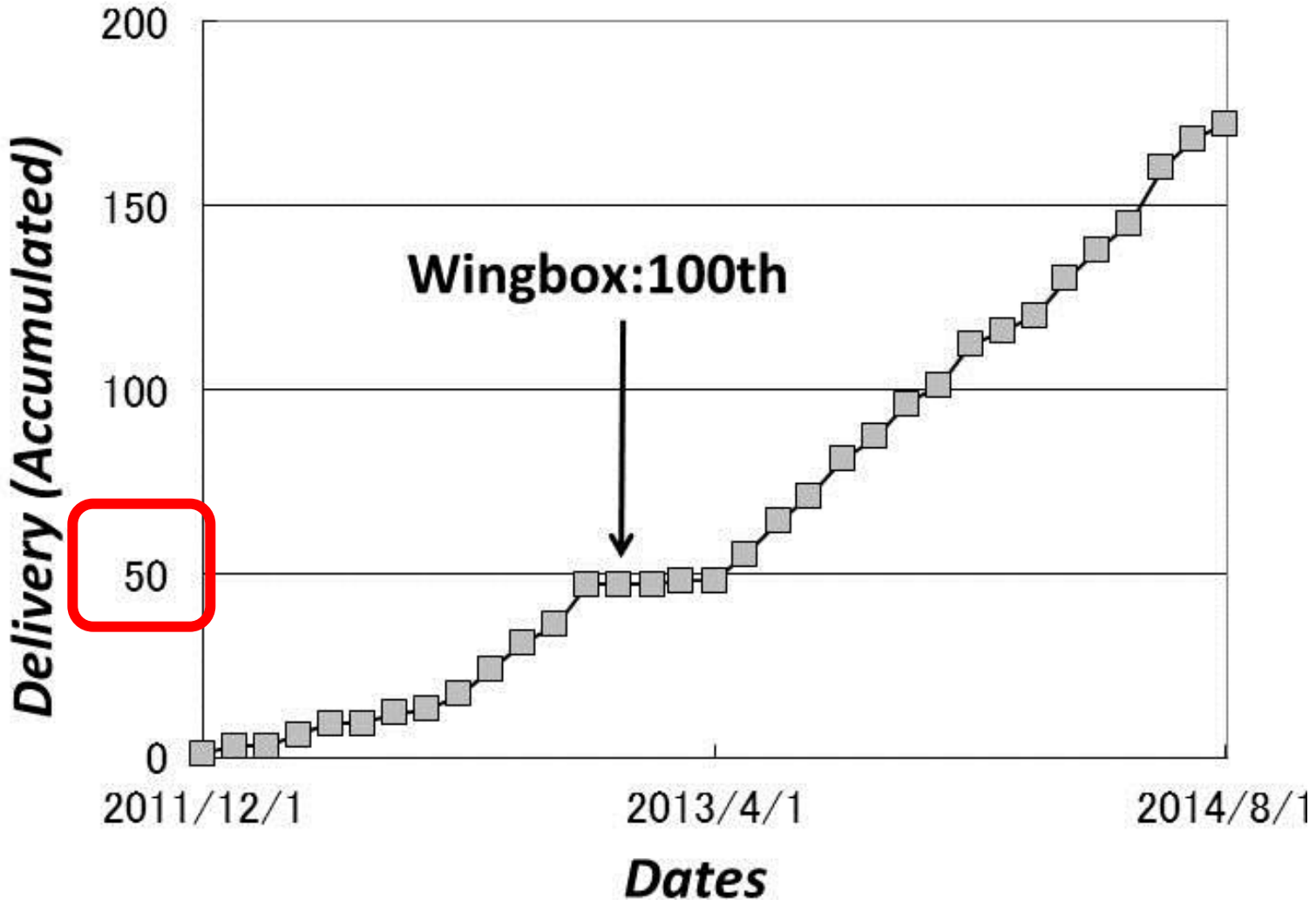


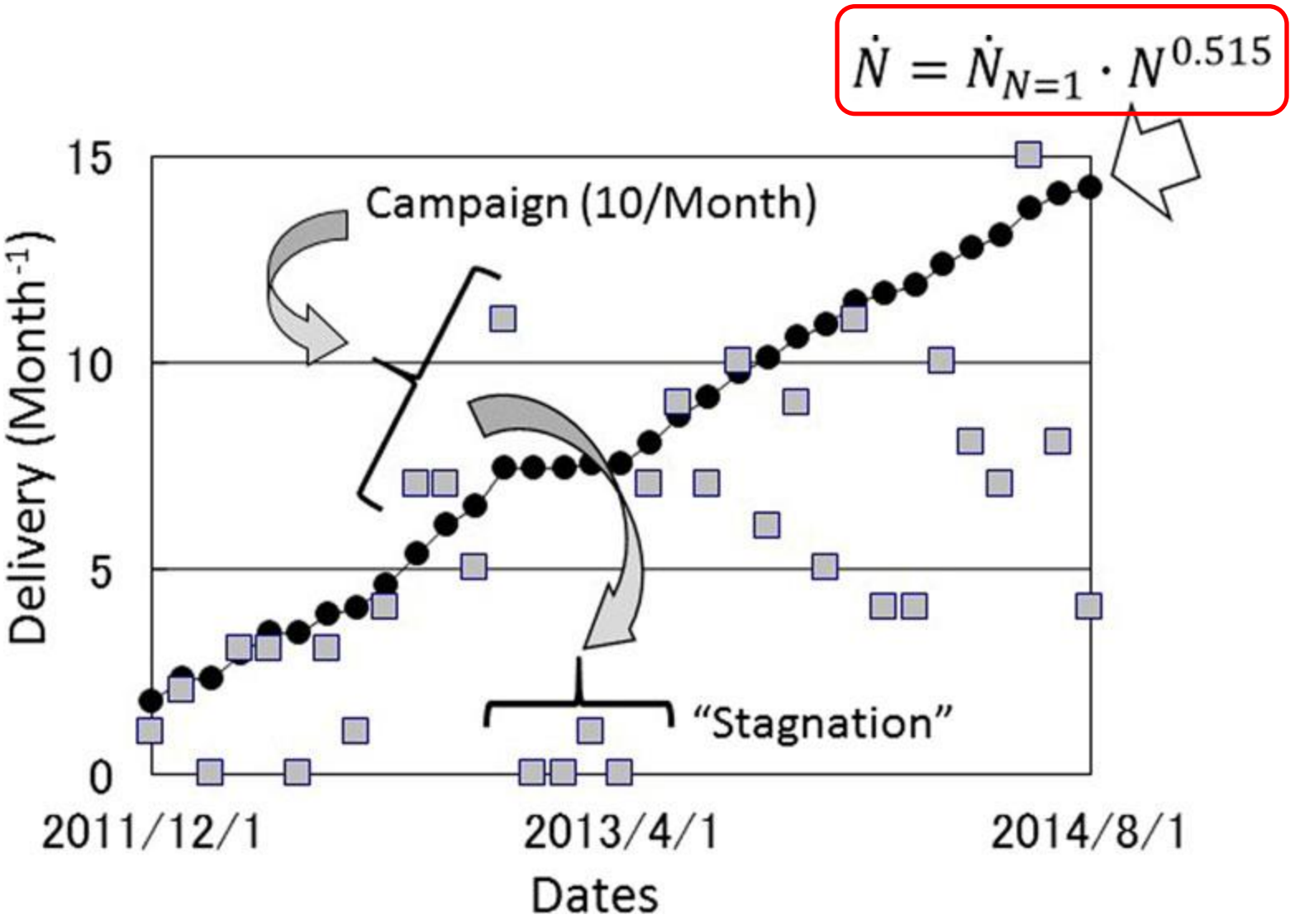
Accumulated Delivery of Boeing787

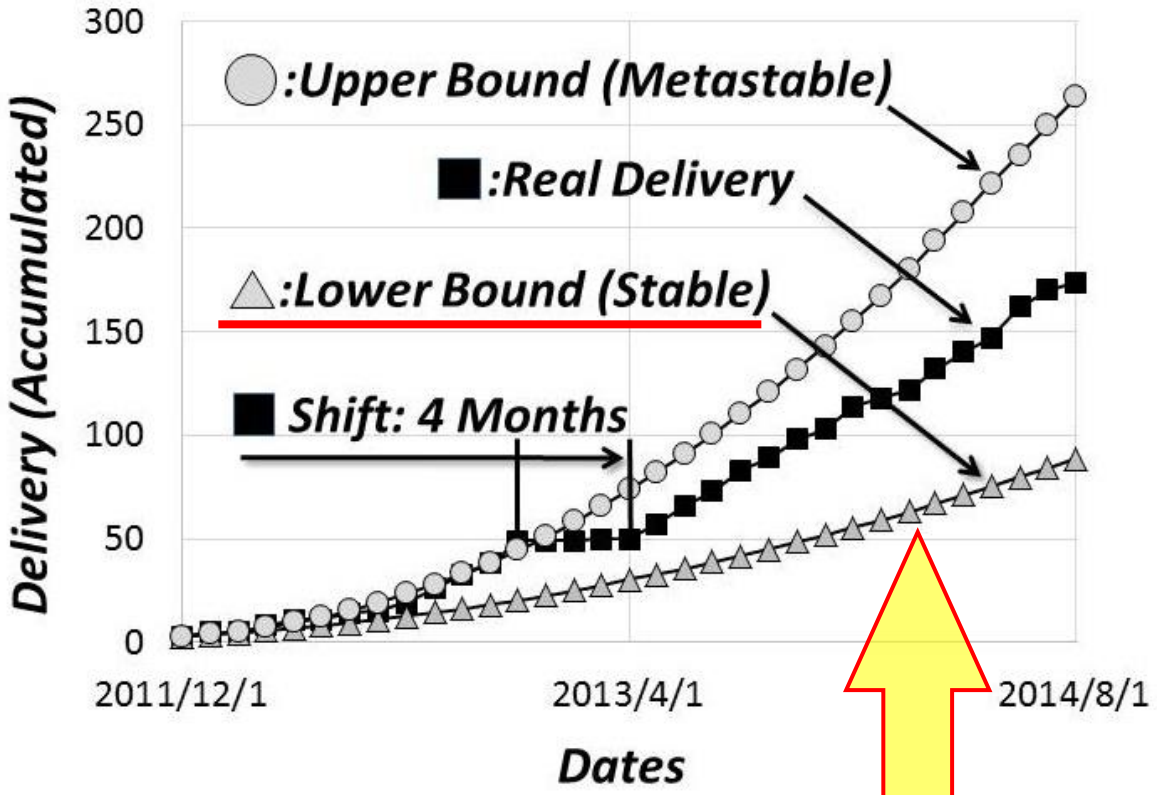


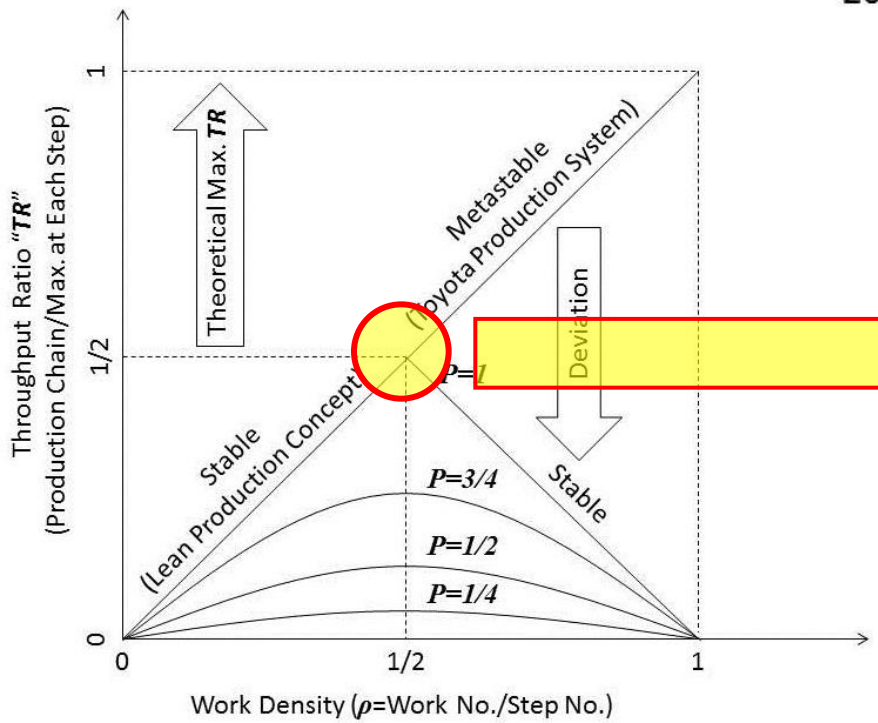

JASDF
Japan Air Self-Defense Force
©JASDF

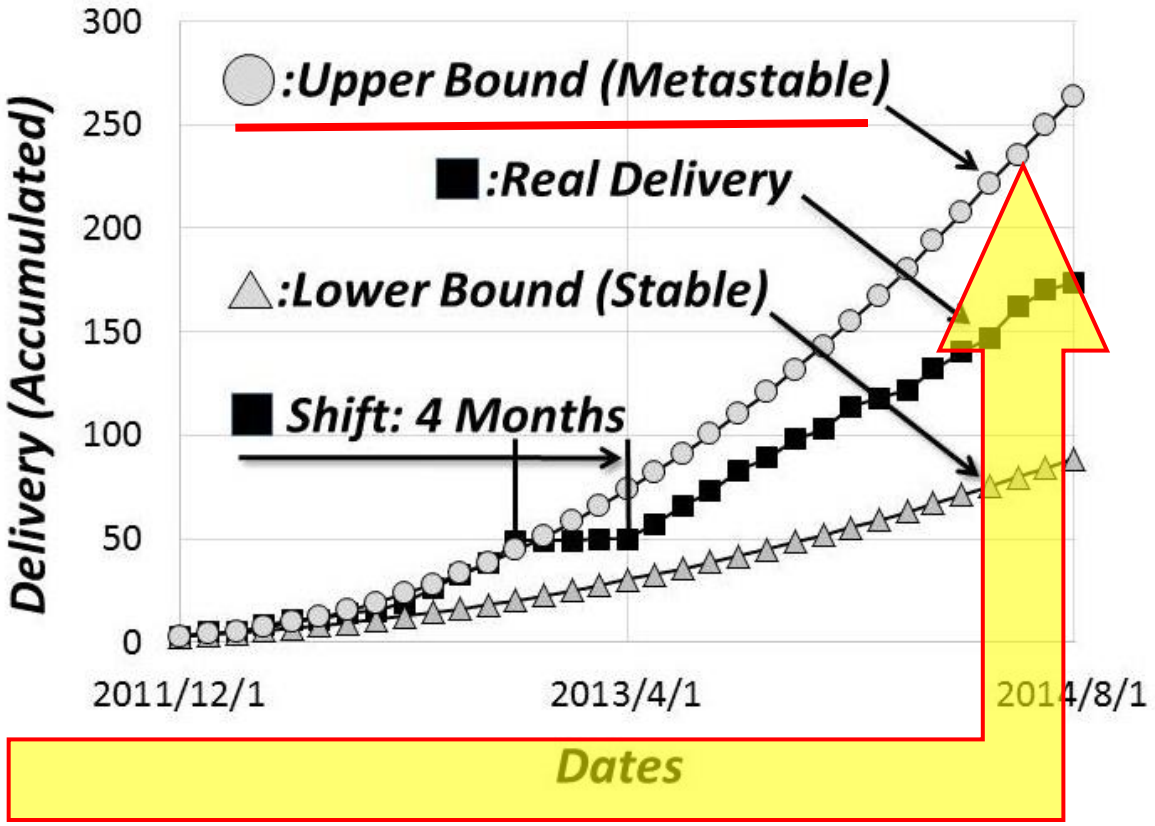
Accumulated Delivery of Boeing787

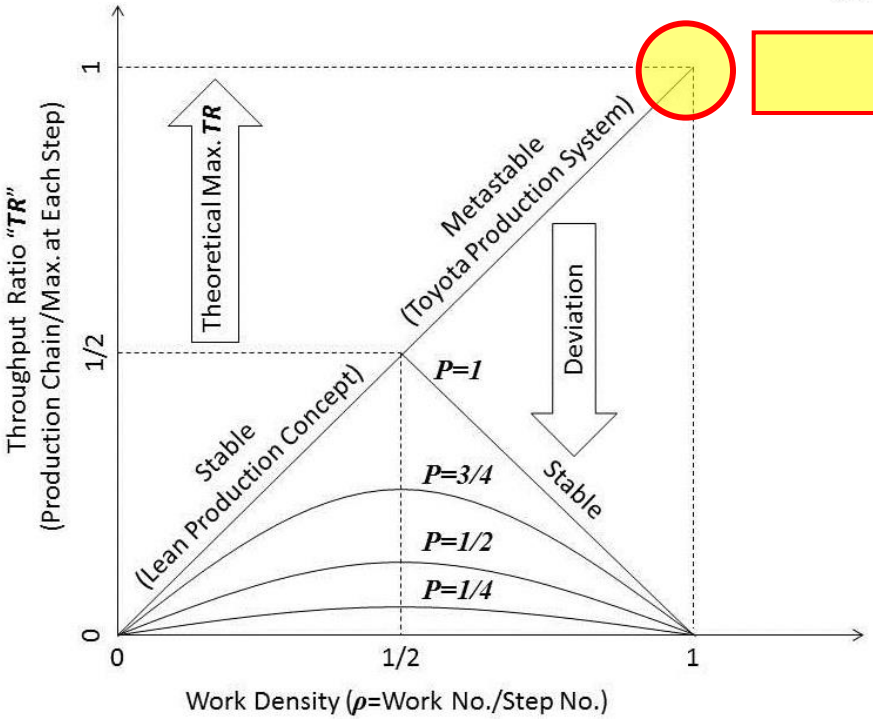


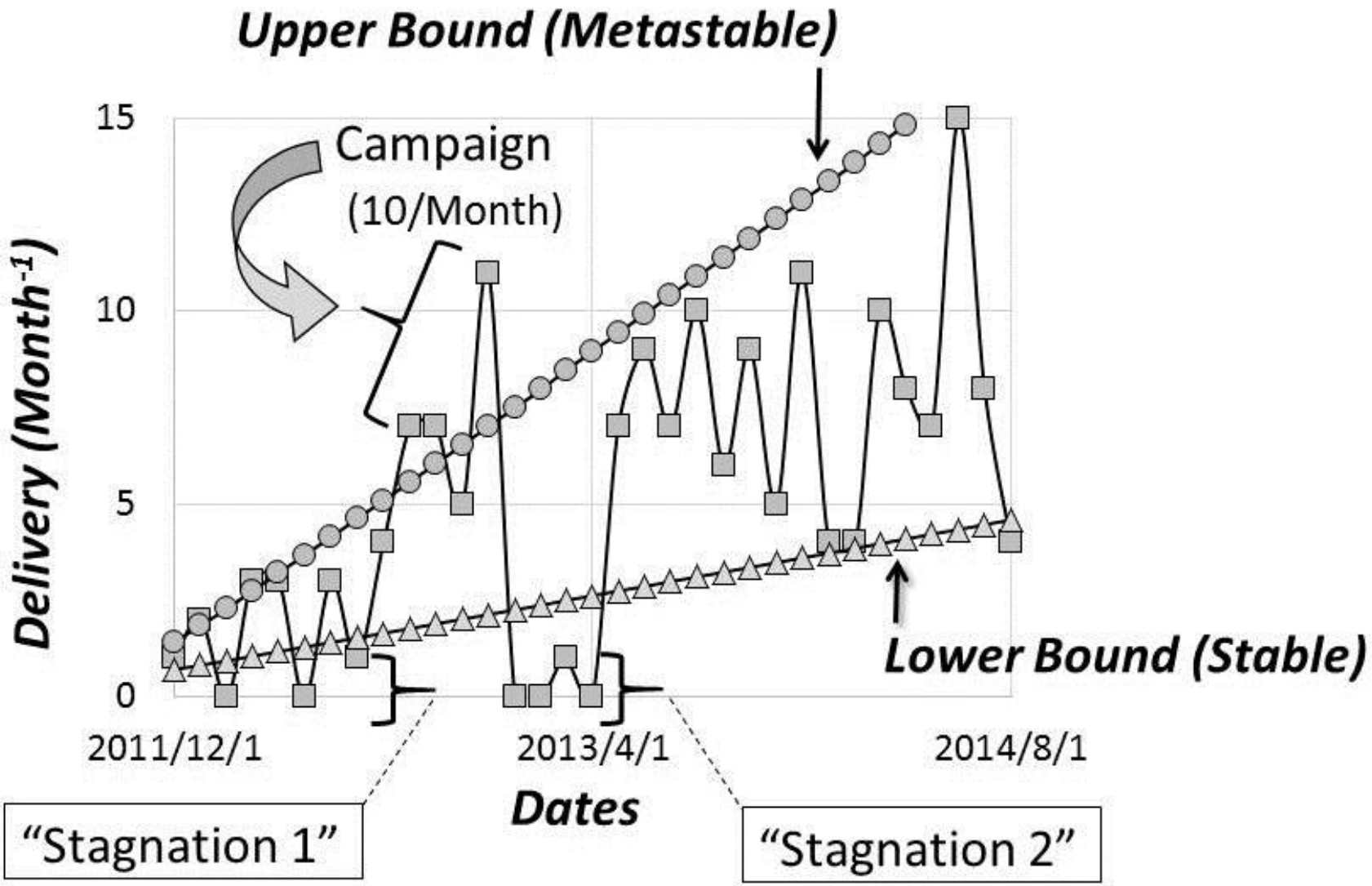

$\dot{N} = \dot{N}_{N=1} \cdot N^{0.515}$
Campaign (10/Month)
"Stagnation"
Delivery (Month^{-1})
15
10
5
0
2011/12/1
2013/4/1
2014/8/1
Dates

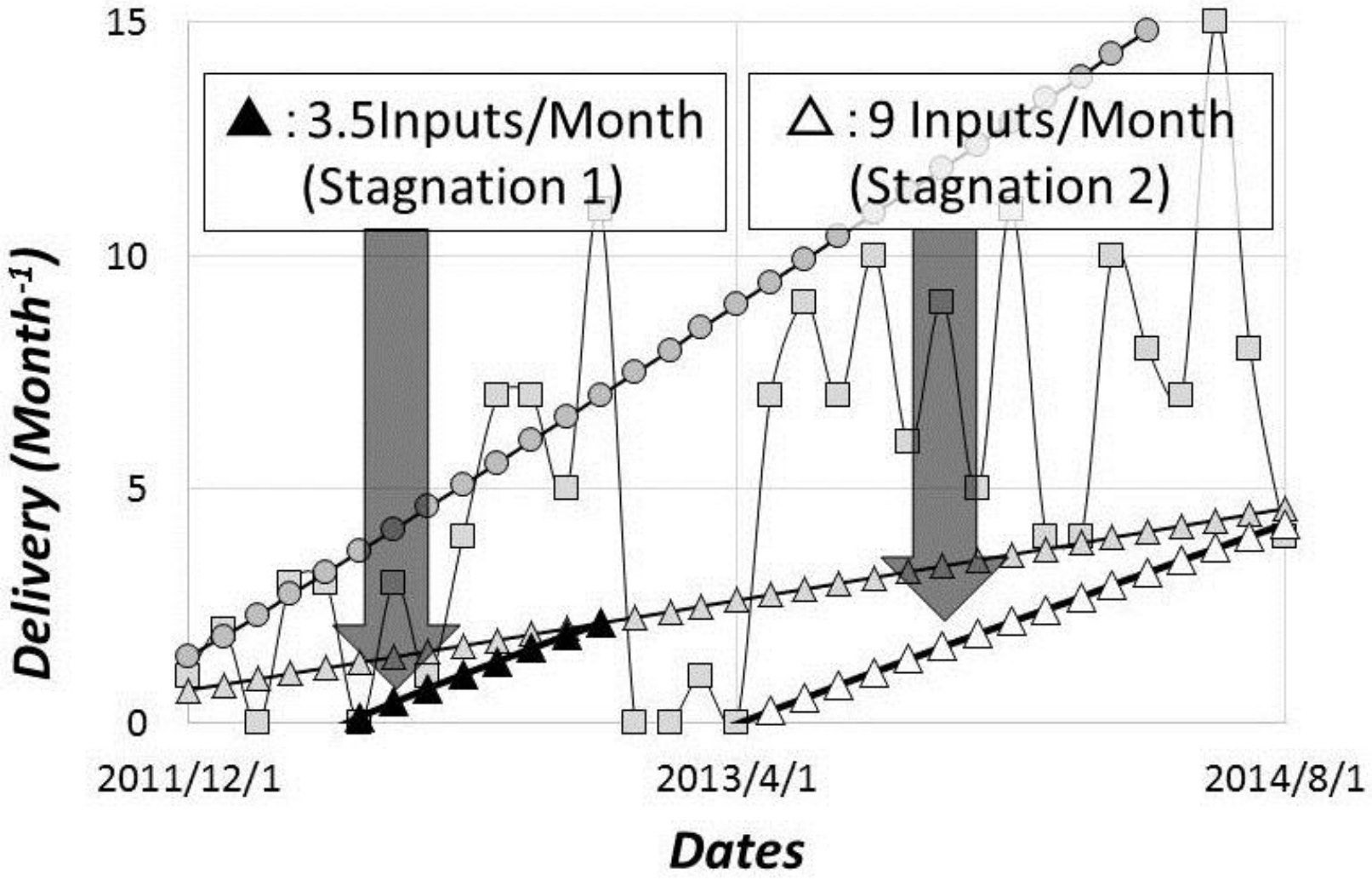

300
250
200
150
100
50
0
Delivery (Accumulated)
:Upper Bound (Metastable)
:Real Delivery
:Lower Bound (Stable)
Shift: 4 Months
2011/12/1
2013/4/1
2014/8/1
Dates


Throughput Ratio "TR"
(Production Chain/Max. at Each Step)
1
1/2
0
Theoretical Max. TR
Metastable
(Toyota Production System)
Deviation
P=1
Stable
(Lean Production Concept)
P=3/4
P=1/2
P=1/4
Stable
0
1/2
1
Work Density (ρ=Work No./Step No.)


300
250
200
150
100
50
0
Delivery (Accumulated)
:Upper Bound (Metastable)
:Real Delivery
:Lower Bound (Stable)
Shift: 4 Months
2011/12/1
2013/4/1
2014/8/1
Dates


Throughput Ratio "TR"
(Production Chain/Max. at Each Step)
1
1/2
0
Theoretical Max. TR
Metastable
(Toyota Production System)
Deviation
P=1
Stable
(Lean Production Concept)
P=3/4
P=1/2
P=1/4
Stable
0
1/2
1
Work Density (ρ=Work No./Step No.)


Upper Bound (Metastable)
Campaign
(10/Month)
15
10
5
0
Delivery (Month-1)
2011/12/1
2013/4/1
2014/8/1
Dates
Lower Bound (Stable)
"Stagnation 1"
"Stagnation 2"


15
10
5
0
▲ : 3.5Inputs/Month
(Stagnation 1)
△ : 9 Inputs/Month
(Stagnation 2)
Delivery (Month-1)
2011/12/1
2013/4/1
2014/8/1
Dates

Contents

1. Introduction:

   CFRP Airframe - Experimental / Mass Production

2. Cell Automaton:

   Lean Production - CFRP Components

3. Stagnation:

   Production Troubles in CFRP Components

4. Discussions

5. Concluding Remarks

CFRP Airframe Delivery

N < 10～20 Units / Month



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Singe-Aisle Twin-Engine Liners

N ～50 Units / Month

If CFRPs・・・

Production Lines:

B787/A350 ×3～4







Even Metal-based B737･･･



By WSJ



By Businessinsider.com

Logistics: Too Tight?

Singe-Aisle Twin-Engine Liners

N ~50 Units / Month

CFRP?







Dreamlifter Operations Center (DOC)



“Buffer” for CFRP Wings


MITSUBISHI
AIRCRAFT CORPORATION
MRJ
Mitsubishi Regional Jet
JA21MJ
MITSUBISHI
AIRCRAFT CORPORATION
Centennial Anniversary
Mitsubishi started airplane business in 1916 March at Kobe.
MRJ is the great corner stone toward a next century.
This picture was shot during 10th MRJ flight, over Ontake and
Fuji mountains with the South Japanese Alps on 4 March 2016.

MRJ

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Concluding Remarks

CFRP Components: Difficult to Produce

Airframe : Mass Production

- **Lean Production - Questionable**
- **Excessive Input – Stagnation / Low Delivery Rate**



Present CFRPs of limited shelf life :

- **Sub Components - Acceptable**
- **Main Components - Stagnation?**

✓B737/A320 Class ⇒Metal + Limited CFRP Components