Business Administration

Lecture No. 15: Flexibility

1. Concept of Flexibility
2. Standardization of Parts
3. Generalization of Process

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1. Concept of Flexibility

Function of Flexibility

Flexibility = softness, accommodation, elasticity, versatility
system's capacity to correspond to change/variety

Secondary, potential factor, compared to QCD

Flexibility of and to what?

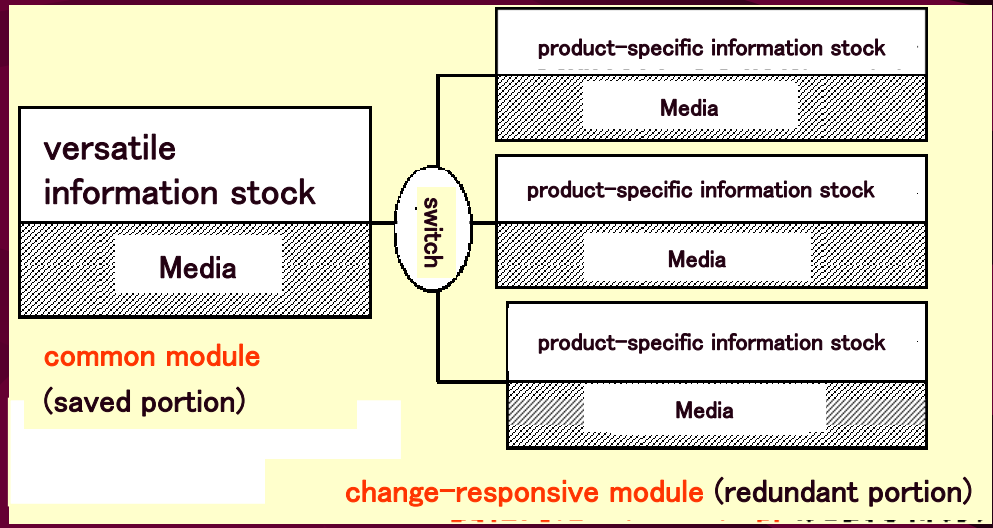
- Flexibility, of cost, quality, deliver, etc.
  to change, variety, etc.

Structure of Flexibility

(1) Common module (facility body, versatile technology, common parts, etc.)

(2) Change-responsive module
(mold, product-specific skills, product-specific parts)

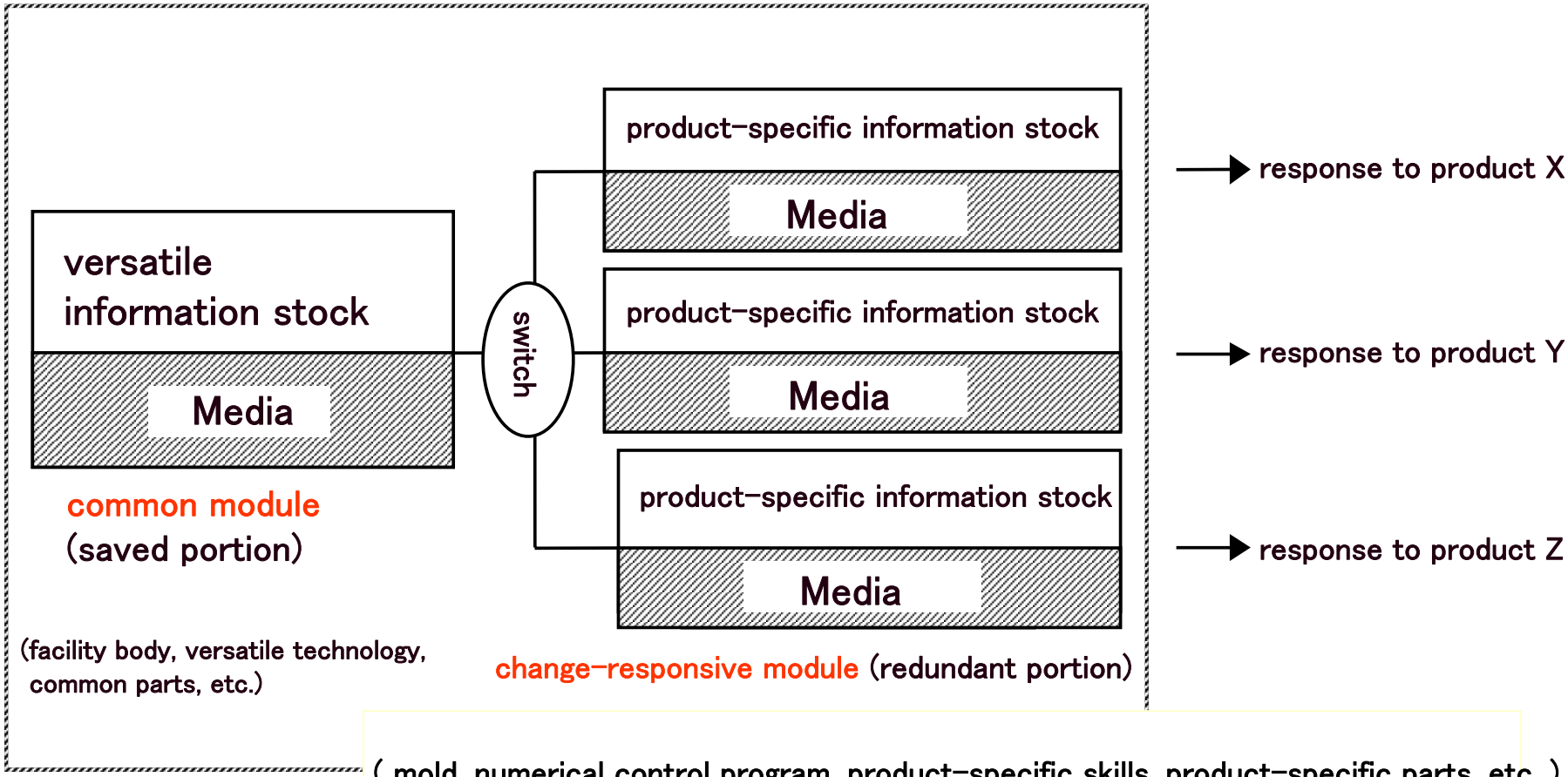
→redundant portion



Switch the latter up to product

examples : press machine and mold
NC machine tool and NC program
common parts and special parts

Basic Structure of Flexibility (Response to Product Variety)



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p310 figure.8.1)

Types of Flexibility (of X to Y ---)

(1) classification regarding to system function (of Y)

re execution possibility ---

re productivity ---

re quality -

(2) classification regarding to environmental change (to X)

re production volume ---

re product variety ---

re product change ---

others

Criteria of Flexibility

magnitude of system's functional change / magnitude of environmental change

for, example, $TC = FC + VC \cdot X$

$$TC / X = AC = FC / X + VC$$

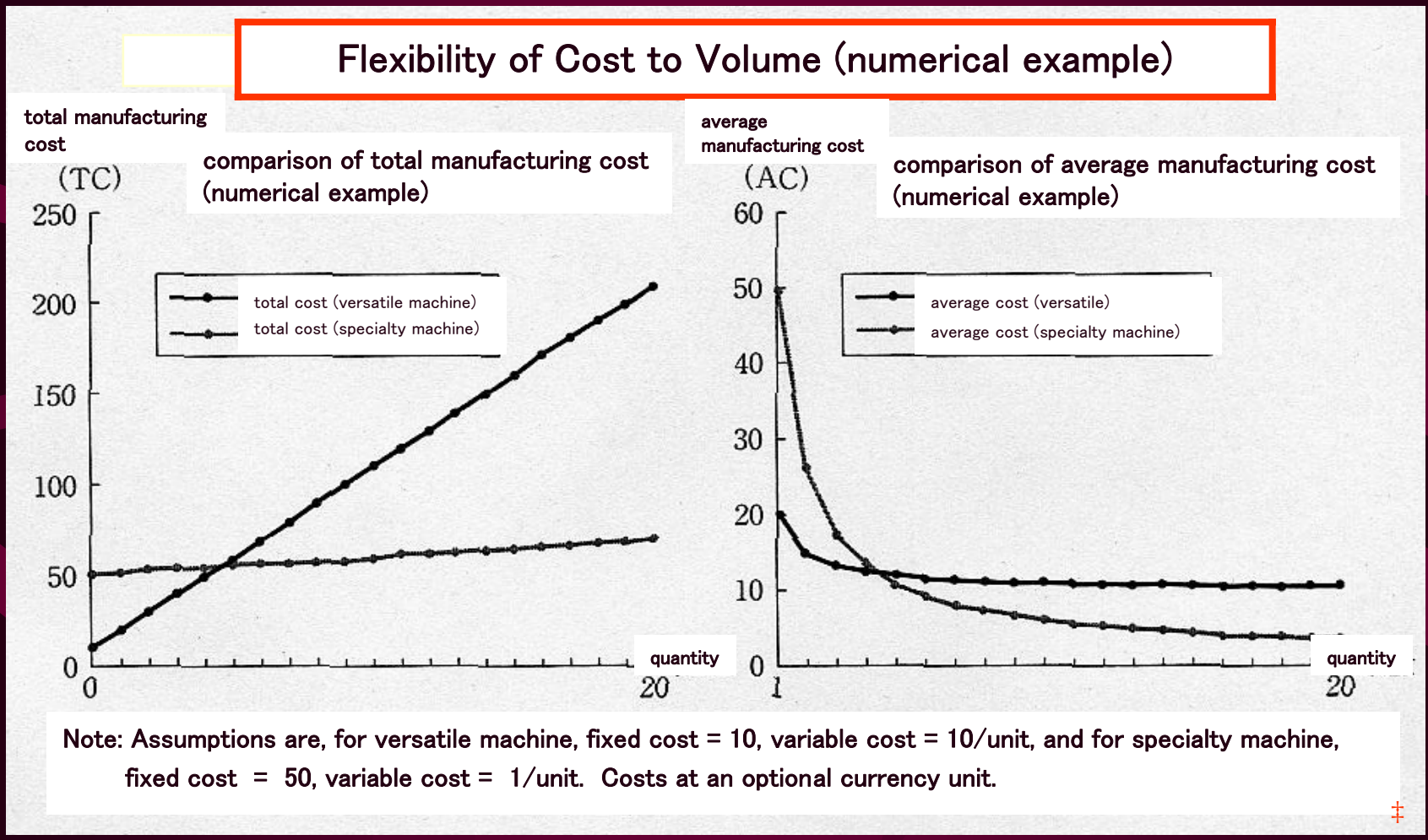
comparison of versatile facilities and specialty facilities

$TC = FC + VC \cdot Q$

$AC = FC/Q + VC$

while, TC = total manufacturing cost ; AC = average manufacturing cost
FC = fixed cost ; VC = variable cost ; Q = production

Flexibility of Cost to Volume (numerical example)



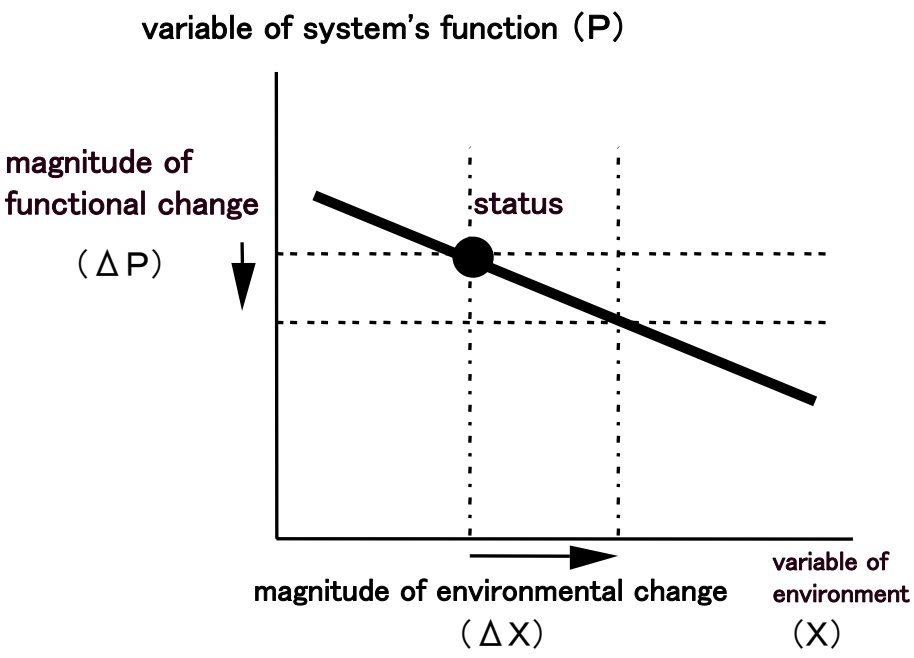
Note: Assumptions are, for versatile machine, fixed cost = 10, variable cost = 10/unit, and for specialty machine, fixed cost = 50, variable cost = 1/unit. Costs at an optional currency unit.

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p313 figure.8.2)

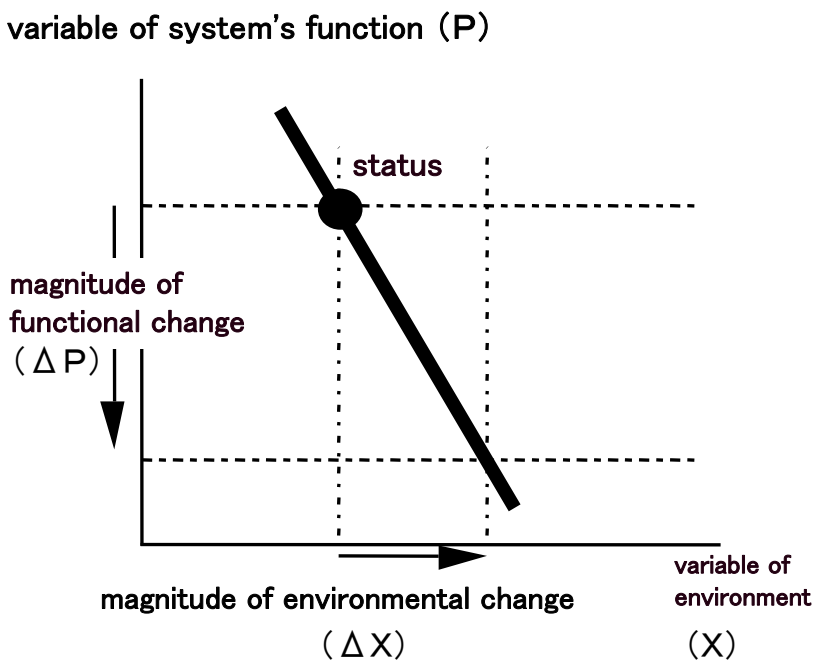
Concept of Flexibility (1) : Expression by "Moderateness of Slope"

flexibility = magnitude of system's functional change / magnitude of environmental change = ΔP / ΔX

system of highly flexibility



system of low flexibility



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Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p314 figure.8.3)

Concept of Flexibility (2) : Expression by "Width of Response-Capable Domain"

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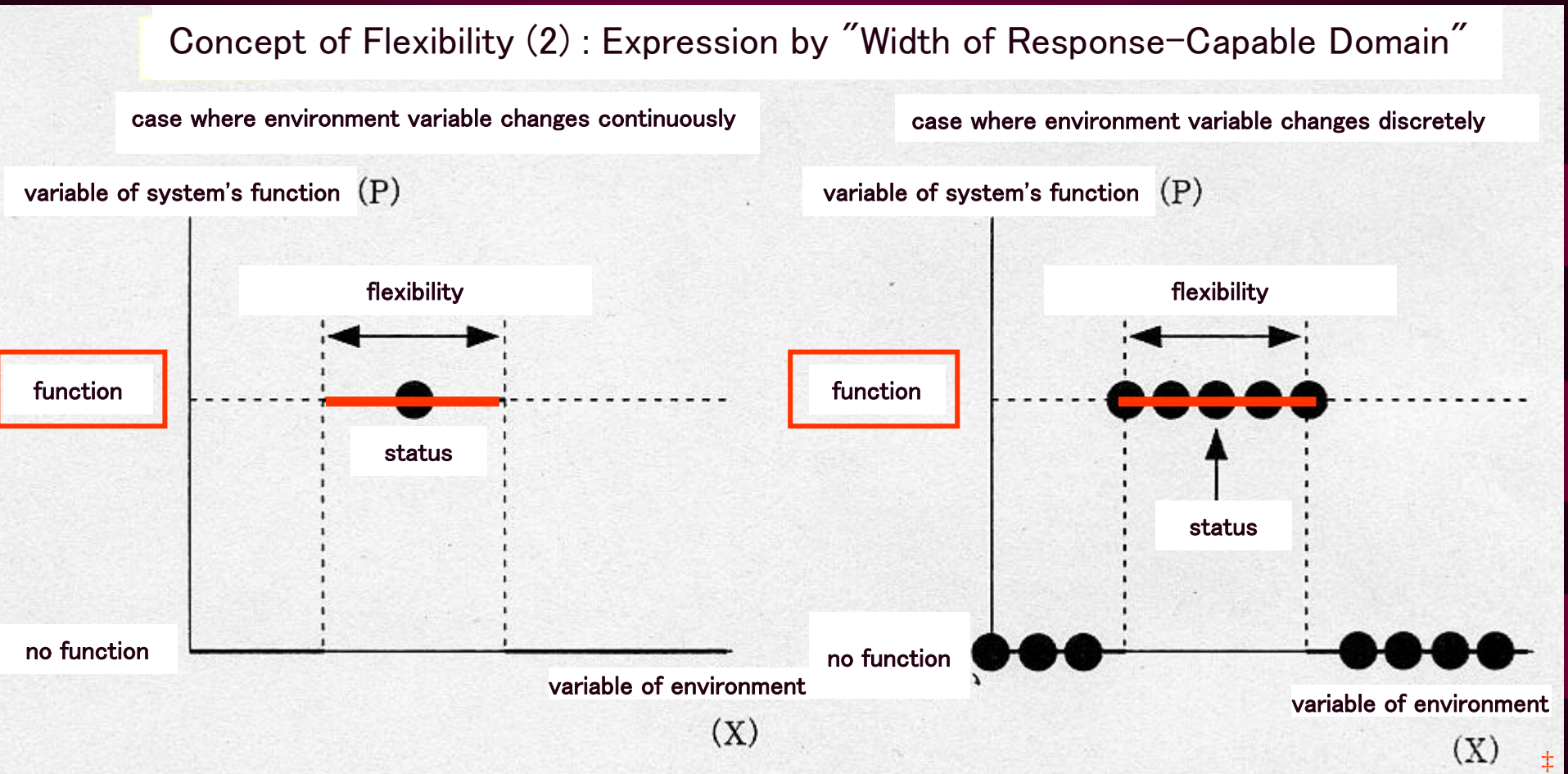

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p315 figure.8.5)

Constituent Elements of Flexibility (Parts Flexibility and Process Flexibility)

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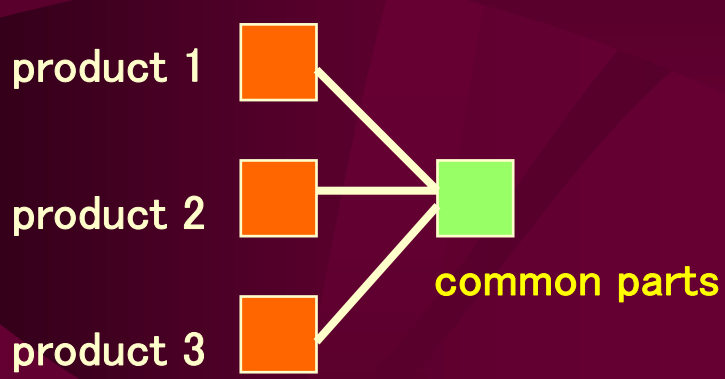
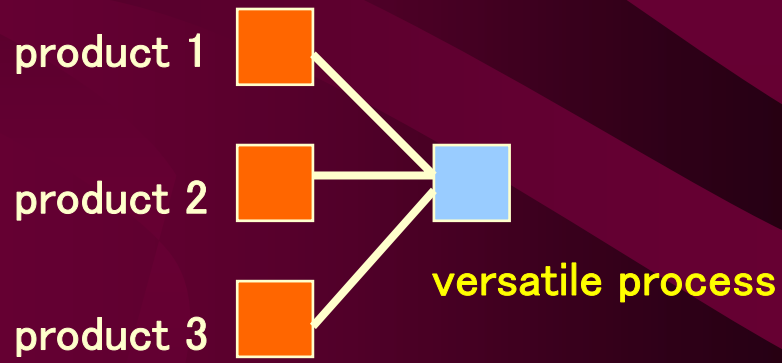
Takahiro Fujimoto 'Note concerning Technology System' Nihon Keizai Shimbun, Inc.
Reference: Moriaki Tsuchiya 'Technical Improvement and Business Maneuver'

Example: Flexibility to Product Change in Terms of Cost

flexibility in parts = parts standardization

flexibility in process = processes generalization



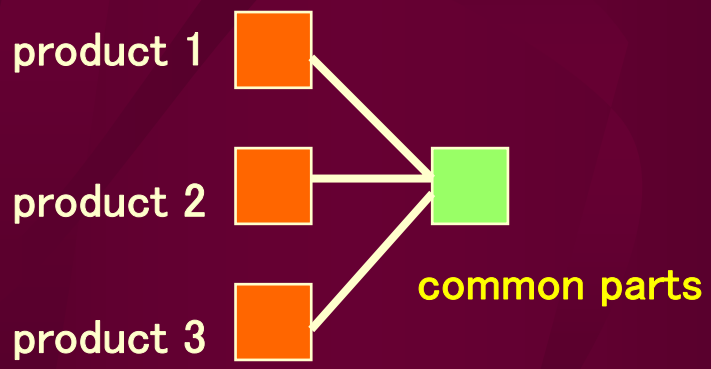


2. Generalization of Parts

Plural variety of finished products share parts of the same design.

example : meter gauge

automobile （to share platform）



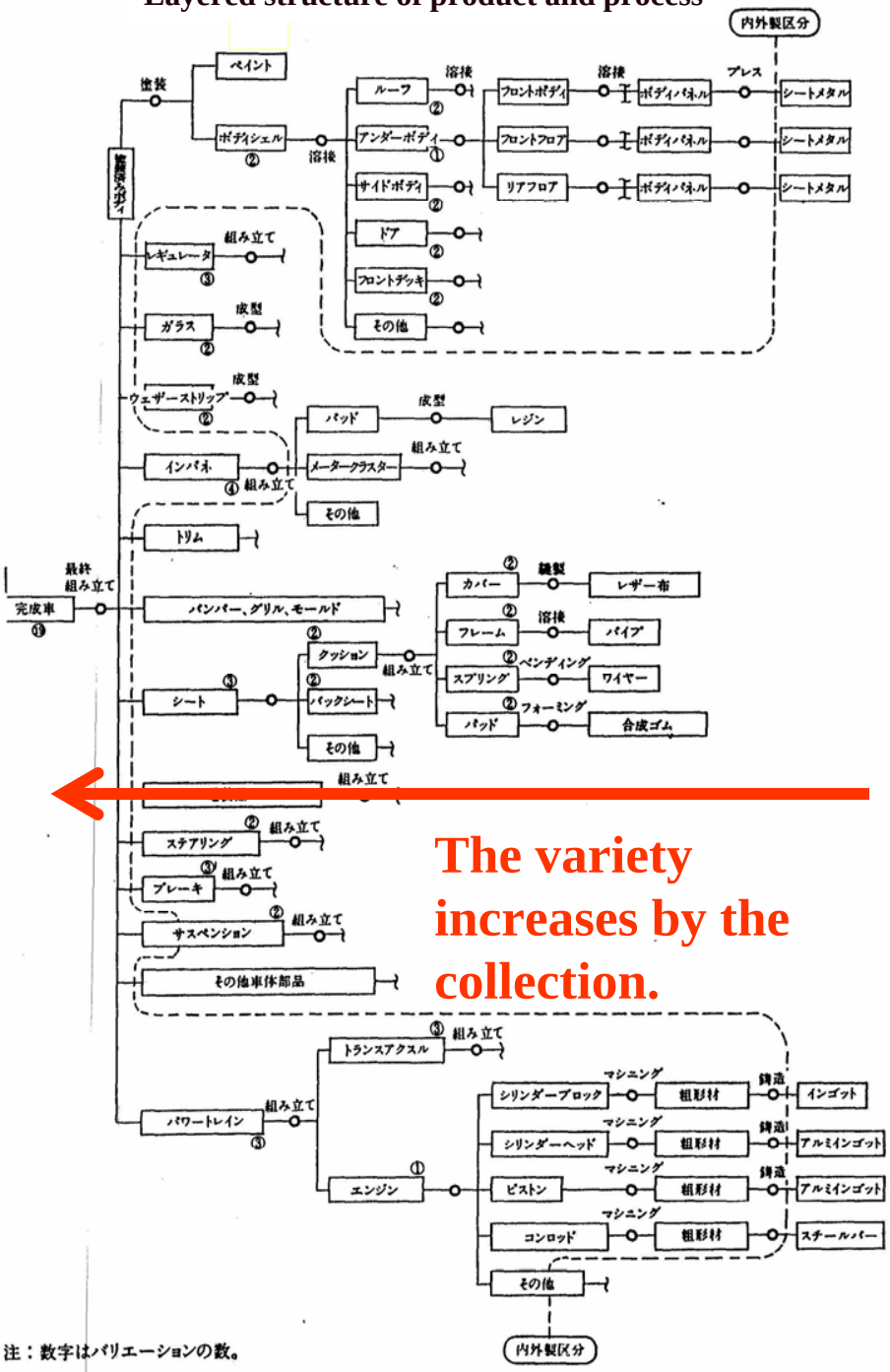
Standardization of Meter Gauge Parts (Denso)

name of parts	variety units under old system	variety units under new system
case	3	3
terminal	13	4
bimetal	8	4
voltage regulator	20	3
base	2	1
base case	4	2
total （A）	50	17
number of combinations theoretically possible（B）	49,920	288
actual meter variety units（C）	60	60
standardization index C／B	0.1%	21%

Author making（reference: Mitsubishi Research Institute "Factory Automation" 1983 ）

Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p317)

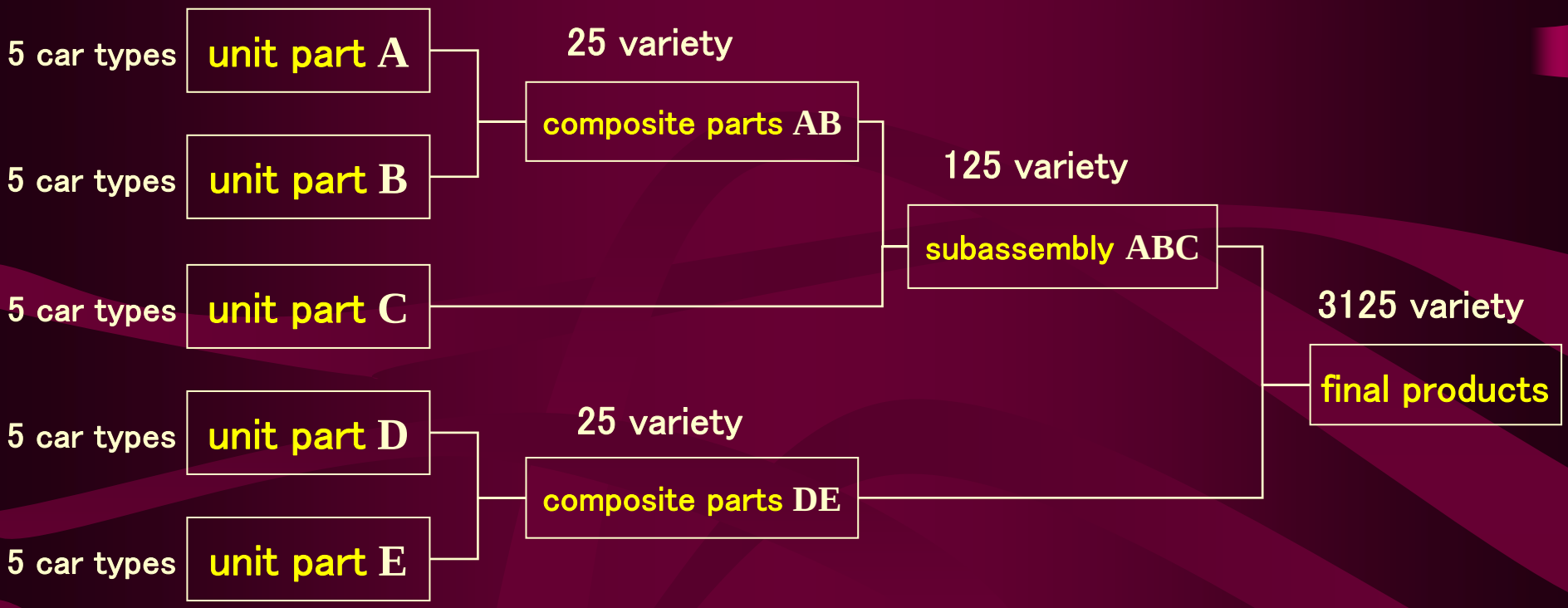
Layered structure of product and process



The variety increases by the collection.

注：数字はバリエーションの数。

Layer Structure of Modular-type Parts and Synergy of Variety



Note: Assuming each unit part being 5 types, all combinations being possible for commercialization.

Distinction in Architecture

Modular architecture

function self-contained, interface standardized, easy to combine

Integral architecture

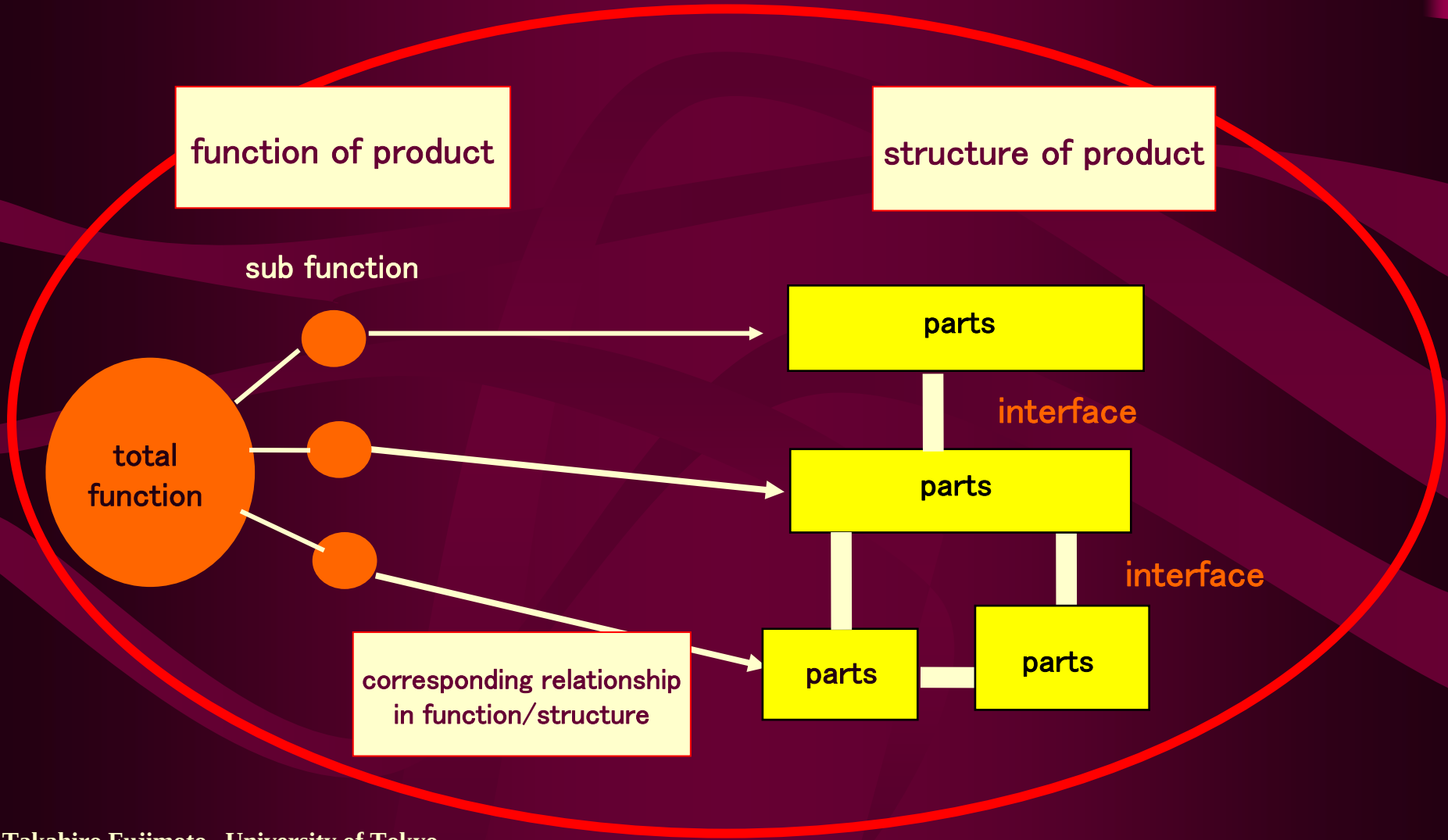
interdependence, interface specialized, lapping required

Open architecture

interface being standardized in industry
gathering among different companies being possible

"Idea of Architect" is called "Architecture"

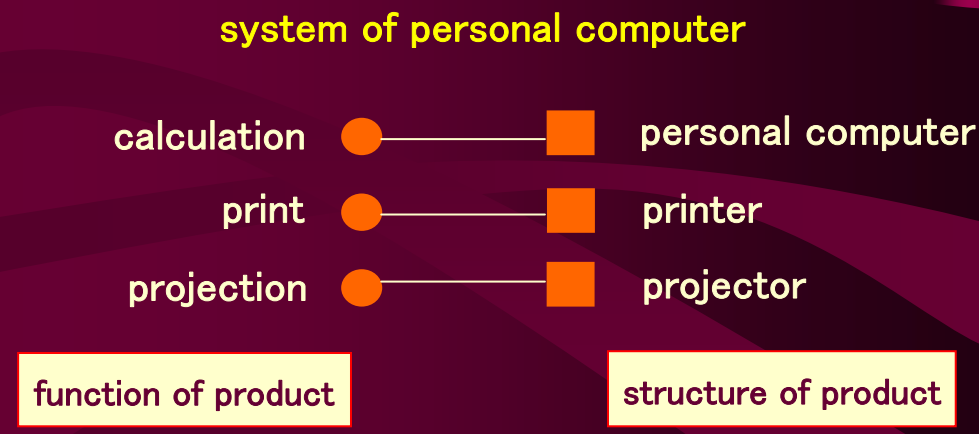
Basic design thought regarding how to allocate functions required for products on each component portion (part), and how to design interface among parts.



Modular (combination) Architecture and Integral (lapping) Architecture

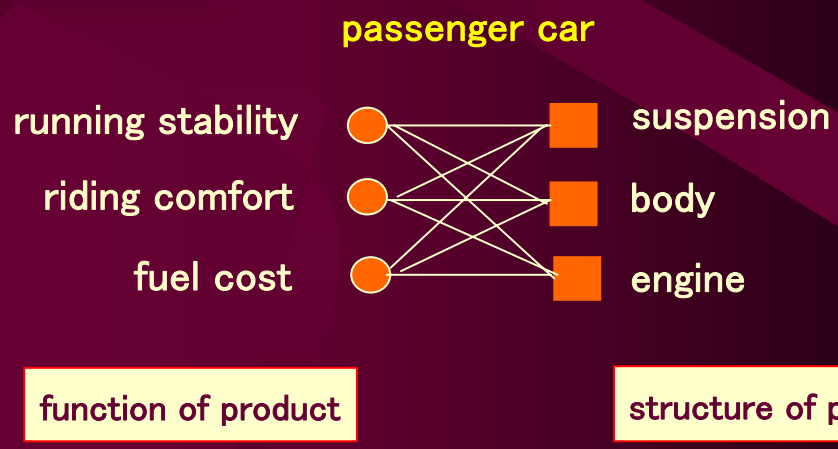
Modular Architecture

modular (combination) model

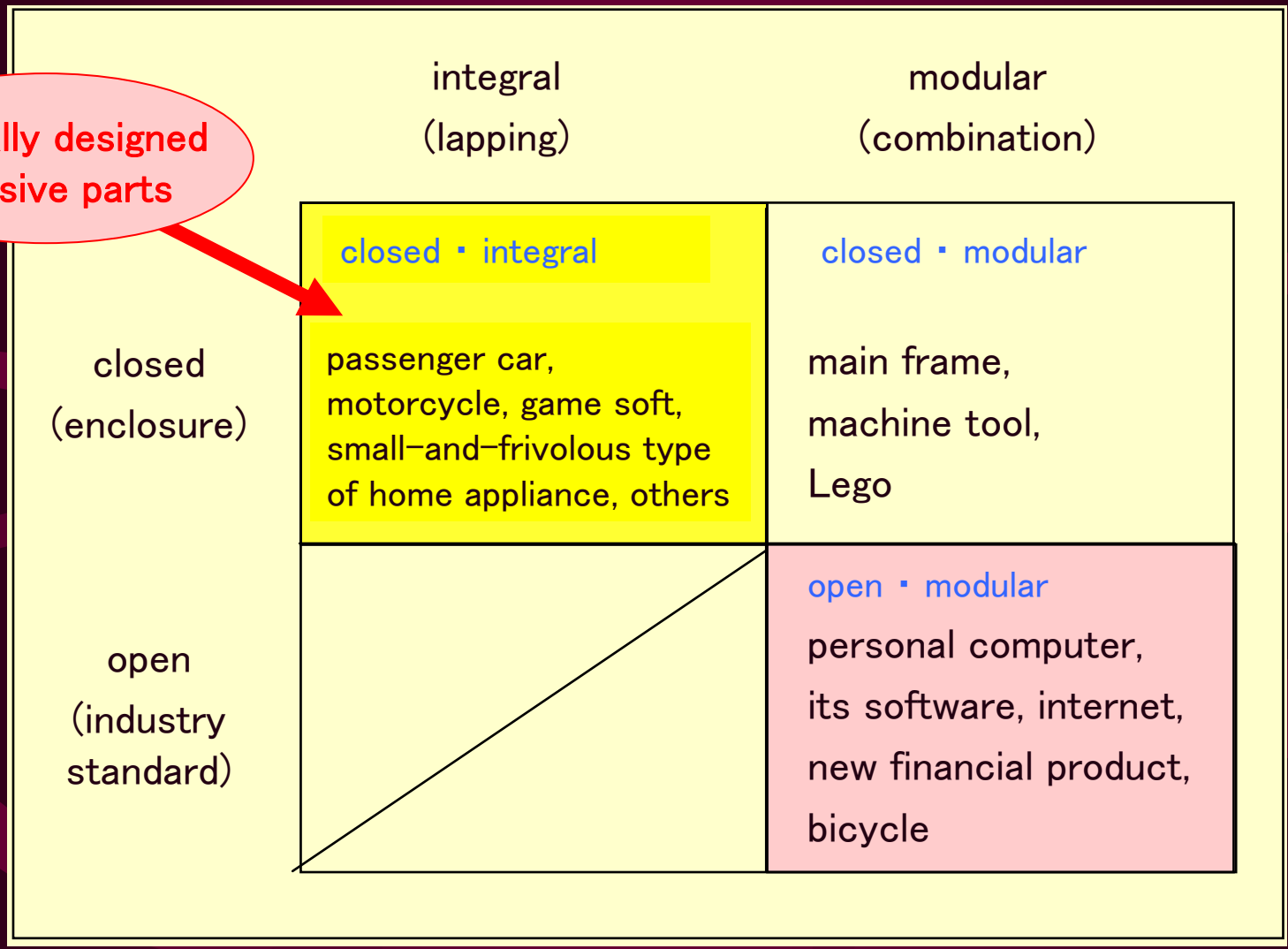


Integral Architecture

integral (lapping) model



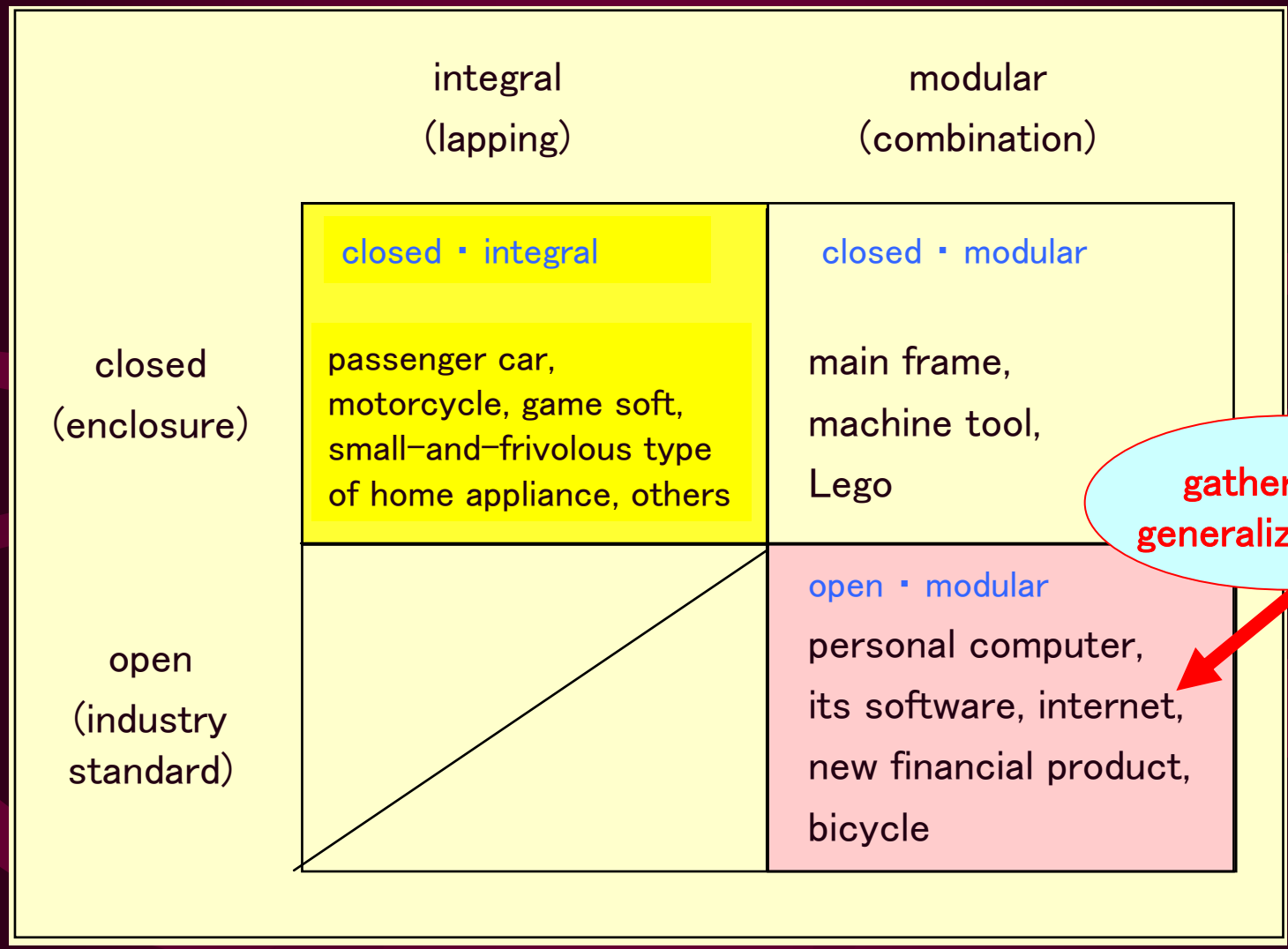
Basic Type of Product Architecture



Lapping Model (Closed Integral) Product: Passenger Car

generalized parts (usable for products of various companies) being less than 10%

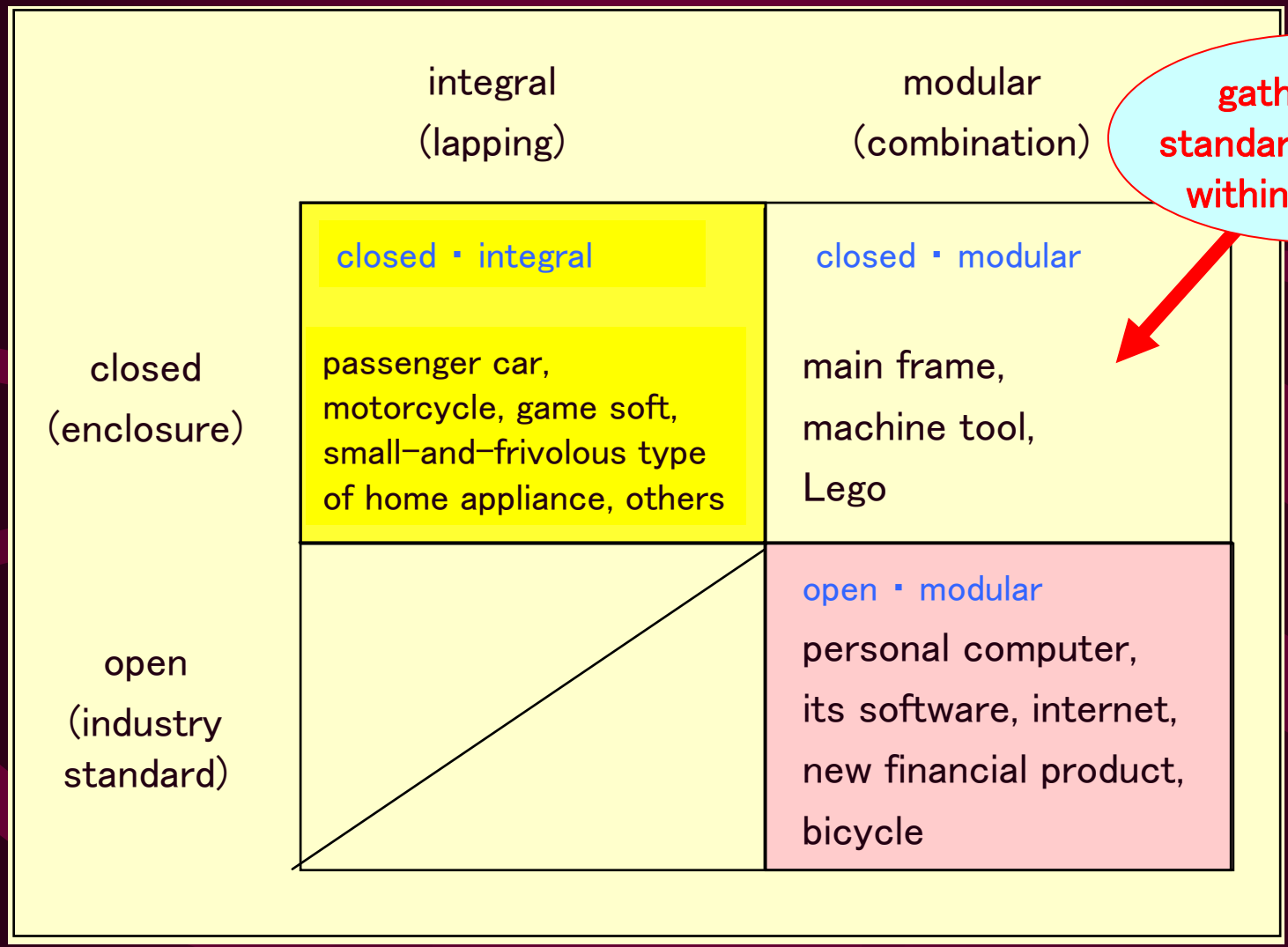
Basic Type of Product Architecture



Product of Open Modular Model (Personal Computer System)

generalized parts (usable for products of various companies) being more than 50%

Basic Type of Product Architecture



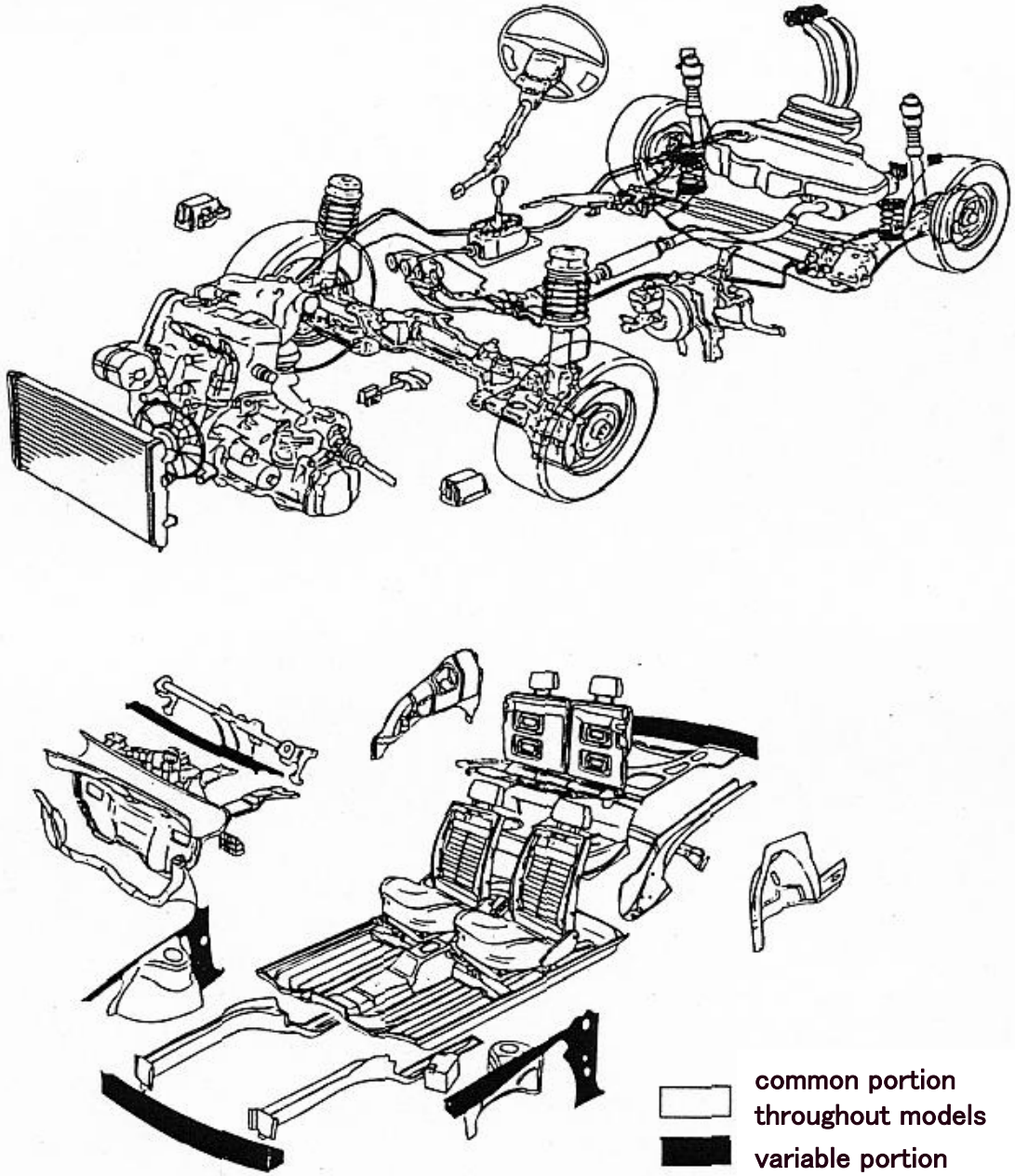
Closed Modular Product (Main Frame Computer)

Produce many variety of products by putting together
"inter-company standardized parts" designed by own company.

Closed Modular (Lego)

Auto's Platform

Auto's standardized platform parts (example of VW Co. in 1998)



Source: VW Co.
Reference: Takahiro Fujimoto
'Introduction to Production Mmanagement'
Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p320)

Models Sharing Platform (Example) ---- Old case

セリカ リフトバック 1800 ST

カリーナ セダン 1600 DOHC GT

Models Sharing Platform (Example) --- Sophisticated nowadays

LEGACY

LEGACY TOURING WAGON

LEGACY LANCASTER

FORESTER

IMPREZA

IMPREZA SPORT WAGON

'Car Guide Book' Japan Automobile Manufacturers Association, Inc. 1999 2000

Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p321)

Standardization of Process Configuration Factors of Parts

What is important for cost reduction is not really
standardization of parts design per se,
but rather sharing of production facilities and jig tools.

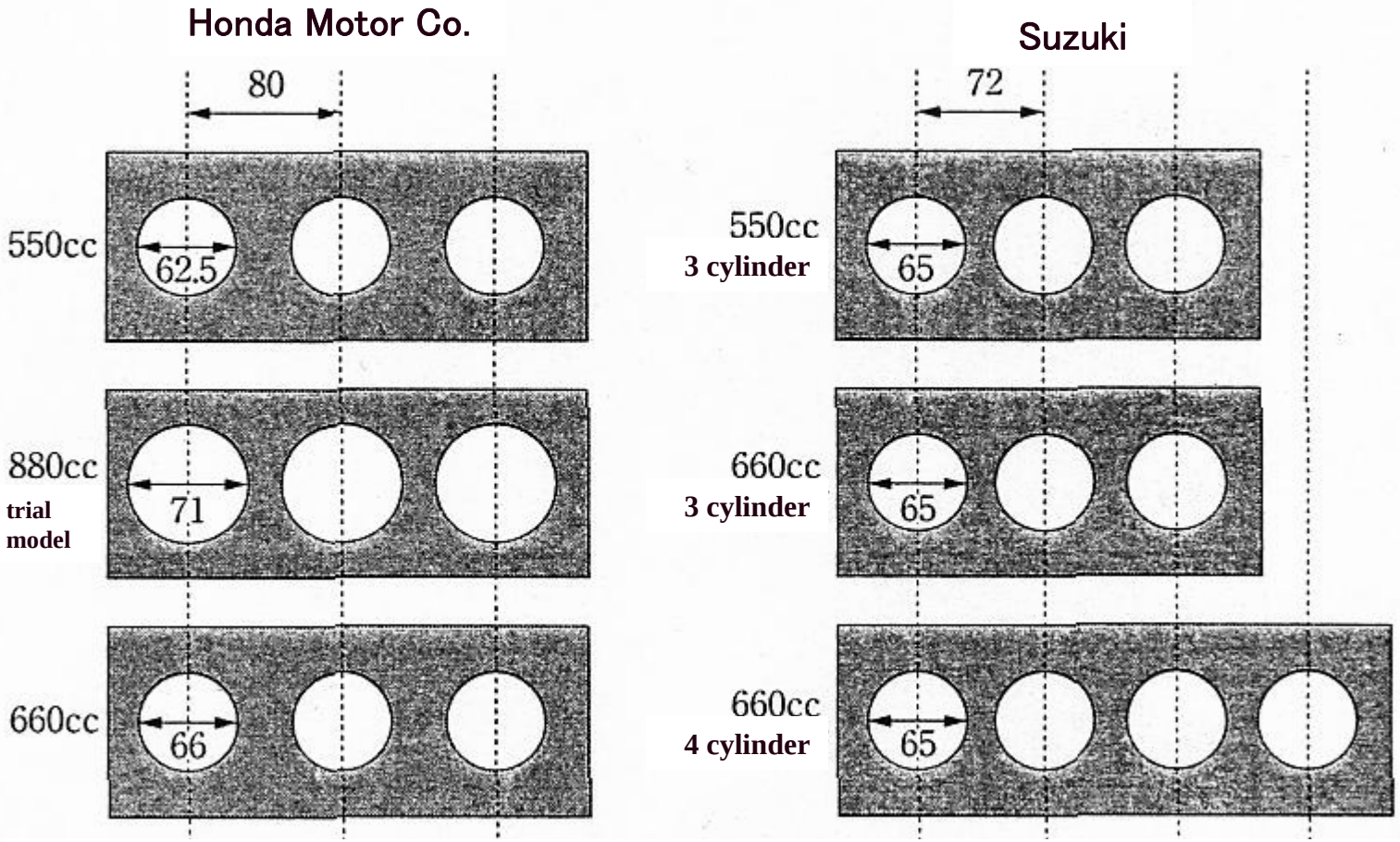
→ standardization of process configuration factors

example: 4-cylinder engine and 3-cylinder engine

ref: group technology (GT)

Process Configuration Factors in Engine Block Design

(Bore Pitch) Example of standardization



Note: Conceptual diagram looking at engine cylinder blocks from above. Circular portions are cylinder cavities which receive a cutting operation with multi-axis tool machines. ‡

Author making (reference: Produced by the author from an usage/attitude survey')

Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p323)

Pros and Cons of Parts Standardization

- volume production effect → cost reduction
- appropriation of existing facilities → quality stabilization
- availability of repair parts
- easier inventory control
- reduction in delivery (Benetton's sweater)
- concern about losing Product Integrity
- concern about retarding Product Differentiation

Status of Standardization of X Car's Body Panel ---too much standardized?

Brand	Body type	Front fender	Rear fender	Door	Window shield	Front grill
Chevrolet Citation	2-door sedan	①	①	①	①	①
	2-door liftback	①	②	①	①	①
	4-door liftback	①	③	②	①	①
Pontiac Phoenix	2-door sedan	②	④	①	①	②
	4-door liftback	②	⑤	②	①	②
Oldsmobile Omega	2-door sedan	③	⑥	③	②	③
	4-door sedan	③	⑦	④	②	③
Buick Skylark	2-door sedan	④	⑧	③	②	④
	4-door sedan	④	⑨	④	②	④
Total number of types	9	4	9	4	2	4

Ref: Industry data. Mitsubishi Research Institute "Future of Automobile" 1981

3. Generalization of Process (Flexibility of Process)

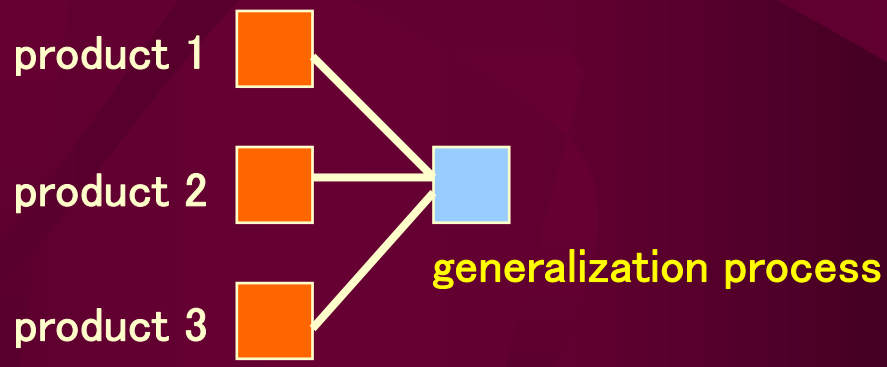
For one process (facility, worker),

having a stock of plural product design information,

in way of switching it,

to respond to plural processing goods.

No time/cost for "set up".



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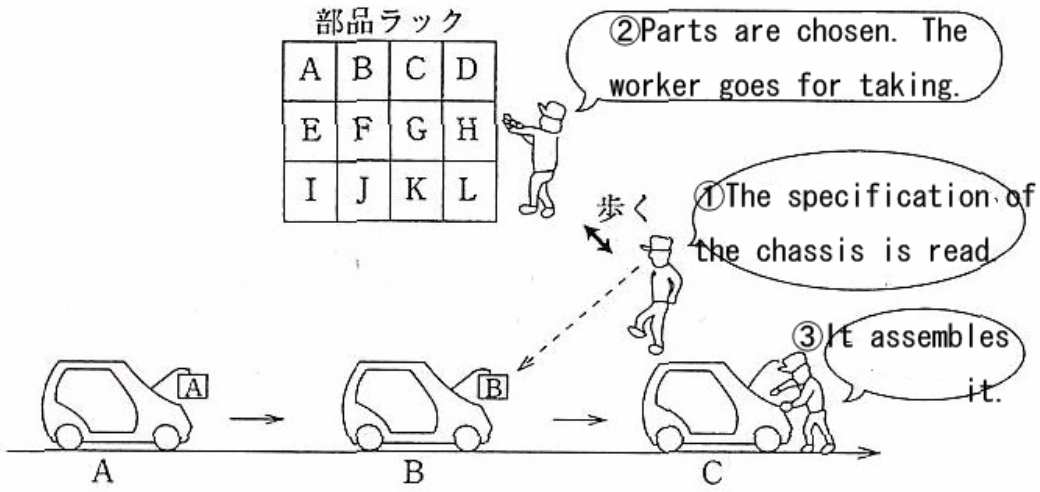
Takahiro Fujimoto 'Note concerning Technology System'
Nihon Keizai Shimbun, Inc.
Reference: Moriaki Tsuchiya
'Technical Improvement and Business Maneuver'

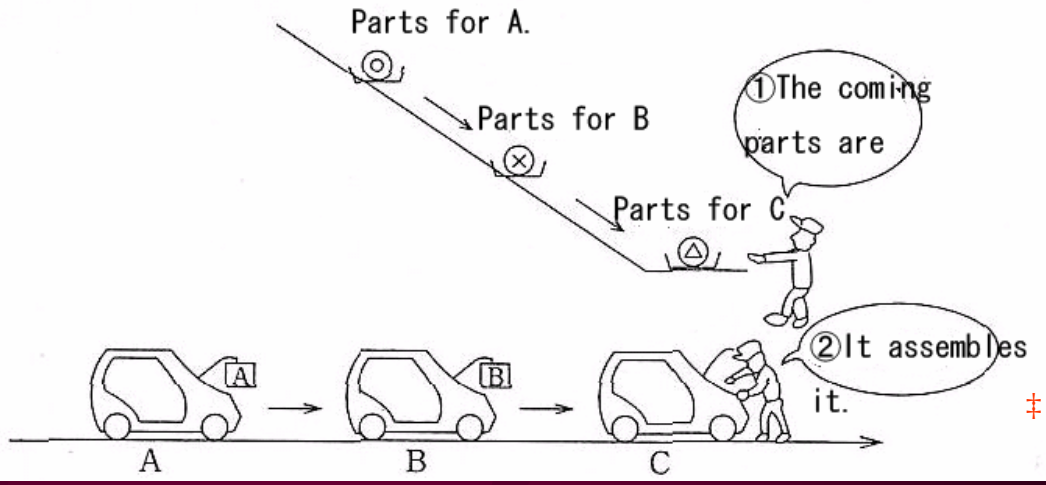
Response of Assembly Line to Product Variety

Correspondence to making to many varieties in assembly line.

a. The worker carries parts from the part rack.



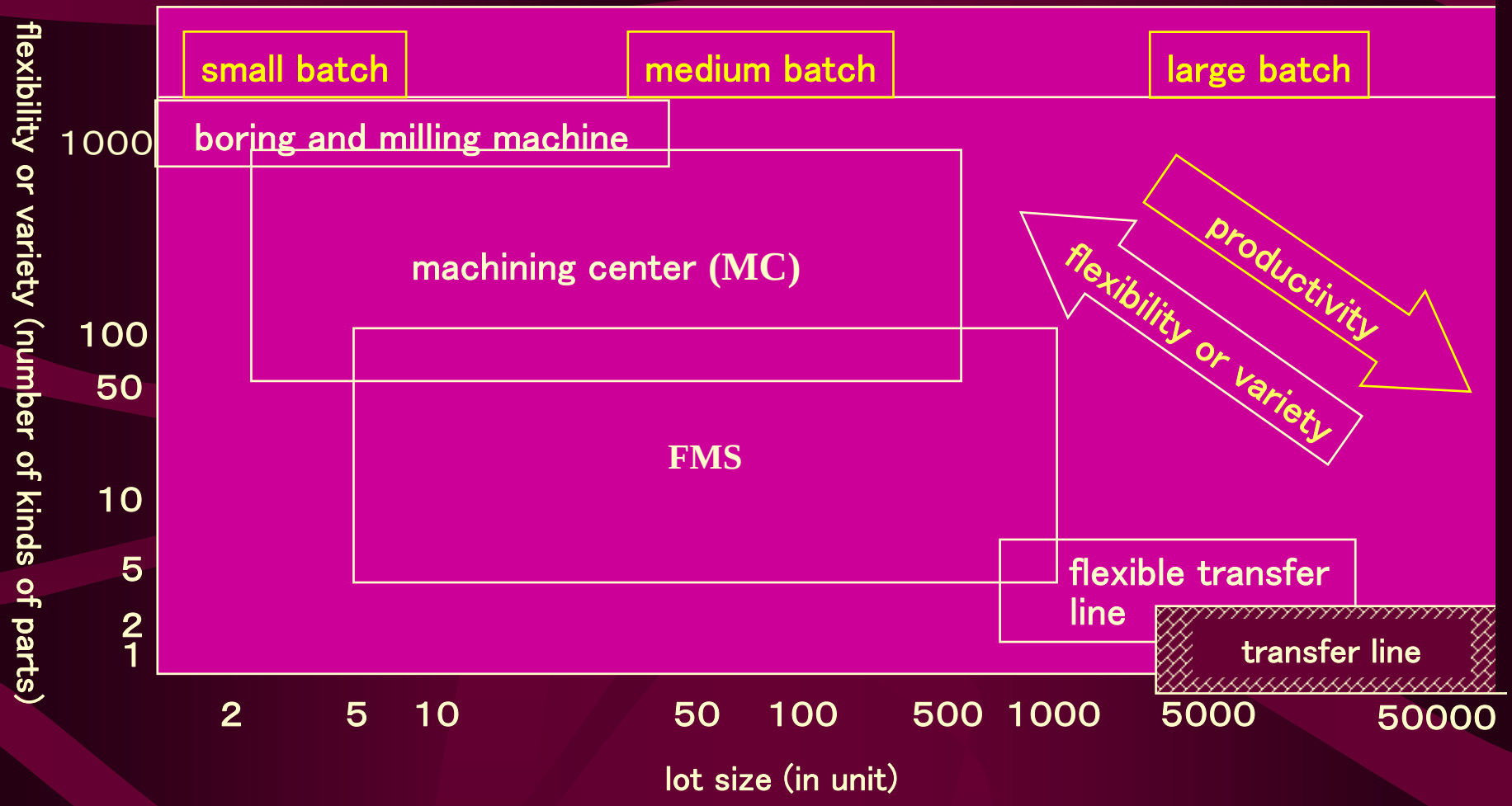
b. Parts are supplied to the line side in the order.



Author making (reference: 'Investigation of actual conditions material')

Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p332)

Generalization of Machine Tool



In the conforming range of FMS as per conventional concept (Iwata Ito)

Yoshimi Ito, Kazuaki Iwata 'Range of agreement of FMS by past concept (Depend on Klahorst).

"Set Up Time" and Its Improvement

In-line set-up = set-up of variety that accompanies an interruption of process works

Off-line se-up = set-up of variety that does not accompany an interruption of process works

--- "transforming in-line set-up to off-line set-up" as the first step

Analysis on cost of set up time

Example: pressing process; web process

Cost Analysis of Set-Up Time

Cost calculation for set-up time , while up to premises, is done in a standard example as follows:

For the purpose of simplification, assume production capacity is constant, and a capacity operation can be maintained. Firstly, consider man-hours (hours of labor or machinery per unit of work) in a lot (one group of numbers when producing the same variety at one time), in the following terms;

$$T_w = T_p + (T_s / X)$$

while, T_w = man-hour required per unit of work

T_p = man-hour for processing works per unit of work

T_s = man-hour for set-up works per lot

X = lot size

Therefore, when personnel charge is C_w, capital charge (or, expense) is C_c, product cost (A C) per unit of work is designated as;

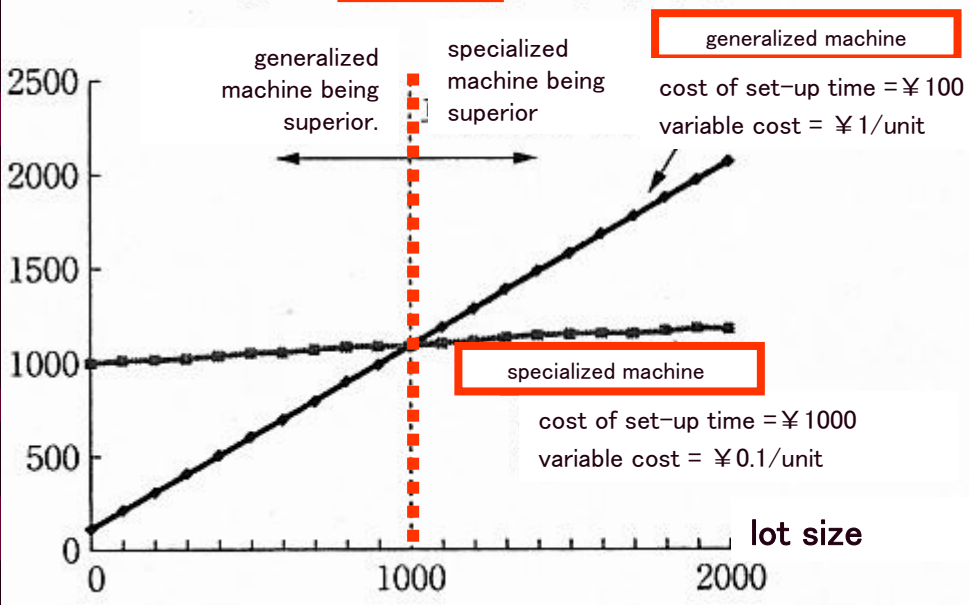
$$AC = (C_w + C_c) T_w = [(C_w + C_c)] T_p + [(C_w + C_c)(T_s / X)]$$

While, in a process where only processing work is automated, the first C_w becomes zero. In a process where set-up time is not necessary, the second number disappears rightly as $T_s = 0$.

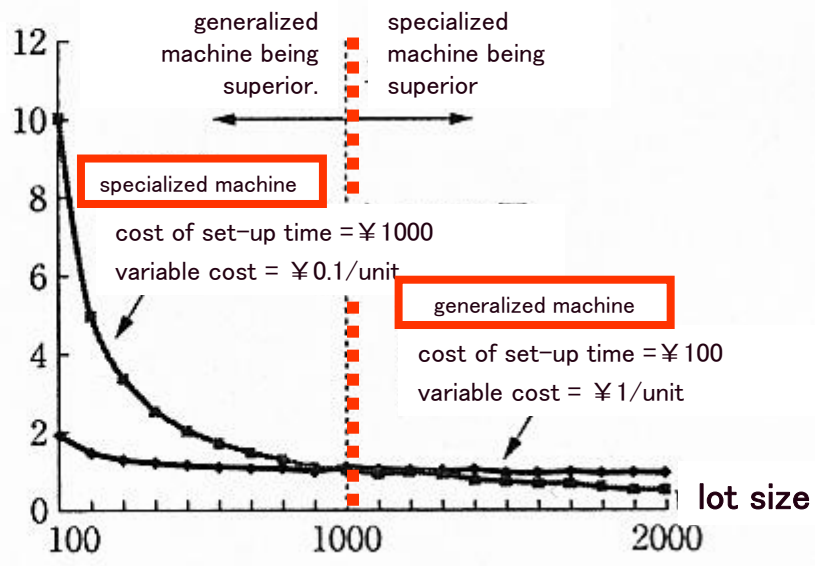
Specialized Machine and Generalized Machine: Cost Comparison of Set-Up Time

Cost Comparison of Set-Up Time (numerical example)

comparison of total cost (numerical example)



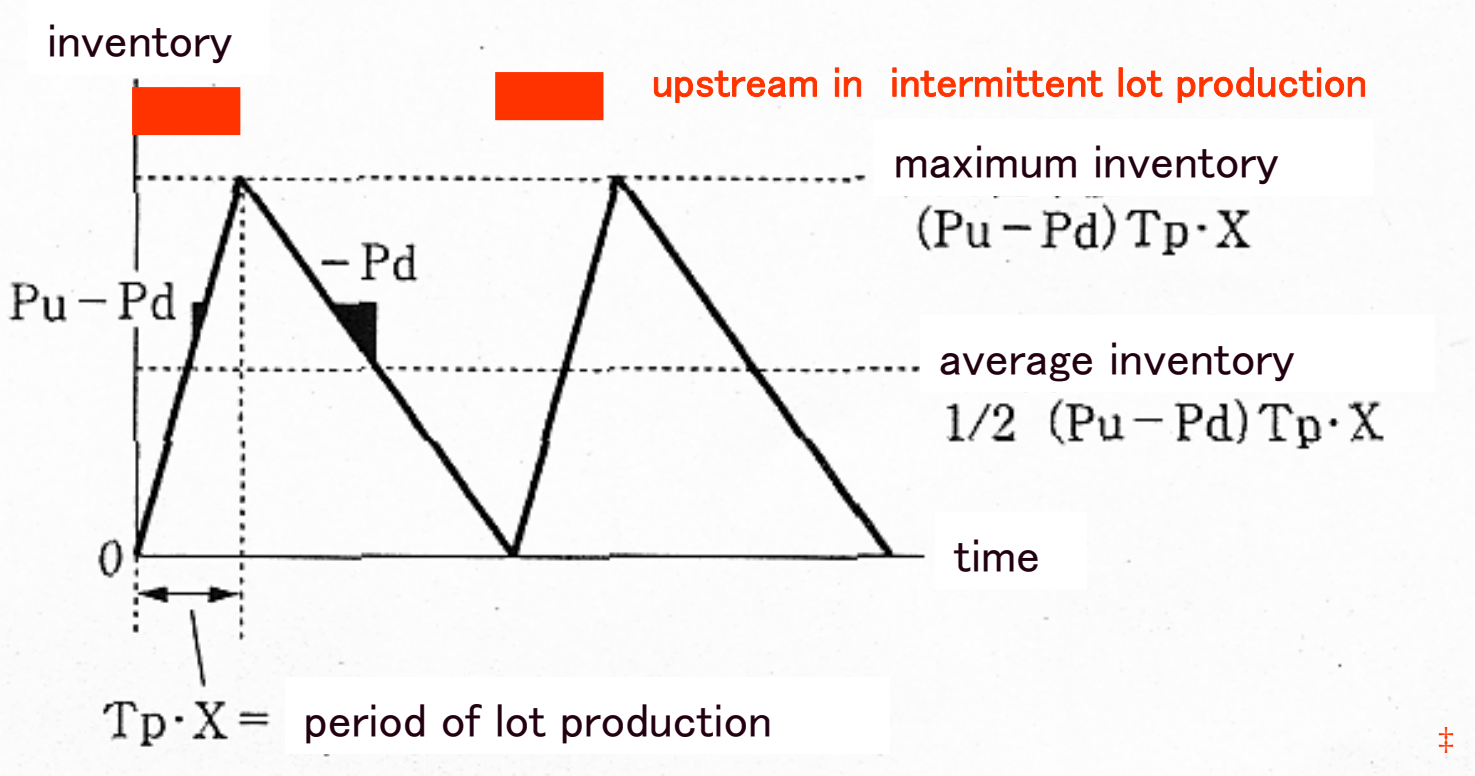
comparison of average cost (numerical example)



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p337 figure.8.27)

For example, when the upstream is in an intermittent lot production, and the downstream in a consecutive welding

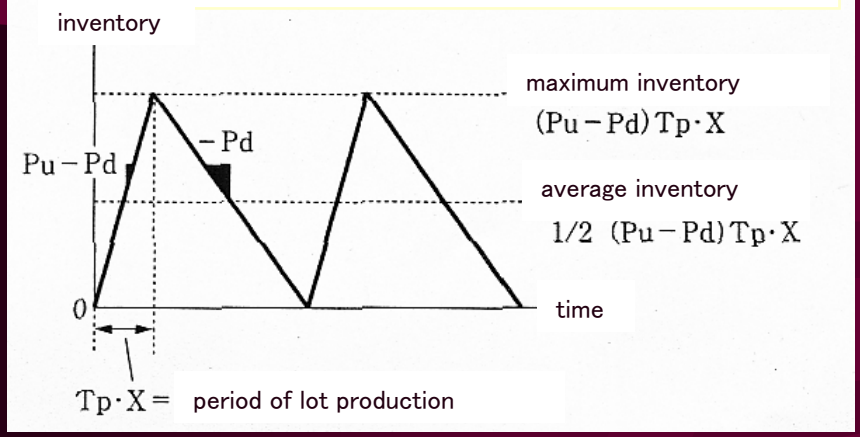
Reference: Movement of cycle inventory
when the upstream runs a lot production in high speed



T p = man-hours for processing work per unit of work
X = lot size
Pu = production unit per hour in upstream (lot production)
Pd = production unit per hour in downstream (consecutive production)

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅰ p337 figure.8.18)

Reference: Movement of cycle inventory
when the upstream runs a lot production in high sp



Cw = labor charge per hour

Cc = capital charge per hour

Cs = set-up time expense per once

Ci = inventory cost per unit

Accordingly, an average cost, with an inventory cost and a set-up time cost being added on, is

$$AC = (Cw + Cc)\,Tp + Cs/X + 1/2[Ci(Pu - Pd)\,Tp \cdot X]$$

in order to calculate a lot size of minimum cost, differentiate X, resulting in zero,

$$-Cs/X^2 + \tfrac{1}{2}\,[Ci(Pu - Pd)\,Tp] = 0$$

therefore, an optimal lot size (X) is:

$$X^2 = \frac{2\,Cs}{Ci\,(Pu - Pd)\,Tp} \quad \therefore \quad X = \sqrt{\frac{2\,Cs}{Ci\,(Pu - Pd)\,Tp}} = \sqrt{\frac{2\,Cs \cdot Pu}{Ci\,(Pu - Pd)}}$$

Flexibility to Change in Total Volume of Production

thought of Just In Time (JIT) ---

equalization

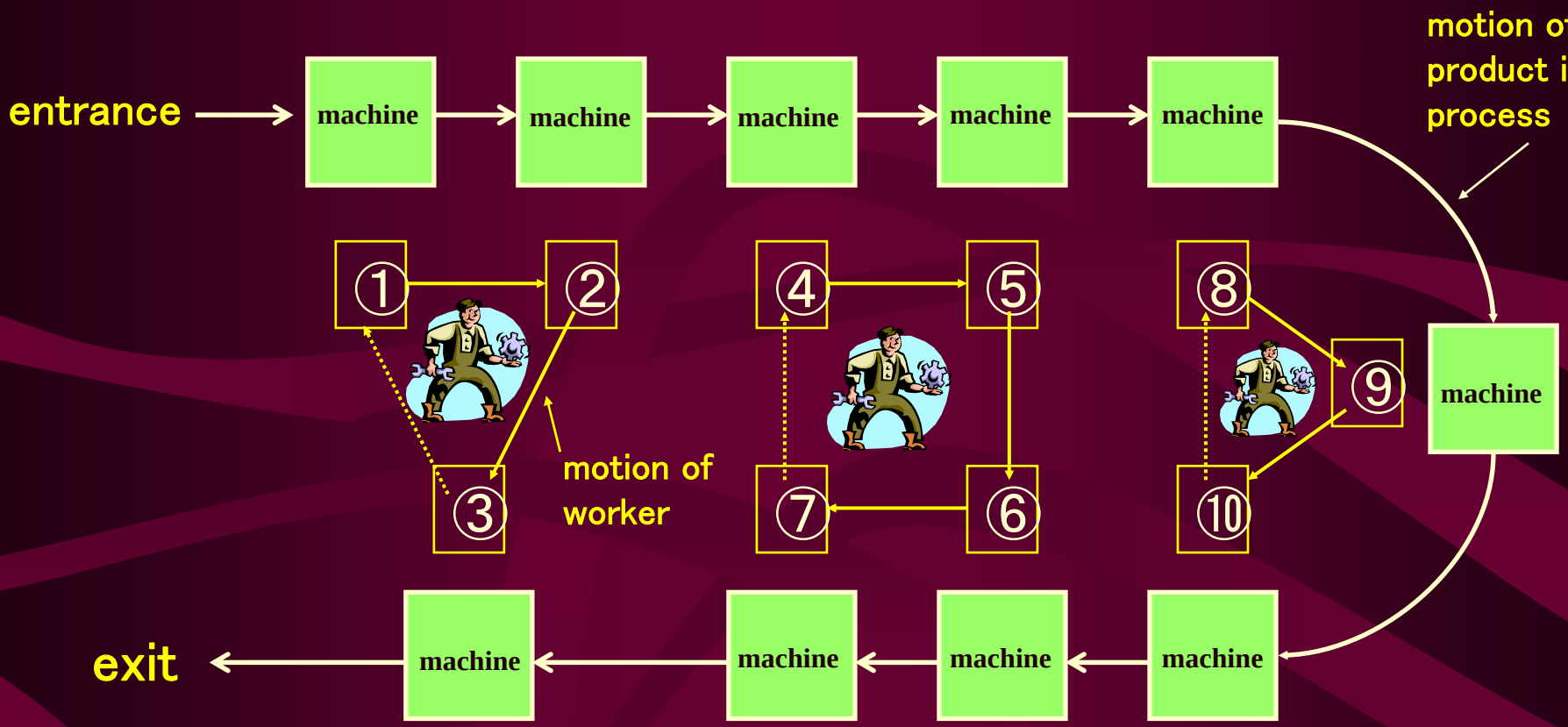
adherence to cycle time

strive for flexibility of process with respect to volume

multi-skilled worker, multi-process handling

U-shape line, "less labor"

U-Shape Line



Multi-process handling: spare waste in walking by patrolling machines. Same person covers the entrance and the exit. When a production volume decreases, cut down on workers and expand the range per one person.

Summary: Overall Optimization of Flexibility

Absorb diversification and change of market needs step by step:

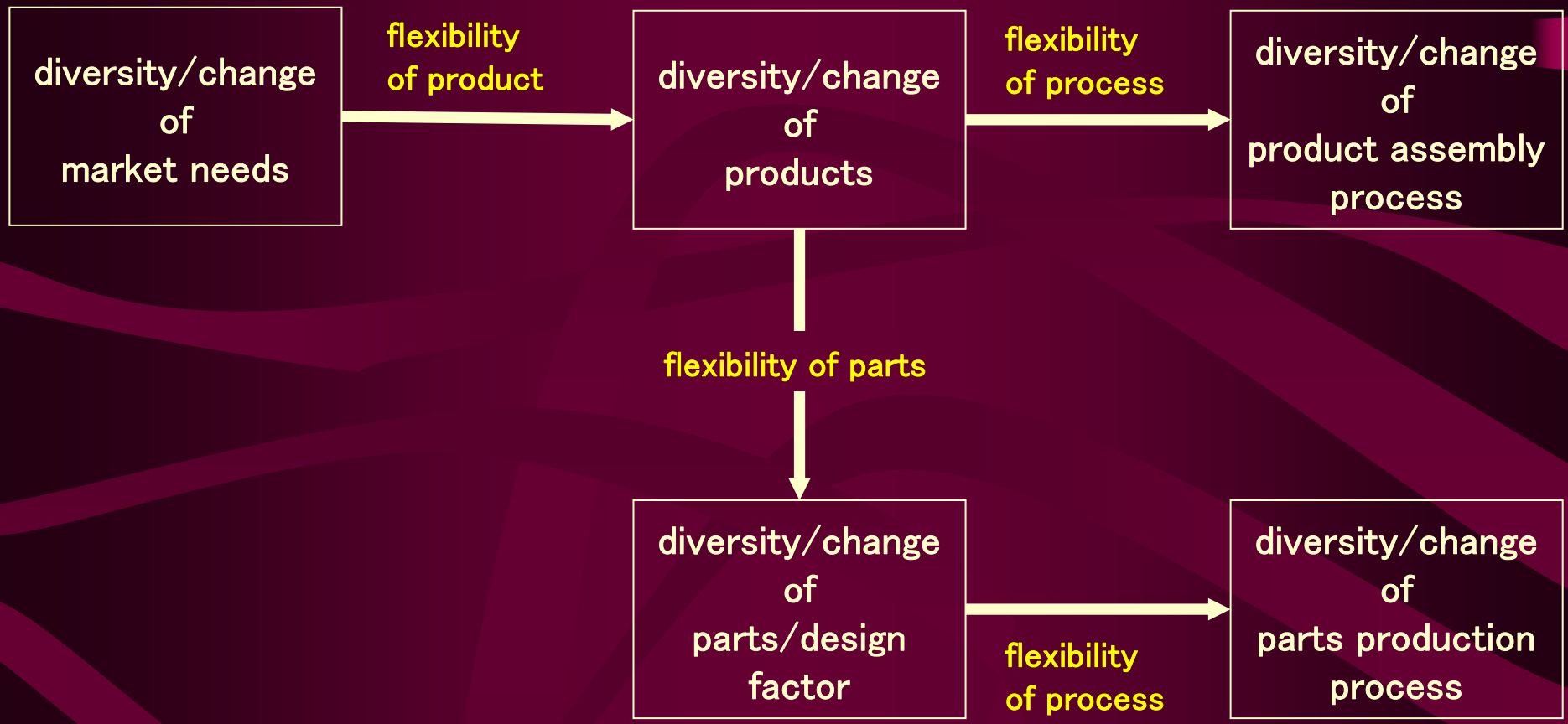
- Flexibility of product (Model-T Ford)
- Flexibility of parts (GM's Slone doctrine)
- Flexibility of process (Toyota)

Flexibility costs money at an appropriate level.

Flexibility should be considered as a necessary evil. (no self-contained objective)

With a minimum flexibility for product, parts, process, achieve a maximum market effectiveness.

Multistage Absorption of Diversity and Change Through Flexibility



One should have an overall perspective on an allocation of flexibility to prioritize where to absorb diversity and change.

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (I p343 figure.8.20)