Modularity and Scalable Manufacturing

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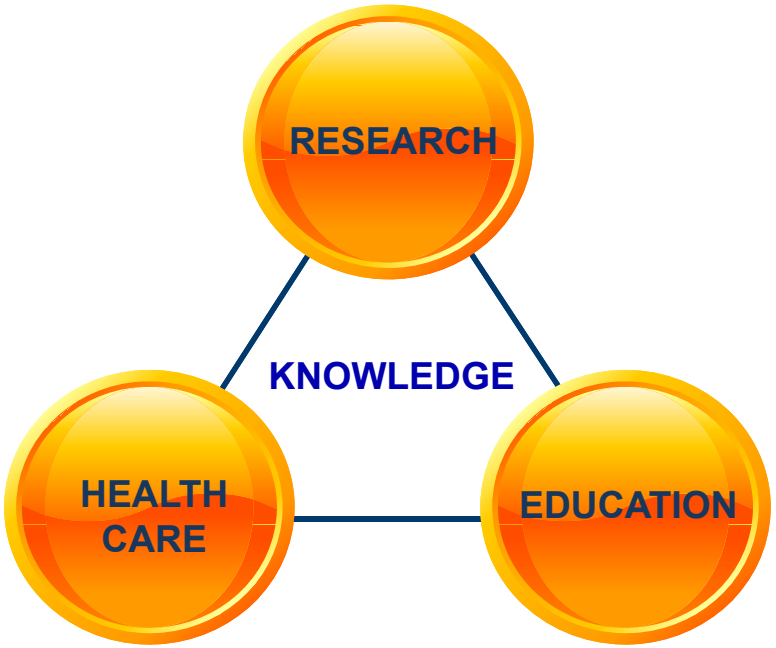
University of Michigan

Excellence Across Breadth



- Established in 1817
- 101 graduate programs in the top 10
- Sample University of Michigan "Firsts"
  - ✓ First to own and operate its own hospital (1869)
  - ✓ First state institution to establish a department of dentistry (1875)
  - ✓ First to have a naval tank for study of ship design (1904)
  - ✓ First to provide instruction in aeronautics engineering (1914)
- Many interdisciplinary research centers and institutes
- Renowned Institute for Social Research

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Michigan Manufacturing Leadership

Prof. Boston (center)

"The machine in the middle was a technical marvel in that it could make large diameter bearing races in the accuracy of 10^{-6} inches."

Professor S. M. Wu, first Anderson Professor of Manufacturing Technology, was a pioneer in applying statistical methods to manufacturing.

Prof. Y. Koren and his team created the science and enabling technologies for reconfigurable manufacturing systems.

Contents

- Evolving Paradigms of Manufacturing
- Mass Customization Enabled by Product Family Architecture
- Reconfigurable Manufacturing Systems
- Delayed Differentiation
- Summary and a Quiz

Craft Production

http://en.wikipedia.org/wiki/Craft_production

Lack of systems

Mass Production

Turn of the Century Ford and the automobile

Henry Ford assembly line at Highland Park, Michigan
http://www.eyewitnesstohistory.com/ford.htm

Model-T Production (Highland Park:~1910)

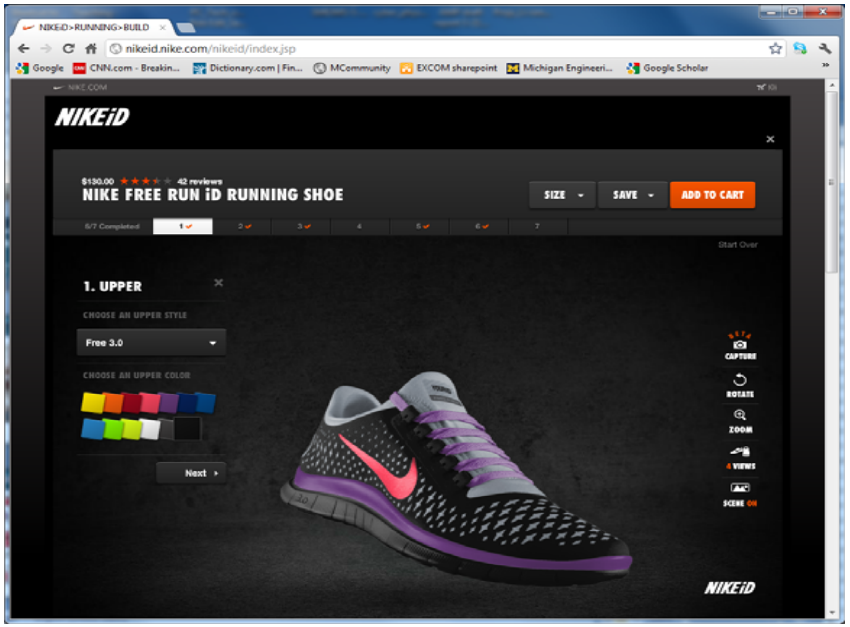
Pre-1912	20-30 per day
1913	100 per day
1914	1000 per day
1915	3000 per day

- **Interchangeable parts**
- **Moving assembly lines –** *Dedicated Manufacturing Systems*
- **Division of labor/Scientific management**
- **Vertical integration**

Mass Customization

Un-upholstered | Latitude upholstery on seat & back | Latitude on seat only

http://www.hermanmiller.com/



BMW 7 Series

10^{17} possible variants

- ***Product family***
- ***Management of variety***
- ***Economy of scale and scope***
- ***Demand for responsive manufacturing systems***

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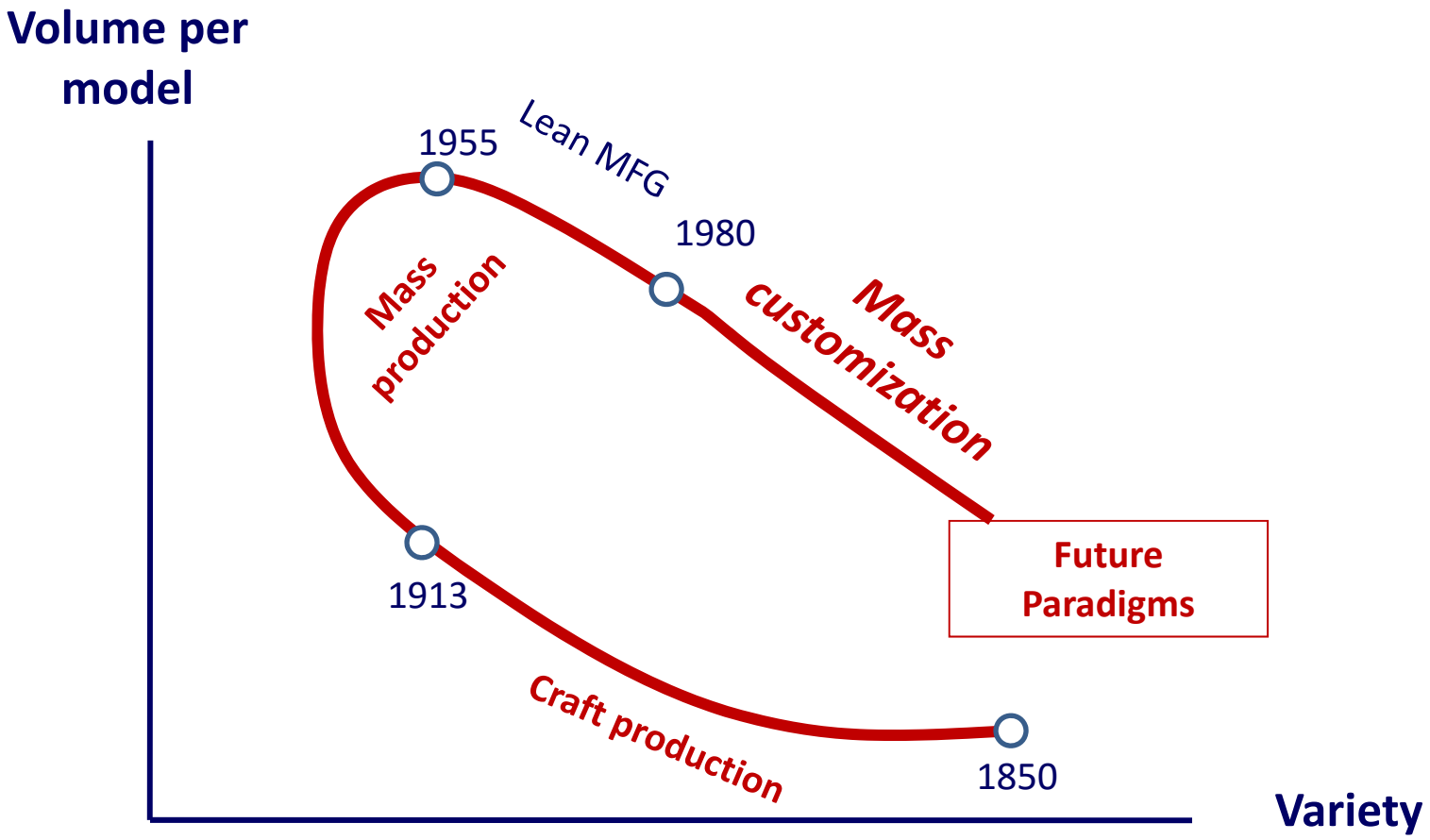
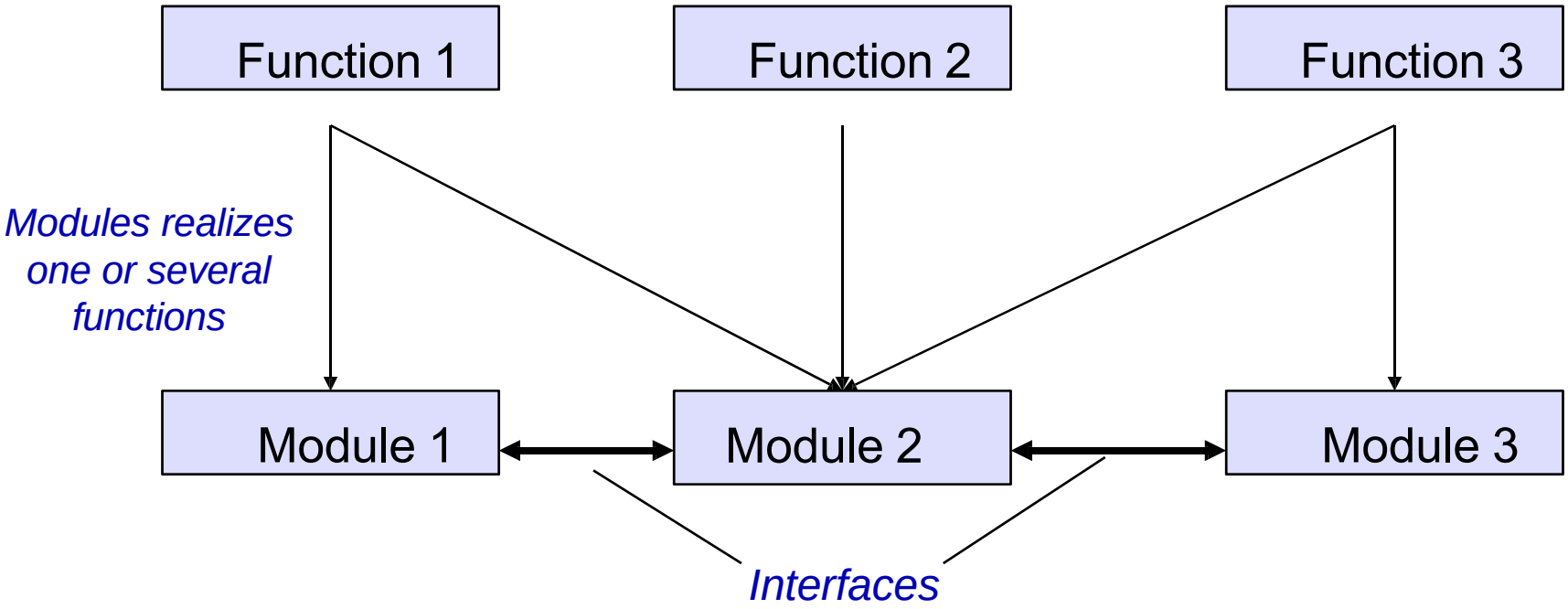
Volume – Variety Relationship in Paradigms of Manufacturing



Product Architecture (PA)

A products *architecture* describes

- *what* it does (its functions),
- *how* it is physically realized (its modules), and
- the *interactions* (interfaces*)* between the modules

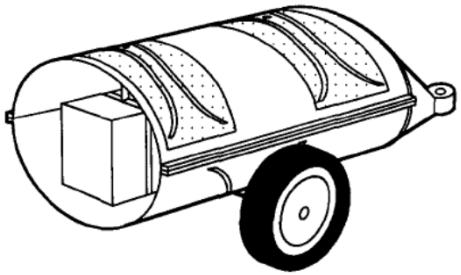


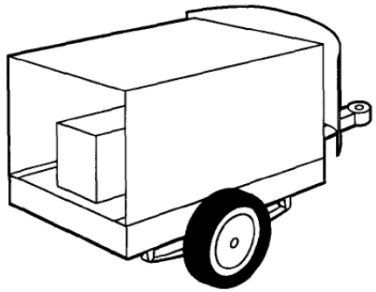
Types of Product Architecture

- **Integrated:**
  - Single structure or a very small number of interacting units
  - Product functions are all contained in one structure and each component can implement a different function
  - Rigid connections among units such that the boundaries between units are not very clear (taking one of the components out may destroy several portions of the device.)
  - More focused development during system level design phase

- **Modular:**
  - Decomposition of a product into modules or components
  - Each module implements one or a few functions – *eliminate or minimize coupling*
  - Interfaces between modules are well defined – *easy "plug and play"*

Example of Modular vs Integral Product





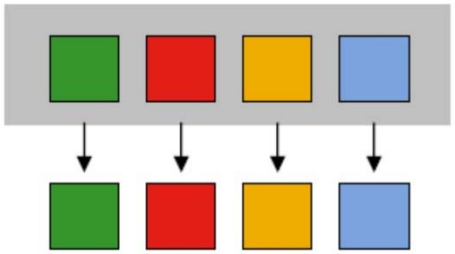
Protect cargo from weather	Upper half
Connect to vehicle	Lower half
Minimize air drag	Nose piece
Support cargo loads	Cargo hanging straps
Suspend trailer structure	Spring slot covers
Transfer loads to road	wheels

Protect cargo from weather	Box
Connect to vehicle	Hitch
Minimize air drag	Fairing
Support cargo loads	Bed
Suspend trailer structure	Springs
Transfer loads to road	Wheels

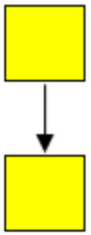
Ulrich, Karl. "The role of product architecture in the manufacturing firm."
Research policy 24, no. 3 (1995): 419-440.

Example of Integral vs Modular Product

Company A designs 4 products, resulting in 4 variants:

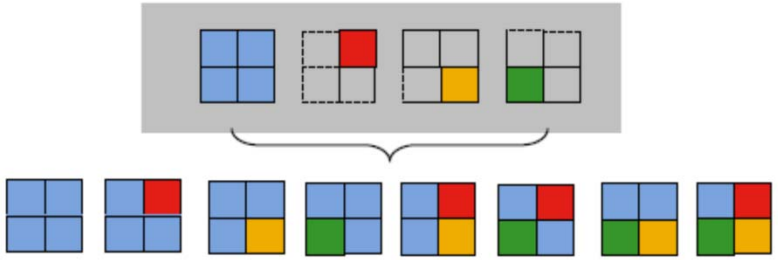


By adding 1 new design, Company A adds 1 variant:

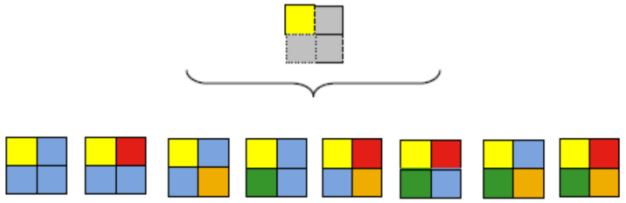


5 designs → 5 variants

Company B designs 1 modular platform with 3 additional modules resulting in 8 total variants:



By adding 1 new module, Company B adds 8 new variants:

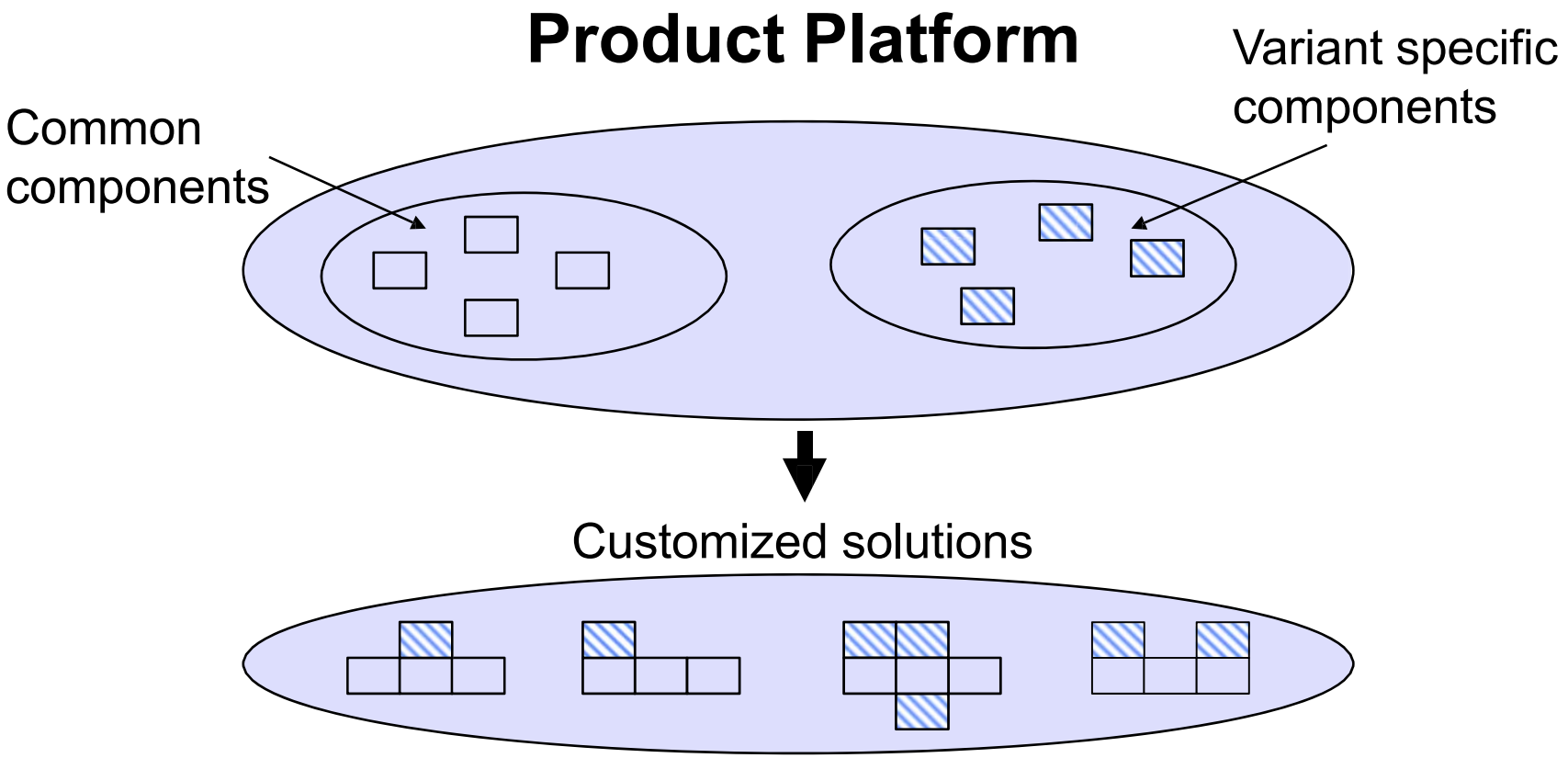


5 designs → 16 variants

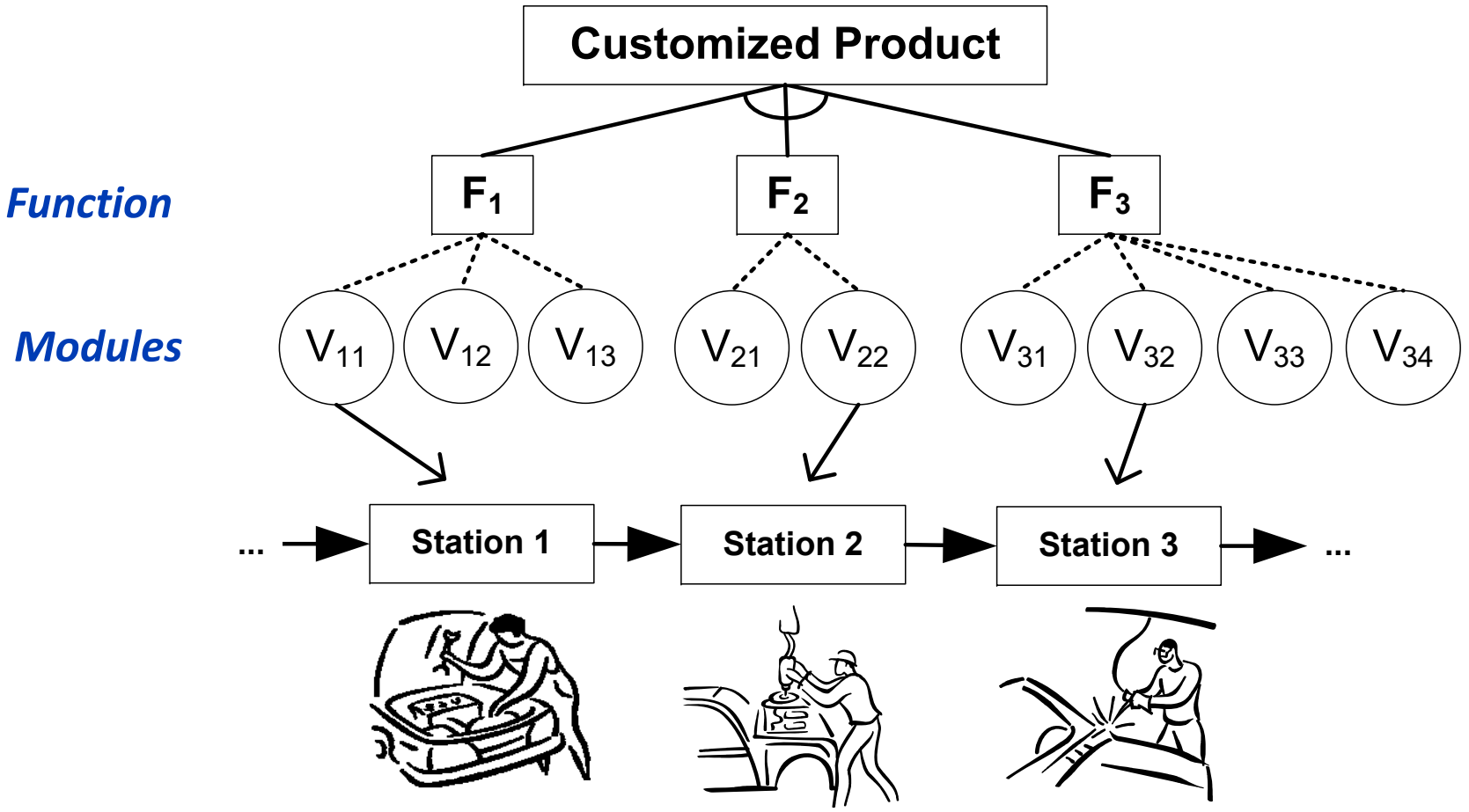
(www.ptcuserworldevent.com/presentations/Modular_Product_Architecture.pdf , 10/17/06)

Product Family

- Platforms: Common components + variant specific components creates a customized solution



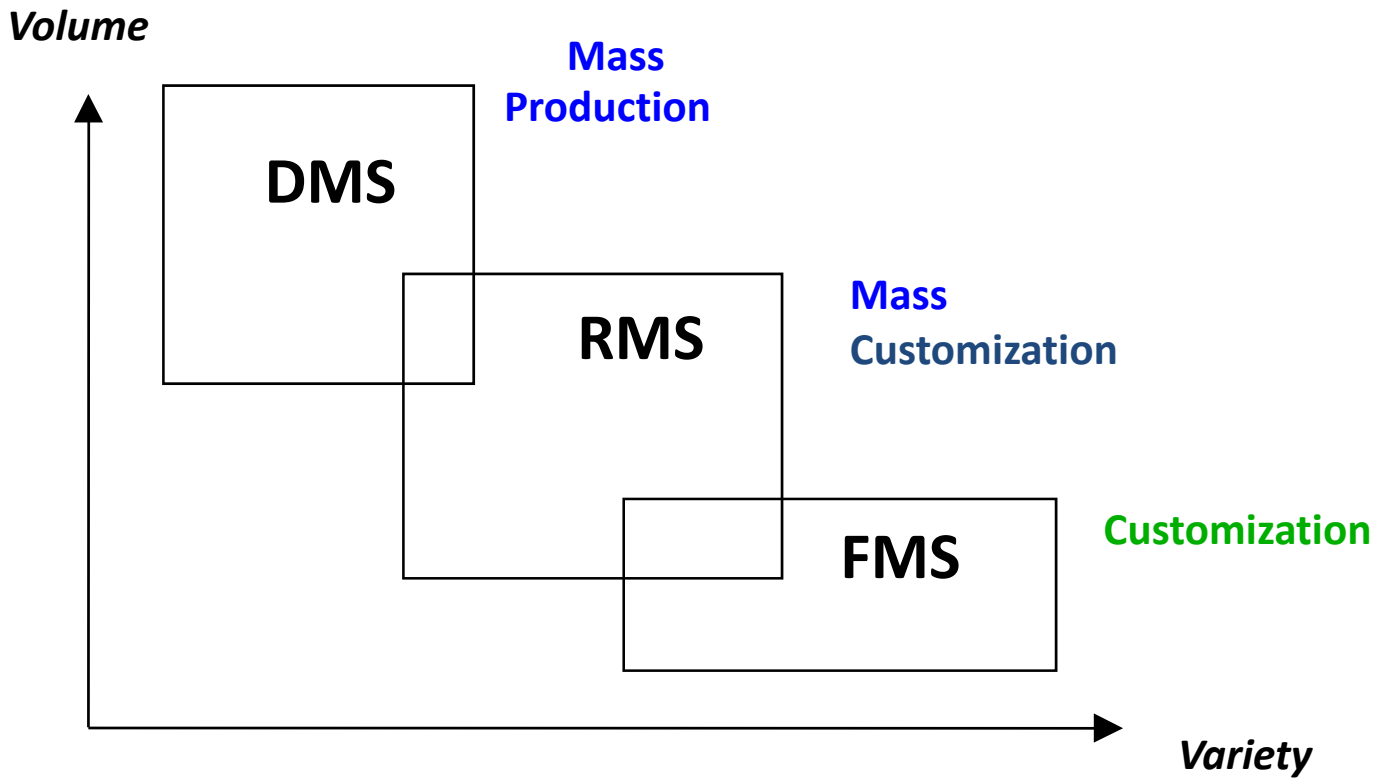
Product Family Architecture



Advantages of Product Families

- Economic product variety
- Development risks
- Low system complexity
- Improved ability to upgrade products
- Enhanced flexibility
- Enhanced responsiveness for manufacturing processes

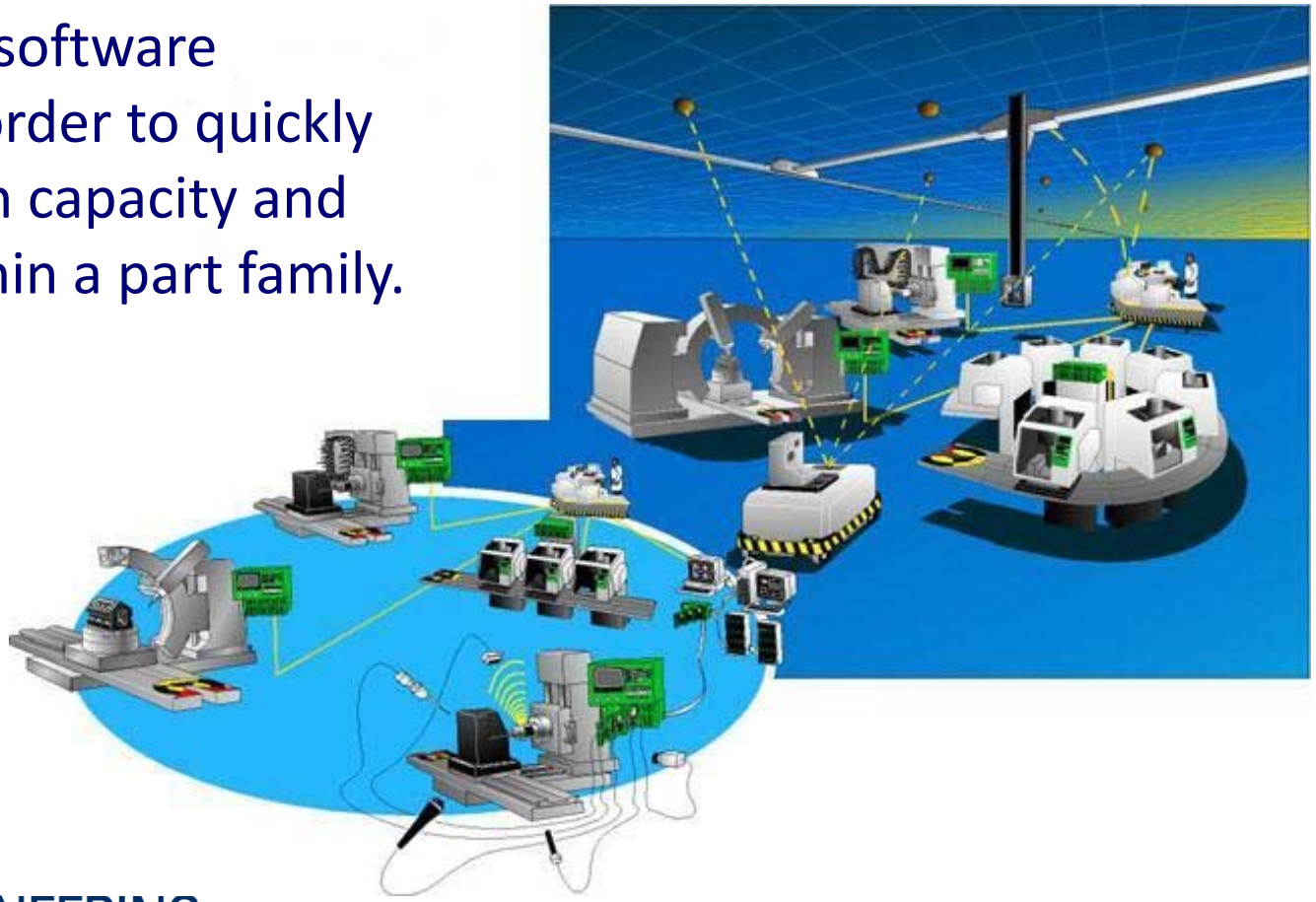
Manufacturing Systems for the three paradigms



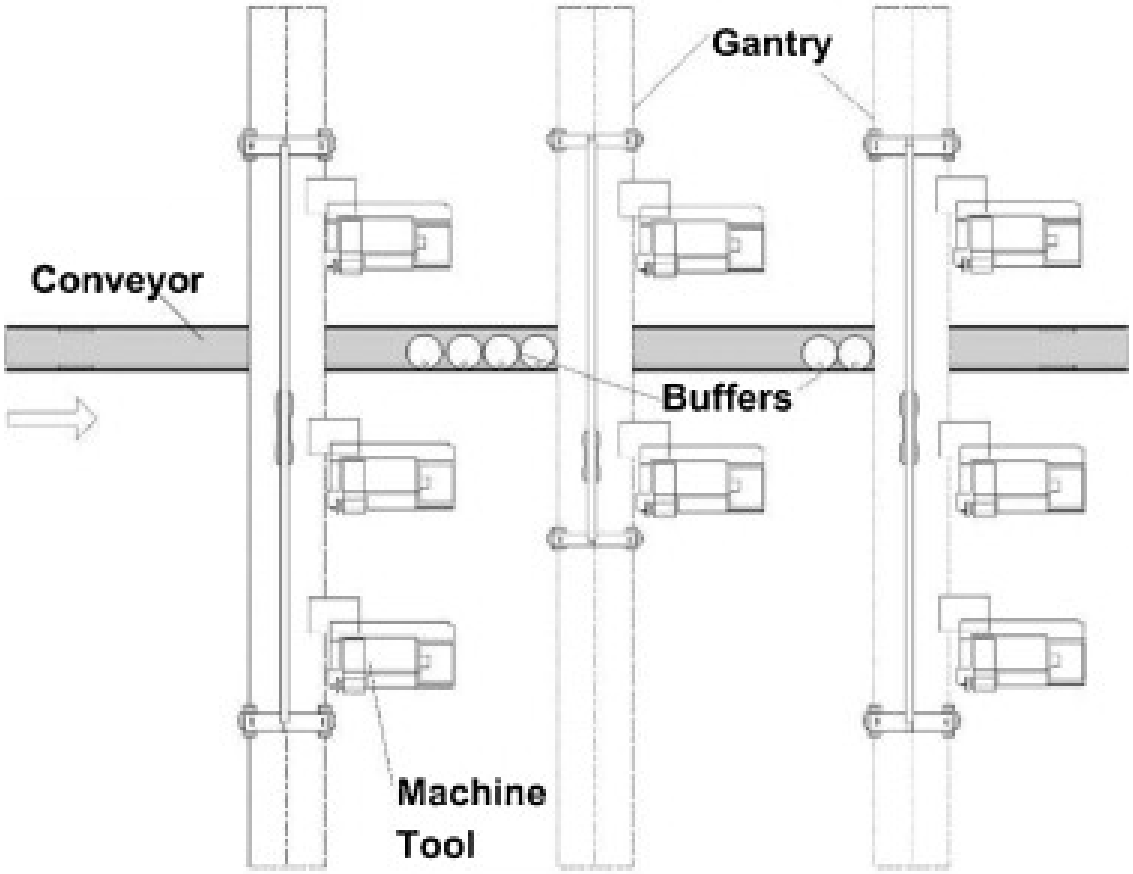
DMS: Dedicated Manufacturing System
FMS: Flexible Manufacturing System
RMS: Reconfigurable Manufacturing System

Reconfigurable Manufacturing Systems (RMS)

An RMS is designed at the outset for rapid change in structure, as well as in hardware and software components, in order to quickly adjust production capacity and functionality within a part family.

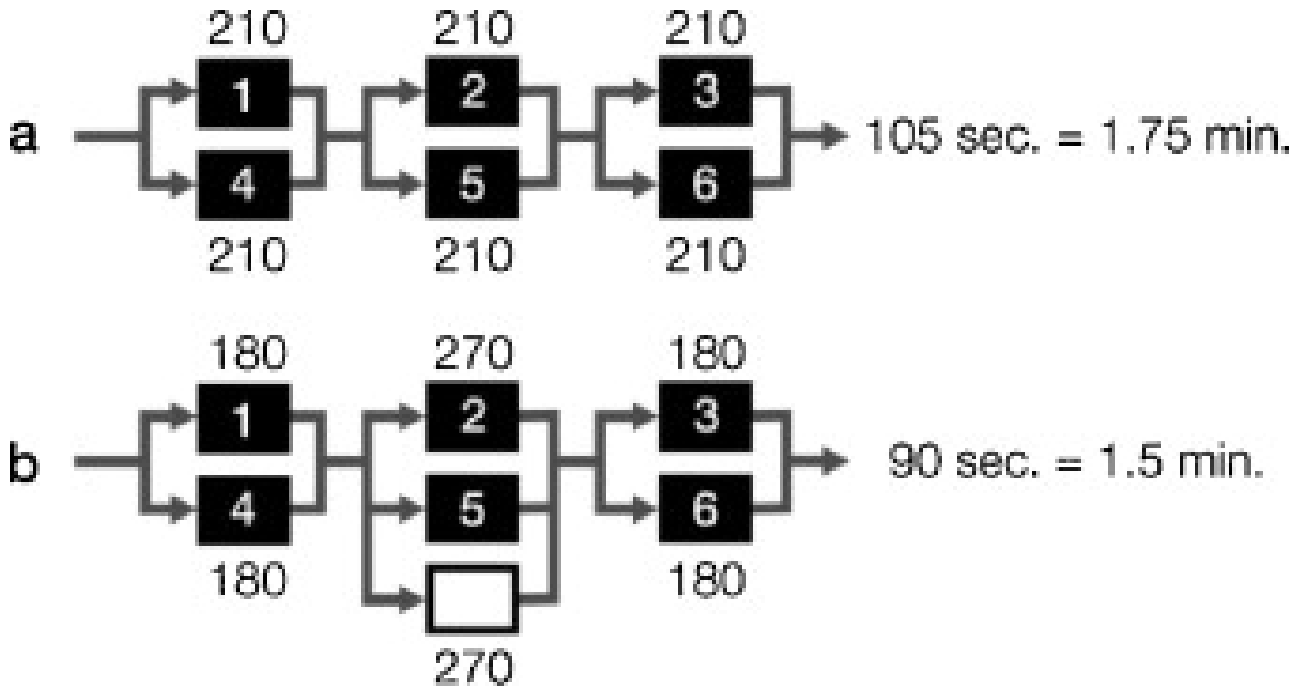


Example of an RMS



Wang and Koren, 2012, "Scalability planning for reconfigurable manufacturing systems"

Scaling of an RMS

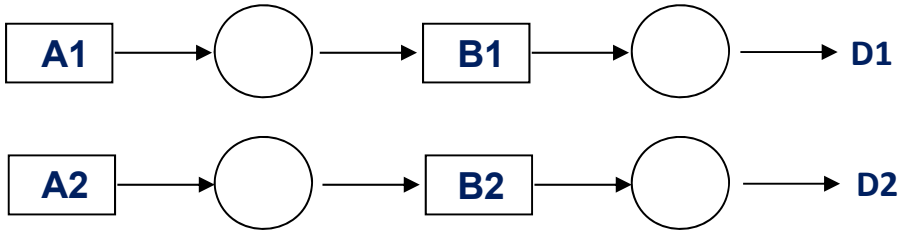


When demand grows, the initial system, a, is cost-effectively scaled-up to Configuration b to meet the new demand.

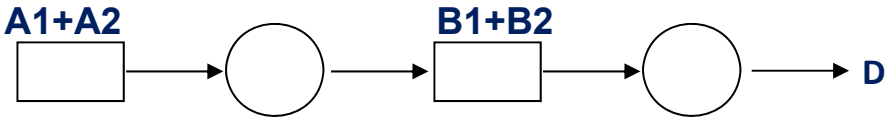
Wang and Koren, 2012, "Scalability planning for reconfigurable manufacturing systems"

Mitigating the Effect of Variety by Delaying Differentiation

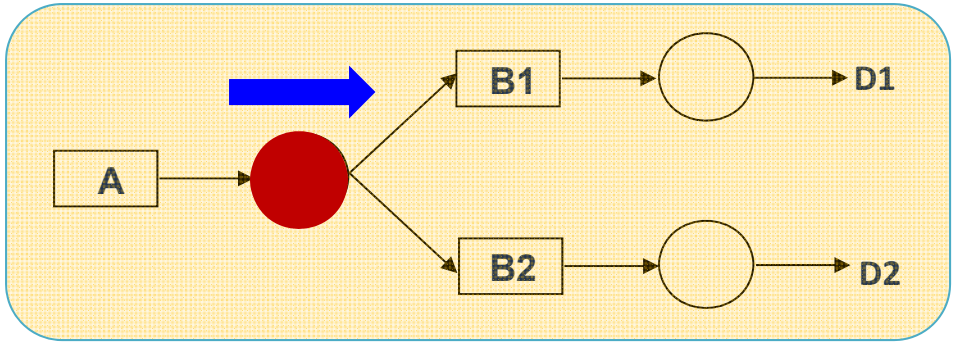
Total differentiation



Mixed model assembly



Delayed differentiation

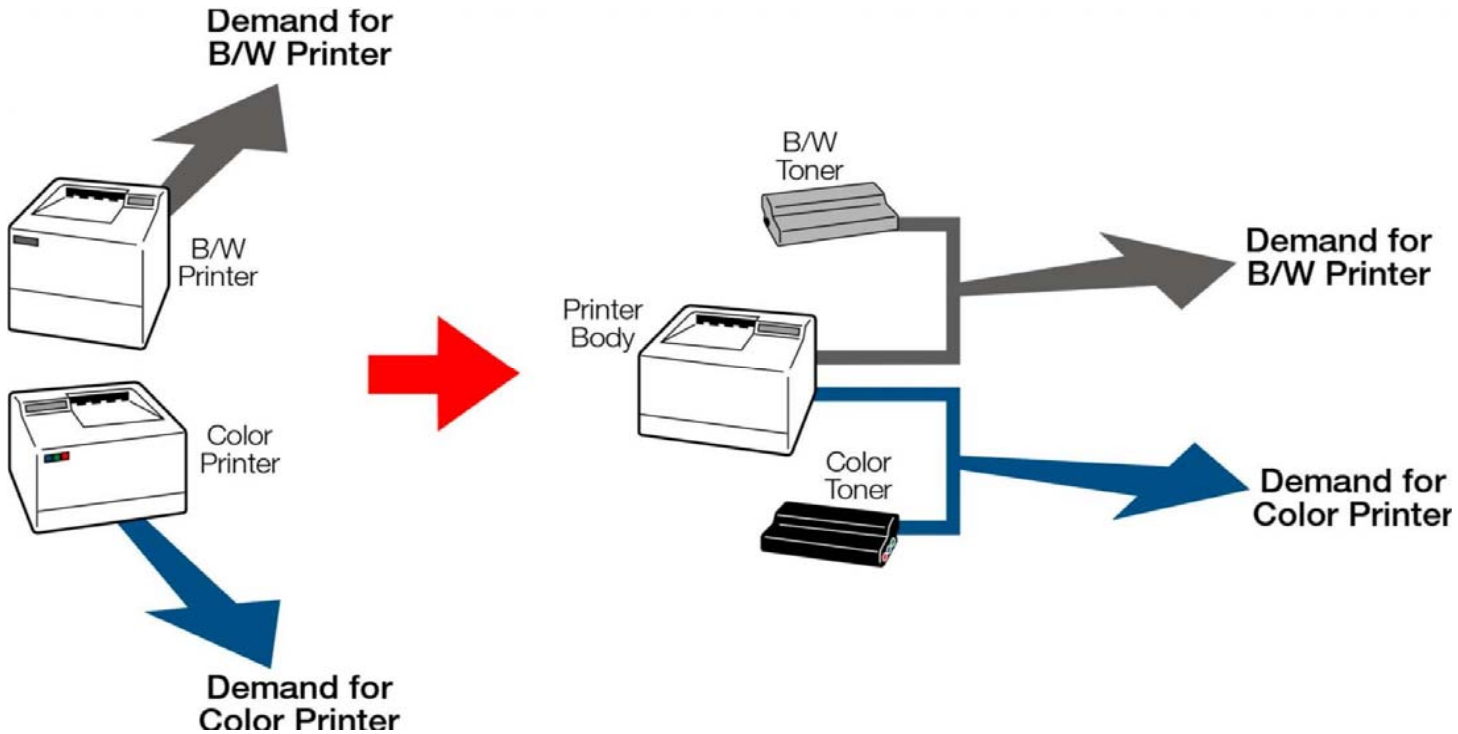


By delaying the point in which the final personality of the product is realized,

- **Flexibility to handle customer change order increased**
- **Inventory cost reduced**
- **Economy of scale: piece cost reduced**
- **Complexity reduced**

An Example of Delayed Differentiation

Modular Designs



Design for Delayed Differentiation

Objective: Delay the point in which the final functions of the product are configured

- increases **flexibility** to handle changing demands of multiple products within the family
- decreases operational and **cost savings**
- more popular differentiating features designed first (postponement differentiation)

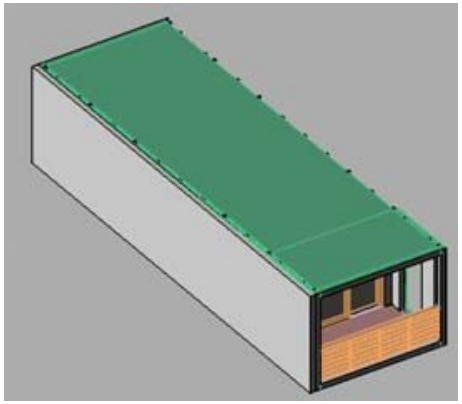
Requirements:

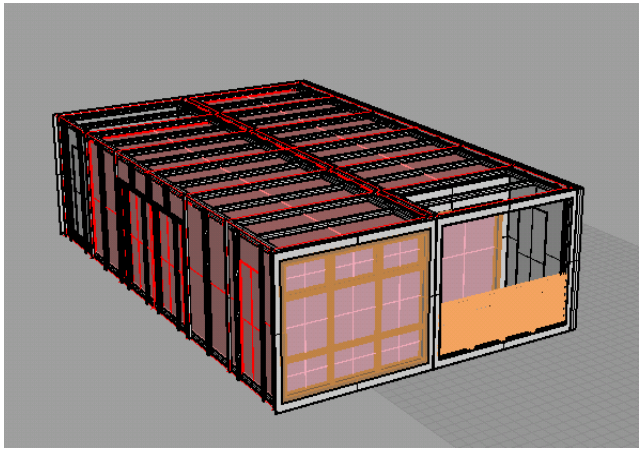
- non-differentiation functions produced first – **dedicated mfg. system**
- differentiation functions could be added later in the process – **flexible and reconfigurable mfg. systems**

Summary

- A product *architecture* describes the product functions, physical realization and the interactions between the modules.
- A *modular* architecture is easy to change, allows for variants, allows for parallelization and local optimization.
- A *platform* is the set of components/modules, processes, knowledge and people, shared by a group of products and contributing to product variants in a family.
- *Reconfigurable Manufacturing Systems* are scalable systems with machines in serial/parallel configurations.

Quiz: What are those?

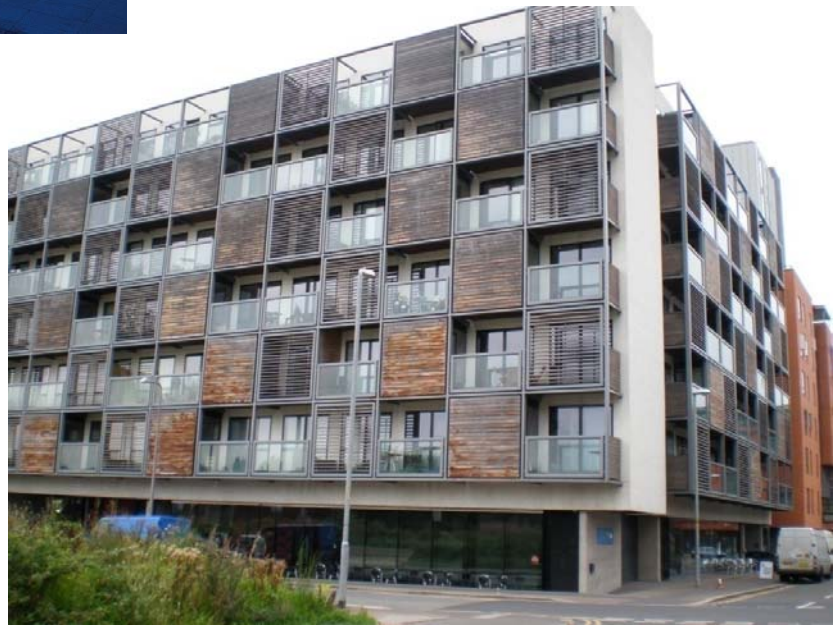




Examples of Modular Products

Watch out: Your future home might well have wheels

http://www.cnn.com/2015/02/05/travel/gallery/mobile-architecture-homes/



MoHo – Modular Homes
(Manchester, UK)